Regional Review Workshop on Completed Research Activities

Proceedings of Review Workshop on Completed Research Activities of Crop Research Directorate held at Adami Tullu Agricultural Research Center, Adami Tullu, Ethiopia, 15-20 November, 2021.

Editors
Tesfaye Letta and Girma Mengistu

Oromia Agricultural Research Institute

P.O.Box 81265 Finfinnee, Ethiopia

Correct citation: Tesfaye Letta and Girma Mengistu, (eds.). Proceedings of Review Workshop on Completed Research Activities of Crop Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Oromia, Ethiopia 2021.

Organized by:- Communication Affairs Team

Table of Contents

Protocol optimization for micro propagation of banana varieties (Musa spp.) using shoot-tip culture

Gerema Amente*[1], Megersa Gemechu[1] and Imiru Chimdessa[1]
[1]Adami Tulu Agricultural Research Center, P. O. Box 35, Batu, Ethiopia,
Corresponding author* amente2015@gmail.com

Abstract

Conventional vegetative propagation of banana generally has low production; transmission of diseases and poor preservation of original plant genetic material. Micro propagation is currently the only practical means of achieving rapid, large-scale production of disease-free quality planting material. The present study was conducted with the objective to optimize quick and reproducible in vitro micro propagation protocol for three banana varieties (Grandnaine, Poyo and Butuza) grown in Oromia. Experiments on shoot tip culture initiation, shoot multiplication and in vitro rooting were laid out in Completely Randomized Design with 3x2x2, 5x4x3 and 4x3 factorial treatment arrangements respectively. Data were subjected to analysis of variance and significant means were separated using Duncan's Multiple Range Tests. With regard to shoot multiplication, Grandnaine showed a maximum of 12.67shoots per explant with 2.17cm shoot length on a medium fortified with 3.5mg/l BAP alone, while Poyo produced a maximum of 13.00 shoots per explant with 2.15cm mean shoot length on a medium supplied with 3.0 mg/lBAP and 0.2mg/l IBA. Likewise, Butuza produced maximum of 11.33 shoots per explant with mean shoot length 2.9 cm on medium fortified with 4.0 mg/l BAP + 0.3 mg/l IBA. Half MS semi solid medium containing 1.0 mg/l IBA induced the highest rooting with 8 mean root number per shoot for Grandnaine. For Poyo, half MS medium supplemented with 1.5mg/l IBA induced the highest rooting response with mean root number per shoot of 7.6. Similarly, half MS medium supplemented with 2.0 mg/l IBA induced highest rooting response with 8 mean root number per shoot. In conclusion, this study can be used for rapid and mass in vitro propagation of these three elite banana varieties.

Keywords: - Micro propagation, Banana Varieties, 6-Benzylaminopurine, acid, Indole butyric acid,

Introduction

Banana (*Musa* spp. AAA) is an important fruit crop of the Musaceae family, widely grown in developing countries, and is the second largest fruit crops in the world after citrus (Madhulatha P et al 2004). Banana originated from the South East Asian region, where the greatest diversity of edible banana is found (Stover RH et al 1985). Ethiopia is among the tropical countries where its vast areas are suitable for banana cultivation, and has also the opportunity for exporting fresh banana fruits. Banana production in the country ranges from homestead to large commercial plantations under rain fed and/or with supplementary irrigation conditions (Asmare D et al. 2012).The materials used for conventional propagation are corms, suckers, and sword suckers. Since, on average only 5 to 10 suckers can be obtained per plant per year, the traditional clonal propagation method appears to be unable to supply the increasing demand for healthy planting materials of banana. Conventional vegetative multiplication of banana has been found to express several negative impacts including, low production, transmission of diseases and poor preservation of original plant genetic material (Ngomuo*etal.*, 2014). In order to augment conventional propagation and to avoid constraints imposed by some pathogens, *in vitro* approach has been considered due to its potential to provide genetically uniform, pest- and disease-free planting materials (Tripathi 2003). Propagation of banana through in vitro techniques has been reported by several authors using different explant sources as well as regeneration pathways (Alango K. *et al* 2018Kagera*et al*. 2004, Philip S and Michael R D. 2012,J. Lohidas and D. Sujin 2015, Bhosale U.P et al 2011). Shoot tip culture has been routinely used for the rapid clonal propagation of banana genetic resources since 1985. Micro propagated plants establish more quickly, grow more vigorously, have a shorter and more uniform production cycle, and produce higher yields than conventional propagules (Robinson *et al*., 1993).

Even though many reports are available on banana micro propagation through shoot tip culture, plants could exhibit great variation under *in vitro* conditions in terms of shoot establishment, shoot proliferation, and regeneration of shoots and roots because of several factors such as genotype, explant type, culture media composition, plant growth regulators (PGR) and culture environment (Vuylsteke1998, Wijerathna YM A.M. *et al, 2016,*Y.A. Kaçar*et al.* 2010, Asmare D *et al.* 2012). Therefore, this study was initiated to optimize quick and reproducible *in vitro* micro propagation protocol for three banana varieties grown in Ethiopia. The protocols mainly composition of media that include concentrations and combinations of plant growth regulators are largely plant genotype dependent and are also influenced by water quality and techniques used in different laboratories. For this purpose, the effects of different cytokinins and auxins at various concentrations on shoot initiation, multiplication and elongation, and *in vitro* rooting were studied. The effect of acclimatization media mix on banana plantlets growth was also studied.

Materials and Methods

Plant Materials: Three cultivated banana varieties in Ethiopia, namely Poyo, Grand naine and Butuza were used as experimental materials. Sword explants were obtained from healthy looking, field grown varieties from Adami Tulu Agricultural Research Center (ATARC) banana propagation nursery. The pseudo stems at the lower parts of the suckers containing meristems were used as explants. The shoot tips were the starting materials. This study was conducted at the Plant Tissue Culture Laboratory of ATARC, Oromia, Ethiopia.

Culture Media Preparation and Sterilization: The culture medium used for this study was modified Murashige and Skoog (MS, 1962) basal medium. The required amount of macronutrient, micronutrient, and vitamins from respective stock solution were dissolved in double distilled water along with 30 g/L sucrose and 7g/l agar-agar type-I. The final volume was made upto the required level with double distilled water and then divided into required volume of treatments, to which amount of PGRs from stock solution were added in combinations at different concentrations. The pH was adjusted in all cases to 5.8 by using 1N NaOH and/or 1N HCL before autoclave and gelling with agar. The media was poured into washed and dried culture jars of 60 ml volume and then, capped and labeled properly. The medium was autoclaved at 1.2 KPa and 121ºC for 20 min, and then cooled at room temperature before use. The autoclaved medium was kept in a shelf for three days (72hr) to make sure that there is no any microbial contamination.

Explant Preparation and Surface Sterilization: Explants were excised from young suckers of the three banana varieties. The superfluous corm tissue, roots, and leaf sheathes were trimmed and removed by sharp knife. Explants were washed carefully in running tap water for 15 min with detergent solution (largo) to remove adherent soils. The leaf sheaths near the bases were again removed leaving the young leaves around the meristem until the shoot tip became about 1.5 cm in length. Then the explants were dipped in 3gm/l solution of mancozeb fungicide for 10 min and rinsed three times by autoclaved distilled water. The explants were then briefly sterilized by 2% sodium hypochlorite solution for 15min followed 70% ethanol for one minute. After rinsing three times with autoclaved distilled water, the explants were excised into final size (about 5 mm) under laminar air flow hood.

Shoot Tip Culture Establishment: Surface sterilized explants were placed on MS medium containing a combination of N6 benzyl aminopurine (BAP: 1.5 and 2.5 mg/l) and indole-3-acetic acid (IAA: 0.0 and 0.5 mg/l) for shoot tip initiation. The factorial treatment was 3x2x2 combinations arrangements. Thirty culture jars with each jars having one shoot tip explants were cultured for each three varieties (30 shoot tips per treatment).The initiated cultures were incubated for 8 weeks aseptically at 25±2ºC under 16/8hr cool white, fluorescent lights. Data of shoot initiation were recorded four weeks after culture.

Invitro shoot proliferation: The same MS medium supplemented with a combination of BAP (2.0, 2.5 3.0, 3.5 and 4.0 mg/l) and IBA (0.0, 0.2, 0.3, and 0.5 mg/l) was used for shoot proliferation. The experiment was laid out in CRD with three factorial combination of five levels of BAP ; four levels of IBA and three levels of banana varieties (Poyo, Grandnaine and Butuza) resulting in 5x4x3 factorial treatment structure. After 8 weeks of initiation stage contamination-free shoots were decapitated and split longitudinally into two or more parts depending on vigor and thickness. Then, they were transferred to multiplication medium. However, smaller shoots were not split; rather they were put three together in a culture vessel. The multiplication rate was studied by sub culturing the shoots on MS media every 3 weeks for 5 cycles. Data on number of shoots per explants, number of leaves and length of shoots were carefully recorded during each sub culturing.

In Vitro Rooting of Shoots: In root development stage, well grown shoots with expanded leaves were separated and transferred singly to fresh rooting half MS medium with different concentrations indole butyric acid (IBA) (0.5, 1.0, 1.5, and 2.0 mg/l). After 6 weeks of culture, root growth, data on number of roots per shoot and length of roots (cm) were recorded. For each treatment, four shoots in each jar (12 shoots per treatment) were lined up randomly in CRD with three replications.

Acclimatization and Hardening of Plantlets:

In vitro rooted plantlets were taken out of the culture jars and the roots were carefully washed with water to remove all the traces of the rooting medium. Plantlets were disinfected with Ridomil (2.0 g/l) for 3 min to prevent fungal infections before transplanting. Individual plantlets were then transferred into small polybags filled with sterile soil mixtures top forest soil, farm yard manure and sand soil in 2:1:1/2 ratio. The soil mixtures were sterilized by drying oven at 180^{o}C for an hour. Then, plants were later transferred to bigger polybags that were filled with top forest soil and manure in the ratio of 2:1. The hardened plants were finally transferred to the field and successfully established and evaluated for it fruit.

Experimental Design and Data Collection

The treatments were arranged in a Completely Randomized Design (CRD) with factorial arrangements. In the initiation stage, the number of explants survived and initiated shoots were recorded which was expressed as percentage. Explants were sub cultured five times and after each subculture, the number of shoots per explant, number of leaves per shoot and shoot length for each variety were counted. In the rooting stage, leaf numbers (determined by counting all leaves per plant), and root numbers (determined by counting all roots per plant), were examined. In the acclimatization and hardening stage, survival of transplanted plants (determined by counting all live plants), plant height, pseudo stem diameter, and leaf numbers were also examined.

Data Analysis

In the present study, the treatments were the plant growth regulators (the cytokinin - BAP; and the auxins - IBA) with various concentration levels, and the banana varieties at each micro propagation stage. Furthermore, survival percentages were calculated for acclimatization and hardening plantlets. Experimental data were analyzed By R software using Multiple Analysis of Variance at 95% of confidence level. When F-Test showed statistical significance at $p < 0.05$ level, means were separated according to Duncan Multiple Range Test (DMRT) Procedure.

Results and discussions

Shoot Initiation: In the present study, *in vitro* culture of banana shoot tips resulted hard meristematic ball like structure in initiation media containing different concentrations of BAP and IBA. The cultured shoot tip turned brown in color from the initial creamy white in a few days after inoculation. Four weeks later, the external leaf primordia of explants turned green and globular hard coat mass grew from which adventitious plantlets were developed. Among the treatment combinations considered, the maximum shoot tip initiation response 100% sprout was obtained from explants cultured on MS medium supplemented with 3.0mg/l BAP the Grandnaine banana variety. Likewise poyo and Butuza variety gave maximum shoot imitation on MS medium supplemented with 2.5mg/l BAP and 2.5mg/l BAP respectively (Table 1). A similar result has been reported by Asmare Dagnew *et. al.* (2012*)* using MS medium supplemented with 2.0 to 3.0 mg/l BAP. Cronauer and Krikorian (1984) and Vuylsteke (1998) were also reported BAP as the most commonly preferred cytokinin used in banana tissue culture. Furthermore, Al-Amin *et al*. (2009) observed the color change of culture meristems to brown in 4 to 5 days and a development of a green hard ball like structure after 30 to 35 days of inoculation.

Azam *et al.*2009 found that cultured shoot tips were visible as a swelling and greenish color after 10 -15 days of inoculation in MS media supplemented with different concentrations of BAP. Al-amin *et al.*2010 were also observed meristematic ball like structure in regeneration media containing different concentrations of BAP and NAA.

Table 1: Effect of different concentrations of BAP along with IBA and BAP alone on shoot initiation of three banana varieties

Treatments PGR(mg/l)	Name of banana varieties								
	Grandnaine			Poyo			Butuza		
	explants cultured	initiated shoots	survival %	explants cultured	initiated shoots	survival %	explants cultured	initiated shoots	survival %
2BAP+0.0IBA	20	10	50	20	16	80	30	28	93.3
2BAP+0.5IBA	20	15	75	20	16	80	30	26	86.6
2.5BAP+0.0IB	20	17	85	20	18	90	30	24	76.6
2.5BAP+0.5IB	20	18	90	20	17	85	30	21	70
3BAP+0.0IBA	20	20	100	20	16	80	30	22	73.3
3.5BAP+0.5IB	20	17	85	20	14	70	30	20	66.6

Invitro Shoot Multiplication

After 8 weeks of culture initiation, when shoots with at least one leaf are emerged, shoots were transferred to multiplication medium. It has been reported that multiple shoots could be produced from sliced shoot tips of banana and plantain (Cronauer and Krikorian, 1984). Analysis of variance revealed that the interaction effects of variety, BAP and IBA was significant (Variety * BAP * IBA = $p < 0.05$) on the number of shoots per explant, average shoot length (cm) and number of leaves per shoot. The interaction of genotype, BAP and IBA indicated that all the three factors are dependent on each other for *in vitro* shoot proliferation of banana varieties. The maximum number of shoot per explants were obtained on MS medium supplemented with a combination of BAP and IBA at concentrations of 3.5/0.0, 3.0/0.2, and 3.5/0.3 mg/l for Grand Naine, Poyo and Butuza respectively (Table 3, figure 4,5 and 6). Adenine-based cytokinin particularly BAP is the most commonly preferred cytokinin to affect shoot multiplication rate in several *Musa* spp. (Cronauer and Krikorian, 1984; Vuylsteke, 1998). Khatun*et a, 2017* stated the highest shoot number per explant (3.4) with 5.0 mg/L BAP+2.0 mg/L IBA.The formation of multiple shoots and buds in banana varieties were promoted by supplementing the reported with relatively high concentrations of cytokinins. With increase in BAP concentration from 2mg/l to 3.5mg/l numbers of shoots/ explant increased were increased from 4.67 to 12.67, 5.0 to 7.3 and 6.67 to 8.0 in Grand Naine, Poyo and Butuza respectively.The number of shoots increased with the increase of BAP concentration up to 3.5 mg/l and then decreased. Ferdous, M.H *at el* 2015, reported increase of shoots with increase of BAP hormone concentration up to 5mg/l and the decreased. It was experimental that all the explants of banana varieties did not behave similar *in vitro* in terms of multiplication.

Table 2: ANOVA summary of Effect of BAP and IBA on invitro Shoot Multiplication

Source of variation	DF	Mean Square (MS)		
		No of shoots	Shoot length(cm)	No of leaves
IBA	3	30.272*	0.9688*	2.4667 *
BAP	4	29.778**	1.8958**	10.2417*
Varieties	2	5.272*	4.0112*	10.4222 *
IBA*BAP	12	22.041**	0.5957*	2.8231**
IBA* Varieties	6	38.694**	1.4322**	5.9333 **
BAP* Varieties	8	15.015***	0.5073***	3.5750 ***
IBA*BAP* Varieties	24	23.012***	0.5089***	2.5676***
CV%		26.6	22.6	18.2
SE		2.713	0.6898	1.44

DF =Degree of freedom, SE=Standard Error, BAP = 6- Benzylaminopurine, IBA = Indole butyric acid,CV = Coefficient of variation, *=p≤0.05, **=p≤0.01,***=p≤0.001

Table 3: The effect of BAP and BAP on number of shoots per explant, Shoot length and number of leaves per shoot

PGR(mg/l)		Banana Varieties								
		G/Naine			Poyo			Butuza		
BAP	IBA	NS	SL	NL	NS	SL	NL	NS	SL	NL
2.0	0.0	4.67	2.10	3.00	5.00	1.42	3.00	6.67	1.83	1.67
2.5		5.67	1.50	4.00	5.67	1.53	2.33	6.33	2.13	3.33
3.0		6.67	3.42	3.67	6.00	2.03	4.33	8.00	1.73	2.33
3.5		12.67	2.17	3.00	7.33	2.28	2.33	6.00	2.53	3.33
4.0		8.00	1.25	2.33	7.67	2.02	4.33	7.33	2.17	4.33
2.0	0.2	7.00	2.17	3.67	7.33	2.70	2.00	7.00	1.40	3.67
2.5		6.67	1.67	4.33	8.00	1.79	2.00	6.33	2.30	5.33
3.0		5.67	1.13	3.00	13.00	2.15	3.33	9.00	2.02	4.33
3.5		6.00	1.20	4.33	8.67	2.65	2.33	7.00	1.60	5.67
4.0		5.00	2.00	2.67	6.00	2.47	3.67	6.00	2.38	5.00
2.0	0.3	5.33	1.77	1.67	7.67	2.90	3.00	5.00	1.76	2.67
2.5		7.00	1.23	3.00	7.67	2.35	3.33	7.67	1.99	5.00
3.0		5.67	1.37	2.00	8.33	2.50	2.33	9.00	2.77	3.33
3.5		5.00	2.03	4.67	6.67	2.62	4.00	11.33	2.98	6.00
4.0		6.00	2.47	3.67	5.67	2.83	2.00	8.00	2.36	2.00
2.0	0.5	5.67	2.57	3.00	6.00	2.50	3.33	5.67	1.53	2.67
2.5		6.00	1.77	3.00	7.00	2.76	1.67	4.67	1.40	2.67
3.0		7.33	1.80	4.00	5.33	1.94	1.33	5.00	1.61	4.00
3.5		7.00	2.23	6.00	4.67	3.13	3.33	4.67	2.42	4.00
4.0		4.33	2.00	5.00	7.67	3.33	3.67	6.33	2.30	2.67
CV%		16.6	12.6	8.2	16.6	12.6	8.2	16.6	12.6	8.2
SE		2.71	0.69	1.44	2.71	0.69	1.44	2.71	0.69	1.44

Ns=number of shoots, SL=Shoot length, NL=number of leaves

Figure 1: Grand naine shoot initiation on 3mg/l BAP

Figure 2: Poyo shoot initiation on 2.5mg/l BAP

Figure 3: Butuza Shoot Initiation on 2mg/l BAP

Figure 4: Grand naine shoot proliferation on 3.5mg/l BAP

Figure 5 Poyo shoot multiplication on 3mg/l BAP and 0.2mg/l IBA

Figure 6 Butuza Shoot multiplication on 3mg/l BAP and 0.3mg/lIBA

In Vitro Rooting of Shoots:

ANOVA showed significant ($p \leq 0.05$) effect of all main and interaction effect of varieties and, IBA on number of roots per shoot, number of leaves per shoot and shoot length in three varieties indicating the interdependence of these factors on *in vitro* root induction. Fine roots began to be induced from the basal portion of the shoots after 9-11 days in Grandnaine, while 10-13 days in Poyo and Butuza cultivars on treatments fortified with different concentration. Rooting can be stimulated when individual shoots are transferred to a basal medium without any PGR (Cronauer and Krikorian, 1984; Jarret *et al*., 1985). However, auxins induce further root initiation in bananas (Vuylsteke, 1989). Highest numbers of roots (8.0, 7.67 and 8.0) were observed on the medium supplemented with 1mg/l IBA, 1.5mg/l IBA and 2mg/l IBA, for Grandnaine, Poyo and Butuza respectively. While in the control medium produced 4.33, 3.67 and 4.0 roots per shoot for Grandnaine, Poyo and Butuza respectively. These results are in agreement with the findings of Preeti R. *et al*, 2018 who obtained 11 maximum numbers of roots per shoot on 1mg/l IBA for red banana variety. Similarly M.M.H. Molla *et al* 2017 reported maximum number of roots (7.80) in BARI Kola-4 on ½MS medium supplemented with 0.5 mg/l IBA. IBA is known to plays an important role in the formation and development rooting. Root formation and plant regeneration with IBA has been reported by Agastian *et al.* (2006) and Naika and Krishna (2008)

Table 4: Effect of IBA different concentration on *in vitro* rooting and root growth on half MS media

IBA	Name of banana Varieties *Grandnaine*			*Poyo*			*Butuza*		
	NR	NL	RL	NR	NL	RL	NR	NL	RL
0.0	4.33	4.67	4.00	3.67	4.00	3.67	4.00	3.00	3.00
0.5	6.00	2.33	3.00	5.67	5.00	4.33	5.00	4.67	4.00
1.0	8.00	5.00	5.33	4.67	4.67	5.67	5.33	5.33	5.67
1.5	5.00	3.67	4.67	7.67	5.67	6.33	6.33	4.67	4.67
2.0	6.67	4.00	3.67	6.00	3.33	3.33	8.00	7.33	3.67


Figure 7: Grand naine rooting on 1mg/l IBA Figure 8; Poyo shoot rooting on 1.5mg/l IBA

Figure 9: Butuza shoot rooting on 2mg/l IBA

Acclimatization of three banana varieties

After sufficient shoot and root development, the small plantlets were taken out from culture vessel carefully without damaging any roots. Excess media around the root was washed off by running tap water to prevent further microbial infection. *In vitro* rooted plantlets were transferred into plastic tray filled with sterile soil mixtures top forest soil, farm yard manure and sand soil in 2:1:1/2 ratio. Then, plants were later transferred to bigger polybags containing top forest soil and manure in the ratio of 2:1. The hardened plants were finally transferred to the field and successfully established for further evaluation

Banana Varieties								
Grand naine			Poyo			Butuza		
No plant lets potted	No of plantlets survived	% of survival	No plant lets potted	No of plantlets survived	% of survival	No plant lets pot ted	No of plantlets survived	% of survival
300	270	90%	250	230	92%	270	250	92.5%

Conclusions and Recommendations

From the result obtained in the present study, it is concluded that the developed protocol is helpful for rapid *in vitro* propagation of the banana planting materials and hence enhance the availability of healthy and true to type planting materials and accordingly, the information below was obtained. For shoot tip culture initiation and establishment, Grand naine Poyo and Butuza varieties showed best performance on 3.0 mg/L BAP, 2.5 mg/L BAP and 2.0 mg/L BAP respectively, without IBA concentration. A combination of 3.0 mg/LBAP + 0.2 mg/LIBA was the best combination for shoot multiplication of Poyo while 3.5mg/l BAP without IBA and 4.0mg/L BAP + 0.3 mg/l IBA were the most selected combinations for Grand naine and Butuza respectively. For *in vitro* rooting, half strength MS semi-solid medium fortified with 1.0 mg/l IBA alone was best concentration for variety Grandnaine, while half MS medium supplemented with 1.5 mg/L and 2.0mg/lIBA were the best growth regulator concentration for poyo and Butuza respectively.

Based on the results of the present study, the following recommendations were made:

In the future, it will be better to determine optimum volume of liquid medium per a given jar or flasks so as to develop efficient protocols for the above mentioned varieties using Bioreactor system. It is also recommended to optimize protocols for these varieties using other type of plant growth hormone concentration and combination so as to get best multiplication. It is best to use Automatic green house for primary acclimatization of banana plantlets under strictly controlled relative humidity and temperature to reduce loss of plantlets during acclimatization processes.

References

Agastian P, Williams L, IgnacimuthuS(2006).. *In vitro* propagation of *Justiciagendarussa* Burmf.–A medicinal plant. Indian J. Biotechnol.; 5(2): 246–248

Alango Kelta, Sunil T. Hajare and Akilu Banjaw (2018) . Studies on *in vitro* Micropropagation in Banana.*Int.J.Curr.Microbiol.App.Sci7*(7): 3366-3375

Asmare Dagnew, Surafel Shibru, Abel Debebe, Alemshet Lemma, Lemma Dessalegn, Behailu Berhanu, WorkuBeyene and Yulien Miguelez Sierra(2012). Micropropagation of Banana Varieties (*Musa* spp.)Using Shoot-Tip Culture.Ethiop. J. Agric. Sci. 22:14-25.

Bhosale U.P., Dubhashi S.V., Mali N.S. and Rathod H.P. (2011) In *vitro* shoot multiplication in different species of Banana. Asian Journal of Plant Science and Research, 1 (3):23-27.

Cronauer, S.S. and A.D. Krikorian. 1984. Multiplication of *Musa* from excised stem tips. *Annals of Botany*, 53:321-328.

Ferdous, M.H., Billah, A.A.M., Mehraj, H., Taufique, T. and Uddin, A.F.M.J(2015). BAP and IBA pulsing for in vitro multiplication of banana cultivars through shoot-tip culture*J.Biosci. Agric. Res.*, 3(2): 87-95.

J. Lohidas and D. Sujin(2015). Effect of Growth Hormones in the Micropropagation of Banana cv.MattiPlant Archives 15 (1), 307-314.

Kagera, A.G., G.R. Kagera, C.B.M. Kagera, I. Van den Houwe and R. Swennen. (2004). Rapid mass propagation and diffusion of new banana verities among small scale farmers in north western Tanzania.*African Crop Science Journal*, 12(1):7-17

M.M.H. Molla1*, D. Khanam1, Z.A. Firoz2, S.P. Chakma3 S.C. Halder1 and M.A. Salam

(2017). In Vitro Production of Banana Plantlets and their validation at Hill Valleys.*SAARC J. Agri.*,15(1): 67-76.
Madhulatha P et al (2004) Influence of liquid pulse treatment with growth regulators on *in vitro* propagation of banana (*Musa* spp. AAA). Plant Cell Tissue Organ Cult 76:189–192
Naika HR, Krishna V(2008).. Plant regeneration from callus culture of *Clematis gouriana* Roxb.–A rare medicinal plant.Turk. J. Biol.; 32(2):99–103.
Ngomuo, M., Mneney, E. and Ndakidemi, P (2014). The *in vitro* Propagation Techniques for Producing Banana Using Shoot Tip Cultures.*American J. of Plant Sciences*, 5, 1614
Philip Sipen and Michael R Davey(2012).. Effects of N6-benzylaminopurine and Indole Acetic Acid on In Vitro Shoot Multiplication, Nodule-like Meristem Proliferation and Plant Regeneration of Malaysian Bananas (*Musa* spp.)*Tropical Life Sciences Research, 23(2), 67–80*
PreetiRajoriya, Vivek Kumar Singh, Nancy Jaiswal and RohitLall (2018).Optimizing the effect of plant growth regulators on *in vitro* micro propagation of Indian red banana (*Musa acuminata*). Journal of Pharmacognosy and Phytochemistry. 628-634
Robinson, J.C., C. Fraser and K. Eckstein.(1993). A field comparison of conventional suckers with tissue culture banana planting material over three crop cycles. *Journal of Horticultural Science*, 68:831-836.
Stover RH, Simmonds NW. Bananas. Longman, London. Vuylsteke D, De Langhe EA (1985). Feasibility of in vitro propagation of bananas and plantains.*Trop. Agric*. (Trinidad). 62: 323-328.
Tripathi, L. (2003). Genetic engineering for improvement of *Musa* production in Africa. *African Journal of Biotechnology*, 2(12):503-508.
Vulysteke, D.R. 1998. Shoot-tip culture for the propagation, conservation and distribution of *Musa* germplasm. *International Institute of Tropical Agriculture* (IITA), Ibadan, Nigeria.
Y.A. Kaçar,, B. Biçen, İ. Varol, Y.Y. Mendi1,, S. Serçe3 and S. Çetiner. Gelling agents and culture vessels affect *invitro* multiplication of banana plantlets ((2010). *Genetics and Molecular Research* 9 (1): 416-424.
YapaMudiyanselage A.M. Wijerathna, HerathMudiyanselage P.C. Kumarihami. Effects of Different Hormonal Concentrations and Culture Medium on Multiplication and Rooting of Stage II Banana (*Musa cavendishii*) (2016).*Not SciBiol*, , 8(1):69-72. DOI: 10.15835/nsb.8.1.9749.
Al-amin M, Karim MR, Amin MR, Rahman S, Mamun ANM.*In vitro* micropropagation of Banana (*Musa* sp.)(2009). *Bangladesh J. Agril. Res*.; 34(4):645-659.
Azam FMS, Islam S, Rahmatullah M, Zaman A. Clonal propagation of Banana (*Musa* sp.) cultivar 'BARI-1' (AAA genome, sapientum subgroup)(2010). Acta Hort.; 879.
FahimaKhatun, M. E. Hoque, HomayraHuq, Md. Adil,Kh. Ashraf-Uz-Zamanand Mominul Haque Rabin. Effect of BAP and IBA on *in vitro* Regeneration of Local Banana Variety of Sabri(2017)..*BJI, 18(1): 1-10*

Performance Evaluation of Improved Groundnut (*Arachis hypogaea* L) Varieties in Mid Rift Valley of Oromia, Ethiopia

Urgaya Balcha[1]* and Temesgen Dinsa[1]

[1]Adami Tulu Agricultural Research Center, P. O. Box 35, Batu, Ethiopia,

Corresponding author*: urgayab@gmail.com

Abstract

Groundnut (Arachis hypogaea L.) *plays an important role as a food as well as cash crop in Ethiopia. Low production and productivity, which is mainly associated with lack of access to improved varieties, was one of the major problems in groundnut production. Seven groundnut varieties were evaluated in 2019 and 2020 cropping seasons at Dugda, Lume and Adami Tulu districts of East Shoa zone, in the Mid rift valley of Oromia. The trial was laid out in the Randomized Complete Block Design (RCBD) with three replications. To this end, this study was conducted with the objective of evaluating the adaptability of improved groundnut varieties in the experimental areas. AMMI analysis showed that environments, varieties and their interaction effects were significantly different. The stability and high yielding ability of the varieties have been graphically depicted by using the AMMI bi-plot. The variation for seed yield among the varieties was significant at different environments. A variety Bulki was the most stable followed by Babile-2 and local varieties across the studied environments. In GGE bi-plot analysis; IPCA1 and IPCA2 explained 60.8% and 29.1% of variation, respectively, while, groundnut variety by environment interaction and made a total of 89.90% of variation. Based on overall analysis, varieties Bulki (*20.97*qtls ha-1) and Babile2 (*21.08*qtls ha-1) were identified as most stable and thus recommended for production in the study area and simila agro-ecologies.*

Key word: AMMI, Evaluation, Groundnut, Variety

Introduction

Groundnut (*Arachis hypogaea* L.) (2n=4x=40) belongs to the family *Leguminosae*, subfamily *Papilionoidae*, tribe *Aeschnomeneae*, sub-tribe *Stylosanthinae*, genus *Arachis*and species *hypogaea* (Isleib*et al*., 1994). It is stated that the botanical name of groundnut is derived from two Greek words *Arachis* meaning 'legume' and hypogaea meaning 'below ground', referring to the formation of pods in the soil. Ntare (2007) reported that after fertilization, the aerial flowers grow downward and the ovary at the end of the elongated stalk 'peg' enters the soil in a positive geotropic manner where the ovary at the tip of the peg grows into the pod containing the seeds.

Groundnut is an important monoecious annual legume in the world mainly grown for oilseed, food and animal feed (Pande et al., 2003). It is reported that groundnut was introduced to Ethiopia by Italian explorers in 1920s (Adugna,1991). Then first introduced to Hararghe, eastern Ethiopia and later on disseminated to lowlands of western Wollega, Gamogofa,Illubabor,Gojam, Shoa and Wollo (Adugna 1991). In 2019/20 cropping season, the total land coverage of groundnut in Ethiopia is 87,925.23 ha and the annual production is estimated to be 1,565,331.62 quintals with a average productivity of about 17.80 tons ha^{-1} (CSA, 2019/2020). It is the second important lowland oilseed of warm climate, which is relatively new to Ethiopia as compared to sesame. It is an important food and cash crop in the semi-arid areas of the eastern, western, southern and north western parts of Ethiopia (Adugna, 1991) Groundnut is a rich source of energy due to its high oil and protein contents. The oil content of the seed varies depending on the varieties and agronomic conditions. It contains 48-50% oil and 26-28% protein, and a rich source of dietary fiber, minerals, and vitamins. Groundnuts are rich in vitamins and contain at least 13 different types of vitamins that include vitamins A, B, C and E along with these, groundnuts are also rich in 26 essential minerals such as calcium, iron, zinc, boron, etc.(Janila *et al*., 2013). As a legume, groundnut fixes atmospheric nitrogen in soils and thus improves soil fertility and saves fertilizer costs in subsequent crops. This is particularly important when considered in the context of the rising prices of chemical fertilizers which makes it difficult for small scale farmers to purchase them. In livestock farming communities, groundnut can be used as fodder for livestock and increases productivity as the groundnut haulm and seed cake are rich in digestible crude protein content.

Ground nut is among oil crop that has many important value for farmers, private investors and country in general. The production of this valuable crop in Ethiopia is common in East part of the country majorly in Afar and Babile areas. But seeing the reality there are many potential areas favorable for the production of the crops among which central rift valley areas of East Shewa zone having best edaphic and environmental factor that suits for the production of this crop. According to survey result of (ATARC, 2018), sole cropping is dominantly practiced in West Arsi and East Shewa Zones. This practice brought soil infertility problem which leads to low crop production. Therefore producing groundnut in this area has an advantage in crop diversification in helping the reduction of the use of chemical fertilizers and used as fixing atmospheric nitrogen in to usable form.

Even though, groundnut is very important oil crop in our country, its distribution through the country was limited to a certain areas. Besides, many improved varieties were released from research institutions but not well reached to the farmers. Production and the usage of improved seeds is one of the most efficient ways of raising crop production. Lack of access to improved varieties in mid rift valley Ethiopia is the main problem that hampers production of this crop. Therefore, the currently research was initiated with objectives to evaluate groundnut varieties under mid rift valley conditions and to select suitable varieties for this agro ecology.

Materials and Methods

Description of the study area: The experiment was conducted at Adami Tulu, Dugda and Lume Districts. Detailed description of the experimental materials used in this study is indicated in the following table.

Table 1. Lists and descriptions of groundnut varieties used in the experiment

No	Variety	Days to maturity	Areas of adaptation		Yield (tha^{-1})		Released center	Year of release
			Altitude	Rainfall	Research	Farmers		
1	Babile-1	131	750-1650	569-1100	24	19	HU	2016
2	Babile-2	132	750-1650	569-1100	20	18	HU	2016
3	Babile-3	142	750-1650	569-1100	24	17	HU	2016
4	DAMKT-2016	112	740	350-700	25	22	Werer	2016
5	ICGV-94205	144-156	740-1650	740-1370	23	17	Werer	2008
6	ICGV-94222	146-157	740-1650	740-1370	21	18	Werer	2008
7	ICGV-93164	130-155	740-1650	740-1370	26	20	Werer	2008
8	Fetene	115	750-1650	569-740	30	25	Werer	2009
9	BaHa gudo						HU	2012
10	Baha Jido						HU	2012

HU= Haramaya University

Experimental Design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each variety was planted in plot size of 9 m^2 (3 m plot width x 3 m row length) and accommodated five rows at 0.6 m interval. There was 0.1 m distance between plants within a row. The spacing between plots and blocks were 0.5 m and 1 m, respectively. Fertilizer was not apply, but weeding and all other recommended agronomic practice was applied to all locations.

Data Collected

Plant height: The length of the central axis of the stem was measured from the soil surface up to the tip of the stem. Five plants from each plot were randomly taken and measured.

Number of primary branches: The average number of primary branches per plant from five plants was recorded.

Pod length: Using a digital caliper, the length of five pods were measured and recorded in centimeter from each five selected plants.

Number of pods per plant: were determined as the mean value of five randomly selected plants.

Number of seeds per pod: The mean number of seeds per pod was obtained by counting the number of seeds collected from five pods from each five selected plants.

Days to flowering: It was recorded as the number of days from sowing to 50% of the plants in the plot started flowering.

Days to maturity: It was recorded as number of days from sowing to the stage when 90% of pods matured.

Dry pod yield (kg/ha): This was measured after harvesting the whole pods from the net plot and converted to kilograms per hectare after sun drying.

100-seed weight: It was recorded by counting hundred seeds from a bulk of shelled seeds and weighed using a sensitive balance.

Data Analysis

All the data were subjected to ANOVA by using the GLM Procedure of R Software(R, 2018). Mean separation was performed at $P<0.05$ using least significant difference (LSD).

Results and Discussions

Additive Main Effects and Multiple Interaction (AMMI) model ANOVA

The AMMI analysis can be used to diagnose whether a specific sub-case provides a more appropriate analysis. AMMI has no specific experimental design requirements, except for a two way data structure. The results of AMMI model for seed yield are presented in Table 2. Mean square of the first IPCA was highly significant ($p<0.001$) and significant for PC2. The first PC axis (PC1) score explained 60.8% of the variation in GEI, while the second PC axes accounted for 29.1% of the variability. Many researchers witnessed that the best accurate AMMI model prediction can be made using the first two IPCAs. Therefore, the dataset obtained from the interaction of seven varieties tested at 6 environments was best predicted by the first two IPCAs.

Table 2: AMMI ANOVA of Grain yield (Qtl/ha) for Ground varieties over locations

Sources of variation	Df	Sum Sq	Mean Sq	F value	Pr(>F)	Explained (%)
Environment (E)	5	527.1644	105.4329**	5.682682	0.006475	37.71
Replication/E	12	222.6404	18.55337**	2.652501	0.005339	15.92
Genotype (G)	6	180.2844	30.04741^{ns}	1.926211	0.108908	12.9
GxE	30	467.9769	15.59923**	2.23016	0.002937	33.47
PC1	10	284.3933	28.43933***	4.07	0.0002	60.8
PC2	8	136.3459	17.04324**	2.44	0.0215	29.1
PC3	6	28.2315	4.70525^{ns}	0.67	0.6741	6
PC4	4	13.75828	3.439571^{ns}	0.49	0.743	2.9
PC5	2	5.247951	2.623976^{ns}	0.38	0.6852	1.1
Residuals	72	503.6162	6.99467	#N/A	#N/A	

Analysis of Variance (ANOVA) was done for grain yield and other nine yield related traits mentioned below. Mean square of analysis of variance for all varieties at different environmental conditions for grain yield and yield related traits are presented in Table 3. The combined analysis of variance showed that year and location effects were significant for all parameters. Location by variety was highly significant for grain yield. Loc*Year were highly significant for Number of primary branches, Plant height, pod length, seed per pod and grain yield. Loc*Year*Varieties were highly significant for number of primary branches and grain yield. This suggests that grain yield of ground nut varieties varies across environmental conditions.

Table 3: Mean square values of yield and yield components of groundnut varieties combined over location

Source of variation	DF	Mean squares									
		DF	DM	NPB	PH	PL	PP	SPP	ShP	HSW	Yld
Rep	2	0.21^{ns}	3.51	0.12^{ns}	22.23^{ns}	0.10^{ns}	732.51^{ns}	0.01^{ns}	4274.14^{ns}	3.50^{ns}	9.76^{ns}
Loc	2	0.09^{ns}	0.83	3.95^{ns}	123.95***	1.85**	1168.98***	0.51***	164.84^{ns}	1.59^{ns}	16.94^{ns}
Year	1	0.21^{ns}	1.99^{ns}	679.25***	1495.16***	0.20^{ns}	172.13^{ns}	0.65**	1775.6***	3.50^{ns}	9.38***
Variety	6	23.75***	91***	1.21^{ns}	7.07^{ns}	0.32^{ns}	81.42^{ns}	0.09^{ns}	203.49^{ns}	713.77***	30.05***
Loc*Variety	12	0.09^{ns}	1.65^{ns}	4.48^{ns}	5.84^{ns}	0.34^{ns}	63.67^{ns}	0.07^{ns}	69.89^{ns}	1.46^{ns}	21.20***
Loc*Year	2	0.09^{ns}	4.64	32.78***	113.14***	1.33**	210.03^{ns}	0.80***	87.85^{ns}	1.59^{ns}	179.86**
Year Variety	6	0.09^{ns}	1.14	1.76^{ns}	23.25^{ns}	0.63^{ns}	25.75^{ns}	0.07^{ns}	0.79^{ns}	1.53^{ns}	4.24^{ns}
Loc*year*Variety	12	0.09^{ns}	2.38	6.05**	12.65^{ns}	0.40^{ns}	43.28^{ns}	0.06^{ns}	26.75^{ns}	1.46^{ns}	15.68*
Error	82	0.09	2.06	3.10	16.35	0.45	75.01	0.09	136.48	1.54	8.61
CV (%)		0.69	1.03	27.58	8.79	20.72	17.64	10.00	17.90	1.72	15.22
LSD		6.6	4.8	1.86	7.6	4.2	3.8	5.6	9.6	4.4	5.43

Where: ***= Very highly Significant at $p \leq 0.001$, ***= highly Significant at $p \leq 0.01$, *= Significant at ≤ 0.05, ns= not Significant at ≤ 0.05, *Means with the same letter are not significantly different. DF = Days to 50% Flowering, DM = Days to 90% maturity PH = Plant height, NBR =Number of primary branches per stand, PL= Pod length, PP= Number of pods per plant, SPP =Seed per pod, ShP= Shelling percentage, HSW =Hundred seed weight, Yld =yield per hectare (Qt), CV(%) = Coefficient of Variation, LSD= Least Significant difference

Mean performance of the varieties for the characters

Range and mean values for the eight characters are presented in Table 4. The variation with respect to days to flowering and days to maturity was ranged from 43.34 to 46.31 and 136.60 to 143.14 respectively, showing a wide range of variation among the varieties for maturity. Based the study result, the early maturing varieties were Baha Jido and Bulki while the variety with the longest days to mature was Roba. There is no significance difference for number of pods per plant, plant height, pod length and seeds per pod. The highest number of primary branches, plant height, pod length, pods per plant, seeds per pod and shelling percentages were recorded by variety Bulki. The highest yield was recorded by Babile-2 (21.08) variety and followed by Bulki (20.97) and local check (19.27) varieties.

The results of this work is in harmony with the finding of (Habte *et al.* 2020) who reported that the highest grain yield of groundnut was recorded for the variety Bulki and Babile in east Hararghe zone.

Table 4: Combined mean values of 7 Groundnut varieties for grain yield and other agronomic characters at Adami Tulu, Dugda and Lume, during 2019-2020

S.N	Varieties	DF	DM	NPB	PH	PL	PP	SPP	ShP	HSW	Yld
1	Babile2	43.95^{d}	140.94^{a}	6.29^{a}	45.76^{a}	3.11^{a}	49.89^{ab}	3.08^{a}	67.85^{ab}	79.83^{a}	21.08^{a}
2	Baha Jido	43.34^{e}	136.60^{f}	6.63^{a}	45.43^{a}	3.21^{a}	48.24^{a}	3.10^{a}	61.85^{ab}	73.38^{d}	18.87^{b}
3	Bulki	45.73^{b}	137.44^{ef}	5.98^{a}	46.36^{a}	3.50^{a}	52.16^{a}	3.17^{a}	69.12^{a}	64.94^{f}	20.97^{a}
4	Local	43.76^{d}	139.25^{c}	6.57^{a}	46.85^{a}	3.20^{a}	49.58^{ab}	3.10^{a}	68.32^{a}	77.05^{c}	19.27^{ab}
5	Roba	45.50^{c}	143.14^{a}	6.18^{a}	45.40^{a}	3.14^{a}	49.17^{ab}	3.08^{a}	63.88^{ab}	78.00^{b}	18.55^{b}
6	Werer961	45.41^{c}	137.99^{de}	6.35^{a}	46.65^{a}	3.32^{a}	45.17^{b}	3.14^{a}	60.44^{b}	67.66^{e}	17.63^{b}
7	Werer962	46.31^{a}	138.57^{dc}	6.69^{a}	45.41^{a}	3.29^{a}	48.73^{ab}	3.28a	65.33^{ab}	65.27^{f}	18.59^{b}
Mean		44.86	139.13	6.38	45.98	3.25	49.09	3.14	65.26	72.30	19.28
CV (%)		0.69	1.03	27.58	8.79	20.72	17.64	10.00	17.90	1.72	15.22
LSD		6.6	4.8	1.86	7.6	4.2	3.8	5.6	9.6	4.4	5.43

Where: *Means with the same letter are not significantly different. DF = Days to 50% Flowering, DM = Days to 90% maturity PH = Plant height, NBR =Number of primary branches per stand, PL= Pod length, PP= Number of pods per plant, SPP =Seed per pod, ShP= Shelling percentage, HSW =Hundred seed weight, Yld =yield per hectare (Qt), CV(%) = Coefficient of Variation, LSD= Least Significant difference

AMMI biplot analysis

The interaction principal component (IPCA-1) was plotted in the x-axis whereas the interaction principal component two (IPCA-2) plotted in the y-axis (Figure 1). The AMMI analysis for the first interaction principal component (IPC-1) captured 60.8% and the second interaction principal(IPC-2) component explained 29.1%, the two interaction principal components cumulatively captured 89.9% of the sum of square the genotypes by environment interaction of groundnut varieties, when the interaction principal component (IPCA1) was plotted against IPCA2 , Purchase (1997) pointed out that the closer to the center of the biplot the more stable is the genotype and the vice versa. Accordingly, varieties such as Bulki, Babile-2 and Local were located near to the origin implying that these varieties were stable groundnut varieties in this study.

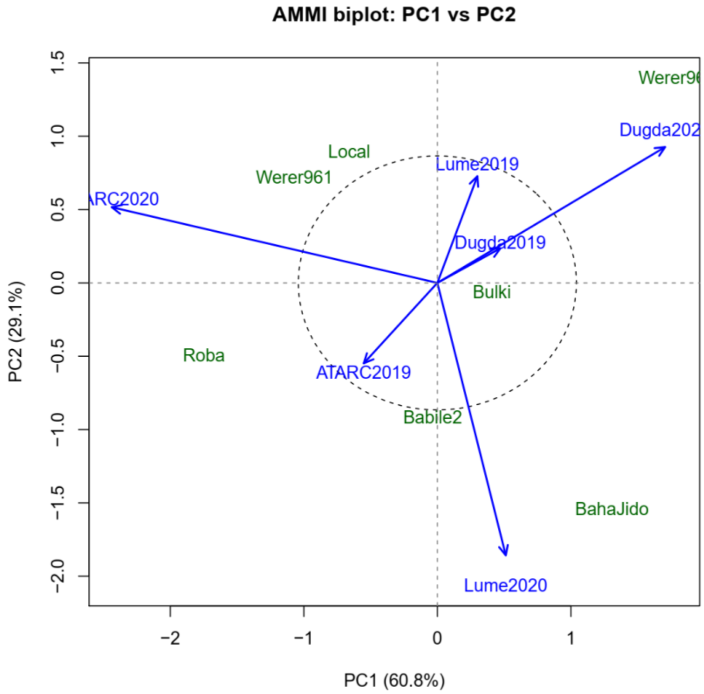


Figure 1: Biplot analysis of GEI based on AMMI for IPCA 1 and IPCA 2 score and mean grain yield of seven varieties at six environments.

Summary and Conclusions

Generally, the present study entails the presence of significant variations among groundnut varieties. Based on the combined analysis result, the varieties Bulki and Babile-2 showed better performance over the other varieties with respect to seed yield. AMMI analysis, regression coefficient, deviation from regression and GG biplot results also revealed that Bulki and Babile-2 varieties were relatively stable varieties. Accordingly these two varieties are recommended for the study area and similar agro ecologies. Hence if the above mentioned varieties are demonstrated and popularized to the small scale holder farmers and commercial farms they can boost the income of poor farmers and commercial farms.

Acknowledgement

The authors would like to acknowledge Oromia Agricultural Research Institute (OARI) for funding during 2019/20 to 2020/21 and Adami Tulu Agricultural Research Center for facilitating the working conditions throughout the research period.

References

AdugnaWakjira, 1991. A review of the recent groundnut breeding activities in Ethiopia. Paper Presented at the first national oil seed workshop, 3-5 Dec 1991, Addis Ababa Ethiopia.

CSA (Central Statistical Agency). 2016. Federal Democratic Republic of Ethiopia: Central Statistics Agency. Agricultural Sample Survey 2015/2016 (2008 E.C.) (September January 2015/2016). Volume VII. Report on Crop and Livestock Product Utilization (Private Peasant Holding, *Meher*Season). Statistical Bulletin No.586. Addis Ababa, July, 2016. Pp.135.

Isleib, T.G., Wynne, J.C., and Nigam, S.N. 1994. Groundnut breeding, In: the groundnut crop. J.Smartt (ed.) Chapman and Hall, London, U.K., pp. 552-623

Ntare, B.R., Diallo, A.T., Ndjeunga, J. and Waliyar, F. 2007. Groundnut Seed Production Manual. pp. 24

Pande S, Bandyopadhyay R, Blümmel M, NarayanaRao J, Thomas D, Navi SS (2003). Disease management factors influencing yield and quality of sorghum and groundnut crop residues. Field Crops Res. 84(1-2): 89-103

R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.URL https://www.R-project.org/.

CSA (Central Statistics Agency). Agricultural Sample Survey 2019/2020 (2012 E.C.). Report on Area and Production of Major Crops (Private Peasant Holdings, *Meher* Season). Volume I Addis Ababa, Ethiopia (2020).

Purchase J L (1997). Parametric analysis to describe genotype environment interaction and yield stability in winter wheat. Ph.D. Thesis, Department of Agronomy, Faculty of Agriculture of the University of the Free State, Bloemfontein, South Africa.

Habte Berhanu, Adugna Hunduma, Motuma Dalasa and Abebe Getachew (2020). Performance evaluation of Groundnut Varieties in Eastern Parts of Ethiopia. In the Proceedings of Review Workshop on Completed Research Activities of Crop Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Oromia, Ethiopia 2020. pp: 198-206

Appendix

Appendix Table 1: Mean yield (qtls/ha) of seven groundnut varieties over years and locations

S.N	Varieties	Adami Tulu		Dugda		Lume		Comm. Mean
		2019	2020	2019	2020	2019	2020	
1	Babile2	20.91	22.56	17.37	21.07	22.62	22.01	21.09
2	Baha Jido	17.11	16.04	17.59	18.21	22.39	21.88	18.87
3	Bulki	18.00	22.20	18.65	21.82	24.08	21.09	20.97
4	Local	17.64	22.79	17.95	18.38	22.92	15.97	19.27
5	Roba	17.04	24.62	14.84	14.97	21.38	18.50	18.56
6	Werer961	16.27	21.93	14.93	15.70	22.23	14.72	17.63
7	Werer962	14.68	16.93	16.82	23.16	23.81	16.17	18.59
	Env. Mean	17.38	21.01	16.88	19.04	22.78	18.62	19.28
	LSD 0.05	2.86	4.10	2.61	3.56	4.61	4.81	1.47
	CV (%)	11.33	13.41	10.61	12.84	13.92	17.75	13.71

Appendix Table 2. Regression coefficient (bi) and squared deviation from linearity of regression (s2di) by the test varieties revealed using Eberhart and Russell model.

	Genotype	Yi	CVi	Bi	P_bi	s2di	P_s2di	Wi2	Di	StabVar	YSi
1	Babile2	21.09	9.3	0.66 ns	0.078	-0.26 ns	0.474	11.19	5.78	6.28	9
2	Baha Jido	18.87	13.95	0.48**	0.009	4.88*	0.021	35.68	7.35	26.85	-5
3	Bulki	20.97	10.89	0.95 ns	0.803	-1.51 ns	0.842	3.33	5.33	-0.32	8
4	Local	19.27	15.01	1.10 ns	0.604	0.58 ns	0.299	11.87	6.06	6.85	4
5	Roba	18.56	20.7	1.32 ns	0.097	5.22*	0.017	32.73	7.44	24.37	-7
6	Werer961	17.63	19.81	1.39*	0.042	0.73 ns	0.274	16.13	6.11	10.43	-1
7	Werer962	18.59	20.84	1.10 ns	0.601	8.88**	0.002	45.07	8.36	34.74	-6

Evaluation of Improved Haricot Bean (*Phaseolus vulgaris* L) Varieties at East Shoa, Mid rift valley of Oromia

Urgaya Balcha[1]* and Temesgen Dinsa[1]

[1]Adami Tulu Agricultural Research Center, P. O. Box 35, Batu, Ethiopia,

Corresponding author*: urgayab@gmail.com

Abstract

Haricot bean (Phaseolus vulgaris L.) is one of the most important food legumes of Ethiopia and it is considered as the main cash crop and the least expensive source of protein for the farmers in many lowlands and mid altitude of the country. Low production and productivity, which is mainly associated with lack of access to improved varieties, was one of the major problems in haricot bean production. Seven haricot bean (Phaseolus vulgaris L.) varieties and one local check were evaluated in 2019 and 2020 cropping seasons at Dugda, Lume and Adami Tulu districts of East Shoa zone, Mid rift valley of Oromia. The trial was laid out in the randomized complete block design with three replications. Combined analysis of variance (ANOVA) showed significant variability among varieties for all the parameters studied such as days to heading, days to maturity, number of pods/plant, number of seeds/pod, plant height and seed yield. The varieties Awash-2 and Sikiya were found to be high yielding varieties with mean seed yield levels of 24.02 and 23.35 qtls ha-1, respectively. Therefore these two varieties are recommended for production in the study area and similar environments.

Keywords: Haricot bean, Seed yield, Variety, Evaluation

Introduction

Haricot bean (*Phaseolus vulgaris* L.) is an important pulse crop in Ethiopia and in the world. The crop ranks first globally while it stands second next to faba bean in Ethiopia (Walelign W., 2017). Common bean (*Phaseolus vulgaris* L.) is an annual herbaceous plant domesticated independently in ancient Mesoamerica and in the Andes, and now is grown worldwide for both dry seeds or as a green bean. Apart from providing the subsistence needs such as food to many people in the world, beans are also sold in local markets and urban areas to provide cash to farmers and traders. Of the five domesticated species of Phaseolus, the common bean (*P. vulgaris*) is the most widely grown, occupying more than 85% of production area sown to all Phaseolus species in the world (Fekadu, 2007). It is produced primarily in tropical low-income countries, which account for over three quarters of the annual world production.

Haricot bean (*Phaseolus vulgaris* L.) is one of the most important food legumes of Ethiopia and it is considered as the main cash crop and the least expensive source of protein for the farmers in many lowlands and mid altitude of the country. In Ethiopia, population is growing in more rate than the agricultural production does. To feed this increasing population the agricultural production should grow accordingly with the same pace or even more. Pulses crops are the most important crops in the national strategy of food self-reliance and foreign exchange earnings. Therefore, to increase the productivity of the farmers, it is crucial to increase the awareness of farmers towards the usage of different improved technologies that increase their production and accelerate food security through proper implementation. The national average productivity of haricot bean is about 18.22 tons ha^{-1} for white haricot bean and 16.79 tons ha^{-1} red haricot bean (CSA, 2019/2020). Access to new and improved agricultural technologies is limited in East Shewa zone particularly in the study areas, most probably due to lack of involvement of our center to do any research on pulse crops including haricot bean and others. Currently there are several new varieties released in our country which are expected to be best for our mandate areas. So far, the national and regional research institutions in the country have released many varieties for commercial production. However, these technologies did not tested for their adaptability potential under mid rift valley part of Oromia and did not reach the smallholder farmers living in mid rift valley parts of Oromia. Therefore, to overcome the above stated problems and to acquaint smallholder farmers with new technologies, introduction and evaluation of widely grown pulse crops including haricot bean varieties has paramount importance.

Materials and Methods

Description of the study area: The experiment was conducted at Adami Tulu, Dugda and Lume Districts.

Experimental materials and design: The eight newly released determinate type haricot bean varieties were used. The Randomized Complete Block Design with three replications was used. Experimental unit comprised five rows of 3 meters length with row-to-row distance of 40 cm and plant-to-plant distance of 10 cm.

Table 1: Lists and descriptions of haricot bean varieties used in the experiment.

No	Variety	Days to maturity	Areas of adaptation		Yield (tha^{-1})		Released center	Year of release
			Altitude	Rainfall	Research	Farmers		
1	SCR-26-26	75-90	1300-1900	500-1100	25-31	18-27	Hawassa	2017
2	Fetenech	75-90	1300-1900	500-1100	26	20	Hawassa	2017
3	Gorossa	89	1100-1950	500-850	17-27	17-23	Melkasa	2017
4	Awash Mitin	94	1100-2100	500-1100	20-25	19-23	Melkasa	2017
5	Derash	94	1000-1850	500-750	21	19-21	Melkasa	2017
6	Zoasho	87	1100-1950	500-850	19-24	21	Melkasa	2017
7	Awash-2						Melkasa	2013
8	Awash-1						Melkasa	1990

Data collected

Days to flowering: was recorded as the number of days from sowing to when 50% of plants in a net plot produced flower through visual observation.

Days to physiological maturity: This was recorded as the number of days from sowing to the time when about 90% of the plants in a plot had mature pods in their upper parts with pods in the lower parts of the plants turning yellow. The yellowness and drying of leaves were used as indication of physiological maturity.

Plant height: It was measured as the height (cm) of ten randomly taken plants from the ground level to the apex of each plant at the time of physiological maturity from the net plot area and the means were recorded as plant height.

Number of pods per plant: Number of pods were counted from ten randomly taken plants from the net plot area at harvest and the means were recorded as number of total pods per plant.

Number of seeds per pod: It was recorded from ten randomly taken pods from each net plot at harvest.

Grain yield (qt ha-1): The four central rows were threshed to determine seed yield and the seed yield was adjusted to moisture level of 10%. Finally, yield per plot were converted to per hectare basis and the average yield was reported in kg ha-1

Statistical Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the General Linear Model (GLM) of SAS software (Version 9.3) and the interpretations were made following the procedure described by Gomez and Gomez. Least Significance Difference (LSD) test at 5% probability level was used for mean comparison when the ANOVA result showed significant differences.

Results and Discussions

Analysis of Variance

The collected data were analyzed using SAS statistical package software (SAS, 2006 version 9.3). Analysis of Variance (ANOVA) was done for grain yield and other six yield related traits indicated above. Mean square of analysis of variance for all genotypes at different environmental conditions for grain yield and yield related traits are presented in Table 2. The combined analysis of variance showed that year and location effects were significant for all parameters. Year*variety effects were highly significant for plant height and grain yield. Loc*Year*Varieties were highly significant for plant height and grain yield. Location by variety effects were highly significant only for plant height and non significant for all other traits including yield. This suggests that grain yield of haricot bean varieties did not vary across environmental conditions.

Table 2: Mean Square values from ANOVA for Haricot bean Parameters

Source	DF	DH	DM	PH	NPB	NPP	SPP	Yld
Rep	2	157.54 ^{ns}	134.89 ^{ns}	103.99 ^{ns}	1.42 ^{ns}	23.20 ^{ns}	1.55 ^{ns}	16.20 ^{ns}
Loc	2	57.92***	6.27 ^{ns}	2287.1***	7.50***	1095.21**	0.01 ^{ns}	146.4*
Year	1	4.34 ^{ns}	52.56***	20175.8**	128.82**	160.86*	0.02 ^{ns}	389***
Variety	7	145.86**	417.45**	1192.08**	1.08*	346.02***	1.47 ^{ns}	173.2*
Loc*Variety	14	0.70 ^{ns}	0.95 ^{ns}	132.73***	0.50 ^{ns}	33.53 ^{ns}	0.81 ^{ns}	10.96 ^{ns}
Loc*Year	2	246.6***	20.02*	870.57***	19.32***	639.60***	4.10*	41.50*
Year*Variety	7	1.30 ^{ns}	1.41 ^{ns}	397.40***	0.50 ^{ns}	54.24*	1.17 ^{ns}	39.9**
Loc*Year*V	14	1.77 ^{ns}	0.87 ^{ns}	195.02***	0.26 ^{ns}	33.48 ^{ns}	1.30 ^{ns}	12.63 ^{ns}
Error		6.95	6.70	56.77	0.44	24.91	0.95	10.36
R^2		0.75	0.84	0.88	0.83	0.75	0.40	0.73
CV		5.57	2.85	13.11	17.10	21.50	16.88	15.98
Root MSE		2.63	2.58	7.52	0.66	4.99	0.97	3.21
Mean		47.32	90.64	57.34	3.90	23.2	5.77	20.14

Where CV=Coefficient of Variation, R^2= R-Square, DF=Degree of freedom, DH= Days to heading, DM=Days to maturity, PH=Plant height in cm, NPB=Number of primary branches, PP=Number of pods per plant, SPP= Number of seeds per pod, Yld= Yield in quintals per hectare

Mean performance of the varieties for the characters

Range and mean values for the eight characters are presented in Tables 3. The variation with respect to days to heading and days to maturity was ranged from 42.16 to 51.94 and 80.50 to 96.66 respectively, showing a wide range of variation among the varieties for maturity. Based the study result the early maturing variety was Derash and the variety with the longest days of maturity was SCR-26-26(Sikiya). The plant height ranges from 46.13(Derash) to 68.00(Awash-2). The highest number of pods per plant, seeds per pod and yield was recorded by the variety Awash-2. The highest yield was recorded by variety Awash-2(24.02) followed by Sikiya (23.35) and Awash -2 (25.68), whereas the lowest yield was recorded by variety Derash (16.37). This work is in harmony with the finding of (Motuma *et al.* 2020) who reported that the highest grain yield of Market type haricot bean was recorded for the variety Awash-2 in east Hararghe zone.

Table 3: Mean Values of each Haricot bean varieties

		DH	DM	PH	NPB	NPP	SPP	Yld	Rank
1	SCR-26-26(Sikiya)	51.94 ^{a}	96.66 ^{a}	63.63 ^{ab}	3.62 ^{cd}	20.50 ^{b}	5.85 ^{ab}	23.35 ^{a}	2
2	Awash-2	47.55 ^{c}	91.11 ^{c}	68.00 ^{a}	3.68 ^{bcd}	28.92 ^{a}	6.24 ^{a}	24.02 ^{a}	1
3	Awash-1	48.00 ^{bc}	91.38 ^{c}	64.08 ^{ab}	3.55 ^{d}	27.41 ^{a}	5.90 ^{ab}	22.68 ^{a}	3
4	Awash Mitin	46.66 ^{cd}	87.94 ^{d}	58.23 ^{c}	4.00 ^{abc}	28.80 ^{a}	6.04 ^{ab}	20.41 ^{b}	5
5	Derash	42.16 ^{e}	80.50 ^{e}	46.13 ^{d}	4.05 ^{abc}	18.60 ^{b}	5.66 ^{ab}	16.37 ^{b}	8
6	Gorossa	47.55 ^{c}	93.27 ^{b}	49.76 ^{d}	4.11 ^{ab}	19.63 ^{b}	5.42 ^{b}	17.14 ^{c}	6
7	Zo-asho	49.33 ^{b}	93.50 ^{b}	60.11 ^{c}	4.06 ^{ab}	20.18 ^{b}	5.57 ^{b}	20.51 ^{c}	4
8	DAB-277	45.38 ^{d}	90.77 ^{c}	48.76 ^{d}	4.17 ^{a}	21.62 ^{b}	5.48 ^{b}	16.37 ^{c}	7

Where DH= Days to heading, DM=Days to maturity, PH=Plant height in cm, NPB=Number of primary branches, PP=Number of pods per plant, SPP= Number of seeds per pod, Yld= Yield in quintals per hectare

Summary and Conclusions

Generally, the present study entails the presence of significant variations among haricot bean varieties. Based on the combined analysis result, the varieties Awash-2 and Sikiya offered better performance over the other varieties regarding seed yield. Accordingly, these two varieties are recommended for production in the study area and similar agro ecologies. Hence if the above mentioned varieties are demonstrated and popularized to the small scale holder farmers and commercial farms they can boost the income of poor farmers and commercial farms.

Acknowledgment

The authors would like to acknowledge AGP-II for funding during 2019/20 and Oromia Agricultural Research Institute (OARI) for funding during 2020/21 and Adami Tulu Agricultural Research Center for facilitating the working conditions throughout the research period.

References

CSA (Central Statistics Agency). Agricultural Sample Survey 2019/2020 (2012 E.C.). Report on Area and Production of Major Crops (Private Peasant Holdings, *Meher* Season). Volume I Addis Ababa, Ethiopia (2020).

Fekadu Gurmu. 2007. Participatory Varietal Selection of Haricot Bean (Phaseolus vulgaris L.) Varieties in UmbulloWacho and Beresa Watersheds in the Southern Region. In: Operational Research and Capacity Building for Food Security and Sustainable Livelihoods. Proceedings of Irish Aid Supported OperationalResearch Review Workshop 11-13 January 2007. Hawassa University, Awassa, Ethiopia..

Motuma Dalasa, Habte Berhanu and Adugna Hunduma(2020) Adaptation trial of Market Types Common Bean(*Phaseolus Vulgaris* L.) Varieties in Eastern Hararghe Zone, Oromia. In the Proceedings of Review Workshop on Completed Research Activities of Crop Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Oromia,Ethiopia 2020. pp: 251-56

R Core Team (2018). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.URL https://www.R-project.org/.

SAS., 2003. SAS Online Doc, Version 9.3. SAS Institute Inc., Cary NC., USA

Shumi D, Alemayehu D, Afeta T, Debelo B. Effect of Phosphorus Rates in Blended Fertilizer (NPS) and Row Spacing on Production of Bushy Type Common Bean (Phaseolus Vulgaris L.) at Mid-land of Guji, Southern Ethiopia. J Plant Biol Soil Health. 2018;5(1): 7.

Talekar N.S. (2000). Chinese cabbage. Proceedings of the 1st International Symposium on Chinese Cabbages. AVRDC, Shanhua, Tainan, Taiwan. pp. 67-69.

WalelignWorku. 2017. Haricot Bean Production Guide: with emphasis on southern Ethiopia

Appendix

Appendix Table 1. Mean Values of each Haricot bean varieties at each years and Locations

	Location	DH	DM	PH	NPB	NPP	SPP	Yld
1	A/Tullu	46.29^{b}	90.25^{a}	52.35^{b}	3.73^{b}	28.61^{b}	5.78^{a}	22.1^{a}
2	Dugda	48.47^{a}	90.72^{a}	65.22^{a}	4.36^{a}	21.45^{a}	5.78^{a}	19.58^{b}
3	Lume	47.20^{b}	90.95^{a}	54.45^{b}	3.63^{b}	19.56^{b}	5.75^{a}	18.75^{c}
	Mean	47.32	90.64	57.34	3.90	23.20	5.77	20.15

Appendix Table 2: Mean Values of each Haricot bean varieties at each years and Locations

S.N	Variety	2019 A/Tullu	Dugda	Lume	2020 A/Tullu	Dugda	Lume	Com. Mean
1	Awash-1	24.32	26.24	24.54	22.08	20.42	18.49	22.68
2	Awash-2	24.92	26.32	20.36	24.66	24.39	23.47	24.02
3	Awash Mitin	19.54	28.38	14.51	22.45	19.85	17.78	20.42
4	DAB-277	15.90	22.13	14.27	18.47	11.30	17.85	16.65
5	Derash	17.23	17.89	11.74	20.15	15.30	15.96	16.38
6	Gorossa	13.81	21.82	15.81	20.09	14.14	17.22	17.15
7	SCR-26-26	22.74	25.39	22.74	21.51	25.51	22.24	23.36
8	Zo-Asho	19.81	27.25	16.47	23.43	14.43	21.68	20.51
Env. Mean		19.78	24.43	17.55	21.61	18.17	19.34	20.15

Performance Evaluation of Improved Soya Bean (*Glycine max* (L.) Varieties in Districts of East Shoa Zone

Temesgen Dinsa* and Urgaya Balcha,
Adami Tulu Agricultural Research Center, P.O. Box 35, Batu, Ethiopia
*Corresponding author: temesgendinsa@gmail.com

Abstract

The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC), Lume and Dugda Districts during 2019 and2020 main cropping seasons with the objective to identify adaptable and high yielding soya bean variety/ies for East Shewa Zone. Ten released soya bean varieties were used as a planting material. The experiment was laid down in Randomized Complete Block Design (RCBD) with three replications. The plot size was 3m × 3 m (9 m^2) having 5 rows and a spacing of 0.60 m between rows and 0.50 m between replications, 1 m between blocks. Data on plant height(cm), number of pods per plant, number of seeds per pod, days to flowering, days to maturity, grain yield (kg ha^{-1}), were collected and analyzed. The genotype and environment main effects and genotype x environment interaction effect were significant on soya bean varieties. AMMI model shows environment accounted 47.68%, GXE 20.56%, genotype 15.22% of the total variation. The high percentage of environment is an indication that the major factor that influence yield performance of soybean in the study area is the environment. The first two IPCAs are the most accurate model that could be predicted the stability of the genotype and each explained 30.34% and 25.83% respectively of the total variation in GEI. According, to the results of stability parameters (ASV, and GGE- Biplot) and mean yield it revealed that Gozella and Davis varieties are the most stable varieties across test location. Therefore, Gozella and Davis were recommended for production in the study area and similar agro-ecologies.

Key words: Soya bean, Genotype by Environment Interaction, Stability, AMMI, GGE-Biplot

Introduction

Soya bean [*Glycine max* (L.) Merrill] is an important source of edible vegetable oil and protein for both humans and animals; and it improves soil fertility by fixing atmospheric nitrogen (Worku and Astatkie, 2011). In the International trade market, soybean ranks number one among the major oil crops with an average protein contents of 40% on dry matter basis. It has the highest protein contents of all field crops and is second only to groundnut in terms of oil content (20%) among the food legumes. Dugje *et al.* (2009) reported that soybean is more protein rich than any of common vegetable or legume food sources in Africa.

The introduction of soybean crop to Ethiopia dated back to 1950s with the objective of supplementing the diet of Ethiopians especially during long periods of partial fasting (Asrat 1965). The first effort made under research was to conduct adaptation trial of recommended varieties along with recommended cultural practices in some parts of the country. Soybean breeding program in Ethiopia relies at first place on selecting of varieties with good yield and secondly for classifying Varieties based on maturity groups (early, medium, and late) to identify environments that the Varieties are best adaption**.** It is an ideal crop for improved nutrition, food security, sustainable crop production and suitable in livestock integration systems. Production and the usage of improved seeds is one of the most efficient ways of raising crop production. Even though, soya bean is very important oil crop in our country, its distribution through the country was limited to a certain areas. And also many improved soya bean varieties were released from research institutions but not well reached to the farmers. Adaptation study of the released varieties by different institution/ research centers/ is the good approach in selection the best variety/ies which solve the limitation of improved seed distribution. Therefore, the objective of this study was to identify the adaptability of improved soya bean varieties that gives best yield for the study area and similar agro ecologies.

Materials & Methods

Experimental Material

Table 1.Lists and descriptions of soybean varieties were used in the experiment

No	Variety	Maturity	Areas of adaptation	Yield (tha^{-1})	Released center	Year of release
1	NYALA	90-108	Short season growing Agro ecology	18.1	PARC	2014
2	NOVA	90-108	Short season growing Agro ecology	22.5	HwARC	2012
3	WILLIAMS	90-108	Short season growing Agro ecology	19-32	PARC	2012
4	PAWE- 01	100-120	Mid altitude Agro ecology	24.4	PARC	2012
5	PAWE- 02	100-120	Mid altitude Agro ecology	25.5	PARC	2012
6	GOZELLA	90-108	Short season growing Agro ecology	20.2	PARC	2010
7	WELLO	100-120	Mid altitude Agro ecology	19-32	PARC	2012
8	DAVIS	100-120	Mid altitude Agro ecology	25-30	PARC	2010
9	BOSHE	100-110	Short season growing Agro ecology	-	BARC	2003
10	JALALE	100-100	Short season growing Agro ecology	-	BARC	2008

Key; PARC= Pawe Agricultural Research Centre, HwARC = Hawassa Agricultural Research Center, BARC = Bako Agricultural Research Centre

Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The study was conducted at Adami Tulu, Lume and Dudga Districts. Experimental unit comprised five rows of 3 meters length with row-to-row distance of 60 cm and plant-to-plant distance of 5 cm. Weeding and all other recommended agronomic practice was followed for all locations.

Data collection

Data collected on plant basis

Plant height: The length of the central axis of the stem was measured from the soil surface up to the tip of the stem.

Number of primary branches: The average number of branches per plant was counted.

Pod length: The length of pods was measured using meters and recorded in centimeter from each five sampled plants.

Number of pods per plant: Were determined by counting total number of pods per plant.

Number of seeds per pod: The mean number of seeds per pod obtained by counting the number of seeds.

Data collected on plot basis

Days to flowering: Was recorded as the number of days from sowing to 50% of the plants in the plot started flowering

Days to maturity: Was recorded as number of days from sowing to the stage when 90% of pods matured.

Grain yield (kg/ha): It was determined by weighing total yield on the plot and converted to hectare

Statistical Analysis

Analysis of variance was calculated using the following model:

$Yij = \mu + Gi + Ej + GEij$

Where Yij is the corresponding variable of the i^{-th} genotype in j^{-th} environment, μ is the totalmean, Gi is the main effect of i^{-th} genotype, Ej is the main effect of j^{-th} environment, GEij is the effect of genotype x environment interaction.

The AMMI model:

AMMI analysis was used for analyzing GEI to identify patterns of interaction and reduce background noise. It combines conventional ANOVA with principal component analysis. Besides, it provides more reliable estimates of genotype performance than the mean across sites as well as to identify target breeding environments and to choose representative testing sites in those environments. This model will also help to select varieties with good adaptation in targeted breeding environments (Angela et al 2016). The model used for this analysis is indicated below:

$$Y_{ij} = \mu + g_i + e_j + \sum_{1}^{N} \lambda_k \gamma_{ik} \delta_{jk} + \varepsilon_{ij}$$

Where Yij is the grain yield of the i-th genotype in the j-th environment, μ is the grand mean, gi and ej are the genotype and environment deviation from the grand mean, respectively, ʎk is the eigenvalue of the principal component analysis (PCA) axis k, Υik and δjk are the genotype and environment principal component scores for axis k, N is the number of principal components retained in the model, and $\mathcal{E}ij$ is the residual term.

GGE- biplot

GGE-bi-plot methodology, which is composed of two concepts: the bi-plot concept. (Gabriel, 1971) and the GGE concept (Yan *et al.*, 2000), was used to visually analyze the METs data. This methodology uses a biplot to: show the factors (G and GE) that are important in genotype evaluation and that are also the source of variation in GEI analysis of METs data (Yan ,2001).The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al.*, 2000).

AMMI Stability Value (ASV): ASV is the distance from the coordinate point to the origin in a two-dimensional plot of IPCA1 scores against IPCA2 scores in the AMMI model (Purchase, 1997). Because the IPCA1 score contributes more to the GxE interaction sum of squares, a weighted value is needed. This weighted value was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 to the interaction sum of squares as follows:

$$ASV = \sqrt{[(SS_{IPCA1} \div SS_{IPCA2})(IPCA1score)]^2 + (IPCA2score)^2}$$

Where, SSIPCA1/SSIPCA2 is the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASV values indicate more stable varieties across environments (Purchase, 1997).

Genotype Selection Index (GSI): Stability is not the only parameter for selection as most stable varieties would not necessarily give the best yield performance. Therefore, based on the rank of mean grain yield of varieties (RYi) across environments and rank of AMMI stability value RASVi), genotype selection index (GSI) was calculated for each genotype as:

GSIi = RASVi + RYi

A genotype with the least GSI is considered as the most stable (Farshadfar, 2008). Analysis of variance was carried out using statistical analysis system (SAS) version 9.2 software (SAS Institute Inc., 2008). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 18th edition.

Result and Discussion

The combined analysis of variance for all varieties at different environmental conditions for grain yield and yield related traits was presented in Table 2. The result revealed that locations and varieties showed highly significant differences ($P \leq 0.01$) for all studied parameters. While year had significant effect only on number of branch per plant, pod length, number of pod per plant and grain yield. Location by variety had significant effect on number of branch per plant, number of pod per plant and grain yield. Year by varieties had non-significant effect on the studied and indicate that season was not affected the response of varieties on the studied parameters. Location by varieties by year had significant effect on plant height, pod length number of pod per plant and number of seed per pod.

Table. 2. Combined analysis of Soya bean varieties at ATARC, Dugda and Lume districts tested for two years (2019 & 2020)

Source	Df	DF	DM	NBP	PH(cm)	PL	NPPP	NSP	Yield (Q/ha)
Rep	2	35.08 ns	26.40 ns	1.10 ns	79.9 ns	0.53 ns	34.35 ns	0.28*	0.15 ns
L	2	392.7**	2581.9*	10.5**	1792.5**	17.4**	5587.9**	0.9**	473.5**
Yr	1	3.2ns	27.22 ns	127.6**	261.12 ns	89.4**	23043**	0.22 ns	411.0**
V	9	216.0**	425.3**	4.02**	1493.9**	0.67*	339.22*	0.3**	175.6**
Lc*Vr	18	5.36 ns	26.11 ns	3.59**	99.11 ns	0.48*	191.82*	0.06 ns	118.6**
Lc*Yr	2	1.25 ns	5.40 ns	32.44*	103.84 ns	23.6**	6584.4**	0.24*	86.129 ns
Vr*Yr	9	5.631 ns	9.77 ns	0.98 ns	284.98 ns	0.21 ns	156.84 ns	0.09 ns	32.71 ns
L*Vr*Y	18	9.91 ns	10.66 ns	0.78 ns	134.61*	0.64*	219.1*	0.11*	52.29 ns
Error	118	12.8	15.97	0.92	85.41	0.322	106.57	0.059	33.01
R^2		0.628	0.839	0.756	0.707	0.84	0.825	0.57	0.62
CV		6.287	3.55	20.30	14.93	15.86	22.44	8.38	23.34
Root mse		3.49	3.99	0.96	9.24	0.56	10.32	0.244	5.74

Key: ns= non-significant, *= significant, **= highly significant, V= Varieties, L= Location, Yr= Year, L*V = Location by Varieties, V*Yr = Varieties by year, L* Yr = Location by year, L*V*Yr= Location by Varieties by year, GY= Grain Yield, DF= Days to flowering, DM= Days to maturity, NCP= Number of cluster per plant, NPC= Number of pod per cluster, NPP= Number of pod per plant, NSP= Number of seed per pod, PH=Plant height

Yield Performance of soybean varieties across locations

Mean performance of the tested soybean varieties were presented in table 3. It revealed that some varieties continually performed best at some group of environment and some were inconsistently perform across the environments. The average grain yield ranged from 5.78 qun/ha at ATARC on station in 2019 to 31.26 qun/ha at Dugda in 2020 with grand mean of 16.25 qun/ha. The average grain yield across the environment ranged from 12.35 qun/ha for pawe-01 variety to the 22.74 qun/ha for Gozella variety. This large portion of variation might be due to the genetic potential of the varieties. Gozella and Davis varieties were high yielder than other varieties across the studied environments. However, Pawe -01 variety had the lowest yield potential across the tested locations. Similarly (Arega et al., 2018) were reported differential yield response to different environment of medium set soybean varieties. The difference in yield ranks of varieties across the locations showed the high cross over types of GxE interaction (Yan and Hunt, 2001; Asrat et al., 2009).

Agronomic performance yield related parameters

Pawe-01 and Pawe-02 varieties showed late to heading as well as late to maturity while Gozella and nyala varieties had shorter days to heading. Davis, Williams, Nyala had showed early to mature and important varieties for the area. Davis and Boshe varieties had higher number of branches per plant while pawe-o1 had lower number of branch per plant. Pawe-01, Pawe -02 Boshe and Wello varieties showed higher plant height while Nyala was the shortest variety. Davis and Gozella varieties showed higher number of pod per plant than other varieties while

Jalale variety had lower number of pod per plant. Gozella (22.74 qun ha^{-1}) and Davis (19.14 qun ha^{-1}) varieties were the high yielder varieties as compared to other varieties across the studied environments. However, Pawe- 02 (12.86 qun ha^{-1}) and Pawe -01 (12.35 qun ha^{-1}) varieties had showed the lowest yield potential across the tested locations.

Table.3. Over year and across location mean performance of grain yield (Qt/ha) of soybean varieties

Varieties	2019			2020			Com.
	ATARC	Dugda	Lume	ATARC	Dugda	Lume	Mean
Gozella	18.86^{ab}	25.70^{a}	14.71	25.55^{a}	31.26^{a}	20.37	22.74
Davis	23.21^{a}	18.54^{ab}	10.93	18.74^{ab}	28.81^{a}	14.60	19.14
Williams	21.29^{ab}	19.11^{ab}	10.25	25.55^{a}	13.44^{c}	17.25	17.82
Wello	16.36^{ab}	14.82^{bc}	9.59	17.62^{ab}	30..81^{c}	12.25	16.91
Jalale	17.91^{ab}	20.91^{ab}	8.83	17.70^{ab}	19.03^{bc}	12.50	16.15
Nyala	19.21^{ab}	8.96^{c}	11.71	15.77^{abc}	28.00^{ab}	12.04	15.95
Boshe	20.06^{ab}	13.92^{bc}	11.37	15.44^{abc}	17.04^{c}	9.04	14.48
Nova	14.78^{b}	19.15^{ab}	8.68	17.77^{ab}	15.40^{c}	9.02	14.14
Pawe-02	5.78^{c}	11.84^{bc}	14.58	7.00^{c}	15.40^{c}	22.58	12.86
Pawe-01	6.29^{c}	8.06^{c}	16.84	8.96b^{c}	16.11^{c}	17.84	12.35
Mean	16.38	16.10	11.75	17.01	21.53	14.75	16.25
CV %	13.3	18.5	17.7	11.0	14.9	22.6	23.35
LSD	6.54	8.69	9.61	9.04	9.21	13.31	3.79
F test	**	**	Ns	**	**	Ns	**

Table.4. Combined mean yield and agronomic traits of soya bean varieties tested at ATARC, Dugda and Lume districts for two years (2019 & 2020)

Varieties	DF	DM	NBP	PH	PL	NPPP	NSP	Yield
Gozella	51.94^{d}	112.56^{c}	4.5^{bc}	60.42^{b}	3.69^{a}	52.52^{a}	2.74^{d}	22.74^{a}
Davis	53.06^{cd}	109.78^{d}	5.5^{a}	51.02^{cd}	3.62^{ab}	53.09^{a}	2.77^{d}	19.14^{ab}
Williams	53.11^{cd}	106.33^{e}	4.30^{bc}	56.18^{bc}	3.5^{abc}	42.62^{cd}	3.02^{ab}	17.82^{bc}
Wello	60.11^{a}	116.94^{b}	4.93^{b}	74.55^{a}	3.303^{bc}	50.46^{ab}	2.93^{abc}	16.91^{bc}
Jalale	56.78^{a}	113.44^{c}	4.77^{b}	56.178^{bc}	3.74^{a}	41.97^{d}	2.73^{d}	16.15^{bcd}
Nyala	51.94^{d}	106.44^{e}	4.51^{bc}	49.67^{d}	3.86^{a}	44.82^{bcd}	3.04^{a}	15.95^{b-e}
Boshe	55.22^{bc}	1016.89^{b}	5.46^{a}	71.51^{a}	3.62^{ab}	50.81^{ab}	2.95^{ab}	14.48^{cde}
Nova	52.94^{cd}	106.67^{e}	4.62^{bc}	58.77^{b}	3.59^{abc}	42.23^{cd}	3.05^{a}	14.137^{cde}
Pawe-02	60.06^{a}	118.7^{ab}	4.79^{b}	69.63^{a}	3.64^{ab}	42.4^{cd}	2.86^{bcd}	12.86^{de}
Pawe-01	60.6^{a}	120.06^{a}	4.02c	71.06^{a}	3.22^{c}	48.91^{abc}	3.01^{ab}	12.35^{e}
LSD	2.3	2.63	0.64	6.10	0.33	6.81	0.16	3.79

Key: GY= Grain Yield, DF= Days to flowering, DM= Days to maturity, NCP= Number of cluster per plant, NPC= Number of pod per cluster, NPP= Number of pod per plant, NSP= Number of seed per pod, PH=Plant height, NB= Number of branch per plant, 100SW= Hundred seed weight

Additive Main Effect and Multiple Interaction (AMMI) Model

The AMMI model ANOVA for grain yield is presented in Table 5. This analysis also revealed the presence of highly significant (P< 0.01) differences among soybean varieties for grain yield performance. The variation was largely due to environmental variation (47.68%). GEI and genotype accounted 20.56% and 15.22% of the total variation, respectively. As indicated above, the high percentage of environmental variation is an indication that the major factor that influence yield performance of soybean is the environment. The result revealed that there was a differential yield performance among the varieties across testing environments and the presence of strong genotype by environment (G X E) interaction. Similar findings have been reported in previous studies (Kaya et al., 2006; Farshadfar et al., 2012).

As G x E interaction was significant, further calculation of genotype stability is possible. In the AMMI ANOVA, the GEI was further partitioned using PCAs scores. The result of ANOVA showed that the first two IPCAs were highly significant at ($P<0.01$) implying the inclusion of the first two interactions PCA axes in the model. Considerable percentage of GEI was explained by IPCA1 (30.34%) followed by IPCA2 (25.83%).This result revealed that there were differential yield performances among soybean varieties across testing environments due to the presence of GEI. The presence of GEI could complicate the selection process of superior varieties and might reduce the selection efficiency in a breeding program According to Gauch (2006).

Table 5.Additive main effect and multiplicative interaction analysis of variance (AMMI) for grain yield of 10 soybean varieties.

Source	D.F	S.S	M.S	Ex. SS %
Varieties	9	1580	175.6**	15.22
Environments	2	4947	2473.5**	47.68
Block	6	28	4.6^{ns}	0.26
Interactions	18	2134	118.6**	20.56
IPCA 1	10	1704	170.4**	30.34
IPCA 2	8	430	53.7^{ns}	25.83
Residual	150	5686	39.5	

Key: DF = Degree of freedom, S.S = Sum of square, M.S = Mean of square, IPCA = Interaction principal component axis, ** = highly significance difference, Ex. SS% = Explained sum of square.

Evaluation of varieties based on GGE-bi-plot model

The estimation of yield and stability of genotype were done by using the average coordinates of the environment (AEC) methods (Yan, 2001; Yan and Hunt, 2001). The average environment is defined by the average values of PC1 and PC2 for the all environments, and it is presented with a circle. The average ordinate environment (AOE) defines by the line which is perpendicular to the AEA (average environment axis) line and pass through the origin. This line divides the varieties in to those with higher yield than average and in to those lower yield than average. By projecting the varieties on AEA axis, the varieties are ranked by yield; where the yield increases in the direction of arrow. In this case the highest yielding varieties are Gozella, Davis and Williams but the lower yielder varieties are Pawe1 and Pawe2 figure (1).Stability of the varieties depends on their distance from the AE abscissa. Varieties closer to or around the center of concentric circle indicated these varieties are more stable than others. Therefore, the greatest stability in the high yielding group had varieties Gozella, Davis and William. The genotype ranking is shown on the graph of genotype so-called "ideal" genotype (Fig 1). An ideal genotype is defined as one that is the highest yielding across test environments and it is completely stable in performance that ranks the highest in all test environments; such as variety in this case was Gozella.

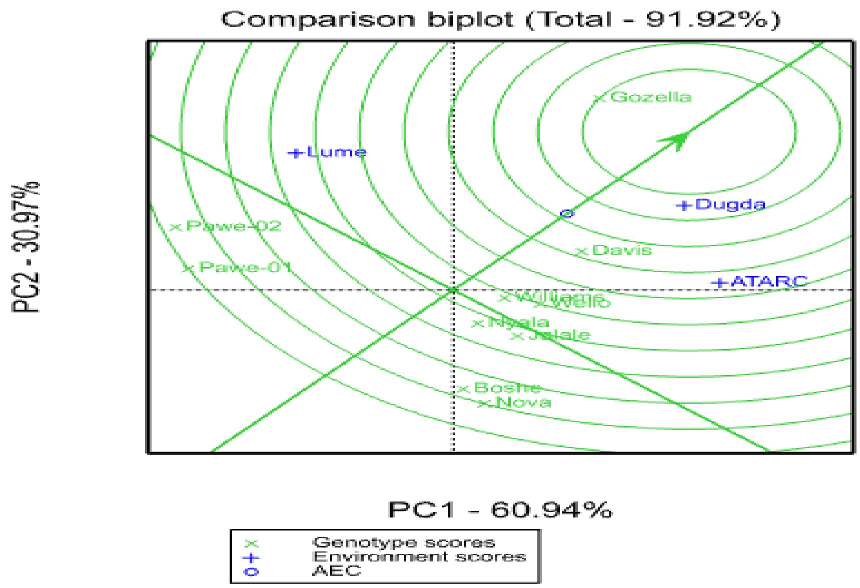


Figure 10. GGE bi-plot based on Varieties focused scaling for comparison of varieties for their yield potential and stability

Genotypes by Environment Interaction (GGE) Bi-plot Analysis

GGE biplot is an essential tool for addressing the mega environment issues, by showing which cultivar won in which environments, and it was effective for visualizing in mega-environment identification Yan W., et al (2000). Polygon views the GGE biplot showing the mega-environments and their respective highest yielding varieties (figure 2), and explicitly displays the "which-won-where pattern" as a concise summary of the GEI pattern derived from multi-environment yield trial data set for the three locations.The polygon dictated that Gozella, Davis, Nova, Pawe-01 andPawe-02 were vertex Varieties, whereas the remaining Varieties lie inside the polygon. The winning Varieties for each sector are those placed at the vertex. Therefore, Davis is winner at both ATARC and Dugda locations similarly Gozella variety winning at Dudga environment. Pawe -01 and Pawe-02 better performed at Lume environment but below the grain mean grain yield (figure 2).

AMMI Stability Value (ASV): The importance of AMMI model is in reduction of noises if the principal component did not cover much of the GE sum of squares (Guach and Zobel 1996). It is the distance from zero in two dimensional scatter of IPCA1 score against IPCA2 scores. Since theIPCA1 score more contributes more to the GEI sum of square, it has to be weighted by the proportional difference between IPCA1 and IPCA2 scores to compensate for the relative contribution of IPCA1 and IPCA2 to the total GEI sum of square. According to stability parameter, a genotype with least ASV score is the most stable. The varieties such as Davis, Gozella, Williams and Nyala varieties had least ASV value and were the most stable respectively (Table 6). The high interaction of Varieties with environment was confirmed by high ASV value and difference in ranking order, suggesting unstable yield across environment. The most unstable varieties were Pawe-02, Pawe-02 and Boshe (Table 6).

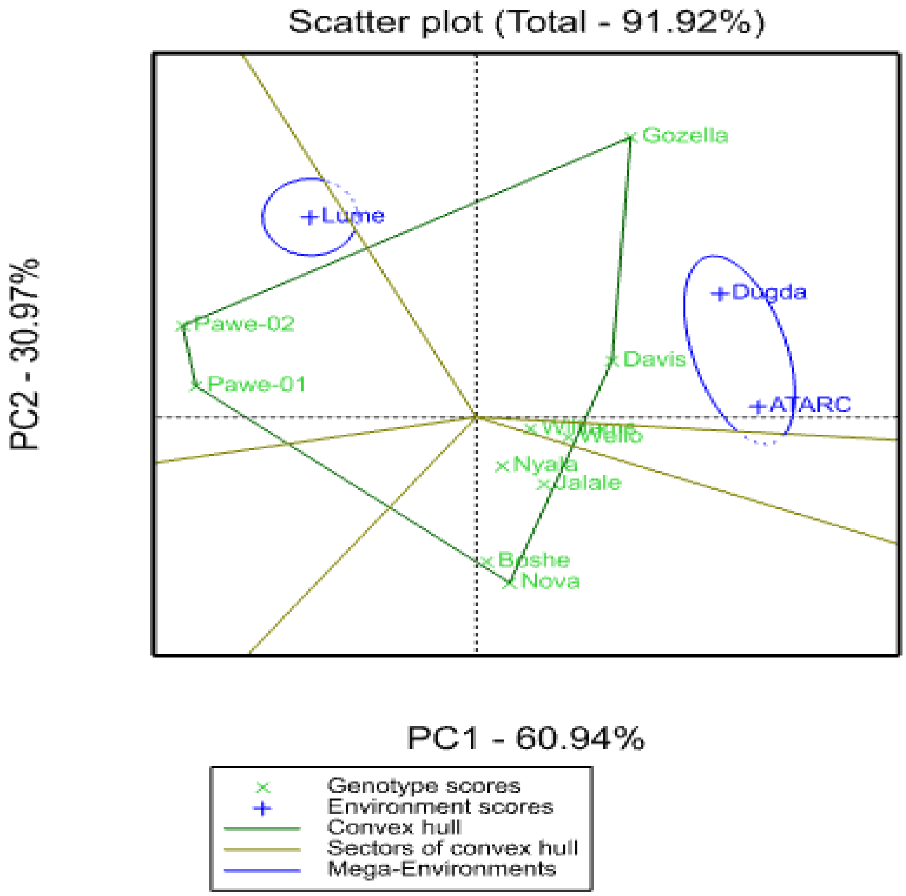


Figure 2. The GGE biplot to show which Varieties performed best in which environment.

Table 6.Mean grain yield of 10 Soybean varieties, AMMI stability values, Cultivar Superiority value and genotypic selection index

Varieties	Mean Yield	RYi	$IPCA_1$	$IPCA_2$	ASV	ASVi	GSIi
Boshe	14.48	7	1.558	0.898	6.239	8	15
Davis	19.14	2	4.947	-0.496	1.839	1	3
Gozella	22.74	1	0.353	-1.210	1.849	2	3
Jalale	16.15	5	0.713	-0.276	2.839	6	11
Nova	14.14	8	0.709	0.020	2.809	5	13
Nyala	15.95	6	0.559	0.153	2.222	4	10
Pawe-01	12.35	10	-2.410	0.304	9.553	9	19
Pawe-02	12.87	9	-2.739	-0.271	10.857	10	19
Wello	16.91	4	0.700	-1.189	3.017	7	11
Williams	17.82	3	0.110	2.016	2.062	3	6

Key: RYi =Rank of grain yield, IPCA = Interaction principal component axis, ASV = AMMI Stability value, ASVi = Rank of AMMI Stability value,

Conclusion

The genotype and environment main effects (genotype and environment) and genotype x environment interaction effect were significant on soya bean varieties. Gozella and Davis varieties were the higher yielder than other varieties through the studied environments. However, Pawe- 02 and Pawe -01 varieties had the lowest yield potential through the tested locations. AMMI model shows the variation was largely due to environmental variation. The high percentage of environmental variation is an indication that the major factor that influence yield performance of soybean is the environment. Gozella and Davis were plotted to the ideal varieties considered as desirable varieties based on GGE bi-plot graph and stable varieties while Pawe1 and Pawe2 were far from the ideal varieties considered as most unstable varieties with poor performance across locations. Gozella and Davis varieties had least AMMI stability values and genotypic selection index value and were widely adaptable and stable high yielding varieties and thus were recommended for the study area.

Acknowledgment

The authors thank Oromia Agricultural Research Institute for funding the research activity and Adami Tulu Agricultural Research Center for facilitation and Pulse and Oil Crops Research Team acknowledged for their technical support during field evaluation.

Reference

AsratFeleke (1965). Progress Report on Cereals, Pulses and Oilseeds Research, Branch ExperimentStation DebreZeit Ethiopia.

Dugje, I. Y., Omoigui, L.O., Ekeleme, F., Bandyopaolhyay, Lava Kumar, R. P. and Kamara, A. Y. 2009. Guide to soybean production in northern Nigeria. IITA, Ibadan. 21pp.

Farshadfar, E., Mohammadi, R., Aghaee, M. and Vaisi, Z. 2012.GGE biplot analysis of genotype ×environment interaction in wheat-barley disomic addition lines.*Australia Journal of Crop Sciences*6:1074-1079.

Gauch HG, Zobel RW, 1992. AMMI analysis of yield trials. In: Genotype by environment interaction. pp. 85-122 (Kang, M. and Gauch, H. eds.). Boca Raton. CRC press, New York.

Gauch, H.G.2006.Statistical analysis of yield trials by AMMI and GGE.Crop Sciences. 46:1488-1500.

Kaya, Y., Akcura, M. and Taner, S. 2006.GGE-bi-plot analysis of multi- environment yield trials in bread wheat *Turkish Journal of Agriculture* 30:325- 337.

Purchase, J.L., Hatting H., and Vandenventer, C.S. 1997. Genotype x environment interaction of winter wheat in South Africa: II. Stability analysis of yield performance .South Afr J Plant Soil, 17: 101-107.

Worku, M. and Astatkie, T., 2011. Row and plant spacing effects on yield and yield components of soya bean varieties under hot humid tropical environment of Ethiopia. *Journal of Agronomy and Crop Science*, *197*(1), pp.67-74.

Yan W and Hunt LA.(2001). Interpretation of genotype x environment interaction for winter wheat yield in Ontario. Crop Sci 41: 19-25.

Yan, W., Hunt, L.A., Sheng, Q. and Szlavnics, Z. 2000. Cultivar evaluation and mega environment investigation based on the GGE biplot. *Crop Science*, 40: 597–605.

Genotype by Environmental Interaction and Green Pod Yield stability of Snap Bean (*Phaseolus vulgaris* L.) Genotypes in East Shewa Zone

Temesgen Dinsa*[1] , Urgaya Balcha[1] and Fiseha Tadesse[2]
[1]Adami Tulu Agricultural Research Center, P.O. Box. 35, Batu, Ethiopia
[2]Selale UniversityP.O. Box. 245, Salale Ethiopia
*Corresponding author: *temesgendinsa@gmail.com*

Abstract

The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC), Lume and Dugda Districts during 2019 and2020 main cropping seasons with the objective to identify adaptable and high yielding snap bean genotypes for East Shewa Zone and similar agro ecologies. Ten snap bean genotypes were used as a planting material. The experiment was laid down in Randomized Complete Block Design (RCBD) with three replications. The plot size was 3m × 2 m (6 m^2) having 6 rows and a spacing of 0.40 m between rows and 0.50 m between replications, 1 m between blocks. Data on plant height(cm), number of pods per plant, number of seeds per pod, days to flowering, days to maturity, pod yield (kg ha^{-1}), were collected and analyzed. The genotype and environment main effects (genotype and environment) and genotype x environment interaction effect were significant among snap bean genotypes for seed yield . AMMI model shows environment effect accounted for 41.35%, GXE 12.96%, genotype 31.27% of the total variation. The high percentage of environment is an indication that the major factor that influence yield performance of Snap bean is the environment. The first two IPCAs are the most accurate model that could be predicted the stability of the genotype and contributed 31.3 and 10.1% for IPCA-I and IPCA-II respectively of GEI. According, to stability parameters (ASV, and GGE- Biplot) and mean yield results G-24 and G-12genotypes are the most stable genotypes across test locations. Therefore, these genotypes were proposed as candidate genotypes for possible release.

Keywords: Snap bean, Genotype by Environment Interaction, Stability, AMMI, GGE-Biplot

Introduction

Snap bean (*Phaseolus vulgaris* L.), is an herbaceous annual plant domesticated independently in ancient Mesoamerica and in the Andes, and now is grown worldwide for both dry seed or as a green bean. Thousands of legume species exist but snap bean in any form is the most eaten by human beings compared to any other legume (Broughton et al., 2003).When snap bean is used for its unripe fruit; it is termed as green bean or snap bean. They are one of the most important legume vegetable crops and contributes substantial amount of protein to human diet. Nitrogen fixation and the subsequent internal supply of nitrogen (N) from their symbiosis with rhizobia make legume crops richer in protein in dry weight basis than all other plants (Broughton et al., 2003). Morphologically it is grouped into determinate (bush), half (semi-determinate) runner and indeterminate (pole) types based on the growth habit. The determinate types are short erect plants with a height of 25 to 38 cm and spread of 10 to 20 cm (Decoteau, 2000). Their growth is terminated with reproductive meristem (inflorescence). Flowering in cultivars having a determinate growth habit is concentrated (usually 5-6 days). These cultivars are used for short-season production, and successive plantings every two weeks are needed for a continuous supply. Flowering in indeterminate type extends for 15 - 30 days. The half runner types combine the characteristics of both determinate and indeterminate types and referred to as semi-determinate types. Flowers of snap bean are borne axially, the corolla may be white, creamy-yellow, pink or violet. The flowers are usually self-fertile and pollination takes place at the time when the flower opens. Snap bean pods are normally ready for harvest 50-60 days after planting, some 14 - 28 days after the first flower appeared, even though variation occurs in different altitudes and cultivars (Kay, 1979).

In Ethiopia, snap bean is economically one of the most important vegetable crops grown for both export and local markets. It is mostly grown in the Rift Valley region, especially for export. Snap bean production in Ethiopia has increased from time to time both for export and local markets. In addition to large commercial vegetable farms which produce snap bean for export, snap bean is increasingly popular for small-scale vegetable producers for local markets. Although the market demand in both international and local is very high, the production is low due to lack of improved variety in East Shewa Zone. Therefore the present study was initiated with an objective to identify high yielding and stable snap bean genotypes for the study areas.

Materials & Methods

Ten snap bean genotypes were evaluated in this study. Descriptions of the test entries used in this study is indicated in table 1. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications at ATARC, Lume and Dugda Districts. Plot sizes will 2 m x 3 m (6m^2). Each plot had five rows with 0.1 m between plants within each row and 0.4 m between rows with a row length of 3 m. The distance between adjacent blocks was 1 m. NPS and Urea was applied at the rate of 142 and 79 kg/ha respectively and with seed rate of 60kg/ha. The two outer rows were considered border rows. Weeding and all other recommended agronomic practice was followed for all locations.

Table 1.Lists and descriptions of Snap bean genotypes were used in the experiment

No	Genotypes/Codes	Pedigree	Source
1	G10	HAV 130	CIAT
2	G12	Tarrot	CIAT
3	G19	HAB 404	CIAT
4	G24	Oxinel	CIAT
5	G25	LOIRET BLAC PETITE GRAIN	CIAT
6	G26	LOIRET BLAC GROSSE GRAIN	CIAT
7	G30	HAV134	CIAT
8	C1	Contender	MARC
9	C2	BC 44	MARC
10	C3	Plati	MARC

Data collected on plant basis

Plant height: The length of the central axis of the stem was measured from the soil surface up to the tip of the stem.

Number of branches: The average number of branches per plant was counted.

Pod length: The length of pods was measured using meters and recorded in centimeter from each five sampled plants.

Number of pods per plant: Were determined by counting total number of pods per plant.

Data collected on Plot Basis

Days to flowering: Was recorded as the number of days from sowing to 50% of the plants in the plot started flowering

First Harvesting: was recorded as number of days from sowing to the when the pod reached to first harvesting.

Green pod yield (Qt/ha): It was determined by weighing total yield on the plot and converted to hectare.

Statistical Analysis

Analysis of variance is calculated using the following model:

$Yij = \mu + Gi + Ej + GEij$

Where Yij is the corresponding variable of the i-thgenotype in j-thenvironment, μ is the totalmean, Gi is the main effect of i-thgenotype, Ej is the main effect of j-thenvironment, GEij isthe effect of genotype x environment interaction.

The AMMI model:

AMMI is used for analyzing GEI to identify patterns of interaction and reduce background noise. It combines conventional ANOVA with principal component analysis. Provide more reliable estimates of genotype performance than the mean across sites. To identify target breeding environments and to choose representative testing sites in those environments. To select genotypes with good adaptation in targeted breeding environments (Angela et al 2016).The model used for this analysis is indicated below:

$$Y_{ij} = \mu + g_i + e_j + \sum_{1}^{N} \Lambda_k Y_{ik} \delta_{jk} + \varepsilon_{ij}$$

Where Yij is the grain yield of the i-th genotype in the j-th environment, μ is the grand mean, gi and ej are the genotype and environment deviation from the grand mean, respectively, ʎk is the eigenvalue of the principal component analysis (PCA) axis k, Yik and δjk are the genotype and environment principal component scores for axis k, N is the number of principal components retained in the model, and Ɛij is the residual term.

GGE- biplot

GGE-bi-plot methodology, which is composed of two concepts, the biplot concept (Gabriel, 1971) and the GGE concept (Yan *et al.,* 2000), was used to visually analyze the METs data.

This methodology uses a bi-plot to show the factors (G and GE) that are important in genotype evaluation and that are also the source of variation in GEI analysis of METs data (Yan , 2001).The GGE-bi-plot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al.,* 2000).

AMMI Stability Value (ASV): ASV is the distance from the coordinate point to the origin in a two-dimensional plot of IPCA1 scores against IPCA2 scores in the AMMI model (Purchase, 1997). Because the IPCA1 score contributes more to the GxE interaction sum of squares, a weighted value is needed. This weighted value was calculated for each genotype and each environment according to the relative contribution of IPCA1 toIPCA2 to the interaction sum of squares as follows:

$$ASV = \sqrt{[(SS_{IPCA1} \div SS_{IPCA2})(IPCA1score)]^2 + (IPCA2score)^2}$$

where, SSIPCA1/SSIPCA2 is the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASV values indicate more stable genotypes across environments (Purchase, 1997).

Genotype Selection Index (GSI): Stability is not the only parameter for selection as most stable genotypes would not necessarily give the best yield performance. Therefore, based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value RASVi),genotype selection index (GSI) was calculated for each genotype as:

GSIi = RASVi + RYi

A genotype with the least GSI is considered as the most stable (Farshadfar, 2008). Analysis of variance was carried out using statistical analysis system (SAS) version 9.2 software (SAS Institute Inc., 2008). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 15th edition statistical package VSN International (2012).

Results and Discussions

Analysis of variance

The combined analysis of variance for all genotypes at different environmental conditions for pod yield and yield related traits are presented in Table 2. The result revealed that genotypes showed highly significant ($P \leq 0.01$) for all parameter studied except number of branch per plant. While year had significant effect on major parameters only on number of pod per plant and pod yield. Location by genotypes had significant effect on pod diameter and green pod yield. Year by genotypes had non-significant effect on the studied and indicate that season was not affected the response of genotypes on the studied parameters. Location by genotypes by year had significant effect on pod diameter.

Table.2 Combined analyses of 10 Snap bean genotypes tested in Snap bean regional variety trial at Adami Tulu, Dugda and Lume, during 2019-2020

S.V	Df	Mean Squares								
		DF	DfH	PB	PH	PL	NPP	PW	PD	PY Qt/ha
Rep	2	14.5	74.106	0.07	9.1	9.76	158.74	1.107	0.57	468.4
G.	9	163.5**	253.74**	0.696	140.4**	120.8**	161.82**	5.295**	5.2**	2699.8**
L.	2	0.67	0.375	17.28	636**	8.637	991.28**	1.165	74.44**	16549.6**
Yr	1	0.672	6.05	159.42	9461.3	7.2	377.80*	0.391	3.86	7111.4**
L*G	18	0.85	0.99	0.504	84.5	0.84	53.35	1.61	4.06**	23391.7***
G*Yr	9	0.857	1.84	0.519	121.1	9.81	110.67*	1.9	2.77	4732.4
L*Yr	2	0.67	1.017	9.17	1097**	396	54.4	9.8	11.91**	4697.1
L*G*Yr	18	0.857	0.981	0.599	89.2	2.73	36.65	0.68	5.45**	10297.2
CV%		1.2	5.4	6.3	17.3	12.2	13.1	3.7	9.7	31.2

Key: G= Genotype, L= Location, Yr = Year, L*G = Location by Genotype, G*Yr = Genotype by year, L* Yr = Location by year, L*G*Yr = Location by genotype by year, DF= Days to flowering, DfH= Days to Frist harvest, NPP= Number of pod per plant, SP= Number of seed per pod, PH=Plant height, PB=Primary Branch, PW= Pod Weight PD= pod diameter, PY= Pod yield

Agronomic Performance for Green Pod Yield Related Parameters

Agronomic performance of snap bean genotypes was presented in table 3. G-12genotypes showed early to heading as well asdays to first harvest. G-30 (61.33cm) and G- 19 (41.19cm) had longer plant height than other genotypes while shorter plant height was recorded on G- 12 (14.64cm) and G-26 (41.19 cm). G-24 (16.25cm) and G-12 (17.04 cm) had longer pod length as well as these had more number of pods per plant while G-26 and G-30 genotypes had minimum pod per plant. G-24 (110.55qun ha^{-1}) and G-12 (108qun ha^{-1}) genotypes was the higher pod yield than other genotypes through the studied environments. However, C2 (85.71qun ha^{-1}) and C1 (83.88qun ha^{-1}) genotypes had the lowest pod yield potential through the tested locations.

Table 3. Combined Mean agronomic performance of 10 snap bean genotypes tested in Snap bean regional variety trial at Adami Tulu, Dugda and Lume, during 2019-2020

SN	Gen.	DF	DfH	BP	PH	PL	NPP	PW	PD	PY
1	G-26	49.06^{ab}	79.06^{a}	4.2	41.19^{d}	12.32^{cd}	44.09^{bc}	6.03^{bc}	6.5^{ab}	99.91^{ab}
2	G-30	48^{ab}	73.72^{bc}	4.04	61.33a	9.95^{f}	49.0^{abc}	5.52^{c}	7.2^{a}	88.34^{bcd}
3	G-24	47.11^{b}	68.39^{de}	3.62	43.38^{cd}	16.25^{a}	57.4^{a}	7.29^{a}	6.37^{ab}	110.55^{a}
4	G-25	48.44^{ab}	74.94^{b}	4.05	49.33^{cd}	11.93^{c-e}	51.26^{abc}	5.77^{bc}	6.44^{ab}	99.29^{abc}
5	G-12	39.39^{c}	67.28^{e}	3.77	41.64^{d}	17.04^{a}	57.74^{a}	6·76^{ab}	6.46^{ab}	108.48^{a}
6	G-10	48.78^{ab}	79.78^{a}	3.57	58.77^{ab}	10.40^{ef}	47.74^{abc}	6.08^{bc}	6.42^{abc}	78.68^{d}
7	G-19	49.67^{a}	74.89^{b}	3.89	60.10^{ab}	9.71^{f}	47.28^{abc}	5.84^{bc}	5.01c	78.21^{d}
8	C1	48.78^{ab}	70.67^{cde}	4.01	54.24^{abc}	10.96^{d-f}	54.62^{ab}	6.$^{9a-c}$	5.85bc	85.71^{bcd}
9	C3	48.11^{ab}	71.94^{b-d}	4.06	38.47^{d}	14.46^{b}	56.28^{ab}	6.38^{abc}	6.47^{ab}	97.35^{abc}
10	C2	48.0^{6ab}	72.06^{b-d}	4.0	4231^{d}	12.76^{c}	41.56^{c}	6.29b^{c}	6.48^{ab}	83.88^{cd}
Mean		47.53	73.27	3.92	49.08	12.58	50.88	6.19	6.32	93.0
CV (%)		3.9	4.9	19.2	21.7	11.7	23.5	17.6	18.1	15.9
SE		1.8	3.6	0.75	10.64	1.47	5.9	1.08	1.44	14.77
LSD (5%)		1.2	2.3	ns	7.02	0.9	3.94	0.72	0.75	9.75

Key: DF = Days to heading, DfH = Days for first harvest, NBP = Number of branch per plant, PH (cm) = Plant height, PL (cm) = Pod length, NPP = Number of pod per plant, PW (g) = Pod weight, PD (mm) = Pod diameter, PY (Qt/ha) = pod yield per hectare, CV(%): Coefficient of variations, SE: standard error of the mean, LSD: Least significant differences, ‡ Means within each column followed by the same letter are not significantly different from each other based on the 0.05 probability level of LSD.

Yield performance of Snap bean Genotypes Across Locations

Mean performance of the tested snap bean was presented in table 4. It revealed that some genotypes continually performed best some group of environment and some were inconsistent across the environments. The average grain yield ranged from the lowest 64.7 qun/ha at Dugda on station in 2019/20 to the highest 122.3qun/ha at ATARC in 2020/21 with grand mean of 93.0qun/ha. The average grain yield across the environment ranged from the lowest of G19 78.21 qun/ha to the highest of 110.55 qun/ha for G24. This large portion of variation might be due to the genetic potential of the genotypes. G24 and G12 genotypes were the higher yielder than other genotypes through the studied environments. However, G19genotypes had the lowest yield potential through the tested locations. Similarly (Arega et al., 2018) were reported differential yield response to different environment of snap genotypes. The difference in yield ranks of genotypes across the locations showed the high cross over types of GxE interaction (Yan and Hunt, 2001; Asrat et al., 2009).

Table. 4. Over year and across location mean performance of grain yield (Qun/ha) of snap bean genotypes

Genotypes	2019/20			2020/21			Com.	
	ATARC	Dugda	Lume	ATARC	Dugda	Lume	Mean	RYA%
G26	101.13^{abc}	109.3^{ab}	82.91	103.34^{abc}	108.86^{ab}	87.24^{ab}	99.91^{ab}	2.64
G30	70.69^{c}	104.4^{ab}	88.28	90.44^{abc}	81.71^{ab}	94.55^{ab}	88.34^{bcd}	-9.01
G24	113.66^{ab}	119.9^{a}	93.22	122.3^{a}	118.85^{a}	95.34^{a}	110.55^{a}	13.55
G25	81.86^{bc}	105.5^{ab}	93.16	103.82^{abc}	111.91^{ab}	96.14^{ab}	99.29^{abc}	1.99
G12	119.48^{a}	110.9^{ab}	102.22	113.64^{ab}	109.33^{ab}	95.18^{ab}	108.49^{a}	11.44
C2	94.95^{abc}	106.6^{ab}	72.94	87.51^{abc}	79.59^{ab}	72.71^{ab}	85.71^{bcd}	-11.64
C1	99.72^{abc}	106.7^{ab}	65.45	$77.8b^{c}$	86.25^{ab}	67.34^{b}	83.88^{cd}	-13.47
G10	82.43^{abc}	64.7^{c}	88.07	86.11^{abc}	77.95^{ab}	72.82^{ab}	78.68^{d}	-18.67
G19	71.45^{c}	83.1^{bc}	78.63	76.1^{c}	68.92^{b}	91.07^{ab}	78.21^{d}	-19.14
C3	106.84^{abc}	115.7^{a}	85.38	108.0^{bc}	98.3^{ab}	73.22^{ab}	97.35^{abc}	
CV %	13.6	9.6	19.7	21.24	15.9	18	15.9	
LSD	22	16.98	28.69	12.8	25.61	27.45	9.75	
F test	**	**	ns	**	**	Ns	**	

Key; RYA% = Relative yield advantage in percent, LSD: Least significant differences, ‡ Means within each column followed by the same letter are not significantly different from each other based on the 0.05 probability level of LSD.

Additive Main Effect and Multiple Interaction (AMMI) Model

The AMMI model ANOVA for green pod yield is shown in Table 5. This analysis also revealed the presence of highly significant ($P< 0.01$) differences among snap bean genotypes for pod yield performance. The variation was largely due to environmental variation (41.35%).Genotype and GEI also accounted 31.27% and 12.96% of the total variation, respectively. As discussed above, the high percentage of environmental variation is an indication that the major factor that influence yield performance of sap bean is the environment. The result revealed that there was a differential yield performance among the genotypes across testing environments and the presence of strong genotype by environment (G X E) interaction. Similar findings have been reported in previous studies (Kaya etal., 2006; Farshadfar et al., 2012).

As G x E interaction was significant, further calculation of genotype stability is possible. In the AMMI ANOVA, the GEI was further partitioned using PCA. The result of ANOVA showed that the first two IPCA were highly significant at ($P<0.01$) implying the inclusion of the first two interactions PCA axes in the model. Considerable percentage of GEI was explained by IPCA1 (31.37%) followed by IPCA2 (10.1%).This result revealed that there were differential yield performances among snap bean genotypes across testing environments due to the presence of GEI. The presence of GEI could complicate the selection process of superior genotypes and might reduce the selection efficiency in a breeding program According to Gauch (2006).

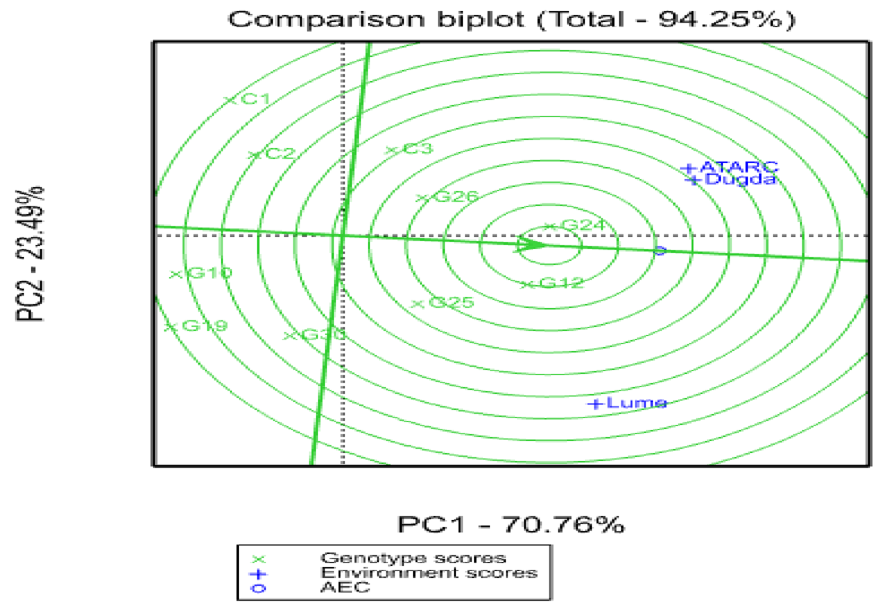
Table 5. Additive main effect and multiplicative interaction analysis of variance (AMMI) for grain yield of 10 snap bean genotypes

Source	D.F	S.S	M.S	Ex. SS %
Genotypes	9	22248	2472**	31.27
Environments	2	29421	14710.5**	41.35
Block	6	1644	274ns	2.31
Interactions	18	9226	513**	12.96
IPCA 1	10	6981	698**	31.37
IPCA 2	8	2246	281*	10.1
Residuals	150	33243	221	

Key: DF = Degree of freedom, S.S = Sum of square, M.S = Mean of square, IPCA = Interaction principal component axis, ** = highly significance difference, Ex. SS% = Explained sum of square.

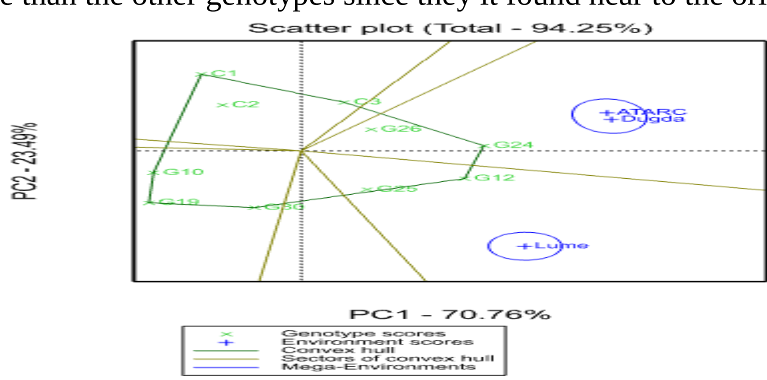
Evaluation of Genotypes Based on GGE-bi-plot model

The estimation of yield and stability of genotype were done by using the average coordinates of the environment (AEC) methods (Yan, 2001; Yan and Hunt, 2001). The average environment is defined by the average values of PC1 and PC2 for the all environments, and it is presented with a circle. The average ordinate environment (AOE) defines by the line which is perpendicular to the AEA (average environment axis) line and pass through the origin. This line divides the genotypes in to those with higher yield than average and in to those lower yield than average. By projecting the genotypes on AEA axis, the genotypes are ranked by yield; where the yield increases in the direction of arrow. In this case the highest yield had genotypes G-24, G-12 and G-26but the lowers had G-10, G-19 and C1 figure (1).Stability of the genotypes depends on their distance from the AE abscissa. Genotypes closer to or around the center of concentric circle indicated these genotypes are more stable than others. Therefore, the greatest stability in the high yielding group had genotypesG-24, G-12 and G-26. The genotype ranking is shown on the graph of genotype so-called "ideal" genotype (Fig 1). An ideal genotype is defined as one that is the highest yielding across test environments and it is completely stable in performance that ranks the highest in all test environments; such as genotypes in this case were G-24 and G-12.



Genotypes by Environment Interaction (GGE) Bi-plot Analysis

GGE biplot is an essential tool for addressing the mega environment issues, by showing which cultivar won in which environments, and it was effective for visualizing in mega-environment identification Yan W., et al (2000). Polygon views the GGE biplot showing the mega-environments and their respective highest yielding genotypes (figure 2), and explicitly displays the "which-won-where pattern" as a concise summary of the GEI pattern derived from multi-environment yield trial data set for the three locations. The polygon dictated that G-24, G-12, C3 G-19 and C1 were vertex genotypes, whereas the remaining genotypes lie inside the polygon. The winning genotypes for each sector are those placed at the vertex. Therefore, G24 is winner at both ATARC and Dugda locations, similarly G-12genotype winning at Lume environment. G-19, G-10 and C1had below the pod grain yield less than the grand mean (figure 2). G-24 is more stable than the other genotypes since they it found near to the origin and has general adaptability.



AMMI Stability Value (ASV): The importance of AMMI model is in reduction of noises if the principal component did not cover much of the GE sum of squares (Gauch, 1992; Guach and Zobel 1996). It is the distance from zero in two dimensional scatter of IPCA1 score against IPCA2 scores. Since the IPCA1 score more contributes more to the GEI sum of square, it has to be weighted by the proportional difference between IPCA1 and IPCA2 scores to compensate for the relative contribution of IPCA1 and IPCA2 to the total GEI sum of square. According to stability parameter, a genotype with least ASV score is the most stable. The genotypes such as G12, G24, C2 and G25genotypes had least ASV value and were the most stable respectively (Table 6). The high interaction of genotypes with environment was confirmed by high ASV value and difference in ranking order, suggesting unstable yield across environment. The most unstable genotypes were G19, G30 and G10 (Table 6).

Table 6. Mean grain yield of 10 Snap bean genotypes, AMMI stability values, Cultivar Superiority value and genotypic selection index

Genotype	Mean	RYi	IPCA1	IPCA2	ASV	ASVi	GSIi
C1	83.88	8	1.95062	-0.67139	6.099963	6	14
C2	85.71	7	0.96937	0.24661	3.023064	3	10
C3	97.35	5	2.04333	0.90802	6.415645	7	13
G10	78.68	9	-2.14106	2.53147	7.120046	8	17
G12	108.49	2	0.27906	1.55846	1.783573	1	3
G19	78.21	10	-3.12314	0.06337	9.707527	10	20
G24	110.55	1	0.92867	0.34149	2.906615	2	3
G25	99.29	4	-0.71569	-2.32922	3.220819	4	8
G26	99.91	3	1.40029	-1.08079	4.484555	5	8
G30	88.34	6	-2.34145	-1.56802	7.444681	9	15

Key: RYi =Rank of grain yield, IPCA = Interaction principal component axis, ASV = AMMI Stability value, ASVi = Rank of AMMI Stability value

Conclusion

The genotype and environment main effects (genotype and environment) and genotype x environment interaction effect were significant on Snap bean genotypes. G-24 andG-12 genotypes were the higher yielder than other genotypes through the studied environments. However, G-10 and G-19 genotypes had the lowest yield potential through the tested locations. AMMI model shows the variation was largely due to environmental variation. The high percentage of environmental variation is an indication that the major factor that influence yield performance of snap bean genotypes is the environment. G-24 and G-12were plotted to the ideal genotypes considered as desirable genotypes based on GGE bi-plot graph and stable genotypes while G-19 and G-30 were far from the ideal genotypes considered as most unstable genotypes with poor performance across locations.G-24 and G-12genotypeshad least AMMI stability and genotypic selection index value and were widely adaptable and stable high yielding genotypes and were proposed as candidate genotypes for possible release.

Acknowledgment

The authors thank Oromia Agricultural Research Institute for funding the research activity and Adami Tulu Agricultural Research Center for facilitation and Horticulture and Spice Research Team acknowledged for their technical support during field evaluation.

References

Broughton, W. J., Hernandez, G., Blair, M., Beebe, S., Gepts, P., Vanderleyden, J. 2003.Bean (*Phaseolus*spp.) – model food legumes. Plant and Soil 252: 55–128.

Chianu, J.N., Nkonya, E.M., Mairura, F.S., Chianu, Justina N., Aknnifesi, F.K. 2011. Biological nitrogen fixation and socioeconomic factors for legume production in sub-SaharanAfrica: a review. Agron. Sustain. Dev. 31: 139 –154.

Decoteau, D.R. 2000.Vegetable crops. Prentice Hall, London.

Kay, D.E. 1979. Food legume crops and product digest No. 3 Tropical products institute, pp.124-140.

Purchase, J.L., Hatting H., and Vandenventer, C.S. 1997. Genotype x environment interaction of winter wheat in South Africa: II. Stability analysis of yield performance .South Afr J Plant Soil, 17: 101-107.

Slaton, N.A., Golden, B.R., DeLong, R.E., Massey, C.G. 2007. Green bean yield as affected by nitrogen Fertilization strategy. Wayne E. Sobbe Arkansas Soil Fertility Studies: AAESResearch Series 558.

Yan W and Hunt LA.(2001). Interpretation of genotype x environment interaction for winter wheat yield in Ontario. Crop Sci 41: 19-25.

Yan, W., Hunt, L.A., Sheng, Q. and Szlavnics, Z. 2000. Cultivar evaluation and mega environment investigation based on the GGE biplot. *Crop Science,* 40: 597–605.

Effect of NPS Fertilizer Rates on Yield Components, Yields and Quality of Coriander (*Coriandrum sativum* L.)

Usman Kedir

Adami Tulu Agricultural research center, Batu/Ziway, Ethiopia

Abstract

Coriander is an important aromatic annual condiment and spice crop grown for both green leaves and dried seeds. The field experiment was conducted at three locations of Adami Tulu, Dugda and Lume for two successive years to identify economically feasible rates of NPS fertilizer. The six level of fertilizers rates (0, 30, 60, 90, 120 and 150 kg NPS ha^{-1}) were laid out in randomized complete block design with three replications. Statistical analysis of the data revealed that highly significant differences in days to 50% flowering (DTF), days to maturity (DTM), plant height (PH), number of seeds per umbel (SPU) in 2019/20 and Number of umbels per plant (UPP) in 2020/21 across three locations were observed. While number of primary branch (NPB), number of umbelets per umbel (UPU), seed yield (SY), and essential oil content (EC) showed highly significant variation in both years with high concentrations on NPS fertilizer rates. The minimum (DTF) 65 from 120 kg NPS ha^{-1}, early maturing (DTM) 116 from 90 kg NPS ha^{-1}, the highest (PH) 131.67cm from 90 kg NPS ha^{-1}, (SPU) 855.5 from 90 NPS kg ha^{-1}, (UPP) 44.47 from 150 kg NPS ha^{-1}, (NPB) 7.47 from 90 kg NPS ha^{-1}, (UPU) 8.93 from 120 kg NPS ha^{-1}, the highest (SY) 18.33q from 90 kg NPS $ha^{-1}$and (EC) 0.79 from 90 kg NPS ha^{-1} were recorded. The results indicated that the overall performance of the seed yield and essential oil content of the crop was the best in both years with respect to NPS fertilizers rates. In general, the economic feasibility of the fertilizer indicated that application of (90, 120 and 120 kg NPS ha^{-1}) with marginal rate of return (1861, 3242 and 658 %) at Adami Tulu, Dugda and Lume in 2019/20 *and application of (90, 120 and 150 kg NPS ha^{-1}) with marginal rate of return (3910, 1574, 1586 %) was obtained at Adami Tulu, Dugda and Lume in 2020/21 respectively. However, as compared to overall two years treatments the highest net benefits increments for (90, 120 and 120 kg NPS ha^{-1}) fertilizer rates were economically feasible. Therefore, the soil nourished with (90, 120 and 120 kg NPS ha^{-1}) at Adami Tulu, Dugda and Lume respectively was suggested to the coriander growers.*

Keywords: *coriander, economic analysis, essential oil content, NPS, yield*

Introduction

Coriander (*Coriandrum sativum*, L.) is an important aromatic annual condiment and spice crop belongs to family *Umbelliferae* (*Apiaceae*) (Hassan *et al*., 2012). It is an annual herb and grown for both green leaves and dried seeds. Coriander is used in many industries, including the manufacture of pharmaceuticals, food and cosmetics. The plant material used for processing by the herbal industry is the fruit (*Fructus Coriandri*) and essential oil (*Oleum Coriandri*) extracted from coriander fruit (Bourdock and Carabin, 2009). The green leaves are used in chutneys, sauce, curry and other preparation because of its pleasant aroma along with flavoring of dishes and seasoning the curry and soups. Coriander seed rich in volatile oil is used as a spice and folk remedy, and essential oil derived from seeds is also used in perfumery, food, tobacco, soft and alcoholic beverage, and pharmaceutical industries and this could be answer why coriander seeds are an important ingredient of curry powder widely used in world cuisines (Moniruzzaman *et al*., 2014 and Yousuf *et al*., 2014). Coriander oil also possesses medicinal properties, such as: antibacterial, anti-fungal or anti-oxidant properties (Singh *et al*., 2006, Matasyoh *et al*., 2009, Asgarpanah and Kazemivash, 2012). Studies indicated that one hectare of coriander allows honeybees to collect about 500 kg of honey (Diederichesen, 1996). The residues left after extraction of the essential oils are used as best ruminant feed since they still contain as nearly the same digestible fat and protein content as the whole fruits (Diederichesen, 1996).

The yield and essential oil content of coriander is influenced by weather conditions, agronomic and genetic factors. The productivity of coriander is influenced by several factors such as soil, varieties, fertilizer management and various agro techniques used for growing crop. Among the production techniques the basic agronomic management practices like time of sowing, planting geometry, seed rate and nutrient management practices plays an important role in enhancing the productivity of the coriander (Kurubetta *et al*., 2008). Nutrients play a vital role in functioning of normal physiological processes during the period of growth and development of the plants. Fertilizations are the major factors affecting the growth, yield and volatile oil content of coriander (Hassan *et al*., 2012). Appropriate use of fertilizers rates are the supreme importance for new released variety. The released variety has its own requirement of fertilizer rates for growth and maturity. Fertilizers applications for crop plays major role in crop yield improvement with better plant health. For sustainability in crop production and improvement in soil health, balanced fertilization is very important (Sharif *et al*., 2004).

Considering the importance of the coriander crop and its nutritional requirements, to have consistently higher yield of quality produce for the recently released coriander varieties, standardization of fertilizer requirement is very important. Therefore, this study was undertaken with the following objectives: to determine the effect of NPS fertilizer rates on yield components, yield and seed quality of coriander; and to identify economically feasible rates of NPS fertilizer in the study area.

Materials and methods

Description of the Study Area

The field experiment was conducted at Adami Tulu, Dugda and Lume site from July to November for two consecutive years of 2019/20 and 2020/21 under rain fed conditions at each location.

Experimental Materials

Plant material: The recently released coriander variety of '*Batu'* was used as test crop. This varieties where released from Adami Tulu agricultural research centers, which have a good adaptation and better performance in the area.

Fertilizer materials: The NPS fertilizers (19% N, 38% P2O5 and 7% S) were used as the sources of fertilizers.

Soil Sampling and Analysis : One representative soil sample was taken at a depth of 0-30 cm from five randomly selected spots diagonally across the experimental field using auger before planting. The sample was air dried under shade. The sample was analyzed for selected physico-chemical properties, namely organic carbon, texture, soil pH, cation exchange capacity (CEC), total N, available P and S.

Treatments and Experimental Design

The treatments were consisted of coriander seeding rates (12 kg ha^{-1}) and five levels of NPS fertilizer rates (0, 30, 60, 90 and 120) where arranged in a randomized complete block design (RCBD) with three replications. The gross plot size was 8 rows of three meter length (3 m×2.4 = 7.2 m^2) with net harvestable rows of 6 with 2.5 m length (2.5 m×2.0 m = 5 m^2) were considered as net plot. The spacing between rows, plots and blocks were 0.30, 0.5 and 1 m, respectively.

Experimental Procedures and Field Management

The experimental field was ploughed with oxen to a fine tilth three times and the plots were leveled manually. According to the design, a field layout was made and each treatment was assigned randomly to the experimental units within a block. Coriander seeds were sown in rows of 30 cm spacing manually by drilling. The whole amount of NPS fertilizer rates were applied at the time of sowing for each treatment. Weeding was done as needed; and harvesting and threshing was done manually.

Crop Data collected

Growth parameters

Days to 50 per cent flowering: The number of days was counted from the date of sowing till 50 per cent of the flowering and recorded as days taken for 50 per cent flowering.

Days to maturity (crop duration): The number days taken to attain maturity was counted from sowing to harvest. The harvesting was done when 90 percent of umbels turned dark green to light brown color the duration in each plot is expressed in number days.

Plant height (cm): The height of the plant was measured in centimeter from the ground level to the top most nodes in the main stem at 90 DAS and expressed in centimeters.

Number of branches per plant: The number of primary branches per plant were counted and recorded at 90 DAS. Secondary branches were recorded at 90 DAS stage and expressed as total number branches per plant.

Yield and yield parameters

Number of umbels per plant: The numbers of umbels in each of five plants were counted at 90 days after sowing and the average value was expressed as number of umbels per plant.

Number of umbellets per umbel: Umbellets were counted in five umbels per plant and average value was per umbel express of number of umbellets per umbel.

Number of seeds per umbel: From each selected plant, five umbels were selected randomly and seeds were counted. Average was recorded as mean seed count per umbel.

Seed yield per hectare (q): The yield per hectare was calculated based on the yield obtained per plot, and expressed in quintals per hectare.

Quality parameters (seed)

Essential oil content (%): Essential oil content was done at Wendo Genet Spice crop laboratory by hydro-distillation of 250 g of coriander at seed powder of each plot was measured and expressed as dry based volume by weight.

Data Analysis

All data collected was subjected to analysis of variance (ANOVA) procedure using GenStat (17^{th} edition) software (GenStat, 2014). The comparisons among treatments means with significant difference for measured characters will be done by LSD test at 5% level of significance.

Economic Analysis

The economic analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on hectare basis in Birr. The concepts used in the partial budget analysis were the mean of seed yield of each treatment, the gross benefit (GB) ha^{-1} (the mean yield for each treatment) and the field price of fertilizers (the costs of NPS). Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer application, was calculated by dividing the net increase in yield of Coriander due to the application of each fertilizers rate. The net benefit (NB) was calculated as the difference between the gross field benefit and the total variable (TVC) using the formula.

NB= GFB -TVC

Where GFB = Gross Field Benefit, TVC = Total Variable Cost

Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield of farmers could expect from the same size field.

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as “D”). The dominance analysis illustrates that to improve farmers' income, it is important to pay attention to net benefits rather than yields, because higher yields do not necessarily mean high net benefits. The discarded and selected treatments using this technique were referred to as dominated and undominated treatments. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:-

$$\text{MRR (\%)} = \frac{\text{Change in NB (NBb}-\text{NBa)}}{\text{Change in TCV (TVCb}-\text{TVCa)}} \times 100$$

Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TVC_a = the immediate lower TVC and TVC_b = the next highest TCV.

The % MRR between any pair of undominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns, the % MRR was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost). Thus, a MRR of 100% implied a return of one birr on every birr spent on the given variable input. The fertilizer cost was calculated for the cost of each fertilizer of NPS (Birr 14.96 kg $^{-1}$) during sowing time. The average open price of Coriander at Ziway, Maki and Koka market was Birr 60 and 70 kg $^{-1}$ in December 2019/20 and 2020/21 respectively during harvesting time.

Results and discussions

Soil Physico-chemical Properties of the Experimental Site

According to the laboratory analysis, the soil texture of the experimental area is sandy loam, loam and clay loam in 20219/20 and loam, clay loam and clay loam in 2020/21 at Adami Tulu, dugda and Lume area respectively. The soil texture influences water contents, water intake rates, aeration, root penetration, and soil fertility. The pH of the soil was 7.53, 7.11 and 6.67 in 20219/20 and 7.79, 6.90 and 8.08 in 2020/21 for AdamiTulu, Dugda and Lume respectively. FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil was within the range for productive soils except for Lume in 2020/21. Sahlamedihin (1999) reported the pH of the soil between (5.00 -7.55) was found within the suitable range for crop production. The Netherlands commission of the ministry of agriculture and fisheries (1985) classified soils having total organic C % greater than 3.50, 2.51-3.5, 1.26-2.5, 0.60-1.25 and less than 0.6 is categorized as very high ,high, medium, low, and very low respectively. According to the Ethiosis (2014) reference soil organic carbon content in both years of the experimental site was low. The result of soil analysis has poor total nitrogen in both years according to the rating of Tekalign *et al*, (1991). Soil analysis also indicated that very high available phosphorus content in both years according to the rating of Olsen *et al*. (1954).

The analysis for available sulfur indicated that optimum for three sites in 2019/20 and Very high, Very high and high results was recorded in 2020/21 at Adami Tulu, Dugda and Lume respectively according to Ethiosis (2014). The CEC value of the soil sample is high in both years except for Lume in 2020/21which recorded very high according to the rating of Landon (1991) which indicates the soil has high capacity to hold exchangeable cations. Cation Exchange Capacity (CEC) is an important parameter of soil, because it give an indication of the type of clay minerals present in the soil, soil texture, organic matter content of the soil and its capacity to retain nutrients against leaching (Sahlamedihin, 1999).

Table 1. Selected physico-chemical properties of the soil of the experimental site before sowing

No	Soil characters	Values of soil samples for two year Adami Tulu		Dugda		Lume		References and rating
1.	Soil texture	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	
	Sand (%)	53.91	48.00	40.58	30.50	36.00	32.87	
	Clay (%)	12.57	19.76	21.22	34.75	29.87	32.51	
	Silt (%)	33.52	32.24	38.20	34.75	34.14	34.61	
	Texture	S. loam	Loam	Loam	C. loam	C.Loam	C. loam	
2.	pH-H_2O(1:1.25) in 2019/20 pH-H_2O(1:2.5) in 2020/21	7.53	7.79	7.11	6.90	6.67	8.08	Ethiosis (2014), <5.5 Strongly, 5.6-6.5 Moderately acidic, 6.6-7.3 Neutral, 7.3-8.4 Moderately alkaline, >8.4 Strongly alkaline
3.	Organic Carbon (OC) (%)	1.05	0.583	1.01	0.74	0.45	0.43	Ethiosis (2014), <0.2 Very low, 2.0–3.0 Low, 3.0–7.0, Optimum, 7.0–8.0 High > 8.0 Very high
4.	CEC (meq/100 gm of soil)	38.18	31.60	32.64	32.43	38.34	46.33	Landon (1991), >40 cmol (+) / kg very high, 25-40 cmol (+) / kg high, 15-25 medium, 5-15 low < 5 cmol (+) / kg very low
5.	Total Nitrogen (%)	0.15	0.07	0.13	0.10	0.06	0.06	Tekalign *et al*. (1991), < 0.05% very low 0.05-0.12% poor 0.12-0.25% moderate > 0.25 % high
6.	Available P (mg P_2O_5/kg soil)	50.74	44.83	20.91	87.16	22.65	38.35	Olsen *et al*.(1954), 3ppm very low, 4-7ppm low, 8-11ppm medium, 12-20ppm high >20ppm very high
7.	Available S (mg/kg soil)	62.12	117.76	29.92	160.23	22.54	95.82	Ethiosis (2014), 20-80 Optimum, 80-100 High, > 100 Very high
8.	EC (mS/cm) (1:1.25) and (1:2.5) in 2020/21	0.51	0.25	0.20	0.33	0.14	0.18	< 2 Salt free 2-4 Very slightly, 4-8 salines 8-16 slightly saline >16 moderately

Days to 50 per cent flowering

The analysis of variance revealed that NPS fertilizer rates highly significant difference ($P < 0.01$) at three locations in 2019/20 and the non significant data was recorded at Adami Tulu and Dugda except for Lume highly significant difference ($P \leq 0.01$) observed in 2020/21 (Table 2). The highest prolonged duration to reach days to flowering was observed in both years in response to zero rates of the fertilizers application. However, the minimum duration of days to flowering (65.67, 65.67 and 65.00) was observed at Adami Tulu, Lume and Dugda respectively with NPS fertilizer rate of 120 kg ha^{-1} in 2019/20, whereas (66.33) with 120 kg ha^{-1} of NPS fertilizer rate at Lume in 2020/21 (Table 2). The performance of coriander from vegetative to reproductive phase might be differed due to production of flowers. Application of fertilizer has been documented to enhance plant growth and development. This might be due to the NPS fertilizer enable plants to more active shoot growth and to synthesize hormones for more flower initiations. The result is similar with Suman *et al*. (2018) reported that bio fertilizer treated plants became physiologically more active and enable to synthesize required amounts of hormones and also reported 50 per cent flowering (47.30 days).

Days to maturity

The main effect of NPS fertilizer rates was highly significantly ($P < 0.01$) on days to maturity of coriander at three locations in 2019/20 years, while highly significantly ($P \leq 0.01$) at Adami Tulu, the non significant was obtained at Dugda and significant difference ($P \leq 0.05$) at Lume was recorded in 2020/21. The early maturing (116.00 days) was obtained from 90 kg NPS ha^{-1} at Lume in 2019/20 whereas the early maturing (103.33 and 106.33 days) was obtained from 150 kg NPS ha^{-1} at Adami Tulu and Lume in 2020/21 respectively. While the longest days to maturity (112.67, 117.00, 124.00 days) and 111.00, 114.3, 112.67 days) was recorded in 2019/20 and 2020/21 at Adami Tulu, Dugda, Lume respectively from both years with zero fertilizer rates (Table 2). This type of variation to attain maturity might be the availability of P element as an energy source in the form of ATP. Hence, P element deficiency has the ability to affect the growth and development of the plant. On the other hand, limitation of P supply has been shown to decrease the production of floral structures (Ma *et al*., 2001). Similarly, Nitrogen deficiency in soil also leads to retarded growth and loss of weight of plant aerial organs as well as premature ripeness of plants (Oliveira *et al*. 2003).

Table 2. Main effects of NPS fertilizer rates on days to heading (DH) and days to maturity (DM) of coriander

Year	In 2019/20						In 2020/21					
Treatment	DTF			DTM			DTF			DTM		
	Location			Location			Location			Location		
NPS rates (kg ha^{-1})	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	69.7b	69.7 c	72.3c	112.7b	117.0c	124.0b	67.3	69.3	71.3b	111.0b	114.3	112.7b
30	69b	69bc	70.3c	112b	115b	121b	66.3	69.0	71b	110b	114.0	110ab
60	69b	68ab	67b	106a	113a	117a	65.3	66.0	66.7a	105a	109.7	107a
9 0	66a	66.0a	67ab	106a	112a	116a	65.7	68.3	66.7a	105a	112.7	108a
120	66a	65.7a	65.0a	107a	111a	117a	63.3	66.7	66a	105a	111.0	107a

150	66a	67a	66ab	107a	112a	117a	64.7	67.3	67a	103a	111.0	106a
LSD(0.05)	1.62 ***	1.88 ***	2.14 ***	2.93 ***	1.62 ***	2.92 ***	NS	NS	3.04 ***	2.44 ***	NS	3.63 **
CV (%)	1.3	1.5	1.7	1.5	0.8	1.3	2.1	2.2	2.4	1.3	1.8	1.8

Plant height (cm)

The main effect of NPS fertilizer rates significantly ($P < 0.01$) influenced plant height of coriander. The main effect of NPS fertilizer rates was highly significant ($P < 0.01$) on Plant height of coriander at three locations in 2019/20 years, while highly significant ($P < 0.01$) and ($P \leq 0.01$) was recorded at Adami Tulu and Lume respectively and the non significant difference at Dugda was obtained in 2020/21. The tallest plant height of (131.67, 121.2 and 127.5 cm) was recorded at Adami Tulu, Dugda and Lume with fertilizer rate of 90, 90 and 120 kg ha^{-1} respectively in 2019/20 and the highest plant height (106.73, 118.1 and 115.07 cm) was recorded at Adami Tulu, Dugda and Lume with fertilizer rate of 120, 150 and 150 kg ha^{-1} in 2020/21 respectively, while the shortest plant height was obtained at zero fertilizer rates in both year. This might be due to the adequate supply of balanced fertilizer increased cell elongation and rapid cell division in the growing portion leading to increased length of internodes. These results were in conformity with Singh (2015) increased plant height may be due to increased uptake of nitrogen, which being the constituent of protein and protoplasm, vigorously induce the vegetative development of the plant.

Number of primary branch (NPB): The analysis of variance indicated that Number of primary branch was highly significant ($P \leq 0.01$) affected by the main effects of NPS fertilizer rates at both years (Table 3). The maximum number of primary branch (7.47, 6.63 and 5.97) was produced at Adami Tulu, Dugda and Lume under application of the NPS fertilizer rates of (90, 90 and 150 kg ha^{-1}) in 2019/20 respectively and (4.80, 4.00 and 4.27) was produced at Adami Tulu, Dugda and Lume under application of the NPS fertilizer rates of (60, 150 and 60 kg ha^{-1}) in 2020/21 respectively. Whereas, the minimum number of primary branches (4.93, 5.23, and 4.80) and (3.47, 3.07, 3.07) were recorded in 2019/20 and 2020/21 from Adami Tulu, Dugda and Lume with zero fertilizer rate respectively. This might be due to balanced NPS nutrient enhances maximum growth of crop and encourages vegetative growth of the crop and also increases the main stem diameter, the biggest and most strongly number of lateral branches, longest internodes length. In line with this result, application of nitrogen encourages vegetative growth, which results in the increased yield of leaves and seeds of coriander (Datta *et al*., 2008). Deficiency of nitrogen induces several morphological and physiological hazards like growth retardation, decreased leaf and branch number (Nasim *et al.*, 2012).

Table 3. Main effects of NPS fertilizer rates on Plant heights (PH) and number of primary branch (NPB) of coriander

Year	In 2019/20						In 2020/21					
Treatments	PH			NPB			PH			NPB		
	Location			Location			Location			Location		
NPS rates (kg ha$^{-1)}$	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	103a	98.0a	97.8a	4.9a	5.23 a	4.80a	93.7a	101.9	93.3a	3.5a	3.07 a	3.07a
30	103a	103ab	108 a	6.1b	5.5a	5.0ab	94.5a	103.9	98ab	4 ab	3.12 a	3.3ab
60	124 b	111bc	120 b	7.3c	6.17 b	5abc	99.8b	116.9	110 c	4.8 c	3.87 b	4.27c
90	132 c	121 d	124 b	7.5c	6.6 b	5.5bc	1045c	115.7	108bc	4.5bc	3.83 b	4.13c
120	127b	120cd	128 b	7.4 c	6.43 b	5.5bc	107d	117.6	109 c	5 bc	3.30 a	3.7ab
150	129b	120cd	127 b	7.2 c	6.43 b	5.97c	102b	118.1	115 c	4bc	4.00 b	3.9bc
LSD(0.05)	6.67*	9.22*	11**	1.1*	0.59*	0.6**	4.1**	NS	9.6**	0.7*	0.5**	0.6**
CV (%)	3.1	4.5	5.0	9.0	5.4	6.1	2.2	6.9	5.0	9.5	7.9	8.9

Number of secondary branch (NSB)

The analysis of variance indicated that number of secondary branch was highly significantly ($P \leq 0.01$) affected by the main effect of NPS fertilizer rates at Lume and significantly ($P \leq 0.05$) affected at Adami Tulu as well as the non significant data was recorded from dugda in 2019/20. Whereas the number of secondary branch was significant ($P \leq 0.05$) at Dugda and Lume except non significant data obtained at Adami Tulu in 2020/21 (Table 4). The maximum number of secondary branch (8.73 and 7.83) was recorded at Adami Tulu and Lume from the application of the highest rates of (120 and 150 kg NPS ha^{-1}) in 2019/20 respectively, as well as (8.87 and 9.67) was recorded at Dugda and Lume from the application of (150 and 90 kg NPS ha^{-1}) in 2020/21 respectively. Whereas, the minimum number of secondary branches (5.67 and 5.70) and (5.27 and 5.00) were recorded in 2019/20 from Adami Tulu and Lume and in 2020/21 from Dugda and Lume with zero fertilizer rate respectively. The increase in number of primary and secondary branches could be due to application of nitrogen as NPS made exuberant growth of the basal buds there by leads to increased branching. This might be due to adequate supply of balanced NPS nutrients associated with high the biomass production leading to vigorous vegetative growth. The application of NPS fertilizer nutrient allows the high number of branch set and provides better canopy structure. Wenting *et al*. (2016) reported that nitrogen deficiency can reduce canopy growth and cause premature senescence, and thereby reduce yields.

Number of umbels per plant (UPP)

The analysis of variance showed that the main effects of NPS fertilizer rates was highly significant ($P \leq 0.01$) and ($P < 0.01$) at Dugda and Lume in 2019/20 and in 2020/21 respectively, on the number of umbels per plant. The highest number of umbels per plant (43.60 and 30.43) was counted at Dugda and Lume in 2019/20 with NPS fertilizer level of 120 kg ha^{-1} respectively. Whereas the maximum number of umbels per plant (44.47, 31.93 and 25.87) was recorded at Adami Tulu, Dugda and Lume in 2020/21 with highest NPS fertilizer level of (150, 150 and 90 kg ha^{-1}) while lowest number of umbels per plant (32.73 and 21.40) and (30.73, 18.40 and 15.80) from Dugda and Lume in 2019/20 and Adami Tulu, Dugda and Lume in 2020/21 respectively at zero level of NPS fertilizer (Table 4). The result showed that giving NPS fertilizer in soil with high P status (87.16 mg/kg P_2O_5) could still increase number of umbels per plant and the number of umbels per plant with highest NPS fertilizer level of (150 kg ha^{-1}) was 44.47. More number of umbels per plant and umbelets per umbel might be attributed to the abundant supply of available phosphorus nutrients from soil convey more translocation from source to arial parts for synthesis proteins and other compounds which probably have led to an improvement in yield and yield related attributes. It is widely found that increasing P as a fertilizer promote reproductive yields (Egle *et al*., 1999) and inflorescence production (Besmer and Koide, 1999), particularly when P is limiting in natural systems (Feller, 1995). The maximum number of umbels per plant (31.70) was reported by Anilkumar *et al*., (2018). Nahed and Darwesh (2015) reported that nitrogen fertilization 60 kg nitrogen feed as urea produced the maximum values of number of umbels per plant and the highest plant height for both seasons.

Table 4. Main effects of NPS fertilizer rates on number of secondary branch (NSB) and number of umbels per plant (UPP) of coriander

Year	In 2019/20						In 2020/21					
Treatments	NSB			UPP			NSB			UPP		
	Location			Location			Location			Location		
NPS rates (kg ha^{-1})	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	5.7 a	5.93	5.70	48.3	32.7 a	21.4a	8.60	5.3a	5.0 a	30.7a	18.4 a	15.8a
30	6.7ab	6.23	6.03	49.1	34.1a	22.6a	9.53	5.73ab	5.9ab	32.8a	20.7ab	18.7ab
60	7abc	6.57	7.10	53.2	40.2 c	26.5b	11.67	8.27 c	8.7c	42ab	28.3bc	21.6bc
90	8.1bc	7.43	7.17	55.9	39.6 c	26.6b	10.33	7.9 bc	9.7c	40ab	32.9c	25.8 c
120	8.7c	7.03	7.53	57.3	43.6 c	30.4b	10.23	7.4abc	7.8bc	44.1b	24.8ab	25.2c
150	7.7bc	6.70	7.83	54.6	39.7bc	26.8b	10.60	8.87 c	8.1bc	44.5b	31.9c	23.4bc
LSD(0.05)	1.7**	NS	0.8**	NS	5.5**	2.5**	NS	2.3 **	2.5**	10.4*	8.8 **	5.2**
CV (%)	12.8	9.5	7.0	8.6	7.9	5.3	13.9	17.5	18.4	14.6	18.5	13.2

Number of umbelets per umbel (UPU)

Analysis of variance revealed that main effects of NPS fertilizer rate were highly significant ($P \leq 0.01$) in 2019/20 on number of umbelets per umbel and significant of ($P < 0.05$) as well as ($P < 0.01$) data was recorded at Adami Tulu as well as Dugda and Lume respectively in 2020/21 (Table 5). The highest number of umbelets per umbel (7.73, 8.93 and 7.13) was counted at Adami Tulu, Dugda and Lume in 2019/20 with NPS fertilizer level of (120 kg ha^{-1}) respectively. Whereas the maximum number of umbelets per umbel (7.40, 7.06 and 6.89) was recorded at Adami Tulu, Dugda and Lume in 2020/21 with NPS fertilizer level of (150, 90 and 60 kg ha^{-1}) respectively, while the lowest number of umbelets per umbel (6.03, 7.75 and 5.81) and (5.63,5.39 and 5.18) from Adami Tulu, Dugda and Lume in 2019/20 and Adami Tulu, Dugda and Lume in 2020/21 respectively at zero level of NPS fertilizer except in 2020/21with 30 kg ha^{-1} from Lume (Table 5). This might be due to the optimum application of NPS results higher number of umbelets per umbel. Izgi (2020) reported that, applications over 60 kg of nitrogen per hectare resulted in a decrease in the number of umbels in the plant.

Number of seeds per umbel (SPU)

The analysis of variance showed that the main effect of NPS fertilizer rates had highly significant ($P < 0.01$) at Lume as well as significant ($P < 0.05$) difference at Adami Tulu and Dugda in 2019/20 on number of seeds per umbel of coriander. Whereas, significant ($P < 0.05$) effect of NPS fertilizer rates were recorded at Dugda and Lume in 2020/21 (Table 5). The highest number of seeds per umbel (855.5, 541.0 and 499.7) was recorded from Adami Tulu, Dugda and Lume with fertilizer rates of (90, 120 and 120 NPS kg ha^{-1}) in 2019/20 as well as (422.93 and 451.81) was recorded from Dugda and Lume with fertilizer rates of (60 and 150 NPS kg ha^{-1}) in 2020/21 respectively. Where, the lowest number of seeds per umbel of (316.14) was recorded from zero NPS fertilizer rates at Dugda in 2020/21 (Table 5). Phosphorus feed as NPS is required in large quantities in young cells, such as shoots and for rapid cell division states more number of flowers and more number of seed set per umbels. The result is in agreement with Yousuf *et al*. (2014) reported that increase in number of capsules per plant is due to production of more number of flowers per umbel, higher percentage of capsule set and reduced shedding of flowers and capsule and resulted in increased yield.

Table 5. Main effects of NPS fertilizer rates on number of umbelets per umbel (UPU) and Number of seeds per umbel (SPU) of coriander

Year	In 2019/20						In 2020/21					
Treatments	UPU			SPU			UPU			SPU		
	Location			Location			Location			Location		
NPS rates (kg ha^{-1})	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	6.03a	7.75 a	5.81a	717a	485.4a	414a	5.63a	5.39a	5.23a	375.8	316.1	339.6
30	6.18a	7.86 a	6.01a	721 a	492.4a	427a	6.0ab	6.12b	5.18a	403.8	339.4	346.8
60	7.32b	8.63b	7.09b	784a	530b	495b	7.1bc	6.70c	6.89b	481.9	422.9	423.8
90	7.59b	8.88 b	7.07b	856b	531.b	492 b	7. bc	7.06c	6.4b	438.4	401.4	431.6
120	7.73b	8.93 b	7.1b	770 a	541.b	500b	7.4c	6.72 c	6.8b	466.5	403.7	418.0
150	7.46b	8.52 b	6.8b	759a	536b	476b	7.4c	6.96 c	6.46b	430.7	416.3	451.8
LSD(0.05)	0.8**	0.5**	0.7**	89 *	34**	41**	1.1**	0.5**	0.5**	NS	64**	75 **
CV (%)	6.3	3.4	6.0	6.4	3.6	4.8	8.5	4.6	4.3	10.7	9.2	10.2

Seed yield per hectare (SYh) (q)

The analysis of variance showed that the main effect of NPS fertilizer rates had highly significant ($P \leq 0.01$) in both years on seed yield of coriander (Table 6). The highest seed yield of coriander (16.27, 16.81 and 14.18 q ha^{-1}) was obtained from Adami Tulu, Dugda and Lume in 2019/20 at NPS fertilizer rates of (90, 120 and 120 kg NPS ha^{-1}) respectively as well as (18.33, 14.23 and 11.44 q ha^{-1}) was recorded from Adami Tulu, Dugda and Lume in 2020/21 with NPS fertilizer rates of (90, 120 and 150 kg ha^{-1}) respectively. While the lowest seed yields were recorded from zero fertilizer applications in both years from all the lowest (6.54 q ha^{-1}) was obtained from Lume in 2020/21 (Table 6). The NPS fertilizer rates at highest rates up to 90 kg ha^{-1} for Adami Tulu and 120 kg ha^{-1} for Dugda caused a significant increase of coriander (*Coriandrum sativum* L.) seed yield in both years. NPS is an essential nutrient in creating the plant growth and development, as well as have many energy-rich compounds that regulate photosynthesis and plant production. This might be the main component N feed as NPS is used for plant amino acids and chlorophyll formation as usually acquired by plants in greater quantity from the soil than any other element. The result is in agreement with, Karoline *et al*., (2016) and Carrubba (2009) Coriander has variable response to N application and its use efficiency depends on the general conditions of soil fertility and such dependence is probably the reason why the adequate supply of N, increases the probability of maximizing production. On the other hand, with higher rates of NPS fertilizer application increase seed yields may be due to Phosphorus feed as NPS have the role of structural, energy transfer and improvement of root growth. The result showed that giving NPS fertilizer in soil with high P status (87.16 mg/kg P_2O_5) could still increase seed yield and the highest seed yield with (90 kg ha^{-1}) NPS fertilizer was 18.33 q ha^{-1}. These results may prove that Coriander crop needs a high demand for phosphorus fertilizer. In line with this results, in as much as P application has been found to increase yields in coriander (Moslemi *et al*., 2012). The increase in the yield might be due to the adequate supply of NPS fertilizer upshots the production of maximum number of umbels and umblets per plant this contributed seed set and increase in yield components. It might also due to; Phosphorus has the role of structural, energy transfer and improvement of root growth and also adjusts the effect of extra nitrogen in maturity delay (Mostafa *et al*., 2012). Wladysław and Justyna (2015) achieved the highest coriander in fruit yield up to 1.84 t ha^{-1} in soil nourished with just 20 kg N ha^{-1}.

Essential oil content (EC) (%)

Essential oil content of coriander was highly significantly ($P \leq 0.01$) affected by main effect of NPS fertilizer rates in 2019/20 and high significant effect of ($P < 0.01$) NPS fertilizer rates in 2020/21 (Table 6). The highest EC of (0.69, 0.66 and 0.66 %) where obtained from main effect of (150, 120 and 60 kg ha^{-1} NPS) in 2019/20 at Adami Tulu, Dugda and Lume respectively (Table 6) and the lowest (0.44, 0.41 and 0.36 %) where obtained from zero kg ha^{-1} NPS in 2019/20 at Adami Tulu, Dugda and Lume respectively. Whereas the highest EC (0.79, 0.77 and 0.60 %) was obtained from the NPS fertilizer rate of (90, 60 and 90 kg ha^{-1}) in 2020/21 at Adami Tulu, Dugda and Lume respectively, while the lowest EC (0.53, 0.42 and 0.32) was obtained at Adami Tulu, Dugda and Lume respectively with 0 kg ha^{-1} NPS fertilizer rates. NPS fertilization caused a significant increase in the essential oil content of coriander, with its highest 0.79 % concentrations determined in seed from plants fertilized with 90 kg NPS ha^{-1}.

This might be attributed to the Nitrogen feed as NPS increased photosynthetic CO_2 fixation which provides more carbohydrates and proteins for metabolism and leads to accumulation of metabolites like oil. Similarly, the uptake of NPS showed positive effect on essential oil content than over the control. Phosphorus aids in root development, flower initiation, seed and fruit development and P has been shown to reduce disease incidence in some plants and has been found to improve the quality of certain crops (Silva and Uchida, 2000). Similarly, P as fertilizer decomposes carbohydrate in photosynthesis, as well as required in many other metabolic processes for normal growth and fatty acid production. Application of phosphorus fertilizer had a positive effect on essential oil content and yield of cumin plant (Tuncturk and Tuncturk, 2006). Sulphur, an essential secondary plant nutrient, plays a vital role in biosynthesis of primary metabolities for improving yield and quality of oil seed crops and for accruing better yield under balanced fertilization (Anwar *et al.*, 2002). Oil concentration in seed increased with S fertilization (Malhi *et al*., 2007).

Table 6. Main effects of NPS fertilizer rates on Seed yield per hectare (SYh) (q) and Essential oil content (EC) (%) of coriander

Year	In 2019/20						In 2020/21					
Treatments	SY			EC			SY			EC		
	Location			Location			Location			Location		
NPS rates (kg ha^{-1})	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	9.60a	10.49a	8.86a	0.44a	0.41 a	0.36a	10.1a	8.60 a	6.54a	0.5a	0.42 a	0.3a
30	10.9a	11.5ab	10ab	0.49a	0.46 a	0.42a	11.0a	9.83a	7.74a	0.6ab	0.6ab	0.3a
60	14.6b	13.3bc	13bc	0.63b	0.60b	0.66b	15bc	12.5b	9.87b	0.7bc	0.77c	0.54b
90	16.3c	14.31c	13.6c	0.66b	0.61b	0.59b	18.3c	12.8bc	9.74b	0.79c	0.70bc	0.60b
120	15.1b	16.8d	14.2c	0.65b	0.66b	0.63b	16bc	14.2c	10.0b	0.75c	0.77 c	0.51b
150	15.1b	15.1cd	14bc	0.69b	0.60b	0.58b	13ab	13.3bc	11.4c	0.78c	0.7bc	0.51b
LSD(0.05)	1.4**	2.4**	3.1**	0.1**	0.1**	0.1**	3.5**	1.5**	1.3**	0.1**	0.2**	0.2**
CV (%)	5.7	9.5	13.9	9.5	11.4	12.5	13.7	6.8	7.9	7.4	15.8	17.9

Partial Budget Analysis

Partial budget analysis is important to identify experimental treatments with an optimum return to the farmer's investment and to develop recommendation for the agronomic data. Experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, yields of farmers are adjusted by 10% less than that of the research results (CIMMYT, 1988). As indicated in Table 7, the partial budget analysis showed that the highest net benefit of (86511.6, 99064.8 and 74776.8) Birr ha^{-1} with marginal rate of return (1861, 3242 and 658 %) was obtained for coriander that received (90,120 and 120 kg NPS ha^{-1}) at Adami Tulu, Dugda and Lume in 2019/20 respectively. However, the lowest net benefits of (51840, 56646 and 47844) Birr ha^{-1} were obtained from the unfertilized treatment at Adami Tulu, Dugda and Lume in 2019/20 respectively. In case of second table 8, the highest net benefit of (113909.4, 87556.2 and 69456) Birr ha^{-1} with marginal rate of return (3910, 1574, 1586 %) was obtained for coriander that received (90, 120 and 150 kg NPS ha^{-1}) at Adami Tulu, Dugda and Lume in 2020/21 respectively. While, the lowest net benefits of (63693, 54180 and 41202) Birr ha^{-1} were obtained from the unfertilized treatment at Adami Tulu, Dugda and Lume in 2020/21 respectively. The results of this study indicate that, the higher economic yield with balanced supply of fertilizer rates obtained at application of (90, 120, 120 kg NPS ha^{-1}) in 2019/20 and (90, 120, 150 kg NPS ha^{-1}) in 2020/21fertilizer rates at Adami Tulu, Dugda and Lume respectively. Therefore, as compared to overall two years treatments of highest net benefits (90, 120 and 120 kg NPS ha^{-1}) fertilizer rates were economically feasible and recommended for production of coriander crop at Adami Tulu, Dugda and Lume respectively and other areas with similar agro ecological condition.

Conclusions and Recommendation

As conclusions, the results indicated that the overall performance of the seed yield and essential oil content of the crop was the best in both years with respect to NPS fertilizers rates. The parameters such as number of primary branch, number of umbelets per umbel, seed yield, and essential oil content showed highly significant variation in both years with high concentrations on NPS fertilizer rates. In general, the higher economic yield and feasible NPS fertilizer rates was the soil nourished with (90, 120 and 120 kg NPS ha^{-1}) at Adami Tulu, Dugda and Lume respectively was suggested to the coriander growers.

References

Ahmad, M.M.,N. yousaf and M.S. Zamir.2000. Response of wheat growth, yield and quality to varying application of nitrogen and phosphorous. *J.Agric.Res*.,38:289-329.

Anwar M., Chand Sukhmal, N. A. A. and P. D. D. 2002. Effect of graded levels of Nitrogen and Sulrphur on yield, Nutrient Accumulation and Quality of Japanese mint (*Mentha arvensis*). *Journal of the Indian Society of Soil Science*, 50(2):174-177.

Ashagre Zeleke and Ermias Habte. 2007. Seed Sciences and Technology. Ambo, West Shoa, Ethiopia.

Assefa M., Johnson M. R. Semoka, N. A. and Tekalign M. 2015. Wheat Response to Applied Nitrogen , Sulfur , and Phosphorous in three Representative Areas of the Central Highlands of Ethiopia-I. *International Journal of Plant & Soil Science*, 8(5):1-11.

Aynehband, A., Moezi, A. A. and Sabet, M. 2010. Agronomic assessment of grain yield and nitrogen loss and gain of old and modern wheat cultivars under warm climate. *African Journal of Agricultural Research,* 5(3):222-229.

Baloch, M.S., I.T.H. Shah, M.A. Nadim, M.I. Khan and A.A. Khakwani, 2010. Effect of Seeding Density and Planting Time on Growth and Yield Attributes of Wheat. *The Journal of Animal and Plant Sciences*, 20(4): 239-240.

Behera, U. K., Pradhan, S. and Sharma, A. R. 2010. Effect of biofertilizers and chemical fertilizers on productivity and quality parameters of durum wheat (*Triticum turgidum*) on a Vertisol of Central India. Archives of Agronomy and Soil Science, 56(1):65-72.

Bekalu Abebe and Arega Abebe.2016.Effect of the Rate of N-fertilizer Application on Growth and Yield of Wheat (*Triticum aestivum* L.) at Gamo-gofa Zone, Southern Ethiopia. Journal of Environment and Earth Science, 6(12):27-34.

Besmer, Y.L., and Koide, R.T. 1999. Effect of mycorrhizal colonization and phosphorus on ethylene production by snapdragon (*Antirrhinum majus* L.) flowers. *Mycorrh.,* 9:161-166.

Cock, R.L. and B.G. Ellis. 1992. Soil management, a world view of conservation Krieger Publishing Company, Malabar, Florida. 413p.

CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo).1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, DF.

Dandan Liu and Yan Shi. 2013. Effects of Different Nitrogen Fertilizer on Quality and Yield in Winter Wheat. *Advanced Journal of Food Science and Technology*, 5(5): 646-649.

Egle, K., Manske, G., Römer, W., and Vlek, P.L.G. 1999. Improved phosphorus efficiency of three new wheat genotypes from CIMMYT in comparison with an older Mexican variety. *J. Plant Nut Soil Sci.*, 162: 353 -358.

Ejaz Ahmad Waraich, R. Ahmad, Saifullah, Shamim Ahmad and A. Ahmad. 2010. Impact of Water and Nutrient Management on the Nutritional Quality of Wheat. *Journal of Plant Nutrition,* 33:640-653.

Ethiosis (Ethiopia Soil Information System). 2014. Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia.

FAO (Food and Agriculture Organization), 2000. *Fertilizers and their use 4th ed*. International fertilizer industry association, FAO, Rome, Italy.

Fatma Gokmen Yilmaz , Mustafa Harmankaya, and S. G. 2014. Yield ,Protein and Nitrogen use efficiency in Bread Wheat Genotypes. *Lucrări Ştiinţifice,* 57 (1): 39-41.

Fernando Salvagiotti , Julio M. Castelların, Daniel J. Miralles, H. M. P. 2009. Field Crops Research Sulfur fertilization improves nitrogen use efficiency in wheat by increasing nitrogen uptake. *Field Crops Research*, 113:170-177.

GenStat. 2014. GenStat Procedure Library Release. 17th edition. VSN International Ltd.

Gomaa, M.A., F. I. Radwan, I. F. R. and W. S. M. 2015. Response of Bread Wheat to Organic and Nitrogen Fertilization. *Middle East Journal of Agriculture Research*, 4(4):712-716.

Hussain, N., Khan, M.B. and Ahmad, R. 2009. Influence of phosphorus application and sowing time on performance of wheat in calcareous soils. *International Journal of Agriculture and Biology*, 10(4):399-404.

Ijaz, A.K. and Hassan, G. 2007. Effect of wild oats (*Avena fatua*) densities and proportions on yield and yield components of wheat. *Pakistan Journal of Weed Science Research*, 12(1-2): 69-77.

Inal, A., Gunes, A., Alpaslan, M., Adak, M. S., Taban, S. and Eraslan, F. 2003. Diagnosis of sulfur deficiency and effects of sulfur on yield and yield components of wheat grown in Central Anatolia, Turkey. *Journal of Plant Nutrition*, 26(7):1483-1498.

Islam, Z.U., S.Khan, J.Bakhat and W.A.Shah. 2002. Frequency of varoius nitrogen levels, lodging and seed quality in wheat. *Asian j. Plant Sci.*, 1:510-512.

Jasemi, S. S., Akbari, G. A., Akbari, G. A., Najafian, G., & Moradi, F. 2014. Nutrition management effects on grain yield, yield components and some physiological characteristics of bread wheat cultivars. International Journal of Agronomy and Agricultural Research (IJAAR), 5(3):1-6.

Kaleem, S., Ansar, M., Ali, M. A., Sher, A., Ahmad, G., and Rashid, M. 2009. Effect of Phosphorus on the Yield and Yield Components of Wheat Variety " Inqlab-91 " Under Rainfed Conditions. *Sarhad Journal of Agriculture*, 25(1):1989-1992.

Khan, H., M.A. Khan, I. Hussain, M.Z. Muhamad Zaman Khan and M.K. Khattak, 2000. Effect of Sowing Methods and Seed Rates on Grain Yield and Yield Components of Wheat Variety Pak-81. *Pakistan Journal of Biological Sciences,* 3(7): 1177-1179.

Kinaci, G. 2000. Effect of zinc microelement on quality of some wheat cultivars grown in Central Anatolia. *Turkish. J. Agri. Forestry*, 24: 601-606.

Landon, J.R. 1991. Booker Tropical Soil Manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. (eds.). John Wiley and Sons Inc., New York.

Li C, Cao W, Dai T. 2001. Dynamic characteristics of floret primordium development in wheat. *Field Crops Research*, 71:71-76.

Maqsood, M., A. Ali, Z.Aslam,M,Saeed and S.Aslam. 2002. Effect of irrigation and nitrogen levels on grian yield and quality of wheat. *Int.J.Agric.Biol.*, 4:164-165.

Memon, K.S. and H.K. Puno .2005. Effect of different nitrogen and phosphorus levels on the yield and yield components of wheat variety Pavan. Agriculture Research Station Dadu, Sindh, Pakistan. *Indus. J. Plant Sci.*, 4: 273-277.

Mohammed, Y. A., Kelly, J., Chim, B. K., Rutto, E., Waldschmidt, K., Mullock, J. and Raun, W. 2013. Nitrogen Fertilizer Management for Improved Grain Quality and Yield in Winter Wheat in Oklahoma. *Journal of Plant Nutrition*, 36:749-761.

Mostafa Moslemi, Abdolhosseini Aboutalebi, Hamed Hasanzadeh and Mehdi Hosseini Farahi. 2012. Evaluation the Effects of Different Levels of Phosphorous on Yield and Yield Components of Coriander (*Coriandrum sativum* L.). *World Applied Sciences Journal,* 19 (11): 1621-1624.

Mudassar, M .Maqbool, Maqbool Ahmad, Anser Ali, Rashid Mehmood, M. A. and M. S. 2012. Optimizing the Method and source of phosphatic Nutrition for Wheat (*Triticum astivum* L.) Under Agro-Climate of Dera Ghazi khan,pakistan. *Pakistan Journal of Nutrition*, 11(9):885-890.

Nahed M. Rashed , and R.Kh. Darwesh.2015. A comparative study on the effect of microclimate on planting date and water requirements under different nitrogen sources on coriander (*Coriandrum sativum*, L.). *Annals of Agricultural Science*, 60(2):227-243.

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean, 1954. Estimation of Phosphorus in soils by extraction with sodium bicarbonate.USDA, Circular 939.

Osman E., Frank E., W. K. and O. F. 2005. Effect of different nitrogen fertilization on yield and bread- making quality of winter wheat. *Agronomy and Soil Science*, 51(5):523-540.

Otteson,B.N., M. Mergoum, J.K. Ransom and B. Schatz. 2008. Tiller contribution to spring wheat yield under varying seeding and nitrogen management. *Agron.J.*, 100:406-413.

Prystupa, P., G.A. Slafer and R. Savin.2003. Leaf appearance, tillering and their coordination in response to NxP fertilization in barley. *J. Plant Soil*, 255: 587-594.

Rafique, S.M. Rashid, M. Akram, M.M. Ahmad, J. Hussain, R. and Razzaq, A. 2010. Optimum seed rate of wheat in available soil moisture under rainfed conditions. *J. Agric. Res*, 47(2): 464-474.

Renata Gaj, Dariusz Górski and Jacek Przyby. 2013. Effect of Differentiated Phosphorus and Potassium Fertilization on Winter Wheat Yield and Quality. *J. Elem. Sci.*,55-67.

Ricardo Campillo , Claudio Jobet, and P. U. 2010. Effects of Nitrogen on Productivity , Grain Quality , and optimal Nitrogen rates In Winter Wheat Cv . Kumpa-Inia in Andisols Of Southern Chile. *Chilean Journal of Agricultural Research*, 70(1):122-131.

Sahlamdihin Sertsu, 1999. Draft guideline for regional soil testing laboratory.NFIA, Addis Ababa, Ethiopia.

Scherer, H. W. 2001. Sulfur in crop production. *European Journal of Agronomy*, 14:81-111.

Singh, C.B., J. Kumar, A.A. Khan, R.A. Katiyar and A.K. Katiyar. 2002. Effect of nitrogen and dates of sowing on yield and quality of wheat (*Triticum aestivum* L.) seeds. *Progressive Agric*., 2:92-93.

Spink, J.H., Semere, T., Sparkes, D.L., Wahley, J.M., Foulkes, M.J., Calre, R.W. and Scatt, R.K. 2000. Effect of sowing dates and planting density of winter wheat. *Ann. App. Biol.*, 137(2): 179-188.

Šramková, Z., Gregová, E., and Šturdík, E. 2009. Chemical composition and nutritional quality of wheat grain. *Acta Chimica Slovaca*, 2(1):115-138.

Usman Kedir, Tamado Tana, Wogeyehu Worku. 2020. Effects of blended (NPSB) fertilizer rates on yield components, yield and grain quality of bread wheat (*Triticum aestivum* L.) varieties at kulumsa, south-eastern Ethiopia. *International Journal of Research Studies in Biosciences*, 8(9): 14-27.

Tanner, D.G., Amanuel Gorfu, and Kasahun Zewde. 1991. Wheat agronomy research in Ethiopia. pp 95-136. In: Haillu Geber-mariam, D.G. Tanner and Mengsitu Huluka (Eds.). Wheat research in Ethiopia; a historical perspective, Addis Ababa, IAR/CIMMYT.

Tekalign Mamo, I. Haque and E.A. Aduayi, 1991. Soil, plant, water fertilizer, animal manure and compost analysis manual. Plant Science Division Working Document 13, ILCA, Addis Ababa, Ethiopia.

Triboi, E., Martre, P., Girousse, C., Ravel, C., Triboi-Blondel, A.M,. 2006. Unravelling environmental and genetic relationship between grain yield and nitrogen concentration for wheat. *Europ. J. Agronomy*, 25:108-118.

Woyema A., Bultosa G. and A. Taa. 2012. Effect of Different Nitrogen Fertilizer Rates on Yield. *African Journal of Food, Agriculture, Nutrition and Development*, 12(3):6079-6094.

Effect of Seed and NPS Fertilizer rates on yield Components, yield and grain quality of bread wheat

Usman Kedir

Adami Tulu Agricultural research center, Batu/Ziway, Ethiopia

Abstract

Bread wheat (Triticum aestivum L.) is an economically important crop due to high demand for food resources. The field experiment was conducted at three locations of Adami Tulu, Dugda and Lume for two consecutive years to identify economically feasible seeding and NPS fertilizer rates. The factorial combinations of three wheat seeding rates (100, 125 and 150 kg ha^{-1}) and six levels of NPS fertilizer rates (0, 50, 100, 150, 200 and 250) were laid out in randomized

complete block design with three replications. Statistical analysis of the data revealed that in 2019/20 interactions between fertilizer and seed rates were significant on parameters such as Harvest index (HI), hectoliter weight (HLW) and grain protein content (GPC) at Adami Tulu; productive tiller (PT) at Dugda and spike length (SL), kernel per spike (KS), thousand kernel weight (TKW), hectoliter weight (HLW) and grain protein content (GPC) at Lume. Whereas in 2020/21 the interactions between fertilizer and seed rates were significant on parameters such as kernel per spike (KS), above dry biomass (ADB) and straw yield (SY) at Dugda. The highest HI (50.35) was obtained from 150 kg NPS ha^{-1} *with 150 kg seed rate* ha^{-1} *and GPC (16.26) from 200 kg NPS with 100 seed rate at Adami Tulu; the highest PT (631.7) from 150 kg NPS with 150 seed rate at Dugda; the highest TKW (39.73) from 200 kg NPS with 100 seed rate and HLW (82.63) from 100 kg NPS with 125 seed rate at Lume in 2019/20. Besides the highest ADB (9864.89) from 250 kg NPS with 100 seed rate and SY (6644.33) from 250 kg NPS with 100 seed rate where recorded at Dugda in 2020/21. In general, as compared to the overall two years treatments of highest net benefits the economic feasibility of the fertilizer over seed rate combination indicated that application of 150 kg NPS* ha^{-1} *fertilizer rates with combination of 150 kg* ha^{-1} *seed rates were economical and recommended for production of bread wheat with supplemented 73 kg N* ha^{-1} *fed as urea .*
Key words: *Bread wheat, economic analysis, fertilizer rate, NPS, Seed rate*

Introduction

Bread wheat (*Triticum aestivum* L.) is an economically important crop due to high demand for food resources as well as the production of the crop in large-scale including uses of irrigation to satisfy demand has become a critical in Ethiopia. The importance of wheat is mainly due to the fact that its seed can be ground into flour, semolina, etc., which form the basic ingredients of bread and other bakery products, as well as pastas, and thus it presents the main source of nutrients to most of the world population (Šramková *et al*., 2009). The nutritional value of wheat is extremely important as it takes an important place among the few crop species being extensively grown as staple food sources.

Fertilizer is the most important input which contributes significantly towards final grain yield of wheat and to exploit the genetic potential of a cultivar (Kaleem *et al*., 2009). Nitrogen is one of the important factors that affect the yield and quality of wheat (Dandan and Yan, 2013). Nitrogen is one of the key nutrients that limit crop growth of cereals in many production systems (Fatma *et al*., 2014). Its application is an important input for wheat production (Ejaz *et al*., 2010). Phosphorus is an essential for cellular respiration, metabolism of starch and fats (Kaleem *et al*., 2009). Application of adequate amount of phosphorus improves wheat grain yield (Alam and Jahan, 2013). Thus, there is a need to apply the adequate level of phosphorus for obtaining higher yield with good quality product of wheat. However, recently it is perceived that the production of such high protein cereals like wheat can be limited by the deficiency of S and other nutrients (Assefa *et al*., 2015). Sulfur is an essential plant nutrient in crop production required for protein and enzyme synthesis as well as it is a constituent of some of the amino acids (Scherer, 2001). Wheat grain protein content is frequently used as the main measurement of grain quality

(Ricardo *et al*., 2010,) and indicators for milling and baking (Mohammed *et al*., 2013). Higher wheat grain yield with better quality requires appropriate seeding rate for different cultivars. Increase in seed rate above optimum level may only enhance production cost without any increase in grain yield (Rafique *et al*., 2010).

Seeding rate is one of the most important production factors. Seed is the most important agricultural input, and it is the basic unit for distribution and maintenance of plant population and it carries the genetic potential of the crop and thus indicates the ultimate productivity of other inputs (Ashagre and Ermias, 2007). Optimum seed rate plays an important role in achieving better yields. On the other hand, using an optimum seeding density can provide suppression of weeds in wheat crop (Ijaz and Hassen, 2007). Combination of optimum seeding rate and fertilizer rates play an important role in achieving economic yield. Thus, the proper seeding rate and addition of adequate nutrients such N, P and S, to soil is important to increase wheat yield either for consumption or industrial purpose. So that, considerations of better seeding and fertilizer rates interactions are main factor for wheat productions.

In the study area seeding rate and NPS fertilizer rates that contain sulfur for economical production of crops without adequate information concerning actual soil requirements. Moreover, there is no recommendation in the study for the interaction of seeding rates and NPS fertilizer rates. Therefore, this study was undertaken with the following objectives:

to determine the effect of seeding rates and NPS fertilizer rates on yield components, yield and grain quality of bread wheat; and to identify economically feasible seeding and NPS fertilizer rates in the study area

Materials and Methods

Description of the Study Area: The field experiment was conducted at Adami Tulu, Dugda and Lume site from July to November for two consecutive years of 2019/20 and 2020/21 under rain fed conditions at each location.

Experimental Materials

Plant material: Bread wheat variety "Ogolcho" was used as test crop. The variety where selected based on its adaptation, better performance in the area.

Fertilizer materials: NPS (19% N, 38% P_2O_5 and 7% S) and Urea 159 kg ha^{-1} (73% N) were used as the sources of fertilizers.

Soil Sampling and Analysis

One representative soil sample will be taken at a depth of 0-30 cm from five randomly selected spots diagonally across the experimental field using auger before planting. The sample will be air dried under shade. The sample was analyzed for selected physico-chemical properties, namely organic carbon, texture, soil pH, cation exchange capacity (CEC), total N, available P and S.

Treatments and Experimental Design

The treatments were consisted of factorial combination of three wheat seeding rates (100, 125 and 150 kg ha^{-1}) and six levels of NPS fertilizer rates (0, 50,100, 150, 200 and 250) where 159 kg ha^{-1} Urea for N source was used and arranged in a randomized complete block design (RCBD) with three replications. The experiments were laid out in a randomized complete block design (RCBD) with three replications in factorial arrangement of 3 x 6 = 18 treatment combinations. The gross plot size were 12 rows of three meter length (3 m×2.4 = 7.2 m^2) with net harvestable rows of 10 with 2.5 m length (2.5 m×2.0 m = 5 m^2) were considered as net plot. The spacing between rows, plots and blocks were 0.20, 0.5 and 1 m, respectively.

Experimental Procedures and Field Management

The experimental field was ploughed with oxen to a fine tilth three times and the plots were leveled manually. According to the design, a field layout was made and each treatment assigned randomly to the experimental units within a block. Bread wheat seeds were sown in rows of 20 cm spacing manually by drilling. The whole amount of NPS fertilizer applied at time of sowing and uniformly supplemented application of 73 kg N ha^{-1} for all treatment except for control with ½ of nitrogen was applied at the time of sowing and ½ nitrogen top-dressed at tiller initiations stage. Weeding was done as needed; and harvesting and threshing was done manually.

Crop Data Collected

Crop phenology and growth parameters:

Days to 50% heading (DTH): days to spike heading was determined as the number of days taken from the date of sowing to the date of 50% heading of the plants from each plot by visual observation.

Days to 90% physiological maturity (DTM): days to physiological maturity was determined as the number of days from sowing to the date when 90% of the peduncle turned to yellow in straw color. It was recorded when no green color remained on glumes and peduncles of the plants, *i.e*. when grains are difficult to break with thumb nail.

Plant height (cm): plant heights were measured from the soil surface to the tip of the spike (awns excluded) of 5 randomly selected plants from the net plot area at physiological maturity.

Spike length (cm): It was measured from the bottom of the spike to the tip of the spike excluding the awns from 10 randomly tagged spikes from the net plot.

Lodging percent: No lodging, there was no data recorded and reported.

Yield components and yield

Number of total tillers: number of total tillers were determined from 0.5 m length quadrant of two rows from the net plot and converted to per meter square of net plot at physiological maturity by counting the number of tillers.

Number of productive tillers: number of productive tillers were determined at maturity by counting all kernel bearing spikes from 0.5 m length quadrant of two rows from the net plot and converted to per meter square of net plot at physiological maturity.

Number of kernels per spike: the mean number of kernels per spike was computed as an average of 5 randomly taken spikes from the net plot area.

Thousand kernels weight (g): thousand kernels weight was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using electronic seed counter and weighed with sensitive balance. Then, the weight was adjusted to 12.5% moisture content.

Aboveground dry biomass (kg ha^{-1}): the aboveground dry biomass was determined from plants harvested from the net plot area after sun drying to a constant weight and converted to kg per hectare.

Grain yield (kg ha^{-1}): grain yield was taken by harvesting and threshing the seed yield from net plot area. The grain weight of each plot was recorded in kg and finally, yield per plot was converted to kg ha$^{-1.}$ The yield was adjusted to 12.5% moisture content.

Straw yield (kg ha^{-1}): Straw yield was obtained as the difference of the total aboveground dry biomass and grain yield.

Harvest index (HI): harvest index was calculated as ratio of grain yield per plot to total aboveground dry biomass yield per plot.

$$\text{HI (\%)} = \frac{\textit{Grain yield}}{\textit{Aboveground dry biomass}} \times 100$$

Grain quality parameters

Hectoliter weight (HLW): It is the weight of flour density produced in a hectoliter of the seed and it was measured by a standard laboratory hectoliter weight apparatus.

Grain protein content (GPC): was determined on a dry weight basis by near infrared reflectance spectroscopy (NIRS), by using " Infratec^{TM} 1241 Grain Analyzer " equipment at Food Science and Nutrition Laboratory of Kulumsa Agricultural Research Center.

Data Analysis

All data collected was subjected to analysis of variance (ANOVA) procedure using GenStat (17th edition) software (GenStat, 2014). The comparisons among treatments means with significant difference for measured characters was done by LSD test at 5% level of significance.

Economic Analysis

The economic analysis were carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting was used. All costs and benefits were calculated on hectare basis in Birr.

The concepts used in the partial budget analysis were the mean grain yield of each treatment, the gross benefit (GB) ha-1 (the mean yield for each treatment) and the field price of fertilizers (the costs of NPS and Urea). Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer, was calculated by dividing the net increase in yield of bread wheat due to the application of each fertilizers rate. The net benefit (NB) was calculated as the difference between the gross field benefit and the total variable (TVC) using the formula

NB= GFB -TVC

Where GFB = Gross Field Benefit, TVC = Total Variable Cost

Actual yield was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same size field.

The dominance analysis procedure as described in CIMMYT was used to select potentially profitable treatments from the range that was tested. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefits) is dominated treatment (marked as "D"). The dominance analysis illustrates that to improve farmers' income, it is important to pay attention to net benefits rather than yields, because higher yields do not necessarily mean high net benefits. The discarded and selected treatments using this technique were referred to as dominated and undominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula:

$$\text{MRR } (\%) = \frac{\text{NB (NBb} - \text{NBa)}}{\text{TCV (TVCb} - \text{TVCa)}} x100$$

Where NBa = NB with the immediate lower TCV, NBb = NB with the next higher TCV, TVCa = the immediate lower TVC and TVCb = the next highest TCV.

The % MRR between any pair of undominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns, the % MRR was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost). Thus, a MRR of 100% implied a return of one Birr on every Birr spent on the given variable input.

The fertilizer cost was calculated for the cost of each fertilizer of NPS (Birr 14.96 kg $^{-1}$) and N/UREA (Birr 14.52 kg $^{-1}$) in 2019/20 as well as NPS (Birr 17.44 kg $^{-1}$) and N/UREA (Birr 16.72kg $^{-1}$) in 2020/21 during sowing time. The average open price of bread wheat at Batu/Ziway, Meki and Mojo market was Birr 16.00kg $^{-1}$ and 20.00 kg $^{-1}$ in January 2019/20 and 2020/21 respectively during harvesting time.

Results and Discussions

Soil Physico-chemical Properties of the Experimental Site

According to the laboratory analysis, the soil texture of the experimental area is sandy loam, loam and clay loam in 20219/20 and loam, clay loam and clay loam in 2020/21 at Adami Tulu, dugda and Lume area respectively. The soil texture influences water contents, water intake rates, aeration, root penetration, and soil fertility. The pH of the soil was 7.53, 7.11 and 6.67 in 20219/20 and 7.79, 6.90 and 8.08 in 2020/21 for AdamiTulu, Dugda and Lume respectively. FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Thus, the pH of the experimental soil was within the range for productive soils except for Lume in 2020/21. Sahlamedihin (1999) reported the pH of the soil between (5.00 -7.55) was found within the suitable range for crop production.

The Netherlands commission of the ministry of agriculture and fisheries (1985) classified soils having total organic C % greater than 3.50, 2.51-3.5, 1.26-2.5, 0.60-1.25 and less than 0.6 is categorized as very high ,high, medium, low, and very low respectively. According to the Ethiosis (2014) reference soil organic carbon content in both years of the experimental site was low. The result of soil analysis has poor total nitrogen in both years according to the rating of Tekalign *et al*, (1991). Soil analysis also indicated that very high available phosphorus content in both years according to the rating of Olsen *et al*. (1954).

The analysis for available sulfur indicated that optimum for three sites in 2019/20 and Very high, Very high and high result was recorded in 2020/21 at Adami Tulu, Dugda and Lume respectively according to Ethiosis (2014). The CEC value of the soil sample is high in both years except for Lume in 2020/21which recorded very high according to the rating of Landon (1991) which indicates the soil has high capacity to hold exchangeable cations. Cation Exchange Capacity

(CEC) is an important parameter of soil, because it give an indication of the type of clay minerals present in the soil, soil texture, organic matter content of the soil and its capacity to retain nutrients against leaching (Sahlamedihin, 1999).

Days to 50% heading

The analysis of variance revealed that NPS fertilizer rates highly significant difference ($P \leq 0.01$) at three locations in both years except at Adami Tulu in 2020/21 (Table 1), the seed rate as well as the interaction of the two factors had no significant effect on days to 50% heading. The highest prolonged duration to reach 50% heading was observed at Adami Tulu, Dugda and Lume in both year in response to the of zero rates of the fertilizers application. However, the minimum duration to 50% heading (53.11, 54.11 and 42.11) was observed at Adami Tulu, Lume and Dugda respectively with NPS fertilizer rate of 150 kg ha^{-1} in 2019/20, whereas (57.8, 57.44) was recorded with 250 kg ha^{-1} of NPS at Dugda and both with 150 kg ha^{-1} NPS and 200 kg ha^{-1} NPS fertilizer rates at Lume respectively was recorded in 2020/21 (Table 1). This might be due to the Nitrogen feed as NPS fertilizer enhance the vegetative development as well as stimulate shoot growth and due minimum duration of heading days. The result in line with the finding of Cock and Ellis (1992) indicated that sufficient nitrogen at right time results in rapid growth and heading. Bekalu and Arega (2016) reported that fertilizer applied 92 kg ha^{-1} minimize the date of heading by eight days compared with control.

Days to 90% physiological maturity

The main effect of NPS fertilizer rate was highly significantly ($P \leq 0.01$) on days to 90% physiological maturity of bread wheat at three locations in both years, while the main effect of seed rate and interactions did not significantly affect days to 90% physiological maturity. The longest days to physiological maturity (107.44, 106.33, 105.44 days) was recorded at Adami Tulu, Dugda, Lume respectively with the zero fertilizer rate whereas the early maturing (103.22, 102.33, 102.89 days) was obtained from 150 kg NPS ha^{-1} at Adami Tulu, Dugda, Lume in 2019/20 respectively. Whereas, the longest days to physiological maturity (102.11, 101.00, 98.39 days) was recorded at Adami Tulu, Dugda, Lume respectively with the zero fertilizer rate while the early maturing (98.67, 97.56 and 95.73 days) was obtained from 150, 200 and 150 kg NPS ha^{-1} at Adami Tulu, Dugda, Lume in 2020/21 respectively. Increasing of NPS level enhanced the earlier anthesis and early maturity of crop over the control. Similar results are reported by Hussain *et al*. (2009) who found that increasing rate of phosphorus enhance earlier production in wheat and ultimately early maturity of crop.

Plant height (cm): The main effect of seed rate significantly ($P < 0.01$) influenced plant height of bread wheat. On the other hand, the main effect of NPS and interaction had no significant effect. The tallest plant (99.44, 92.44 and 86.67 cm) was recorded at Adami Tulu, Dugda and Lume with fertilizer rate of (150, 200 and 150 kg ha^{-1}) in 2019/20 and the highest plant height (87.34, 81.07, 73.69 cm) was recorded at Adami Tulu, Dugda and Lume respectively with fertilizer rate 250 of three location in 2020/21, while the shortest plant height was obtained at zero fertilizer rate in both year. The result indicated that height of wheat plants increased as fertilizer rate increase comparatively at different seeding rates (Table 3).

Table 1. Selected physico-chemical properties of the soil of the experimental site before sowing

No	Soil characters	Values of soil samples for two year						References and rating
		Adami Tulu		Dugda		Lume		
1.	Soil texture	2019/20	2020/21	2019/20	2020/21	2019/20	2020/21	
	Sand (%)	53.91	48.00	40.58	30.50	36.00	32.87	
	Clay (%)	12.57	19.76	21.22	34.75	29.87	32.51	
	Silt (%)	33.52	32.24	38.20	34.75	34.14	34.61	
	Texture	S. loam	Loam	Loam	C. loam	C.Loam	C. loam	
2.	pH-H_2O(1:1.25) in 2019/20 pH-H_2O(1:2.5) in 2020/21	7.53	7.79	7.11	6.90	6.67	8.08	Ethiosis (2014), <5.5 Strongly, 5.6-6.5 Moderately acidic, 6.6-7.3 Neutral, 7.3-8.4 Moderately alkaline, >8.4 Strongly alkaline
3.	Organic Carbon (OC) (%)	1.05	0.583	1.01	0.74	0.45	0.43	Ethiosis (2014), <0.2 Very low, 2.0–3.0 Low, 3.0–7.0, Optimum, 7.0–8.0 High > 8.0 Very high
4.	CEC (meq/100 gm of soil)	38.18	31.60	32.64	32.43	38.34	46.33	Landon (1991), >40 cmol (+) / kg very high, 25-40 cmol (+) / kg high, 15-25 medium, 5-15 low < 5 cmol (+) / kg very low
5.	Total Nitrogen (%)	0.15	0.07	0.13	0.10	0.06	0.06	Tekalign *et al*. (1991), < 0.05% very low 0.05-0.12% poor 0.12-0.25% moderate > 0.25 % high
6.	Available P (mg P_2O_5/kg soil)	50.74	44.83	20.91	87.16	22.65	38.35	Olsen *et al*.(1954), 3ppm very low, 4-7ppm low, 8-11ppm medium, 12-20ppm high >20ppm very high
7.	Available S (mg/kg soil)	62.12	117.76	29.92	160.23	22.54	95.82	Ethiosis (2014), 20-80 Optimum, 80-100 High, > 100 Very high
8.	EC (mS/cm) (1:1.25) and (1:2.5) in 2020/21	0.51	0.25	0.20	0.33	0.14	0.18	Ethiosis (2014), < 2 Salt free 2-4 Very slightly, 4-8 salines 8-16 slightly saline >16 moderately

Table: 2 Main effects of NPS fertilizers and seed rate on days to 50% heading and days to 90% physiological maturity of bread wheat

Year	In 2019/20						In 2020/21					
Treatments	DTH			DTM			DTH			DTM		
	Location			Location			Location			Location		
NPS rate	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	57d	45.4 c	59 d	107d	106d	105b	59.8	62.0 c	58.9c	102c	101d	98.4d
50	56.0c	45.2c	57 c	107d	104.9c	106b	59.1	61.6c	58 ac	101b	101cd	98cd
100	55b	44.2b	55 ab	106c	104 bc	105b	58.6	61.22c	58ab	101b	99 bc	97bc
150	53.1a	42.11a	54.1a	103a	102.3a	103a	58.5	59ab	57.4a	99 a	98 ab	95.8a
200	55b	42.2a	56 bc	104a	103 ab	103a	59	59.2b	57 ab	101b	97.6 a	96ab
250	55bc	42.22a	55ab	105b	103ab	103a	58.94	57.9 a	58.ab	100b	98 ab	96ab
LSD0.05	1.2**	0.96**	1.5**	1.2**	1.19**	1.2**	NS	1.06**	0.5**	1.4**	1.32**	1.1**
Seed rate												
100	55.44	43.94	55.72	105.7	103.61	104.4	58.78	60.22	58.06	100.8	99.00	96.81
125	55.06	43.67	56.39	105.6	104.06	104.0	59.03	60.28	58.33	100.7	99.33	97.08
150	54.89	43.11	55.72	105.3	104.22	103.9	59.19	59.83	57.94	100.6	99.28	97.11
LSD0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	2.1	2.1	2.7	1.2	1.3	1.2	2.3	1.9	1.6	1.7	1.5	1.3

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; NS= non-significant, Means in column followed by the same letters are not significantly different at 5% levels of Significance

Spike length (cm)

The main effect of NPS fertilizer rate had highly significant ($P < 0.01$) effect on the spike length in 2019/20 and only the main effect have significant effect at one location in 2020/21 and the interaction effect of NPS fertilizers and seed rate on spike length have significant influence on this parameter in 2019/20 (Table 4). Thus, the longest spikes (8.37 cm) was recorded at the combined application of with both 150 and 200 kg NPS fertilizer with 150 kg seed rate ha^{-1}, whereas the shortest spikes (6.33 cm) was recorded under application of 0 kg NPS and 150 kg seed rate ha^{-1} (Table 4). The result showed that increasing the rate of NPS at higher levels increased spike length. Increase in spike length might be due to adequate NPS fertilizer applications which resulted in better length of the spike. These results are in agreement with Ahmad *et al*. (2000) he concluded that spike length of wheat was increased significantly with increasing of nitrogen levels.

Table: 3 Main effects of NPS fertilizers and seed rate on plant height and spike length

Year	In 2019/20						In 2020/21					
Treatments	PH			SL			PH			SL		
	Location			Location			Location			Location		
NPS	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	92.7	79.5 a	66 a	8.7 a	7.52 a	6.92a	79.2a	78.98	64.6a	8.43	9.09	7.38a
50	96.4	90.4b	76.2b	9 abc	8.5 bc	8.0b	82ab	78.49	71ab	8.53	9.42	8 ab
100	97.3	89.4b	81bc	9.1bc	7.9 ab	7.9 b	84bc	79.22	65.5a	8.64	8.93	8abc
150	99.4	91.2 b	86.7c	9.1bc	8.4bc	8.2 b	84bc	80.40	71ab	8.94	9.22	8.8bc
200	96.8	92.4b	82.bc	8.9ab	8.2 bc	7.90b	83ab	80.58	72.7 b	8.76	9.44	8.8bc
250	96.9	91.4b	83bc	9.3c	8.52 c	8.1b	87.4c	81.07	73.7b	8.99	9.84	9.33c
LSD0.05	NS	3.75**	6.5**	0.4**	0.56**	0.5**	4.3**	NS	5.9**	NS	NS	1.1**
Seed rate												
100	94.78	91.06	80.1	9.06	8.25	7.93	83.58	79.62	68.64	8.85	9.38	8.19

125	98.44	86.89	78.0	8.92	8.14	7.79	82.94	80.48	70.08	8.67	9.30	8.53
150	96.56	89.33	79.4	9.07	8.11	7.82	82.86	79.27	70.47	8.63	9.30	8.58
LSD0.05	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.1	4.1	8.4	4.1	7.5	5.1	5.5	5.7	9.8	5.2	7.4	15.4

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; NS= non-significant, Means in column followed by the same letters are not significantly different at 5% levels of Significance

Table 4. Interaction effect of NPS fertilizers and seed rate on spike length of bread wheat in 2019/20 at Lume location

NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	7.47 bcd	6.97 ab	6.33 a
50	8.23 de	7.63 bcde	8.20 de
100	8.07 cde	7.93 cde	7.63 bcde
150	8.37 e	7.90 cde	8.37 e
200	7.37 bc	7.97 cde	8.37 e
250	8.07 cde	8.33 e	8.00 cde
LSD(0.05)	0.67 ***		
CV (%)	5.1		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Total number of tillers

The analysis of variance indicated that number of total tiller produced was highly significant ($P < 0.01$) affected by the main effects of NPS fertilizer rates at dugda and lume in 2019/20 and 2020/21 respectively. Whereas, significantly ($P < 0.05$) affected at Lume and Adami Tulu in 2019/20 and 2020/21 respectively and also non significant effect was recorded at Adami Tulu and Dugda in 2019/20 and 2020/21 respectively. The interactions effect of NPS and seed rate was non-significant (Table 5). The maximum number of total tillers (693, 601, 431 m^{-2}) was produced at Adami Tulu, Dugda and Lume under application of the NPS rates of 100, 150 and 150 in 2019/20 respectively and (409, 408, 323 m^{2}) was produced at Adami Tulu, Dugda and Lume under application of the NPS rates of 150, 100 and 250 in 2020/21 respectively. Whereas, the minimum number of total tillers was recorded from the 0 kg NPS except for Dugda 2020/21. Maximum number of total tiller recorded at highest fertilizer as compare to control. Phosphorus fertilization has great influence on wheat yield and its deficiency has been reported as one of the main reasons for reduced number of tillers (Prystupa *et al*., 2003).

Number of productive tillers

The analysis of variance indicated that number of productive tillers was highly significantly ($P < 0.01$) affected by the main effect of NPS fertilizer as well as the interaction effect of NPS in both year. The more number of productive tillers (631.7 m^{-2}) was observed at NPS fertilizer rate of 150 kg NPS ha^{-1} with seeding rate of 150 kg ha^{-1} and the statistically less (485 m^{-2}) was from 0 kg NPS and seeding rate of 100 kg ha^{-1}) (Table 6). Productive tillers are the most important because of the contribution in final yield. The NPS nutrients increased number of productive tillers significantly as compared to control. This might be due to N feed as NPS and also top-dressing of N fertilizer applied at time of tillering initiations. The number of spikes per unit area is set before stem elongation (Li *et al*., 2001) so N fertilization in tillering stage has a significant impact. Increase in number of tiller per unit area is due to increased seeding rate (Ahmad *et al*., 2000, Otteson *et al*., 2008). Similarly, nitrogen fertilization also contributed in increasing tiller production up to an optimum level (Singh *et al*., 2002; Islam *et al*., 2002). Above optimum, the decrease in tillers might be due to the competition for nutrient, light and space. In contrast to the result, Tanner *et al*. (1991) reported that, a seed rate of 125 kg ha^{-1} was sufficient for optimum yield with drilling of either the early maturing cultivars or late maturing.

Table: 5 Main effects of NPS fertilizers and seed rate on total tiller and productive tiller of bread wheat.

	Years											
	In 2019/20						In 2020/21					
Treatments	TT			PT			TT			PT		
	Location			Location			Location			Location		
NPS (kg ha)	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	655	537.8a	316 a	581a	493a	289 a	352a	365.6	203 a	315 a	250.6a	155a
50	684	535.0a	351a	602a	496a	323a	394a	358.9	292 b	378b	227 a	219b
100	693	564ab	364a	606ab	533bc	336a	438b	408.9	304b	408b	315b	217b
150	688	601.1c	431 b	663.3	567c	403 b	410a	387.8	327 b	372b	320b	232b
200	691	583bc	403 b	632b	551bc	376a	399b	390.6	321 b	370b	343b	247b
250	676	563ab	411 b	614ab	529b	386 b	438b	372.8	324 b	399b	238.3a	184b
LSD	NS	33.9*	80.5*	30.9*	33**	80.5*	55**	NS	70**	49.*	61.7*	57 **
Seed rates												
100	677	548.6	343	612.8	515.3	315	409.1	378	288	385.2	296	206.9
125	686	563.3	398	613.9	523.6	371	398.7	379	279	368.4	264	203.9
150	680	580.0	397	622.8	546.1	371	407.1	385	319	367.3	287	215.8
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	5.8	5.4	23.1	5.4	5.3	24.8	15.6	23.6	25.8	14.7	24.2	29.7

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; NS= non-significant, Means in column followed by the same letters are not significantly different at 5% levels of Significance

Table 6. Interaction effect of NPS fertilizers and seed rate on productive tillers of bread wheat in 2019/20 at Dugda location

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	485.0 ab	503.3 abcd	493.3 abc
50	506.7 abcd	505.0 abcd	475.0 a
100	513.3 abcde	540.0 bcdef	545.0 cdef
150	533.3 bcdef	536.7 bcdef	631.7 g
200	550.0 def	535.0 bcdef	568.3 f
250	503.3 abcd	521.7 abcdef	563.3 ef
LSD(0.05)	46.66 **		
CV (%)	5.3		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Number of kernels per spike

The analysis of variance showed that the main effects of NPS fertilizer rates was highly significant ($P < 0.01$) and was significant ($P < 0.05$) at Adami Tulu as well as the interaction effect was highly significant in 2019/20 and 2020/21 at Lume and Dugda respectively on the number of kernels per spike. The highest number of kernels per spike (50.89, 44, and 38.2) was counted at Adami Tulu, Dugda, Lume in 2019/20 with the main effect of NPS fertilizer level of

150, 150 and 250 kg ha^{-1} respectively. Whereas the maximum kernels per spike (47.02) was recorded at Lume in 2020/21 with NPS fertilizer level of 250 kg ha^{-1} while lowest number of kernels per spike was recorded at zero level of NPS fertilizer in both year (Table 7). The maximum number of kernels per spike (40.67) was recorded at NPS fertilizer rate of 250 kg NPS ha^{-1} with seeding rate of 100 kg ha^{-1} and 200 kg NPS with seeding rate of 150 kg ha^{-1} at Lume in 2019/20 respectively (Table 8). While the minimum number of kernels per spike (25) was recorded from 0 kg NPS with seeding rate of 150 kg ha^{-1}) at Lume 2019/20. Increased number of kernel per spike could be due to optimum crop stand with better nutrition of NPS fertilizer. Better nutrition enhanced the source capacity to better fill of the sink. Nitrogen is the most important nutrient which affects the assimilate production and distribution and also affecting directly and indirectly the source-sink relation (Aynehband *et al*., 2010). Usman *et al*. (2020) showed that the highest number of kernels per spike (48.3) was recorded from NPSB fertilizer rate of 150 kg ha^{-1}. Maqsood *et al*. (2002) also found that application of 150 kg N ha^{-1} gave the maximum number of grains per spike. In contrast to this, the maximum number of kernels per spike (51.80) was recorded from 50 kg NPS with seeding rate of 150 kg ha^{-1}) at Dugda in 2020/21 (Table 9). Whereas the minimum number of kernels per spike (39.00) was recorded from 100 kg NPS with seeding rate of 150 kg ha^{-1}) at Dugda in 2020/21. This may be due to the high soil abundance in mineral of nitrogen, phosphorous and sulfur at Dugda in 2020/21 as compare to Lume in 2019/20 was most probably the reason why maximum number of kernels per spike recorded at minimum NPS fertilizer rates (Table 1). Wheat is very responsive to phosphorus fertilizer application on soils that do not provide adequate amounts of this essential nutrient (Mudassar *et al*., 2012).

Thousand kernels weight (g)

Analysis of variance revealed that main effects of NPS fertilizer rate at Lume in 2019/20, seed rate at Adami Tulu in 2019/20 were highly significant and the main effect of NPS fertilizer rate at Dugda in 2019/20 (Table 7) were significant, as well as interaction effects of NPS fertilizer rate and seed rate were highly significant effect ($P < 0.01$) in 2019/20 at Lume (Table 8). As the fertilizer rate increase the TKW was in increased and it was recorded that maximum thousand seed weight (39.24, 35.77, 38.94 g) was obtained with the NPS fertilizer rate of 250 kg ha^{-1} at Adami Tulu, Dugda and Lume in 2019/20 respectively. While the minimum thousand kernels weight (37.47, 34.74, 33.87 g) was obtained with zero NPS fertilizer rate at Adami Tulu, Dugda and Lume in 2019/20 respectively. Were as (40.04 g) was recorded when 150 kg ha^{-1} seed rate was used at Adami Tulu in 2019/20 (Table 7). The maximum number of Thousand kernels weight (39.73) was recorded from 200 kg NPS with seeding rate of 100 kgha^{-1} followed by (39.70) was recorded from 200 kg NPS with seeding rate of 150 kg ha^{-1} at Lume in 2019/20 respectively (Table 10). Maqsood *et al*. (2002) concluded that thousand kernels weight significantly increased with increasing nitrogen levels. Studies have shown that N in wheat mainly represents N accumulated in the vegetative parts until anthesis and translocated to kernel during the reproductive phase. This is mainly due to a reduction in available N when soil N mineralization is not enough to fulfill the crop demand (Fernando *et al*., 2009). Kinaci (2000) reported that the thousand kernels weight was increased with increase in phosphorus level. The seed rate of 150 kg ha^{-1} showed promising results of TKW (40.04 g). The result is similar with Baloch *et al*. (2010) reported that significantly higher thousand grain weight of wheat with seed rate of 150 kg ha^{-1}. Khan *et al*. (2000) found that higher 40.95 g of 1000 seed weight of wheat was recorded from planting of 175 kg ha seed rates.

Table: 7 Main effects of NPS fertilizers and seed rate on kernel per spike and thousand kernel weight of bread wheat

Year	In 2019/20						In 2020/21					
Treatments	KS			TKW			KS			TKW		
	Location			Location			Location			Location		
NPS rates (kg $ha^{-1)}$	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	42.22	35.8a	29.7a	38	34.74	33.8a	38.7	43.36	35.58	35.6	36.4b	31.52
50	48bc	42.0b	36.1b	38.3	34.27	38.0b	40.2	45.51	44.67	36.7	36.1b	30.15
100	45ab	42.3b	38b	37.7	34.01	38.3b	40.0	45.40	41.67	37.0	34ab	32.40
150	50.9c	43.3b	38.2b	38.2	34.56	38.0b	42.5	44.91	45.58	37.5	34ab	32.62
200	46ab	42.0b	37 b	37.4	34.39	38.6b	41.5	45.76	44.74	36.1	33ab	33.71
250	45ab	44.00	38b	39.2	35.77	38.9b	41.9	42.98	47.02	36.1	32.2a	33.70
LSD (0.05	5.2*	4.0**	3.9**	NS	NS	1.34*	NS	NS	NS	NS	3.0 **	NS
Seed rates												
100	47.00	41.17	36.17	37.3a	34.57	37.87	40.48	43.52	42.95	36.00	34.27	33.00
125	44.72	42.61	36.72	36.8a	34.82	37.43	40.10	45.43	44.08	36.42	35.20	32.10
150	46.72	40.94	35.83	40.0b	34.48	37.60	41.80	45.00	42.60	37.09	33.49	31.95
LSD (0.05	NS	NS	NS	1.2 *	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	12.2	9.9	9.9	4.1	4.8	3.3	9.7	10.9	22.6	4.6	9.7	12.4

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; NS= non-significant, Means in column followed by the same letters are not significantly different at 5% levels of Significance

Table 8. Interaction effects of NPS fertilizers and seed rate on kernel per spike of bread wheat in 2019/20 at Lume

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	33.67 bcd	30.33 ab	25.00 a
50	35.00 bcd	34.67 bcd	38.67 d
100	38.67 d	39.33 d	36.33 bcd
150	37.67 cd	38.00 cd	39.00 d
200	31.33 bc	39.33 d	40.67 d
250	40.67 d	38.67 d	35.33 bcd
LSD(0.05)			
CV (%)	9.9		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Table 9. Interaction effect of NPS fertilizers and seed rate on kernel per spike of bread wheat in 2020/21 at Dugda

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	43.07 ab	44.00 ab	43.00 ab
50	39.73 a	45.00 ab	51.80 b
100	47.47 ab	49.73 b	39.00 a
150	44.07 ab	42.33 ab	48.33 ab
200	47.73 ab	44.27 ab	45.27 ab
250	39.07 a	47.27 ab	42.60 ab
LSD(0.05)			
CV (%)	10.9		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Table 10. Interaction effect of NPS fertilizers and seed rate on thousand kernel weight of bread wheat in 2019/20 at Lume

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	35.87 b	32.43 a	33.30 a
50	37.83 bc	38.27 c	38.00 bc
100	37.90 bc	39.50 c	37.53 bc
150	38.03 bc	37.37 bc	38.63 c
200	39.73 c	37.73 bc	38.43 c
250	37.87 bc	39.27 c	39.70 c
LSD(0.05)			
CV (%)	3.3		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Aboveground dry biomass (kg ha^{-1})

Biological yield represents overall growth performance of the plants as well as the crop. The analysis of variance showed that the main effect of NPS fertilizer rates had highly significant ($P < 0.01$) in both year except non-significant difference observed on main effect of NPS at Dugda in 2013 while the interaction effect of NPS fertilizer rates and seed rate was highly significant on above dry biomass of bread wheat in 2020/21 at Dugda (Table 11).

The highest aboveground dry biomass yield (9864.89 kg ha^{-1}) was recorded from 250 NPS kg ha^{-1} with seeding rate of 150 kg ha^{-1} followed by (9574.07 kg ha^{-1}) from 250 NPS kg ha^{-1} with seeding rate of 125 kg ha^{-1} while the lowest aboveground dry biomass yield (6413.06 kg ha^{-1}) was recorded from zero NPS with seeding rate of 100 kg ha^{-1} (Table 12). The increased in biomass production might be due to the higher NPS fertilizer rates application. In conformity with this result, (Jasemi *et al*. 2014) reported vegetative growth and biological yield has much dependence to consumption of chemical fertilizers.

Grain yield (kg ha^{-1})

The analysis of variance showed that the main effect of NPS fertilizer rates had highly significant ($P < 0.01$) in both year except non significant difference observed at Dugda in 2020/21 on grain yield of bread wheat (Table 11). The highest grain yield (4765.78, 3667, 2797 kg ha^{-1}) was obtained from Adami Tulu, Dugda and Lume in 2019/20 at NPS fertilizer rates of 150 kg NPS ha^{-1} respectively as well as (3549, 2975 kg ha^{-1} and 1526 kg ha^{-1}) was recorded from Adami Tulu, Dugda and Lume in 2020/21 with NPS fertilizer rates of 200 and 150 kg ha^{-1} respectively. While the lowest grain yields were recorded from zero fertilizer applications in both years (Table 11). The yield recorded at Lume in 2020/21 is very low this could be due to experimental soil pH was out of the range for productive soils.

It might be other factor for the decrease of yield as the wheat yield is a complex character and is influenced by several attributing factors. The proper environmental conditions are important for maturity date and yield. Due to the outbreak of COVID-19 late sowing in 2020/21 at Lume typically results early maturing and finally affects yields. Spink *et al.* (2000) also observed that delayed sowing shortens the duration of each development phase which ultimately reduces grain filling period and lowers the grain weight. Grain yield was affected by annual weather conditions in the first place, followed by mineral N-fertilization and organic fertilization, respectively (Osman *et al*., 2005).

The balanced plant nutrition is one of the most important factors that increase plant production. Particularly balanced supplementation of NPS nutrition is one of the greatest production inputs for crops. NPS nourished soil is an essential nutrient in creating the plant growth and development, as well as regulates photosynthesis and plant production. Maximum grain yield might be attributed to the improvement in number of productive tillers, spike length, kernels per sipke and thousand kernels weight. It could also due to, top-dressing of N fertilizer applied at time of tillering initiations where bread wheat needs in high amount N (60-70%) at this stage for grain production significantly increased grain yield. At higher N application rates, top-dressing of N fertilizer significantly increased grain yield, improved grain protein content, and grain N uptake (Mohammed *et al*., 2013). Nitrogen is an essential nutrient in creating the plant dry matter, as well as many energy-rich compounds that regulate photosynthesis and plant production (Nahed *et al*., 2015). N is the main component of plant amino acids, nucleic acid and chlorophyll, and is usually acquired by plants in greater quantity from the soil than any other element. N is the most widely used fertilizer nutrient and its consumption has increased substantially in recent decades (Pathak *et al*., 2006).

Phosphorus in NPS nutrition also plays an important role in various metabolic processes. P activates coenzymes for amino acids production which used in protein synthesis and it decomposes carbohydrate in photosynthesis, for normal growth processes. The synergetic effects of those three NPS nutrients convey the enhanced yield components and yield. This might be due to; phosphorus has the role of structural, energy transfer and improvement of root growth and also adjusts the effect of extra nitrogen in maturity delay (Mostafa *et al*., 2012). Sulphur, an essential secondary plant nutrient, plays a vital role in biosynthesis of primary metabolities for improving yield and quality of oil seed crops and for accruing better yield under balanced fertilization (Anwar *et al.*, 2002). So an insufficient S supply can affect both yield and quality of the crops (Inal *et al*., 2003). It is widely found that increasing P as a fertilizer promote reproductive yields (Egle *et al*., 1999) and inflorescence production (Besmer and Koide, 1999).

Table: 11 Main effects of NPS fertilizers and seed rate on above dry biomass and adjusted grain yield of bread wheat

Year	In 2019/20						In 2020/21					
Treatments	ADB			Ad.GY			ADB			Ad.GY		
	Location			Location			Location			Location		
NPS rates	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	9165 a	5679 a	2639a	3695 a	2095 a	1110a	7205a	7036	2988 a	2496a	2296	987a
50	10623 b	8395 b	4812b	4329b	3177b	1949b	8040a	7661	3671b	2983b	2558	1201 a
100	10806 b	8164 b	5586bc	4326 b	3287bc	2373bc	9000bc	8229	3659 b	3047bc	2737	1199 b
150	10741 b	8272 b	7176d	4766b	3667 c	2797c	9567 c	7893	4176 c	3537c	2791	1526 c
200	11451 b	8410 b	5787b	4609b	3511b	2250b	9482 c	8521	4211 c	3549c	2975	1494 c
250	10891 b	9102 b	6191d	4394b	3427b	2322b	10120	9158	4189 c	3391b	2618	1478 c
LSD (0.05	1152.9 ***	1011. ***	1155.8 ***	477.67 ***	378.62***	437.58 ***	1231.9 ***	NS	476.29 ***	500.79 ***	NS	204.88 ***
Seed rates												
100	10473	7591	5045	4327.5	2998.1	2144.2	8901.8	8162.9	3799.4	3090.4	26423	1272.2
125	10878	8110	5488	4376.1	3283.8	2071.1	8895.4	8176.7	3850.6	3242.4	2567	1335.7
150	10487	8310	5563	4356.16	3300.25	2185.30	8909.79	7909.91	3797.11	3168.95	2777.90	1334.42
LSD	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	11.9	12.4	22.5	11.5	11.0	21.1	14.2	16.5	12.9	17.4	18.6	17.2

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; NS= non-significant, Means in column followed by the same letters are not significantly different at 5% levels of Significance

Table 12. Interaction effects of NPS fertilizers and seed rate on above dray biomass of bread wheat in 2020/21 at Dugda

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	6413.06 a	8083.33 abc	6612.90 a
50	7014.96 abc	6476.85 a	9492.68 bc
100	9312.24 bc	7244.41 abc	8131.48 abc
150	7985.18 abc	8264.79 abc	7429.65 abc
200	8387.10 abc	9416.98 bc	7757.50 abc
250	9864.89 c	9574.07 bc	8035.23 abc
LSD(0.05)			
CV (%)	16.5		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Straw yield (kg ha^{-1})

Analysis of variance showed that the straw yield of bread wheat was highly significantly (P < 0.01) affected by the main effects of NPS fertilizer rates at Dugda and Lume except Non significance difference observed at Adami Tulu in 2019/20 where as highly significant (P < 0.01) at Adami Tulu and lume observed except Non significance difference observed at Dugda in 2020/21 (Table 13) and the interaction effect NPS fertilizers and seed rate on straw yield of bread wheat in 2020/21 at Dugda was significant (P < 0.01).

The highest straw yield (6644.33 kg ha^{-1}) was obtained from the highest rates of 250 kg NPS ha^{-1} fertilizers with 100 kg seed rate ha^{-1} followed by (6485.46) from 250 kg NPS ha^{-1} fertilizers with 125 kg seed rate ha^{-1} whereas the lowest straw yield (4095.81 kg ha^{-1}) was recorded from 50 kg NPS ha^{-1} fertilizers with 125 kg seed rate ha^{-1} followed by (4292.80) in response to the application of zero level of NPS fertilizer with 100 kg seed rate ha^{-1} (Table 14). This might be due to balanced supplied of NPS nutrients lead to more vegetative growth and more dry matter accumulation which directly related to an increment in straw yield.

Harvest index

Harvest index is an ability of a cultivar to convert the dry matter into economic yield. The higher the harvest index value, the greater the physiological potential of the crop for the converting dry matter to grain yield. The analysis of variance revealed that the main effects of NPS fertilizer rates at Dugda in 2019/20 and Adami Tulu in 2020/21 had highly significant (P < 0.01) respectively, while the others are non significant effect observed in both years. The significant effect of (P < 0.05) was recorded on main effect of seed at Lume in 2019/20 and the interaction effect of NPS fertilizer rates and seed rate on harvest index of bread wheat in 2019/20 at Adami Tulu was significant effect (P< 0.05) (Table 15). The highest harvest index (50.35) was obtained from 150 kg NPS ha^{-1} with seeding rates of 150 kg ha^{-1} followed by (44.30) from 250 kg NPS ha^{-1} fertilizer with seeding rates of 100 kg ha^{-1} whereas the lowest harvest index (38.01) was recorded from100 kg NPS ha^{-1} with seeding rates of 125 kg ha^{-1} (Table 15). Seed rate did not bring significant effect on most of the yield and yield components at all locations which were consistent in both years. However, its interaction with seeding rate and fertilizer rates had significant effect on some of the yield and yield attributes in both years.

Table: 13 Main effects of NPS fertilizers and seed rate on straw yield and harvest index of bread wheat

Year	In 2019/20						In 2020/21					
Trt	SY			HI			SY			HI		
	Location			Location			Location			Location		
NPS	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	5470a	3584a	1529a	40.25	37.19a	43.8ab	4709a	4741	2001a	34.6 ab	32.76	33.12
50	6293a	5218bc	2863b	40.88	37.96a	42.13b	5057ab	5104	2470b	37.26 b	33.52	32.83
100	6480b	4877b	3213b	40.20	41.15a	44.58b	5953b	5493	2460b	33.8 ab	33.25	32.82
150	5976a	4605b	4379d	44.78	44.59	39.09a	6029c	5275	2650b	37.44 b	33.28	36.57
200	6842b	4899b	3537c	40.30	41.78a	39.16a	5933b	5730	2718b	37.62 b	32.65	35.43
250	6496b	5675 c	3870c	40.58	37.69a	37.39a	6729c	6183	2711b	33.46 a	32.33	35.26
LSD (0.05)	NS	812.2 ***	820.75***	NS	4.26***	NS	884.86 ***	NS	344.99 ***	3.49 **	NS	NS
Seed												

rates												
100	6146	4593	2901	41.53	39.58	44.40 b	5812	5517	2527	34.89	32.45	33.58
125	6502	4826	3416.5	40.29	40.72	38.75 a	5653	5438	2515	36.48	33.51	34.45
150	6131	5010	3378	41.68	39.88	39.97 a	5741	5307	2463	35.70	32.93	34.98
LSD (0.05)	NS	NS	NS	NS	NS	4.21* *	NS	NS	NS	NS	NS	NS
CV (%)	15.1	16.8	26.0	8.4	10.6	13.2	16.7	16.8	13.4	9.6	6.7	9.0

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; NS= non-significant, Means in column followed by the same letters are not significantly different at 5% levels of Significance

Table 14. Interaction effect of NPS fertilizers and seed rate on straw yield of bread wheat in 2020/21 at Dugda

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	4292.80 a	5446.49 abcd	4482.49 ab
50	4755.07 abc	4095.81 a	6460.58 cd
100	6235.02 bcd	4962.70 abcd	5280.35 abcd
150	5423.76 abcd	5476.05 abcd	4925.41 abcd
200	5753.02 abcd	6162.38 bcd	5273.68 abcd
250	6644.33 d	6485.46 cd	5417.92 abcd
LSD(0.05)			
CV (%)	16.8		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Table 15. Interaction effect of NPS fertilizers and seed rate on Harvest index of bread wheat in 2019/20 at Adami Tulu

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	38.41 a	40.48 a	41.87 a
50	41.33 a	43.24 a	38.07 a
100	42.70 a	38.01 a	39.89 a
150	43.51 a	40.50 a	50.35 b
200	38.93 a	40.05 a	41.91 a
250	44.30 a	39.46 a	37.99 a
LSD(0.05)			
CV (%)	8.4		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Hectoliter weight (HLW)

The result showed a highly significant (p<0.01) main effect of fertilizer rates on Hectoliter weight at Lume in 2019/20, while the other main effect NPS and seed rates are Non significant in both years and the interactions effects of NPS fertilizer rates and seed rates were significant (P<0.05) at Adami Tulu (Table 17) and Lume in 2019/20 (Table 18). The highest HLW (82.53) was obtained from 100 kg NPS ha^{-1} fertilizer rate with 125 kg seed rates ha^{-1} in 2019/20 at Adami Tulu while the lowest HLW (78.87) was obtained from 0 kg NPS ha^{-1} fertilizer rate with 125 kg seed rates ha^{-1} in 2019/20 at Adami Tulu and the highest HLW (82.20) was obtained from 200 kg NPS ha^{-1} fertilizer rate with 150 kg seed rates ha^{-1} in 2019/20 at Lume (Table 18) while the lowest HLW (76.73) was obtained from 0 kg NPS ha^{-1} fertilizer rate and 125 seed rates kg ha^{-1} in 2019/20 at Lume (Table 18). This result is in line with that of (Behera *et al*., 2010) who reported that hectoliters weight increased significantly with application of NPK fertilizer and was the highest with application of 125 kg NPK ha^{-1}.

Grain protein content (%): The protein content in flour is the main quality criterion for wheat, especially for bread making (Triboi *et al*., 2006). The high protein contents of Bread wheat due to optimum N application is for bread making and low protein for feed and other uses. Grain protein content was significantly (p<0.01) affected by main effect of NPS fertilizer rates in 2019/20 and non significant main effects of NPS fertilizer rates and seed rates observed in 2020/21, but the interaction between the two factors was highly significant (p<0.01) at Adami Tulu (Table 19) and Lume in 2019/20 (Table 20). The highest GPC of (15.64, 14.25 and 12.01 %) where obtained from main effect of (200,100, 250 kg ha^{-1} NPS) in 2019/20 at Adami Tulu, Dugda and Lume respectively (Table 16) and the lowest (14.43, 12.59 and 10.77 %) where obtained from zero kg ha^{-1} NPS in 2019/20 at Adami Tulu, Dugda and Lume respectively. Whereas the highest GPC (16.26) was obtained from of 200 kg NPS ha^{-1} fertilizer rate with 100 kg seed rates ha^{-1} in 2019/20 at Adami Tulu while the lowest GPC (14.14) was obtained from 0 kg NPS ha^{-1} fertilizer rate with 125 kg seed rates ha^{-1} in 2019/20 at Adami Tulu (Table 19). The highest GPC of (12.72) was obtained from 250 kg NPS ha^{-1} fertilizer rate with 150 kg seed rates ha^{-1} in 2019/20 at Lume (Table 20) while the lowest GPC of (10.60) was obtained from 0 kg NPS ha^{-1} fertilizer rate with 125 kg seed rates ha^{-1} in 2019/20 at Lume (Table 20). Nitrogen in the NPS nutrient is the most recognized element in plant for its presence in the structure of the protein molecule. The increase in grain N uptake and protein content led to an improvement in wheat grain quality (Mohammed *et al*., 2013). Nitrogen fertilization contributes significantly to protein content, especially when fertilizer rates satisfy the requirements of both yield and protein formation (Woyema *et al*., 2012). The grain protein content is directly connected with the overall available nitrogen, both from mineral fertilizers and from mineralization processes in soil (Renata *et al*., 2013). Application of 105 kg N ha^{-1} gave the highest mean values of all yield and its components compared as control treatment such increments might be attributed to the favorable role of nitrogen in encouraging in catabolic processes in wheat plants (Gomaa *et al.*, 2015).

Table: 16 Main effects of NPS fertilizers and seed rate on hectoliter weight and GPC

Year	In 2019/20						In 2020/21					
Treatments	HLW			GPC			HLW			GPC		
	Location			Location			Location			Location		
NPS rates	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume	Atarc	Dugda	Lume
0	81.01	79.79	78.3a	14.43a	12.59a	10.77a	77.73	76.77	74.96	14.14	12.59	12.82
50	81.18	79.61	80.6b	15.21b	14.17b	11.76b	77.82	77.63	75.88	14.71	13.06	13.25
100	81.22	79.46	81.5b	15.08b	14.25b	11.61b	78.14	76.21	76.21	14.29	13.15	13.37
150	81.58	79.76	81.7b	15.19b	14.03b	11.71b	78.53	77.02	75.76	14.64	13.13	13.88
200	80.46	79.46	81.5a	15.64b	13.74b	11.77b	78.89	75.77	76.93	14.22	12.75	14.20
250	81.67	80.24	81.6b	15.45b	13.88b	12.01b	77.58	75.32	77.41	14.12	13.85	13.89
LSD(0.05	NS	NS	1.2**	0.51**	0.55**	0.57**	NS	NS	NS	NS	NS	NS
Seed rates												
100	81.04	79.51	80.62	15.14	13.63	11.63	78.05	77.01	76.62	14.34	13.00	13.63
125	80.92	79.84	80.98	15.05	13.99	11.58	78.12	76.17	76.08	14.25	13.19	13.37
150	81.59	79.81	81.00	15.31	13.71	11.61	78.18	76.19	75.88	14.48	13.07	13.71
LSD0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	1.0	1.1	1.4	3.0	3.9	4.6	1.5	2.7	3.2	5.5	8.2	8.3

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation; NS= non-significant, Means in column followed by the same letters are not significantly different at 5% levels of Significance

Table 17. Interaction effect of NPS fertilizers and seed rate on hectoliter weight of bread wheat in 2019/20 at Adami Tulu

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	82.30 fg	78.87 a	81.87 defg
50	80.50 bcd	80.63 bcde	82.40 fg
100	80.13 abc	82.53 g	81.00 cdefg
150	81.83 defg	81.57 cdefg	81.33 cdefg
200	79.30 ab	81.00 cdefg	81.07 cdefg
250	82.17 efg	80.93 cdef	81.90 defg
LSD(0.05)			
CV (%)	1.0		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Table 18. Interaction effect of NPS fertilizers and seed rate on hectoliter weight of bread wheat in 2019/20 at Lume

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	79.73 bcd	76.73 a	78.40 ab
50	79.60 bc	81.33 cde	80.97 cde
100	80.60 cde	82.63 e	81.33 cde
150	81.30 cde	81.77 cde	81.90 de
200	80.60 cde	81.67 cde	82.20 e
250	81.87 de	81.73 cde	81.20 cde
LSD(0.05)			
CV (%)	1.4		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Table 19. Interaction effect of NPS fertilizers and seed rate on grain protein content of bread wheat in 2019/20 at Adami Tulu

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	14.74 abc	14.14 a	14.42 ab
50	15.35 cd	15.05 bcd	15.22 bcd
100	14.41 ab	14.94 abc	15.87 de
150	14.96 abc	15.26 bcd	15.35 cd
200	16.26 e	15.31 cd	15.36 cd
250	15.09 bcd	15.62 cde	15.63 cde
LSD(0.05)			
CV (%)	3.0		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Table 20. Interaction effect of NPS fertilizers and seed rate on grain protein content of bread wheat in 2019/20 at Lume

Blended NPS (kg ha^{-1})	Seed rate (kg ha^{-1})		
	100	125	150
0	10.92 abc	10.60 a	10.81 ab
50	11.70 bcdef	12.15 defgh	11.43 abcde
100	11.59 abcde	11.72 bcdefg	11.51 abcde
150	11.87 cdefgh	11.55 abcde	11.71 bcdef
200	12.46 efgh	11.37 abcd	11.49 abcde
250	11.22 abcd	12.08 defgh	12.72 fh
LSD(0.05)			
CV (%)	4.6		

LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of Variation

Partial Budget Analysis

Partial budget analysis is important to identify experimental treatments with an optimum return to the farmer's investment and to develop recommendation for the agronomic data. Experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, yields of farmers are adjusted by 10% less than that of the research results CIMMYT (1988). As indicated in Table 21, the partial budget analysis showed that the highest net benefit of (67533.2, 51336.4 and 37531.6) Birr ha^{-1} with marginal rate of return (1048.1, 378 and 679 %) was obtained for seed rates of (150 kg ha^{-1}) bread wheat that received (150 kg NPS ha^{-1}) at Adami Tulu, Dugda and Lume in 2019/20 respectively. However, the lowest net benefits of (47496, 24576 and 10860.8) Birr ha^{-1} were obtained from the seed rate of (100, 100 and 125 kg ha^{-1}) bread wheat that received zero fertilizer at Adami Tulu, Dugda and Lume in 2019/20 respectively. In case of second economic table 22, the highest net benefit of (61838, 49974 and 24549.4) Birr ha^{-1} with marginal rate of return (598, 761, 364 %) was obtained for the seed rates of (125, 100 and 150 kg ha^{-1}) bread wheat that received (150, 100 and 150 kg NPS ha^{-1}) fertilizers rates at Adami Tulu, Dugda and Lume in 2020/21 respectively. While, the lowest net benefits of (39222, 31972.6 and 16347.2) Birr ha^{-1} were obtained from the seed rates of (125, 125 and 100 kg ha^{-1}) bread wheat that received (0, 250 and 0 kg NPS ha^{-1}) fertilizers at Adami Tulu, Dugda and Lume in 2020/21 respectively.

The economically feasible combination indicated that application of (150, 150, 150 kg NPS ha^{-1}) fertilizer rates with similar seeding rates of (150, 150, 150 kg ha^{-1}) in 2019/20 respectively and application of (150, 100, 150 kg NPS ha^{-1}) fertilizer rates with different seeding rates of (125, 100, 150 kg ha^{-1}) in 2020/21 at Adami Tulu, Dugda and Lume respectively. Therefore, as compared to overall two years treatments of highest net benefits (150 kg NPS ha^{-1}) fertilizer rates with combination of (150 kg ha^{-1}) seed rates were economical and recommended for production of bread wheat with supplemented 73 kg N ha^{-1} fed as urea of ½ at sowing time and ½ top dressed at tillering stage of the crop for Adami Tulu, Dugda and Lume respectively and other areas with similar agro ecological condition. In general, from the recommended 150 NPS and 73 N supplemented each combined elemental rate of 101.5% N, 57 % P, and 10.5 % S were used.

Table 21. Summary of economic analysis of the effects of NPS fertilizer rates and seed rates on bread wheat at three locations in 2019/20 cropping season

Treatments		AGY (kg ha^{-1})			Income (ETB ha^{-1}) Grain yield			GFB (ETB ha^{-1})			TVC (ETB ha^{-1})	NB (ETB ha^{-1})			MRR (%)		
Seed rate	Fert	AT	DG	LU	AT	DG	LU	AT	DG	LU		AT	DG	LU	AT	DG	LU
100	0	3068	1636	1217	49096	26176	19479	49096	26176	19479	160	47496	24576	17878			
100	50	4083	2906	1598	65336	46491	25573	65337	46491	25573	3074	62262	43417	22499	1002	1278	313
100	100	4341	2381	2436	69455	38088	38983	69455	38088	38983	4548	64906	33540	34434	179.4	D	810
100	150	3958	3073	2466	63327	49168	39461	63327	49168	39461	6022	57304	43146	33439	D	652	D
100	200	3907	3076	1568	62511	49216	25089	62511	49217	25089	7496	55014	41720	17592	D	D	D
100	250	4011	3118	2292	64175	49894	36674	64175	49894	36674	8970	55204	40924	27704	12.9	D	686
125	0	3415	2115	804	54635	33834	12861	54632	33834	12861	2000	52635	31834	10861	36.9	130	242
125	50	3931	2925	1860	62898	46798	29761	62898	46798	29761	3474	59424	43324	26286	460.5	780	1046
125	100	3749	3299	1916	59991	52776	30662	59991	52776	30662	4948	55042	47828	25714	D	306	D
125	150	4262	3193	2315	68199	51086	37033	68197	51084	37033	6422	61776	44664	30610	456.9	D	332
125	200	4346	3214	2359	69529	51421	37749	69529	51421	37749	7896	61634	43525	29853	D	D	D
125	250	3928	2989	1930	62841	47811	30881	62841	47810	30880	9370	53470	38441	21510	D	D	D
150	0	3493	1907	976	55881	30508	15614	55882	30508	15614	2400	53482	28108	13214	D	148	119
150	50	3676	2747	1804	58816	43950	28857	58816	43950	28856	3874	54942	40076	24982	99.1	812	798
150	100	3589	3195	2054	57432	51116	32870	57432	51116	32870	5348	52084	45767	27522	D	386	172
150	150	4647	3635	2772	74355	58158	44353	74356	58158	44353	6822	67533	51336	37532	1048	378	679
150	200	4192	3191	2149	67067	51056	34379	67067	51056	34379	8296	58771	42760	26083	D	D	D
150	250	3926	3147	2046	62819	50354	32737	62819	50354	32737	9770	53049	40584	22968	D	D	D

Where, AGY = adjusted grain yield; GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr per hectare; D = dominated treatments. Market price of wheat = 16.00 ETB kg^{-1}; Cost of NPS= 14.96 kg^{-1}; Cost of Urea =14.52 ETB kg^{-1}.

Table 22. Summary of economic analysis of the effects of NPS fertilizer rates and seed rates on bread wheat at three locations in 2020/21 cropping season

Treatments		AGY (kg ha^{-1})			Income (ETB ha^{-1}) Grain yield			GFB (ETB ha^{-1})			TVC (ETB ha^{-1})	NB (ETB ha^{-1})			MRR (%)		
Seed rate	Fert	AT	DG	LU	AT	DG	LU	AT	DG	LU		AT	DG	LU	AT	DG	LU
100	0	2483.6	1908.2	917.4	49672	38165	18347	49672	38165	18347	2000	47672	36165	16347			
100	50	2308.7	2033.9	1283.2	46174	40678	25665	46174	40678	25665	3708	42466	36970	21957	D	47	328
100	100	2710.2	2769.5	1233.4	54204	55390	24668	54204	55390	24668	5416	48788	49974	19252	370	761	D
100	150	3127.8	2704.2	1338.4	62556	54084	26767	62556	54084	26767	7124	55432	46960	19643	389	D	23
100	200	3278.6	2399.2	1370.3	65572	47984	27406	65572	47984	27406	8832	56740	39152	18574	77	D	D
100	250	2779.1	2455.4	1490.7	55582	49109	29814	55582	49109	29814	10540	45042	38569	19273	D	D	41
125	0	2086.1	2373.2	1037.1	41722	47463	20742	41722	47463	20742	2500	39222	44963	18242	72	D	13
125	50	2710	2142.9	1258.5	54200	42859	25170	54200	42859	25170	4208	49992	38651	20962	631	D	159
125	100	2877.2	2053.5	1126.0	57544	41071	22519	57544	41071	22519	5916	51628	35155	16603	96	D	D
125	150	3473.1	2469.3	1605.2	69462	49386	32104	69462	49386	32104	7624	61838	41762	24480	598	387	461
125	200	3238.6	2670.9	1587.6	64772	53418	31752	64772	53418	31752	9332	55440	44086	22420	D	136	D
125	250	3124.1	2150.6	1400.1	62482	43013	28003	62482	43013	28003	11040	51442	31973	16963	D	D	D
150	0	2170.1	1917.4	1006.5	43402	38347	20130	43402	38347	20130	3000	40402	35347	17130	137	D	D
150	50	3035.3	2728.9	1061.5	60706	54578	21231	60706	54578	21231	4708	55998	49870	16523	913	850	D
150	100	2638.5	2566.0	1237.4	52770	51320	24748	52770	51320	24748	6416	46354	44904	18332	D	D	106
150	150	2949.6	2361.8	1633.7	58992	47235	32673	58992	47235	32673	8124	50868	39111	24549	264	D	364
150	200	3066.3	2963.7	1523.0	61326	59275	30459	61326	59274	30459	9832	51494	49443	20627	37	605	D
150	250	3252.5	2462.9	1544.4	65050	49258	30889	65050	49258	30889	11540	53510	37718	19349	118	D	D

Where, AGY = adjusted grain yield; GFB = gross field benefit; TVC = total variable costs; NB = net benefit, MRR = marginal rate of return; ETB ha^{-1} = Ethiopian Birr per hectare; D = dominated treatments. Market price of wheat = 20.00 ETB kg^{-1}; Cost of NPS= 17.44 kg^{-1}; Cost of Urea =16.72 ETB kg^{-1}

Conclusions and Recommendation

As conclusions, in respect to the above results on the responses of bread wheat to seeding rates and NPS nutritional levels under different environmental conditions would be very useful in planning of our seeding system and NPS rates for increasing of productions in the specific study area. Seed rate did not bring significant effect on most of the yield and yield components at all locations which were consistent in both years. However, its interaction with seeding rate and fertilizer rates attributes had significant effect on yield component parameters in both years.

In generally, the higher economically feasible seeding and NPS fertilizer rates was the soil nourished with 150 kg seed ha^{-1} and 150 kg NPS ha^{-1} with supplemented 73 kg N ha^{-1}(159 kg Urea ha^{-1}) of ½ at sowing time and ½ top dressed at tillering stage for Adami Tulu, Dugda and Lume respectively was suggested to the wheat growers.

References

Anilkumar GS, Umesha K, Maruthiprasad BN, Shivapriya M and Nithin Kumar VC. 2018. Varietal response of coriander (*Coriandrum sativum* L.) for growth, yield and quality attributes. *Journal of Pharmacognosy and Phytochemistry*, SP3: 35-39.

Anwar M., Chand Sukhmal, N. A. A. and P. D. D. 2002. Effect of graded levels of Nitrogen and Sulrphur on yield, Nutrient Accumulation and Quality of Japanese mint (*Mentha arvensis*). *Journal of the Indian Society of Soil Science*, 50(2):174-177.

Asgarpanah, J. and Kazemivash, N. 2012. Phytochemistry, farmacology and medicinal properties of *Coriandrum sativum* L. *Afr. J. Pharm. Pharmacol*., 6(31): 2340-2345.

Burdock, G.A., Carabin, I.G. 2009. Safety assessment of coriander (*Coriandrum sativum* L.) essential oil as a food ingredient. *Food Chem. Toxic.*, 47:22-34.

Carrubba, A., Catalano, C., Militello, M. 2009. Effects organic and coinventional N fertilizationon quality traits in coriander (*Coriandrum sativum* L.). More Sustainability in Agriculture:New Fertilizers and Fertilization Management. 18th Symposium of the International Scientific Centre of Fertilizers, 174-179.

CIMMYT (Centro Internacional de Mejoramiento de Maíz y Trigo).1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edi tion. Mexico, DF.

Datta S, Alam K, and Chatterjee R. 2008. Effect of different levels of nitrogen and leaf cutting on growth, leaf and seed yield of coriander. *Indian Journal of Horticulture*, 65(2):201-203.

Diederichsen, A. 1996. Coriander (*Coriandrum sativum* L.) Promoting the conservation and use of underutilized and neglected crops. IPGRI, Rome.

Egle, K., Manske, G., Römer, W., and Vlek, P.L.G. 1999. Improved phosphorus efficiency of three new wheat genotypes from CIMMYT in comparison with an older Mexican variety. *J. Plant Nut Soil Sci.*, 162: 353 - 358.

Ethiosis (Ethiopia Soil Information System). 2014. Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia.

FAO (Food and Agriculture Organization), 2000. *Fertilizers and their use 4th ed*. International fertilizer industry association, FAO, Rome, Italy.

Feller, I.C. 1995. Effects of nutrient enrichment on growth and herbivory of Dwarf Red Mangrove (*Rhizophora Mangle*). *Ecol. Monog.*, 65:477-505.

GenStat. 2014. GenStat Procedure Library Release. 17th edition. VSN International Ltd.

Hassan, F.A.S., Ali, E.F. and Mahfouz, S.A. 2012. Comparison between different fertilization sources, irrigation frequency and their combinations on the growth and yield of coriander plant. Australian *Journal of Basic and Applied Sciences*, 6(3): 600-615.

Izgi, M.N.2020. Effects of nitrogen fertilization on coriander (Coriandrum sativum L.): yield and quality characteristics. *Applied ecology and environmental research,* 18(5):7323-7336.

Karoline P. Angeli, Fábio T. Delazari, Carlos Nick, Mariane G. Ferreria and Derly J. H. da Silva. 2016. Yield components and water use efficiency in coriander under irrigation and nitrogen fertilization. *Revista Brasileira de Engenharia Agrícola e Ambiental*, 20(5):415-420.

Kurubetta , K. D., Alagundagi, S. C., Mansur, C. P., Hosamani, S. V. and Uppar, D. S. 2008. Effect of time of sowing, spacing and seed rate on seed production potential and economics of fodder cowpea, *The Andra Agriculture Journal,* 55 (1): 14-17.

Landon, J.R. 1991. Booker Tropical Soil Manual: a handbook for soil survey and agricultural land evaluation in the tropics and subtropics. (eds.). John Wiley and Sons Inc., New York.

Ma, Q., Longnecker, N., and Atkins, C. 2001. Varying phosphorus supplies and development, growth and seed yield in narrow leafed lupin. *Plant and Soil.* 239:79-85.

Malhi, S. S., Gan, Y. and Raney, J. P. 2007. Yield, Seed Quality, and Sulfur Uptake of Brassica Oilseed Crops in Response to Sulfur Fertilization. *Agronomy Journal,* 99:570-577.

Matasyoh, J.C., Maiyo, Z.C., Ngure, R.M., and Chepkorir, R. 2009. Chemical composition and antimicrobial activity of the essential oil of *Coriandrum sativum*. Food Chem., 113, 526-529.

Moniruzzaman, M., M.M. Rahman, M.M. Hossain, A.J.M.S. Karim and Q.A. Khaliq. 2014. Response of Coriander (*Coriandrum sativum* L.) Foliage to Different Rates and Methods of Nitrogen Application. *Bangladesh J. Agril. Res*., 39(2): 359-371.

Mostafa Moslemi, Abdolhosseini Aboutalebi, Hamed Hasanzadeh and Mehdi Hosseini Farahi. 2012. Evaluation the Effects of Different Levels of Phosphorous on Yield and Yield Components of Coriander (*Coriandrum sativum* L.). *World Applied Sciences Journal,* 19 (11): 1621-1624.

Moslemi, M., Aboutalebi, A., Hasanzadeh, H. and Farahi, M.H. 2012. Evaluation the effects of different levels of phosphorous on yield and yield components of coriander (*Coriandrum sativum* L.). *World Applied Sci. J.* 19: 1621-1624.

Nahed M. Rashed and R.Kh.Darwesh.2015. A comparative study on the effect of microclimate on planting date and water requirements under different nitrogen sources on coriander (*Coriandrum sativum*, L.), *Annals of agricultural science*, 60(2):227-243.

Nasim Wajid, Ahmad A, Hammad HM, Chaudhary HJ, and Munis MFH. 2012. Effect of nitrogen on growth and yield of sunflower under semi-arid conditions of Pakistan. *Pakistan Journal of Botany*, 44(2):639-648.

Oliveira, A. P. de, de S. Paiva-Sobrinho, J. K.A. Barbosa, C. I. Ramalho, A. L. P. Oliveira, Oliveira A. P. De and S.de-Paiva Sobrinho. 2003. Rendimento de coentro cultivado com doses crescentes de N (Yield of coriander cultivated with increasing nitrogen levels). *Hortic. Bras.*, 21(1): 81-83.

Olsen, S.R., C.V. Cole, F.S. Watanabe, and L.A. Dean, 1954. Estimation of Phosphorus in soils by extraction with sodium bicarbonate.USDA, Circular 939.

Sahlamdihin Sertsu, 1999. Draft guideline for regional soil testing laboratory.NFIA, Addis Ababa, Ethiopia.

Sharif M, Ahmed M, Sharir MS and Khattak RA,. 2004. Effect of organic and inorganic fertilizers on the yield and yield components of maize. *Pak. J. Agric. Engg. Vet. Sci*., 20(1): 11-15.

Silva J. A., and Uchida, R. 2000. Plant Nutrient Management in Hawaii's Soils, Approaches for Tropical and Subtropical Agriculture, University of Hawaii at Manoa.

Singh, G., Maurya, S., Lampasona, M.P., and Catalan, C.A.N. 2006. Studies on essential oils. Part 41. Chemical composition, antyfungial, antioxidant and sprout suppressant activities of coriander (*Coriandrum sativum*) essential oil and its oleoresin. Flavour Fragm. J., 21, 472-79.

Singh S.P. 2015. Effect of organic manures on growth, yield and economics of coriander (Coriandrum sativum L.). *Journal of Eco-friendly Agriculture* 10(2): 124-127.

Suman, P., D. Lakshminarayana, P. Prasanth and Saida Naik, D. 2018. Effect of Integrated Nutrient Management on Growth Parameters of Coriander (Coriandrum sativum L.) Cultivars under Telangana Conditions. *Int.J.Curr.Microbiol.App.Sci*, 7(11): 2871-2877.

Tekalign Mamo, I. Haque and E.A. Aduayi, 1991. Soil, plant, water fertilizer, animal manure and compost analysis manual. Plant Science Division Working Document 13, ILCA, Addis Ababa, Ethiopia.

Tuncturk, R. and Tuncturk, M. 2006. Effects of different phosphorus levels on the yield and quality components of cumin (*Cuminum cyminum* L.). *Res. J. Agric. Biol. Sci.*, 2: 336–340.

Wenting Li, Binglin Xiong, Shiwen Wang, Xiping Deng, and Lina Yin, H. L. 2016. Regulation Effects of Water and Nitrogen on the Source-Sink Relationship in Potato during the Tuber Bulking Stage. PLoS ONE. 11(1):1-18.

Władysław Szempliński and Justyna Nowak. 2015. Nitrogen fertilization versus the yield and quality of coriander fruit (Coriandrum sativum L.). *Acta Sci. Pol. Hortorum Cultus*, 14(3):37-50.

Yousuf, M.N., S. Brahma, M.M. Kamal, S. Akter and M. E. K. Chowdhury, 2014. Effect of Nitrogen, Phosphorus, Potassium, And Sulphur on The Growth and Seed Yield of Coriander (*Coriandrum sativum* L.). *Bangladesh J. Agril. Res*., 39(2): 303-309

Influence of NPS and Nitrogen Fertilizer rates on bread wheat grain yield and yield components in the highlands of Western Oromia, Ethiopia.

Hailu Feyisa*, Bodena Guddisa, Geleta Gerema, Fufa Anbasa and Meseret Tola
Bako Agricultural Research Center. P. O. Box 3, Bako, West Showa, Ethiopia.
Corresponding author email: thailufeyisa@gmail.com

Abstract

Sustainable wheat production is attained under optimum application of plant nutrients. In this view, a field experiment was conducted in the rainy season of 2018, 2019 and 2020 at Shembu, Gedo and Arjo experimental sites of Western Oromia, Ethiopia to determine the best NPS and N fertilizer rates for sustainable wheat production in the highland areas of Western Oromia.The experiment was laid out in a randomized complete block design with factorial arrangement in three replications. The treatments consisted of four NPS levels (25, 50, 75 and 100 kg NPS ha^{-1}) and three levels of N (23, 46 and 69 kg N ha^{-1}). In addition, previous fertilizer rate (46 kg N ha^{-1}and 41.5 kg P_2O_5 ha^{-1}) and the control plot receiving no fertilizer were included, which constituted a total of 14 treatments. The result of combined analysis of variance showed that applied NPS and N fertilizer rates significantly ($P<0.01$) affected grain yield, dry biomass and harvest index (HI) over location and year. Significantly higher mean grain yield (3.2 t^{-1}) of bread wheat was obtained from the application of 75/69 and 100/69 kg NPS/N ha^{-1}. However, higher net benefit of ETB 39,122.34 ha^{-1} with acceptable marginal rate of return (230%) and value to cost ratio of ETB 9.60 per unit of investment were achieved from the use of NPS rate of75kg ha^{-1} combined with 69 N kgha^{-1} fertilizer rate for bread wheat production in the study areas. Therefore, application of 75 NPS kg ha^{-1} with 69 kg N ha^{-1} was produced better grain yield and economically feasible and recommended for improved wheat production in the areas of Shambu, Gedo and Arjo, and similar agro-ecologies in the country.

Keywords: Bread wheat, Grain yield, Yield components, Fertilizer, NPS and N rate,

Introduction

Despite of a considerable achievement in the agricultural sector, the problem of food security and nutrition remains a challenging issue in Ethiopia. As well, several parts of the country is suffering from unfavorable environmental change whereby a number of areas in the country facing erratic rain fall, drought and soil fertility depletion, and poor farming technologies (Hailu *et al*., 2021; FAO, 2018; Mohamed, 2017; Birara *et al*., 2015) which is worsening food security situation in the country. In addition, to meet the current and future food demand for the population of the country which is expected to reach 190.9 million by 2050 (Population Reference Bureau, 2018) requires the use of improved crop varieties and expansion of the intensification of the current production that ensures sustainable food accessibility at the household level. Wheat *(Triticum aestivum* L.) is one of the main cultivated and popular cereal crops in national and global food security (Dhillon *et al*., 2020) due to its high value as a stable food grain (Ali *et al*., 2016; Iqtidar *et al*., 2010; Braun et al., 2010) and economically valuable crops in various industries as a raw material in the world and even its straw used for animal feed.

Because of its multiple uses, it leads all cereal crops in the world in terms of production and a staple food for one third of the world's population (Husen *et al*., 2006; Lemi and Negash, 2020).
Ethiopia is one of the largest wheat producing countries in the world and it is the second largest producers in sub-Saharan Africa following South Africa and about 1.61 million hectare of land is cultivated for both bread and durum wheat production under rain fed conditions (CSA 2019/20).
In the country, wheat made up of about 15.86% (53,152, 70.33 tones) of the grain cereal production. It can be grown at altitude of 1500 to 3000 meter above sea level (m.a.s.l); with the suitable altitude ranges from 1900-2700 m.a.s.l. It is cultivated by 4.8 millions of farmers and accounts for more than 13.91% (1,789,372.23 ha) of the total cereal production (CSA, 2019/20). However, the mean national and regional yield of this crop is 2.97 and 3.18 t ha^{-1} (CSA, 2019/20) respectively, which is 3-4 t ha^{-1} far below the reported research yields of over 6 t ha^{-1}. For instance, the yield potential of Liban variety can produce up to 5.5 to 6.5 t ha^{-1} at research field and 4.5–5.0 at farmers field (Variety registration, 2015).
Mineral fertilizer application and soil nutrient depletions are among the major factors responsible for the low yield of bread wheat varieties in the country. The trends of the yield crops decline from time to time due to soil fertility depletion because of the continuous crop production for longer period of time. In addition, increased risk of climate change and unsustainable farm land practices could also threaten crop productivity (Hailu and Tolera, 2020; Martini *et al*., 2015). On the other hand, in the soil fertility management practices, the use of inorganic fertilizer application with improved wheat varieties is among the strategic methods to increasing yield of wheat for sustainable production and productivity (Racioppi *et al*., 2020; Hailu 2020; Hamdi et al., 2019). Recently, the Ethiopian Soil Information System (EthioSIS) has reported that several plant nutrients (N, P, S, Zn and B) other than the common use of N and P is also deficient in many parts of the Ethiopian soil (ATA, 2013). While, some soils are also deficient in potassium, copper, manganese and iron, which all potentially hold back crop productivity due to continued utilization of only N and P fertilizers as per the blanket recommendation. Assefa et al. (2015) found that production of wheat can be limited by the deficiency of S and other nutrients. He also reported that significant response of mean grain yield and other yield components of wheat was observed with application of blended NPS. Another author, Tolera et al. (2021) found that application of NPSB and urea fertilizer significantly affected grain yield and other yield traits of wheat in Liban Jawi distric of Western Oromia. Moreover, Lemi and Negash showed that production of bread wheat can be limited by the deficiency of S and other nutrient. On the other hand, Except the EthioSIS map, so far there is no information or research finding on the differential newly released bread wheat varieties to the blended fertilizers in the highland areas of western Oromia specifically in East and Horo Guduru Wallega, and some parts of West Shewa zone.
Thus, knowing the contribution of blended (NPS) fertilizer in maximizing yield in the area are needed to be investigated to explore the yield potential of bread wheat to use as alternative fertilizer sources or replace based on potential yield advantage over the previously recommended Urea and DAP. Therefore, the objective was to determine the best NPS and N fertilizer rates that

are economically feasible for sustainable wheat production in the highland areas of Western Oromia.

Materials and Methods

The experiment was carried out during the rainy season in the districts at Shambu, Arjo and Gedo experimental sub-sites, Western Oromia, Ethiopia for three consecutive years (in 2018, 2019 and 2020). The areas are located in sub-humid that have variable climatic conditions with unimodal rainfall pattern and maximum precipitation being received in months of July and August. The farming systems of the areas are a mixed crop-livestock farming and cultivation of Wheat, tef, maize, and barley are the major crops grown by the farmers in the areas.

The experiment was laid out in a randomized complete block design with factorial arrangement in three replications. The plot size was 2m x 3m. The treatments consisted of four NPS levels (25, 50, 75 and 100 kg NPS ha^{-1}) and three rates of N fertilizer (23, 46 and 69 kg N ha^{-1}). In addition, previous fertilizer rate (46 kg N $ha^{-1}$and 41.5 kg P_2O_5 ha^{-1}) and the control plot receiving no fertilizer were included, which constituted a total of 14 treatments. All the NPS and half N were applied at the time of planting, and half the remaining N was applied at the tillering stage. The experimental field were plowed three times at different time intervals starting from end of April and leveled manually prior to field layout. N fertilizer in the form of Urea was applied at different rates as constituted in the treatments. One recently released bread wheat variety, Liben was used as a test crop for the execution of the experiment. The variety was released by Bako Agricultural Research Center in 2015. The cultivar is well adapted to altitude areas of 2300-2500 m.a.s.l and it requires an annual rainfall of ≥ 900 mm with uniform distribution in its growing periods. Its yield potential ranges from 5.5-6.5 t ha^{-1} at research field and 4.5-5.0t ha^{-1} at farmers field (Variety registration, 2015). It needs 122 to 125 days to maturity, having a white seed color with 42 to 45 gram thousand grain weight and tolerant to major wheat diseases. Its plant height ranges between 75− 90 cm. It performs better if planted from early to late July with seed rate and inter-row spacing for at 125 kg ha^{-1} and 20cm, respectively. The trial was planted at inter-row spacing of 20 cm with drilling sowing method. All other non-treatment management practices were applied as per recommendation for the variety to all experimental plots.

The trial was harvested from 8 rows by excluding two border rows from each side. A net plot size for each plot was 1.4 m x 3 m (4.2 m^2). Plant height, biomass yield, grain yield, harvest index, thousand kernel weight and other relevant agronomic traits were recorded at appropriate growth stages. Costs that vary among treatments were also carried out using the CIMMYT, 1988 procedures. The cost of NPS, N, the cost of labor required for the application of fertilizer and field managements, and the cost for harvesting and threshing were estimated by assessing the current local markets. The cost of urea and blended NPS were ETB 14 and 14.48 per 100 kg with current market price. The wheat grain valued at an average open market price of ETB 900 per 100 kg. The labor cost for field operation was ETB 75.00 per man-day based on government's current scale in the study area and the cost of bread wheat threshing ETB 100 t^{-1} were considered to get the total cost that varied among the treatment. The grain yields harvested were adjusted down by 10% to reflect actual production environments. Gross revenue was calculated as adjusted grain yield multiplied by field price (9.00 ETB kg^{-1}) that farmers receive for the sale of the crop. The net benefit and the marginal rate of return were calculated as per standard manual (CIMMYT, 1988). On the other hand, non-varied costs were not included since all management practices were uniformly applied to each experimental plot. Finally, combined analysis of variance was carried out using Gen Stat 15th Edition software, and Duncan's multiple range tests at P< 0.05 was used to comparing treatment means (Duncan, 1955).

Results and Discussion

The result of combined analysis showed that application of blended NPS and N fertilizer rates significantly (P<0.01) affected grain yield, dry biomass and harvest index (HI) over location and year (Table 1). Similarly, the interaction of applied blended NPS and N fertilizer levels significantly affected grain yield and plant height at 5% significance level, and at 1% for dry biomass. In addition, the main effects of NPS application showed a significant (P<0.01) variation to grain yield and dry biomass. Moreover, the main effect of N rate significant affected all measured parameters, except for thousand kernel weight (TKW). On the contrary, the response of plant height and thousand kernel weight to NPS and N rate did not show significant variations between treatments used over location and year. Further, the interaction of applied NPS and N rates did not show significant variation among the treatments used for TKW, HI and plant height. There were also no significant variations observed to measured TKW, plant height and spike length due to the various applications of NPS rates.

Grain Yield of wheat: As depicted in 2, grain yield of bread wheat were significantly influenced by the application of NPS and N fertilizer rates at all tested sites over years. Tolera *et* al. (2021) and Tagesse et al. (2018) also reported that the main grain yield and dry biomass of bread wheat were significantly affected by the application of blended NPS and N fertilizer rates.

Table 1: Analysis of variance for yield and yield traits as influenced by NPS, nitrogen rates, and interaction effects in 2018, 2019 and 2020 rainy season at Shambu, Arjo and Gedo, western Ethiopia.

MS							
Source of variation	D.f.	GY	DB	TKW	PH	HI	SPL
NPS	3	0.29**	1.09**	2.90^{ns}	23.75^{ns}	47.38*	0.55^{ns}
Nitrogen (N)	2	10.77**	95.98**	2.70^{ns}	496.16**	596.51**	3.60**
Location (Loc)	2	15.79**	325.65**	6.84^{ns}	541.98**	2790.94**	14.19**
Year (Yr)	2	28.6**	66.65**	1152.35**	1031.73^{ns}	4416.42**	3.39**
NPS* N	6	0.051*	0.42**	9.15^{ns}	26.42*	10.52^{ns}	0.26^{ns}
Loc*Yr	4	17.06**	133.49**	78.04**	228.68**	2286.42**	12.71**
NPS* N*Loc	12	0.34**	2.63**	6.31^{ns}	36.20**	54.18**	0.35^{ns}
NPS* N*Yr	12	0.19**	1.21**	8.58^{ns}	21.20*	53.01**	0.41^{ns}
NPS* N*Loc*Yr	24	0.36**	2.49**	6.80^{ns}	13.71^{ns}	43.58**	0.58*
Replication	2	0.01^{ns}	0.11^{ns}	41.09*	32.76^{ns}	76.05*	1.27*
Residual	214	0.021	0.082	5.82	11.87	12.15	0.276
Total	323	–	–		–	–	–

* and ** =significant difference at 5% and 1% probability level, ns = non-significant difference, d.f. = degree freedom= Grain yield, DB= Above ground dry biomass, TKW = thousand kernel weight

The attained grain yield and dry biomass ranged from 1.6–3.2 t ha^{-1} and 3.7 to 7.4 t ha^{-1}, correspondingly. However, the highest mean grain yield (3.2 t ha^{-1}) was obtained when NPS level of 75 and 100 kg ha^{-1} combined with 69 kg ha-1 N was used followed by NPS levels of 50 kg ha^{-1} combined with N rate of 69 kg ha^{-1} which are statistically different (Table 2). In addition, statistically comparable yield (3.0 t ha-1) performance was recorded from application of 25/69 kg NPS/N ha-1. Interestingly, 16% and 50 % significant yield advantage were recorded when 75/69 kg NPS/N ha^{-1} was applied compared to the pervious fertilizer rate (41.5 P2O5 + 46 kg N ha-1) and the control plot receiving no fertilizer application. This indicates application of only N and P containing fertilizers is not sufficient in obtain higher yields and good quality of crops and this might be need to the application of various types of fertilizers that have dissimilar concentrations of plant nutrients. Different scholars reported similar results (Tagesse *et al*., 2018; Desalegn, 2019; Usman *et at*., 2020). Similarly, Tolera et al. (2021) reported that application of integrated use of urea and blended NPSB fertilizer rate were significantly improved growth, yield and yield components of bread wheat at Liben Jawi district, West Shewa zone, Oromia, Ethiopia. Also, Assefa et al. (2015) was found that application of NPS fertilizer significantly affected grain yield and other yield components of wheat. The lowest yield (1.6 t ha^{-1}) was, however, attained from plot receiving no fertilizer as compared to other treatment combinations. This might be attributed to reduced production of photosytate because of deficiencies of nutrient and lower plant density. Similarly, Beyenesh and Nigussie (2017) indicated that plant nutrient deficiencies affected grain development processes in wheat which may have resulted in stomatal closure and early senescence.

The overall yield means despite of treatment differences indicated that there is an increase in the grain yield of bread wheat with increasing the amount of applied blended NPS fertilizer rate to 75 kg ha^{-1} NPS and then minimum increment after that (Figure 1). This suggests that the extra amount of blended NPS fertilizer had little influence on increasing yield and application of extra fertilizer may be inadequately taken by the plant and some of it may have been lost through leaching, denitrification or volatilization (Hailu, 2020; Zerihun and Hailu, 2017). Likewise, higher mean grain yield of wheat increased with the higher levels of N than the lower rates of N and the maximum yield recorded from the higher levels of nitrogen (Table 1 and Figure 1 and 2). This might be due to the role of nitrogen in increasing the vegetative growth of wheat which facilitates the photosynthesis efficiency which promotes dry matter production and increased yield. Similar findings were reported by Bereket et al. (2014; 2012; Przuli et al., 2011; Shirazi et al. 2014). Also Yohannes and Nigussie (2019), and Lemi and Negash (2020) reported that the mean grain yield of wheat significantly increased with increasing rates of nitrogen. Further, Aula et al. (2020) stated that improving wheat grain yield and meet the food needs of the ever-expanding human population, growing of new cultivars together with N fertilization may need to become an integral part of the farming operation in developing country which is true for Western Oromia. Haile et al. (2012) found that increasing N rate from 0 to 120 kg N ha^{-1} increased mean grain yield of bread wheat.

The mean grain yield response to blended NPS and N rates was also considerably varied across the testing sites and seasons (Figure 1 and 2). This might be due to the soil fertility status variation across the testing areas due to management history of the sites for crop production. Similarly, Fresew et al. (2018) stated that variations across years among wheat varieties planted for two consecutive years. Vanlauwe et al. (2015) reported a long-term interplay of geological and landscape conditions and plot-specific management have generated such often called within farm soil fertility gradients variations. Further, Mack (2006) reported a wide range of management practices and production history at each site which subsequently affects treatment response of on-farm research; and each farmer managed his farm on his own way, such as applying either preplan or top dress N rates. Tittonell et al. (2012) reported heterogeneity in soil fertility in these smallholder systems is caused by both inherent soil landscape and human-induced variability across farms differing in resources and practices. The variability in soil properties at farm scale was largly associated with inherent features of each site as well as with within farm variability (2010).

Table 2: The overall mean effects of NPS and N fertilizer rate on Grain yield, dry biomass, and other yield traits of bread wheat in 2018, 2019 and 2020 rainy season at Shambu, Arjo and Gedo, Western Oromia, Ethiopia.

NPS levels (kg ha^{-1})	N level (kg ha^{-1})	Grain yield (t ha^{-1})	Dry biomass (t ha^{-1})	SPL (cm)	PH (cm)	TKW (g)	Harvest index (%)
0	0	1.6	3.7	7.7	66.4	37.5	48.0
25	23	2.4f	5.3g	7.9	69.2	37.4	49.5
25	46	2.7d	6.3de	8.2	73.9	37.5	46.8
25	69	3.0b	7.2b	8.3	75.1	38.1	45.0
50	23	2.5ef	5.4g	7.9	72.0	37.4	48.4
50	46	2.8c	6.4d	8.1	74.4	37.4	45.8
50	69	3.1b	7.1b	8.3	74.9	37.3	43.2
75	23	2.5ef	5.4g	8.0	70.8	38.2	49.5
75	46	2.8c	6.1e	8.1	73.9	36.9	46.8
75	69	3.2a	7.4a	8.2	75.0	38.4	46.0
100	23	2.6e	5.5f	8.0	72.4	38.0	49.5
100	46	2.9c	6.6c	8.2	73.0	38.3	45.0
100	69	3.2a	7.4a	8.4	76.3	37.3	44.2
PR (41.5 P_2O_5 + 46 N)		2.7	6.8	8.2	75.0	38.1	43.5
LSD (5%)		0.08	0.15	0.28	1.8	1.3	1.9
CV (%)		5.2	4.5	6.5	4.7	6.4	7.5

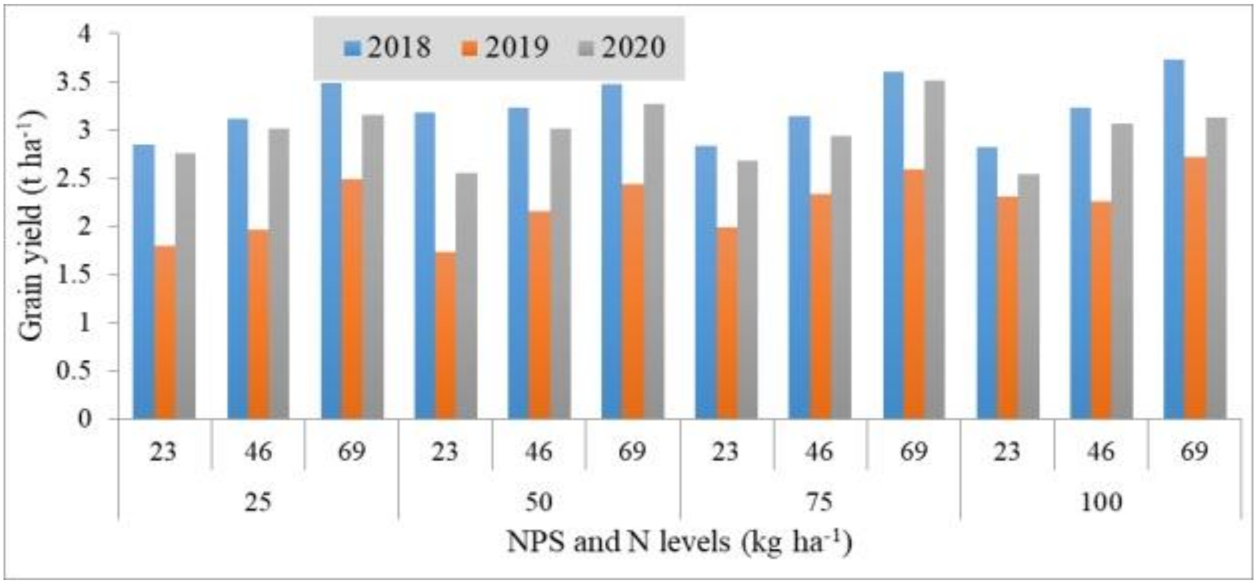


Figure 1: The effects of NPS and N rates on the grain yield of bread wheat in 2018, 2019 and 2020 rainy season at Arjo, Gedo and Shambu

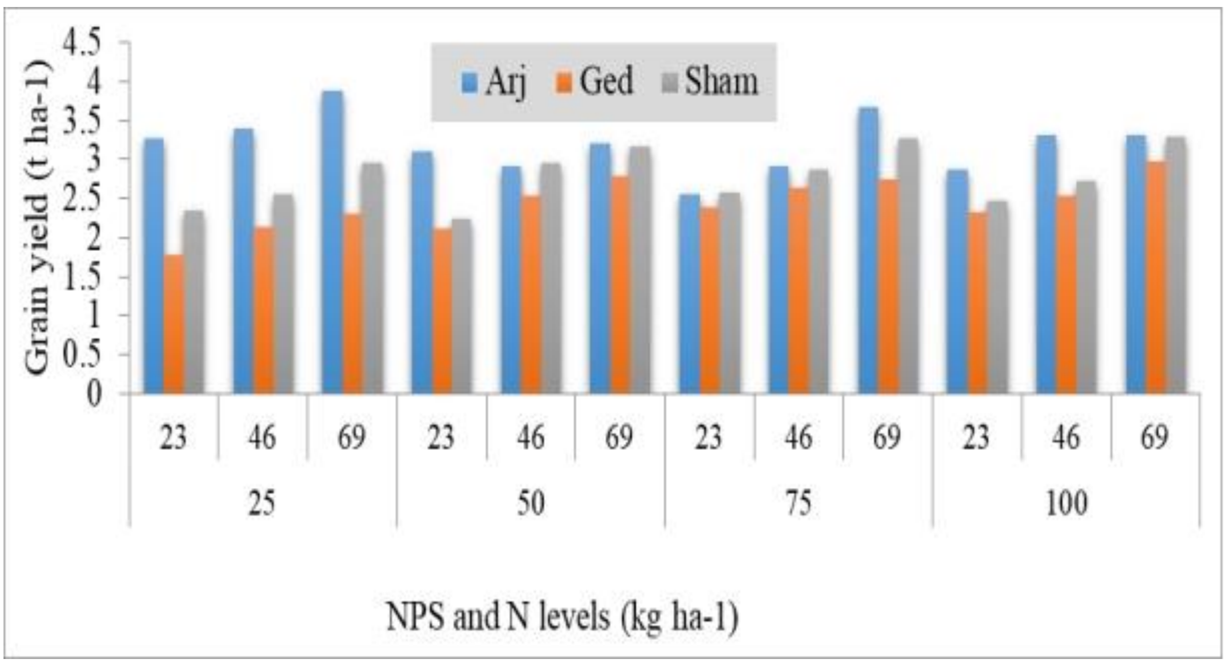


Figure 2: The effects of NPS and N rates on the grain yield of bread wheat across the testing sites.

Crop phenology, growth and yield traits of bread wheat

Blended NPS and N rates also showed significant effects on crop physiology, growth and yield traits of bread wheat across the locations and seasons. The highest biomass yield (7.4 t ha^{-1}) was obtained at 75 and 100 kg NPS ha^{-1} and 69 kg N ha^{-1} followed by 25/69 kg ha^{-1} NPS/N fertilizer rates (Table 2). Interestingly, a considerable biomass yield increment by 9% and 100% were observed when 75/69 Kg NPS/N ha^{-1} was used compared to the previous recommendation and plot receiving no fertilizer, correspondingly. The lowest dry biomass, however, obtained from the control plot without fertilizer. While, higher HI (49.5%) was recorded from the use of 25/23, 75/23 and 100/23 Kg NPS/N ha^{-1}. The lowest HI, however, (43.5%) was recorded from the use of previous recommendations rate (41.5 kg P_2O_5 + 46 kg N). On the other hand, maximum spike length (8.4 cm) and plant height (76.3 cm) were achieved at 100 Kg NPS ha^{-1} and 69 kg N ha^{-1}. The highest TKW (38.4 g) was recorded at NPS levels of 75 kg ha^{-1} and N rate of 69 kg ha^{-1}. Conversely, the lowest significant biomass yield (3.7 t ha^{-1}), spike length (7.7 cm) and plant height (66.4 cm) were attained from the plot receiving no fertilizer compared to other treatment combination. The lower TKW (36.9 g), however, was observed at the application of 75 kg NPS ha^{-1} and N rate of 46 Kg ha^{-1}.

Economic feasibility of NPS and nitrogen fertilizer application rates on bread wheat production

The economic feasibility for means of treatment combinations against the pervious recommendation and the control was also carried out. As indicated in table 3, the partial budget analysis due to application of blended NPS and N fertilizer rates on wheat production was varied. The highest net benefit ETB 39,122.34 ha-1 with marginal rate of return of 230% and value to cost ratio of ETB 9.60 per unit of investment was obtained when 75/69 kg NPS/N ha^{-1} fertilizer rate was used for bread wheat production. The second and third net benefit ETB 38181.93 and 37241.51 with marginal rate of return of 230% and 560% and value to cost ratio of ETB 10.40 and 11.40 per unit of investment were obtained from the use 250/100 and 150/100 kg NPS/N ha-1 for wheat production. Higher values to cost ratio of ETB 18.90 per unit of investment were obtained from application of 25/23 kg NPS/N ha^{-1} for bread wheat production.

Table 3: The effects of blended NPS and N rate on economic profitability of bread wheat production in Shambu, Gedo and Arjo in 2018, 2019 and 2020 rainy season.

Treatments NPS/N levels (Kg ha^{-1})	Grain yield (t ha^{-1})	Adj. GY (t ha^{-1})	Total Cost	Gross Benefit	Net Benefit	D.A	MRR	Value to cost ratio
0/0	1.6	1.4	320.00	21600.00	21280.00	-	-	-
25/23	2.4	2.2	1625.90	32400.00	30774.10		7.3	18.90
50/23	2.5	2.3	2035.50	33750.00	31714.53		2.3	15.60
75/23	2.5	2.3	2425.06	33750.00	31324.94	D	-	12.90
25/46	2.7	2.4	2442.20	36450.00	34007.81		5.6	13.90
100/23	2.3	2.1	2774.65	31050.00	28275.35	D	-	10.20
50/46	2.8	2.5	2851.80	37800.00	34948.64		2.3	12.30
75/46	2.8	2.5	3241.36	37800.00	34558.64	D	-	10.70
25/69	3.0	2.7	3258.50	40500.00	37241.51		5.6	11.40
PR	2.7	2.4	3449.70	36450.00	33000.29	D	-	9.60
100/46	2.8	2.5	3631.00	37800.00	34169.05	D	-	9.40
50/69	3.1	2.8	3668.10	41850.00	38181.93		2.3	10.40
75/69	3.2	2.9	4077.70	43200.00	39122.34		2.3	9.60
100/69	3.2	2.9	4467.25	43200.00	38732.75	D	-	8.70

NPS/N= Blended NPS and Nitrogen Levels (kg ha^{-1}), Adj.GY = Adjusted yield (t ha^{-1}), MRR = Marginal rate of return (%), D.A = Dominated treatments, and 1 USD = 40.0 ETB.

Likewise Tolera et al. (2021) found the maximum net benefit ETB 54064.00 ha^{-1} was obtained with application of 250/250 kg urea/NPSB ha^{-1}, recommended application of 150/100 kg urea/NPSB ha^{-1} for bread wheat in Liban Jawi district. Bekalu and Mamo (2016) also reported that application of 69 kg N ha^{-1} gave higher grain yield and economic benefit of wheat in Southern part of Ethiopia. Furthermore, Assefa et al. (2015) obtained higher economic benefit with the application of higher NPS levels of 69 kg ha-1. Usman (2018) reported that application of 100 kg NPSB ha^{-1} for Hidase and Kingbird, and 150 kg NPSB ha^{-1} were economical feasible and recommended for bread wheat production. Dereje (2018) was found that application of 92 kg N ha^{-1} fertilizer application gave higher net benefit of ETB 79741 ha^{-1} with marginal rate of return of 980% was economically profitable and recommended for bread wheat production.

Conclusions and Recommendations

Application of integrated use of blended and nitrogen fertilizer were significantly improved growth, yield and yield components of bread wheat. Significantly higher (3.2 t^{-1}) mean grain yield of bread wheat was obtained with application of 75/69 and 100/69 kg NPS/N ha^{-1}. However, higher net benefit of ETB 39,122.34 ha^{-1} with marginal rate of return 230% and value to cost ratio of ETB 9.60 per unit of investment was achieved when 75/69 NPS/N ha^{-1} fertilizer rate used for bread wheat production in the highland areas of western Oromia. Therefore, application of 75 NPS kg ha^{-1} with 69 kg N ha^{-1} was produced better grain yield and economically feasible and recommended for improved wheat production in the highland areas of Western Oromia and similar agro-ecologies in the country.

Acknowledgements

First, I would like to thank the almighty God who lives us and lead us to see seed of our work. The authors also thank Oromia Agricultural Research Institute for funding the experiment. The authors are also very grateful to Bako Agricultural Research center for providing all necessary equipment's and logistics during the research work. All the technical and field assistants of Cereal crops technology generation research team are also acknowledged for unreserved effort during executing the experiment.

References

Ali S., Shahid Ibini Zamir M., Farid M., Farooq M.A., Rizwan M., Ahmad R. and Hannan F., 2016. Growth and yield response of wheat (*Triticum aestivum* L.) to tillage and row spacing in maize-wheat cropping system in semi-arid region. Eurasian Journal Soil Science, 5(1): 53-61.

Assefa Menna, J.M.R. Semoka, N. Amuri and Tekalign Mamo (2015). Wheat response to applied Nitrogen, Sulfur and Phosphorous in three representative areas of the central highlands of Ethiopia. International Journal of Plant and Soil Science, 8 (5): 1-11.

ATA (Ethiopian Agricultural Transformation Agency) (2013). EthioSIS (Ethiopian Soil Information System). Soil analysis report. Agricultural Transformation Agency (ATA). Addis Ababa, Ethiopia.

ATA (2014). Soil fertility Status and fertilizer recommendation Atlas for Tigray Regional State, Ethiopia. Ethiopian Agricultural Transformation Agency (ATA), Addis Ababa, Ethiopia.

Aula L., P. Omara, E. Eickhoff, F. Oyebiyi, J.S. Dhillon and W.R. Raun (2020). Effect of winter wheat cultivar on grain yield trend under different nitrogen managements. Agro-systems, Geo-sciences and Environment, 1-7.

Bekalu Abebe and Mamo Manchore (2016). Effect of the rate of N fertilizer application on growth and yield of wheat (*Triticum aestivum* L.) at Chencha, Southern Ethiopia. International Journal of Plant, Animal and Environmental Sciences, 6 (3): 168-175.

Bereket Haileselassie and YirgalemWeldegebreil (2012). Status survey of total plant and total DTPA extractable soil copper, zinc, iron and manganese in different agro ecological zones, soils and districts of Tigray, Ethiopia. Tigray Agricultural Research Institute, Mekelle, Ethiopia.

Bereket Haileselassie, Dawit, Habte, Mehretab Haileselassie, and Gebremedhin Gebremeskel (2014). Effects of mineral nitrogen and phosphorus fertilizers on yield and nutrient utilization of bread wheat (*Tritcum aestivum*) on the sandy soils of Hawzen District, Northern Ethiopia. Agriculture Forestry Fisheries, 3 (3): 189-198.

Beyenesh Zemichael and Nigussie Dechassa (2017). Performance of bread wheat in response to supplemental irrigation and rate of nitrogen application in Enderta, Tigray, Northern Ethiopia. International journal of Life Sciences, 5 (3): 345-36.

Birara Endalew, Mequanent Muche, Samuel Tadesse (2015). Assessment of food security situation in Ethiopia: A Review. Asian Journal of Agricultural Research, 9: 55-68.

Blumenthal J., D. Baltensperger, K. G. Cassman, S. Mason, and A. Pavlista (2008). Importance and effect of nitrogen on crop quality and health, Nitrogen in the Environment: Sources, Problems, and Management, Elsevier, Oxford, 2nd edition.

Braun H. J., Atlin G. and Payne T. (1997). Multi-location testing as a tool to indentify plant response to global climate change. *In*: Reynolds, M.P. (ed.), Climate change and crop Production. Pp 71-91. CABI, Landon, UK.

CSA (Ethiopian Central Statistical Agency) (2019/20). Area and production of major crops. Agricultural Sample survey 2019/2020 (2012 E.C). V1. Statistical Bulletin 587, Addis Ababa, Ethiopia.

Dereje, Dobocha (2018). Response of Lemu and Wane Bread Wheat (*Triticum aestivum* L.) Varieties to Nitrogen Fertilizer rates at Kulumsa, Southeastern Ethiopia. M. Sc Thesis, Hawassa University College of Agriculture, pp: 88.

Desalegn A. (2019). Effects of NPS fertilizer rates on yield and quality attributes of bread wheat varieties in Munessa District, Arsi Zone, Ethiopia. M.Thesis Research. Arsi University, PP: 71.

Dhillon J.E., Eickhoff L., Aula P., Omara G., Weymeyer E., Nambi F., Oyebiyi T., Carpenter and Raun W. (2020). Nitrogen management impact on winter wheat grain yield and estimated plant nitrogen loss. Agronomy Journal, 1-14.

Esayas Lemma (2015). Effect of blended fertilizers on yield and yield traits of durum wheat (*Triticum turgidum* var. durum) varieties in Ada district, Central Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia.

Fageria N.K. and Baligar V.C. (2005). Enhancing nitrogen use efficiency in crop plants, Advanced in Agronomy, 88: 97-185.

Fernandez F.G., Nafziger E.D., Ebelhar S.A. and Hoeft R.G. (2009). Managing nitrogen: in Illinois agronomy handbook. Univ. Illinois Coop. Ext. Serv" Urbana-Champaign, PP. 113-132.

Food and Agriculture Organization (FAO) (2018). The sate of food security and nutrition in the world 2018: Building climate resilience for food security and nutrition.

Fresew Belete, Nigussie Dechassa, Adamu Molla and Tamado Tana (2018). Effect of nitrogen fertilizer rates on grain yield and nitrogen uptake and use efficiency of bread wheat (*Triticum aestivum* L.) varieties on the Vertisols of central highlands of Ethiopia. Agriculture & Food Security, 7 (78): 1-12.

Gehl R. J., Schmidt J. P., Maddux L.D. and Gordon W. B. (2005). Corn yield response to nitrogen rate and timing in sandy irrigated soils, *Agronomy Journal*, vol. 97, no. 4, pp. 1230–1238.

Haile, D., Nigussie D. and Amsalu A. (2012). Nitrogen use efficiency of bread wheat: Effects of nitrogen rate and time of application. Journal of Soil Science and Plant Nutrition, 12(3): 389-409.

Hailu and Tolera Abera (2020). Sensor based validation of nitrogen fertilizer for quality protein maize variety using a handheld normalized difference vegetative index sensor at Bako, Western Ethiopia. African Journal of Plant Science, 14(7): 289-296.

Hailu Feyisa, 2020. The response of maize yield to blended NPS fertilizer rate: Seasonal rainfall variation affected fertilizer application rates. Middle-East Journal of Scientific Research, 28 (5): 401-408.

Hailu Feyisa, Chemada Brihanu, Dagnachew Lule and Kebede Desalegn (2021). On-farm evaluation and pre-scaling up of improved finger millet technologies under rainfed condition in Western Oromia, Ethiopia: A case of East Wollega Zone, Ethiopia. Journal of Agricultural extension and Rural Development, 13(3): 165-172.

Hamdi L., Suleiman A., Hoogenboom G. and Shelia V. (2019). Response of the Durum wheat cultivar Um Qais (*Triticum turgidum* subsp. Durum) to salinity Agriculture, 9: 125.

Husen I., Khan M. A. and Khan E. A. (2006). Bread wheat varieties as influenced by different nitrogen levels. Journal of Zhejiang University of Science, 7(1): 70-78.

Iqtidar H., Khan M.A. and Khan H. (2010). Effect of seed rates on the agro-physiological traits of wheat. Sarhad J. Agric. vol. 26, pp 169-176, 2010.

Lemi Aga and Negash Geleta (2020). Effects of variety and Fertilizer rate on yield of bread wheat (*Triticum aestivum*, L.) varieties in East Wollega Zone, Western Ethiopia. Journal of Agricultural and Biological Sciences, 6(2): 60-71.

Mack, C.J. (2006). Validation of nitrogen calibration Strip technology for prescribing accurate top-dress nitrogen fertilizer. M.Sc. Thesis degree, Oklahoma State University, United States, pp: 40.

Martini D., Taddei F., Ciccoritti R., Pasquini M., Nicoletti I., Corradini D. and D'Egidio M.G. (2015). Variation of total antioxidant activity and of phenolic acid, Total phenolics and yellow coloured pigments in durum wheat (Triticum turgidum L. Var durum) as a function of genotype, crop year and growing area. Journal Cereal Sciences, 65: 175-185.

Nielsen R. B. (2013). Root Development in Young Corn, *in*, Purdue University Department of Agronomy, 2013.

Racioppi M., Tartaglia M., Jose M., De La Rosa M., Marra E., Lopez-Capel E. and Rocco M. (2020). Response of Ancient and Modern wheat varieties to biochar application: effect on hormone and gene expression involved in germination and growth. Agronomy, 10(5): 1-11.

Shirazi, S.M., Z. Yusop, N.H. Zardari and Z. Ismail (2014). Effect of irrigation regimes and nitrogen levels on the growth and yield of wheat. Advances in Agriculture, pp: 1-6.

Tagesse Abera, Ketama Belete and Tamado Tana (2018). Effect of blended NPS fertilizer supplemented with Nitrogen on yield components and yield of bread wheat (*Triticum aestivum* L.). Journal of Natural Science Research, 18 (11): 90-96.

Tittonell P., A.W. Muriuki, K.D. Shepherd, D. Mugendi, K.C. Kaizzi, J. Okeyo, L. Verchot, R. Coe and B. Vanlauwe (2010). The diversity of rural livelihoods and their influence on soil fertility in agricultural systems of East Africa: A typology of smallholder farms. Agricultural Systems, 103: 83-97.

Tittonell, P., A. Muriuki, C.J. Klapwijk, K.D. Shepherd, R. Coe and B. Vanlauwe (2012). Soil heterogeneity and soil fertility gradients in smallholder farms of the east African highlands. Soil Science Society of American Journal, 77: 525-538.

Tolera Abera, Buzayehu Tola, Tolcha Tufa, Adane Adugna and Tesfaye Midega (2021). Effects of blended (NPSB) and Urea fertilizer rate on yield and yield components of wheat in Ultisols of Liban Jawi district, Oromia, Ethiopia. American-Eurasian Journal of Agriculture and Enviromental Science, 21 (2): 87-97.

Usman Kedir, Tamado Tana and Wogeyehu Worku (2020). Effects of blended (NPSB) fertilizer rates on yield components, yield and grain quality of bread wheat varieties at Kulumsa, South-Eastern Ethiopia. International Journal of Research Studies in Biosciences, 8(9): 14-27.

Variety Registration (2015). Crop variety registration for plant variety release. Protection and Quality control Directorate of Ethiopia, № 18, Addis Ababa, Ethiopia.

Yohannes Erkeno and Nigussie Dechassa (2019). Effect of Rates and Time of Nitrogen Application on Growth, Yield and Yield components of Wheat (*Triticum aestivum* L.) in Eastern Hararghe, Ethiopia. Journal of Natural Sciences Research, 9(11): 1-15.

Influence of spacing and seeding rates for finger millet varieties in the Western Oromia

Hailu Feyisa*, Bodena Guddisa, Geleta Gerema, Meseret Tola and Fufa Anbasa
[1]Bako Agricultural Research Center, P. O. Box 3, Bako, West Showa, Ethiopia.
Corresponding author Email address: thailufeyisa@gmail.com

Abstract

The average yield of finger millet is low in Ethiopia, particularly in Western Oromia due to different production constraints. Inappropriate plant population per unit area is among the major factors contributing to low productivity, since growth pattern of the varieties, fertility status of the soil, and cultural practices influence seed rate and inter-row spacing, optimum planting density should be determined to specific area and to specific finger millet varieties to sustain the productivity of this crop. In this view, a field trial was conducted to develop optimum and economically sound seed rates and inter-row spacing for row planting of finger millet in the Western Oromia, Ethiopia. There was a significant effect observed for phonological growth, yield and yield components of finger millet production of finger millet due to various levels of seeding rates and inter-row spacing over location and year. Significantly higher mean grain yield (3.4, 2.6, and 1.8 t^{-1}) and maximum net benefit ETB 26221.3, 19814.52, and 13390.70 ha^{-1} with acceptable marginal rate of return of 4643.5, 584.4 and 363.5% was obtained when 12 kg/50cm, 8 kg/50cm and 15 kg/40cm were attained for Bako-09, Diga-2 and Urji varieties finger millet, correspondingly at Bako and Gute. Thus, 12 kg/50cm, 8 kg/50cm and 15 kg/40cm seed rate and inter-row spacing for Bako-09, Diga-2 and Urji variety respectively, produced better grain yield and economically feasible and recommended for improved finger millet production in the areas of Bako and Gute, Western Ethiopia and similar agro-ecologies in the country.

Keywords: Finger millet, Seed rate, inter-row spacing, yield and varieties.

Introduction

Finger millet (*Eleusine coracana* subsp. *coracana)* is one of the crops underutilized, but the most important plants genetic resources for smallholder agriculture and food security in arid, infertile and marginal lands (Barbeau and Hilu, 1993) which would be play a significant role in the dietary needs and income sources to millions of farmers in developing countries (Asfew *et al*., 2018; Kassahun and Solomon, 2017). Because of its adaptability to a wide range of environments due to its ability to withstanding considerable soil acidity and minimal input requirements as well as performing on marginal lands where other crops cannot perform make the finger millet crops important for future human use (Hailu *et al*., 2021; Soumya *et al*., 2016). It is also the important crop in the diet of children, breast feeding and pregnant women since its calcium content is ten times higher than maize, wheat or rice and three times greater than milk (Kumar *et al*., 2016; Bora, 2013). Ethiopia is amongst the main finger millet growing countries in eastern Africa followed by Kenya (Asfew *et al*., 2018). The results of post-harvest crop production survey of the Ethiopian Central Statistical Authority data from the year 1995-2019/20 indicated that the total area and production of finger millet is generally increasing. For instance, in the year 2018/19 cropping season the total land area, production and productivity of finger millet were about 446,909 ha, 10, 356,295.7, quintals and 2.3 t ha^{-1}, respectively. While, in 2019/20 season, covered 455,580.47 ha of the grain crop area, 11,259,578.67 quintals of the grain production, and 2.5 t ha^{-1} productivity's were drawn from the same crop that shows a change in 2% for total area, 8.72% for total production and 6.63% in productivity. Oromia contributed 20.4% (93,098 ha) of the total cultivable land and 21.13 % (5,914,022 quintals) of total grain production in the country (CSA 2019/20). Particularly in East Wollega Zone, the crop has good potential in Diga, Boneya Boshe, Wayu Tuka, Gida Ayena, Bako-Tibei districts and in the many mandate area of Bako Agricultural Research Center (Hailu *et al*., 2020; Kebede *et al*., 2020). The survey result of the international livestock research institute-system wide livestock programme which was conducted in five districts around Nekemte town, east Wollega zone, indicated that finger millet took 1-3 in area coverage and Diga Woreda was the first growing district of finger millet. In the area, the households widely used this crop as supplementary meals, as bread combined with maize flour, *injera* mixed with *tef* and also used as soup for babies as well as for adults. In addition, it is used in traditional breakfast called "*chachabsa*", porridge, and distilled spirit locally known as *Areke* (Hailu *et al*., 2020; Kebere *et al*., 2006). The straw is also a good source for livestock feeding.

Despite the multi-purpose and the country's potential, the existing production system of finger millet suffers from traditional farming, poor agronomic practices, erratic rainfalls and pest and disease. This situation has caused productivity of the crop to be far below in contrast with yield potential of the crop has been reported to be more than 4.0 tons ha^{-1} (Kebede *et al*., 2019; Mulatu *et al.,* 1995), the current national average is only about 2.4 tons ha^{-1} (CSA, 2019/20). Inappropriate plant population per unit area is another major factors contributing to this yield gap of finger millet, since the growth pattern of the varieties, fertility status of the soil, moisture availability and cultural practices influence optimum planting per unit area (Hailu et al., 2020: Bezawuletaw *et al.,* 2006).

Seed rate is among the factors that manipulate yield of finger millet and the most important agronomic aspect worthing systematic study. Many studies have shown that finger millet sown at a seeding rate of 6-8 kg ha^{-1} produced an average of 6 tillers per plant and 2.5 tons ha^{-1} of grain yield. Previous research work on plant population studies on finger millet showed that most vigorous finger millet was observed when finger millet was planted at 20-30 cm inter-spacing and 10-15 kg seed rate ha^{-1} (Getahun *et al*., 2016). Tekele (2014) reported that the inter-row spacing of 45 cm or the seed rate of 10 kg ha^{-1} is advisable and could be appropriate for finger millet production. While, finger millet varieties produced in different agro-ecological of Ethiopia are categorized in to three seed color groups: brown, black and white varieties. They are also different in their growth patterns like in plant height, tillering capacity of the varieties.

In Western Oromia, Bako Agricultural research center is released eleven finger millet varieties so far released and recommended for different agro-ecological zones. To this point, the first variety, Boneya was released in 2002 followed by Wama in 2007, Bareda in 2009, Gute in 2009, Gudetu in 2014, Addis-01 in 2015, Urji in 2016, Diga-1 in 2016, Bako-09 in 2017 and Diga-2 in

2018 (Variety registration, 2018). However, growers in Bako area's traditionally use broadcasting sowing methods using seed rate of 25-30 kg ha^{-1} regardless of the varietal differences and variation in growth characteristics of the crop. For these reasons finger millet production and productivity in Ethiopia, specifically in Western Oromia is quite limited, particularly because of its low yield, even though a number of varieties have been released by research institutes' in the country. For instance, field managements like urea application, weeding, harvesting and other agronomic practices are difficult for taller varieties like Diga-2 (103.6 cm), Gute (96 cm), Wama (82.5cm) and Bonaya (80 cm) (Variety registration 2018). Further, highly tillering and late maturing varieties (like Diga-2) become lodging at grain filling which results in final poor grain yield. Also, thinning for taller and highly tillering capacity (Diga-2 and Bako-09), and replanting for shorter varieties like Adis-01 (77.4cm) and Urji (84.5cm) is a routine activity after planting in Bako areas that costs the center and farmers in time, energy and money. Moreover, some varieties like Bako-09 produce tillers from the main stem below the soil. However, Diga -2 and Diga-1 varieties producing tillering more of from main stem above the soil. It is therefore, appropriate spacing considering varietal differences in terms of tillering capacity, ear length, number of fingers and plant morphology is important in the case of row planting (Baloch e*t al.*, 2002; Yilma and Abebe, 1986). Thus, the present study was conducted with the objective to develop optimum and economically sound seed rates and inter-row spacing for row planting of finger millet in Eastern Western Oromia, Ethiopia.

Materials and Methods

The experiment was conducted at Bako on-station and Gute sub site experimental fields during the main cropping season of 2019 and 2020. Three inter-row spacing (20, 30, 40 and 50 cm) and three seed rates (8, 12 & 15 kg ha^{-1}) were arranged in factorial randomized complete block design with three replications on a plot size of 3.6 m width x 3.0 m length. Three recently released finger millet varieties, Diga-2 (black seed type), Bako-09 (brown type) and Urji (white seed color) which were released by Bako Agricultural Research Center in 2018, 2017 and 2016 correspondingly, were used as a test crops. The finger millet variety, Diga-2 is a black seed color that is characterized by taller in plant height (about 103.6cm), and majority of its tillers rise from the main stem above the soil. This variety can be grown in a range of 1400-2300 m above sea level and requires an annual rainfall of 1200-1300 mm with uniform distribution in its growing periods. It needs 164 days to maturity. Its yield potential varies between 2.24 and 3.4 t ha^{-1} at research fields' and 2.32 and 2.98 t ha^{-1} at farmers' field (Dagnachew *et al*., 2020). Bako-09 finger millet is the second variety used as a test crop, having a brown seed color and characterized by erect growth habit with medium in height (about 89 cm) and majority of its tillers rise from the main stem below the soil and growing more of horizontally. This variety can be grown in a range of 1400-2300 m above sea level and requires an annual rainfall of 1200-1300 mm with uniform distribution in its growing periods. It needs 146 days to maturity. Its yield potential varies between 2.3 and 2.98 t ha^{-1} at research field and 2.3 and 2.98 t ha^{-1} at farmers' field (Kebede*et al*, 2020). The third variety, Urji is grown in a range of 1600-2300 m above sea level and it requires an annual rainfall of 1200-1300 mm. This variety requires 153-

180 days to maturity, having a white seed color. It has yield potential ranges from 2.1-2.6 t ha^{-1} at research field and 1.8-2.7 t ha^{-1} at farmers' field (Kebede*et al*, 2017).

All field activities were carried out following standard production practices. The experimental plots were plowed 3 times. There was a 1.0m and 1.5 m path between the plots and the blocks respectively. As fertilizer, NPS fertilizers at the recommended rate of 100 kg ha^{-1} were equally applied to all plots by drilling methods at the time of planting. Urea was applied at recommended rate of 90 kg ha^{-1} to all plots by splitting, half at the time of planting whereas, the remaining urea was side dressed at the tillering stage (35-40 DAS). Seed placement and rate were by hand drill at the specified inter-row spacing and seeding rates. All other non-treatment management practices were applied as per recommendation for the finger millet to all experimental plots.

The trial was harvested by excluding border rows from each side. A net plot size for 20cm, 30cm, 40cm and 50cm inter-row spacing was 9, 8.1, 7.2 and 6 m^2, respectively. Plant height, biomass yield, grain yield, ear length, harvest index and other relevant agronomic traits were recorded at appropriate growth stages.

Costs that vary among treatments were also carried out using CIMMYT (1988) manual. The cost of labor required for the planting of seed, inter-row making and field managements, and the cost for harvesting and threshing were estimated by assessing the current local markets. The cost of finger millet seed ETB 100 per 100 kg with current market price. The finger grain valued at an average open market price of ETB 900 per 100 kg. The labor cost for field operation was ETB 75.00 per man-day based on government's current scale in the study area and the cost of finger millet threshing ETB 100 t^{-1} were considered to get the total cost that varied among the treatment. The grain yields harvested were adjusted down by 10% to reflect actual production environments. Gross revenue was calculated as adjusted grain yield multiplied by field price (900.00 ETB t ha^{-1}) that farmers receive for the sale of the crop. The net benefit and the marginal rate of return were calculated as per standard manual (CIMMYT, 1988). On the other hand, non-varied costs were not included since all management practices were uniformly applied to each experimental plot. Finally, combined analysis of variance was carried out using Gen Stat 15th Edition software, and Duncan's multiple range tests at $P< 0.05$ was used to comparing treatment means (Duncan, 1955).

Results and Discussion

There was significant effects ($P<0.01$) observed for grain yield and dry biomass due to various levels of seeding rates and inter-row spacing of finger millet varieties over location and year (table 1). Ear length also significantly ($P<0.05$) affected due to various levels of seeding rates and inter-row spacing. In contrary, the response of number of fingers per plant and plant height to various levels of seeding rates and inter-row spacing did not show significant variations. Moreover, varieties, seed rate and inter-spacing significantly affected grain yield, dry biomass, ear length and number of finger while this interaction due to varietal differences significantly affected all parameters, except plant height (Table 1). Therefore, separate analysis for each finger millet varieties were done since the different varieties considerably affected the response of the treatments.

Grain Yield, Yield traits and Crop phenology of Finger millet Varieties

As indicated in table 2, and figure 1 and 2 the use of different levels of seed rate and inter-row spacing were significantly affected mean grain yield, yield traits, crop phenology and growth of finger millet varieties, except for plant height. On the other hand, the harvested mean grain yield and other yield traits of finger millet varieties exhibited that there were differences among the varieties. To this, the attained grain yield and dry biomass for Bako-09 variety ranged from 2.0 to 3.4 t ha^{-1} and 8.4 to 12.9 t ha^{-1}, respectively. However, the maximum mean grain yield (3.4 t ha^{-1}) was obtained from seed rates of 12 and 15 kg ha^{-1} and inter-row spacing of 50 cm followed by seed rate of 15 kg ha^{-1} combined with inter-row spacing of 40 cm which are statistically different (Figure 1). Yield advantage of 14% was recorded when 12 kg ha^{-1} seed rate and 50 cm inter-row spacing was used compared to the pervious recommendation (15 kg seed rate ha^{-1} and 40 cm inter-row spacing for all varieties) in the study area. This might be due to increase in ear length and number of tillers per plant. Chekol et al. (2018) also showed that the optimum seed rate uses effectively the available nutrients, moisture and sun light. This indicates appropriate use of agronomic practices is a major factors in obtain higher yields and good quality of crops and this might be need to the application of various seed rates and inter-row spacing for different

Table 1: The overall analysis of variance for yield and yield traits of finger millet varieties as influenced by Seeding rate and spacing, and the interaction effects in 2019 and 2020 main season at Bako and Gute, western Ethiopia.

		MS					
Source of variation	D.f.	GY (kg ha^{-1})	DB (kg ha^{-1})	Ear L (cm)	№ of fingers ear^{-1}	PH (m)	№ of tillers
Varieties (Var)	2	55.54^{**}	746.0^{**}	396.02^{**}	15.18^{**}	3.08^{**}	18.4^{**}
Spacing (Sp)	3	9.03^{**}	146.3^{**}	0.71^{ns}	1.08^{ns}	0.01^{ns}	0.59^{ns}
Seeding rate (Sd)	2	3.35^{**}	23.8^{**}	1.29^{ns}	0.33^{ns}	0.47^{*}	0.36^{ns}
Var*Sp	6	0.29^{**}	5.9^{**}	1.98^{*}	0.43^{ns}	0.01^{ns}	0.18^{ns}
Var*Sd	4	0.40^{**}	8.5^{**}	0.84^{ns}	3.06^{*}	0.01^{ns}	0.24^{ns}
Sp*Sd	6	0.56^{**}	12.6^{**}	1.79^{ns}	0.58^{ns}	0.02^{ns}	0.67^{*}
Var*Sp*Sd	12	0.22^{**}	4.9^{**}	1.70^{*}	1.66^{*}	0.01^{ns}	0.61^{*}
Var*Sp*Sd*Loc*Yr	12	0.32^{**}	3.1^{**}	2.48^{*}	1.00^{ns}	0.02^{ns}	0.56^{*}
Location (Loc)	1	26.30^{**}	4590.9^{**}	67.41^{**}	929.57^{**}	5.93^{**}	13.87^{**}
Year (Yr)	1	9.45^{**}	43.7^{**}	72.33^{**}	91.39^{**}	0.09^{*}	145.1^{**}
Replication	2	0.17^{ns}	18.6^{**}	19.39^{**}	31.40^{ns}	0.01^{ns}	5.14^{**}
Residual	286	0.06	1.5	0.88	0.67	0.01	0.26
Total	431	–	–	–	–	–	–
LSD (5%)		0.20	0.97	0.76	0.66	0.08	0.81
CV (%)		11.9	12.1	9.5	10.8	8.8	18.4

* and ** =significant difference at 5% and 1% probability level, ns = non-significant difference, d.f. = degree freedom, Gy = Grain yield, DB= dry biomass and PH = Plant height, № of tillers $plant^{-1}$= Number of productive tillers $plant^{-1}$, Var = Finger millet varieties, Sp = Inter-row spacing (cm) and Seed rate (kg ha^{-1})

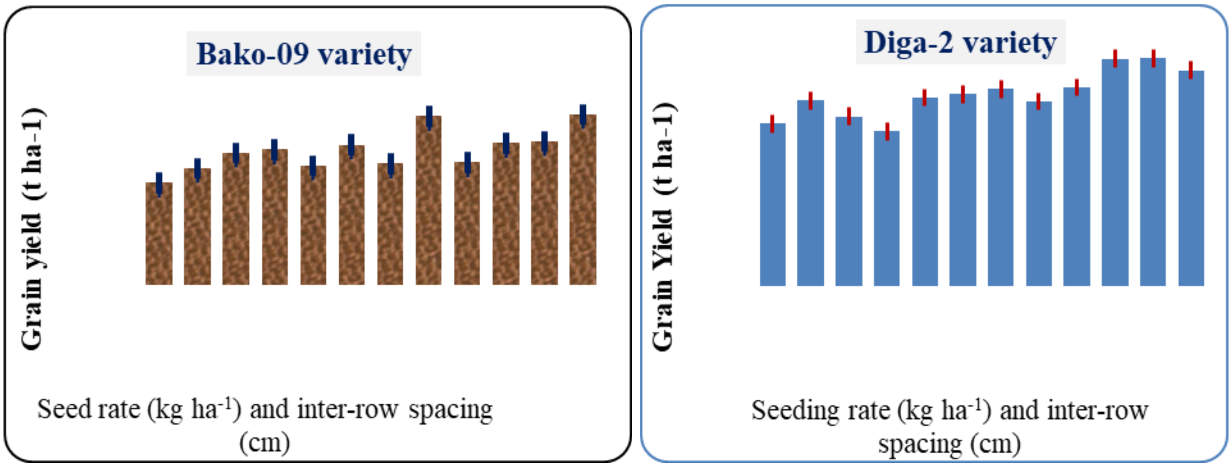


Figure 1: Effects of seed rate and inter-row spacing on grain yield for Bako-09 (left) and Diga-2 (right) finger millet varieties in 2019 and 2020 season at Bako and Gute, Western Ethiopia.

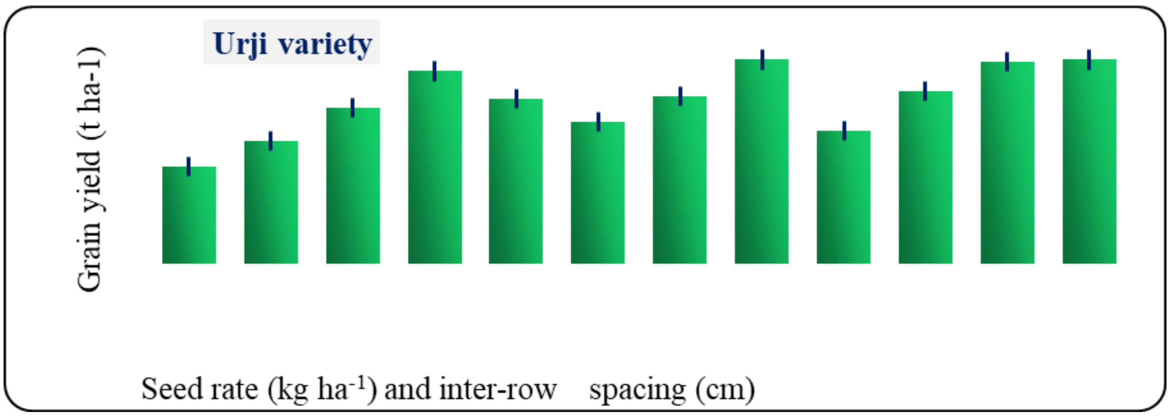


Figure 2: Effects of seed rate and inter-row spacing on grain yield forUrji finger millet variety in 2019 and 2020 cropping season at Bako and Gute, Western Ethiopia.

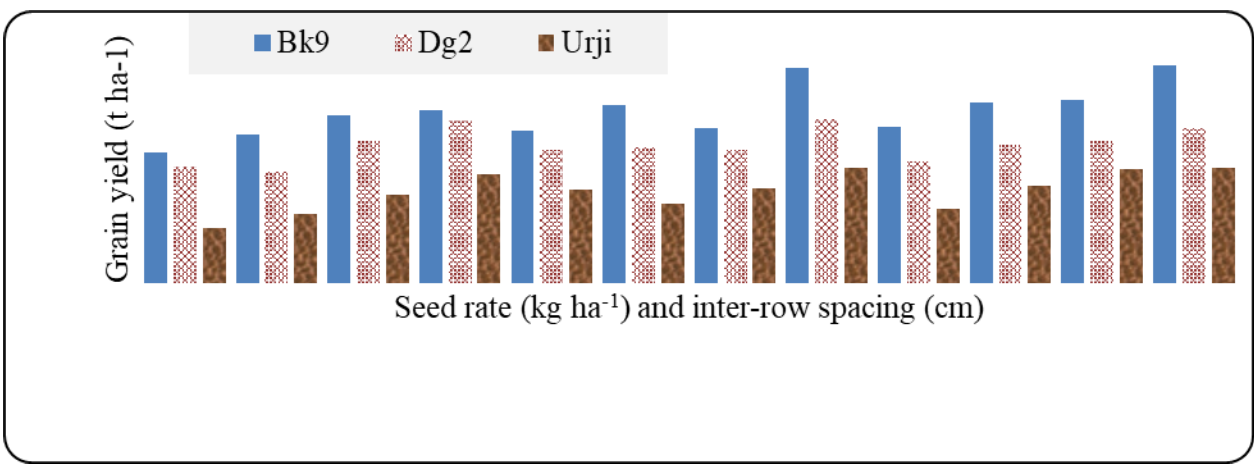


Figure 3: The mean effects of seed rates and inter-row spacing on Grain yield finger millet varieties in 2019 and 2020 season at Bako and Gute, Ethiopia

Varieties of finger millet that have dissimilar growth characteristics. Different scholars reported similar results (Hailu *et at*., 2020; Wedajo *et al*., 2018; Sarawale *et al*., 2016). Getahun *et al*.

(2016) found that 15 kg ha^{-1} seed rate and 40 cm spacing between rows gave the maximum grain yield (1926.8 kg ha^{-1}) of finger millet Tadesse variety at in Asosa zone of Gumuze region. They were also reported that grain yield of finger millet significantly increased from 1499.3 to 1926.8 kg ha^{-1} with the decrease of seed rate from broadcast (25 kg ha^{-1}) to 15 kg ha^{-1}. Another author, Chekol and Birhanu (2018) also indicate that 15 kg ha^{-1} seed rate with 30 cm gave the higher mean grain yield (2214.4 kg ha^{-1}) followed by the combination of 10 kg ha^{-1} seed rate with 50 cm spacing between rows at MerbLekhe district of central Tigray.

While, the higher dry biomass (12.9 t ha^{-1}), ear length (8.8 cm) and number of productive tillers per plant of were attained when 12 kg ha^{-1} seed rate and 50 cm inter-row spacing was practiced for Bako-09 variety (Table 2). Whereas, maximum number of fingers ear^{-1} (7.6) was achieved from the combination of 8 seed rate with 30 cm spacing, and 12 seed rate with 50cm space between rows. The highest harvest index (32.3%) was, however, recorded at seed rate of 12 kg ha^{-1} with 30 cm inter-row spacing. This indicates growth parameters and yield traits of finger millet contributed to grain yield directly or indirectly. Similarly, Getahun *et al*. (2016) reported that ear length, number of finger per plant and plant height contributed to grain yield mainly by enhancing their high and positive direct and indirect effect.

Conversely, the lowest grain yield (2.0 t ha^{-1}) and dry biomass (8.4 t ha^{-1}) were obtained from the lower seeding rate (8 kg ha^{-1}) and narrow spacing (20 cm) between rows compared to the other treatment used form the same variety (Figure 1 and Table 2). On the other hand, the minimum ear length (8.0 cm) was attained from the use of 8/30, 15/40 and 15/50 seed rate (kg ha^{-1})/inter-row spacing (cm). The lowest number of fingers (6.9) ear^{-1} and HI (25.8%) were, however, achieved when 15/30 and 8/50 seeding rate (kg ha^{-1})/spacing (cm) between rows respectively, practiced. Minimum number of productive tillers was obtained from the use of 8/20 and 15/20 seed rate/spacing used. In the same fashion, seed rate and row spacing between rows were significantly affected all measured parameters for Diga-2 finger millet variety (Figure 1 and Table 2). For this variety, the highest grain of 2.6 t ha^{-1} was obtained from the use of 8 and 12 kg seed rate ha^{-1} with 50 cm inter-row spacing followed by yield of 2.6 t ha^{-1} which was obtained when 8 kg ha^{-1} seeding rate and 50 cm spacing practiced (Figure 1). Whereas, maximum dry biomass (14.7 t ha^{-1}), ear length (11.9 cm) and average number of productive tillers (3.4) plant^{-1} were achieved from the combination of 8 kg ha^{-1} seed rate and 50 cm inter-row spacing treatments. Maximum number of finger (7.9) ear^{-1} was, however, observed at 8kg/30cm and 8kg/50cm seed rate and spacing between rows. While, the highest plant height (1.32 m) and HI (20.6%) were recorded when 12 kg ha^{-1} seed rate combined with 40 and 50cm spacing, and 8/20 seed rate/inter-row spacing treatments used, correspondingly. Inversely, minimum grain yield (1.7 t ha^{-1}) and HI (16.4%) for Diga-2 variety were obtained from the use of 8 kg ha^{-1} seed rate and 30 cm inter-row spacing (Figure 1 and Table 2). On the other hand, the lowest dry biomass (10.4 t ha^{-1}) and ear length (11.2 cm) were attained from the lower seed rate and narrow inter-spacing treatments. The minimum number finger (7.2) ear^{-1} and average number of productive tillers (2.9) plant^{-1} were recorded from the use of 12kg/20cm, and 8kg/20cm, 12kg/30cm and 15kg/40cm seed rate/inter-row spacing respectively.

For the Urji variety, the highest grain yield (1.8 t ha^{-1}) was achieved from the seed rate and spacing of 12kg/50cm, 15kg/40cm and 15kg/50cm treatments followed by 8 kg ha^{-1} seed rate and 50 cm inter-row spacing (Figure 2). This indicates the maximum yield obtained from the higher seed rate and wider row spacing between rows. This might be due to the high tillering capacity and number of ears $penicle^{-1}$ of the variety over the rest of the varieties used in the experiments. The more number of tillring per plant can cover the wider space between rows which can utilize the resources like space, sunlight and plant nutrients effectively than the taller and less tillering capacity of varieties. Grain yield per plant had a strong positive association with finger number per ear and tillering capacity of the variety. Chekol and Birhanu (2018), and Getahun *et al*. (2016) reported similar results. On the other hand, the higher dry biomass (9.3 t ha^{-1}), ear length (10.7 cm), number of finger (8.5) ear^{-1}, number of productive tillers (3.5) $plant^{-1}$ and plant height (1.1 m) were observed at seed rate (kg ha^{-1}) and row spacing (cm) of 12/50, 15/40, 12/30, 8/40 and 12/40 respectively (Table 3). While, maximum HI (23.9%) was recorded when 12/30 and 15/30 seed rate (kg ha^{-1})/row spacing (cm) was used. The lowest grain yield (0.9 t ha^{-1}), dry biomass (6.0 t ha^{-1}) and HI (18.9%) were, however, attained from the use of minimum seeding rate and narrow row spacing (Figure 2 and Table 3). Whereas, the lowest ear length (9.3 cm) and number of finger (6.8) $plant^{-1}$, and plant height (0.9 m) were achieved from the combination of 8 kg ha^{-1} seed rate with 30 cm inter-row spacing, and 12 kg ha^{-1} seed rate with 30 cm spacing between rows, respectively. The lower number of productive tillers (2.5) $plant^{-1}$ was observed at seed rate of 12 kg ha^{-1} with inter-row spacing of 50 cm and 15 kg ha^{-1} and 40 cm inter-row spacing treatments. The overall yield means despite of varietal differences indicated that there is an increase in the grain yield of finger millet varieties with increasing the spacing between rows (Figure 3).

Table 2: The mean effects of seeding rates and inter-row spacing on dry biomass, and other yield traits of Bako-09 and Diga-2 finger millet varieties in 2019 and 2020 season at Bako and Gute, Ethiopia.

Bako-09 variety									Diga-2 variety							
Treatments		DB ($t\ ha^{-1}$)	Ear L (cm)	№ of fingers	№ of tillers	PH (m)	HI (%)		Treatments		DB ($t\ ha^{-1}$)	Ear L (cm)	№ of fingers	№ of tillers	PH (cm)	HI (%)
Sd	Sp								Sd	Sp						
8	20	8.4h	8.0cd	7.2cd	2.2fg	1.0abc	28.5cde		8	20	10.4g	11.2d	7.4bcd	2.9de	1.32a	20.6ab
	30	8.9fg	8.1bcd	7.6a	2.4cdef	1.0c	29.4bcde			30	11.8ef	11.4cd	7.9a	3.1bcde	1.28ab	16.4d
	40	9.1f	8.3abc	7.5a	2.4abcd	1.1abc	31.5ab			40	11.9e	11.3cd	7.3cd	3.2abc	1.22b	20.45abc
	50	11.8b	8.5abc	7.5a	2.4cde	1.0bc	25.8f			50	14.7a	11.9a	7.9a	3.4a	1.29ab	19.0bc
12	20	8.6gh	7.5d	7.2bcd	2.2g	1.1abc	30.6abc		12	20	12.3d	11.4cd	7.2d	3.0cde	1.23b	18.6c
	30	10.0e	8.0cd	7.0de	2.3def	1.1ab	32.3a			30	12.4d	11.6abc	7.4bcd	2.9e	1.27ab	18.5c
	40	10.3e	8.7ab	7.4ab	2.5abc	1.1ab	26.2f			40	11.5f	11.5bcd	7.6abc	3.2ab	1.32a	20.3abc
	50	12.9a	8.8a	7.6a	2.6a	1.1ab	27.4ef			50	14.4b	11.5bcd	7.4cd	3.1bcd	1.32a	20.2abc
15	20	10.1e	8.1bcd	7.5a	2.2efg	1.1a	27.7def		15	20	10.0g	11.8ab	7.7ab	3.2abc	1.26ab	21.3a
	30	10.4de	7.7d	6.9e	2.4bcde	1.1a	29.8bcd			30	11.9e	11.6abc	7.4cd	3.2ab	1.28ab	19.2bc
	40	10.7d	8.0cd	7.1d	2.5ab	1.1a	29.2bcde			40	12.1de	11.3cd	7.5bcd	2.9de	1.29ab	19.8abc
	50	11.2c	8.0cd	7.4abc	2.4cdef	1.1ab	32.5a			50	13.1c	11.4cd	7.3d	3.0bcde	1.29ab	19.7abc
LSD (5%)		0.38	0.55	0.24	0.13	0.05	2.0		LSD (5%)		0.33	0.31	0.28	0.22	0.07	1.7
CV (%)		4.6	8.3	4.1	7.0	5.9	8.7		CV (%)		3.3	3.3	4.6	8.8	7.1	10.8

Sd = Seed rate ($kg\ ha^{-1}$), Sp = Inter-row spacing (cm), DB= dry biomass yield ($t\ ha^{-1}$), Ear L = Ear length (cm) № of fingers= Nubmber of finger ear^{-1}, № of tillers = Number of productive tillers $plant^{-1}$, PH = Plant height (m) and HI = harvest Index.

Table 3: The mean effects of seeding rates and inter-row spacing on dry biomass, and other yield traits of Urji finger millet varieties in 2019 and 2020 season at Bako and Gute, Ethiopia.

Treatments		DB	Ear L	№ of	№ of	PH	HI
Sd	Sp	(t ha^{-1})	(cm)	fingers	tillers	(m)	(%)
8	20	6.0i	10.3ab	7.9b	2.7def	1.0abcd	18.9d
	30	6.1i	9.3c	6.8c	2.8cde	1.0bcd	20.7c
	40	7.3g	10.3ab	7.9b	3.5a	1.0cd	21.2c
	50	8.9bc	10.1b	7.9b	3.0bc	1.0bcd	21.4c
12	20	8.3de	10.5ab	8.3ab	2.8cde	1.0abc	20.6c
	30	6.6h	10.8a	8.5a	2.8cdef	0.9d	23.9a
	40	8.0ef	10.1b	8.1ab	2.8cd	1.1a	20.7c
	50	9.3a	10.3ab	8.1ab	2.5ef	1.0abc	23.7a
15	20	6.3hi	10.3ab	7.9b	3.1b	1.0abc	22.0bc
	30	7.6fg	10.5ab	7.8b	2.7def	1.0abc	23.9a
	40	9.2ab	10.7ab	8.3ab	2.5f	1.0ab	23.3ab
	50	8.6cd	9.4c	8.2ab	3.1b	1.0abcd	23.8a
LSD (5%)		0.39	0.55	0.48	0.24	0.06	1.6
CV (%)		6.2	6.7	7.4	10.2	8.0	8.8

Sd = Seed rate (kg ha^{-1}), Sp = Inter-row spacing (cm), DB = Dry biomass (t ha^{-1}), Ear L = ear length (cm), № of fingers = Number of finger $plant^{-1}$, № of tillers = Numbers of productive tillers $plant^{-1}$, PH = plant height (m) and HI = Harvest Index (%).

Varieties used in this experiments, the highest yield were observed from the wider inter-row spacing (50 cm) than the narrow spacing (Figure 1, 2 and 3). The wider spacing between the rows could be covered and utilized with tillering of the varieties. Also, the longest plant height cover wider spacing by their canopy and require wider space to utilize the sunlight for photosynthesis and root growth for absorbing available plant nutrients and moisture. Chekol and Birhanu (2018) stated that the longest plant height was observed from the interaction mean effect of 50 cm spacing and 20 kg ha^{-1} seed rate. The authors also reported that the longest plant height does not directly correlate with biomass yield and grain yield. Getahun *et al*. (2016) reported that 15 kg ha^{-1} seed rate with 50 cm spacing between rows gave the tallest plant height. From this finding, it could conclude that plant growth parameters like plant height, number of fingers ear^{-1} and productive tillers per plant contributed to the final grain yield largely by enhancing their high and positive direct and indirect effect with yield. On the other hand, the lower and higher not increase the grain yield of finger millet. Since, lower seed rate not fully cover the area, it gives the weeds the chance to grow in between the space which create competition with the crops for available nutrients and moisture. On the other, higher seed rates increase number of plant population above the optimum density and also increase the competitions between the plants for the available resources like sunlight, space and nutrient. Maximum yield was observed from the optimum seed rate 12 kg ha^{-1} for the varieties used in the experiments.

Over all, the mean grain yield of the varieties indicated that Bako-09 had the highest grain yield (3.4 t ha^{-1}) followed by 2.6 t ha^{-1} for Diga-2 and 1.8 t ha^{-1} for Urji finger millet varieties (Figure 3). In the contrary, the lower grain yield (2.0 t ha^{-1} for Bako-09, 1.7 t ha^{-1} for Diga-2 and 0.9 t ha^{-1} for Urji variety) was attained from the use of 8 kg ha^{-1} seed rate combined with 20 cm inter-row spacing for all varieties used as a test crop in the study. Urji variety gave the minimum grain yield (0.9 t ha^{-1}) and dry biomass (6.0 t ha^{-1}) compared to the other varieties used. This differences in yield among varieties might be due to the genetic makeup of the varieties/genotypes and the contribution of the environment to the observed variation in yield (Hailegebrial *et al*., 2017; Hailu *et al*., 2020; Wedajo *et al*., 2018). Also the growth characteristics' of the varieties were different. For instance, Bako-09 finger millet is the variety known by having a brown seed color and characterized by erect growth habit with medium in plant height (about 1.1 m) and majority of its tillers rise from the main stem below the soil with the average mean number of productive tillers was (2.4) $plant^{-1}$. On the other hand, the finger millet variety, Diga-2, is a black seed color that is characterized by taller in plant height ((1.36m) than the others, and majority of its tillers rise from the main stem above the soil. Also, its mean ear length (11.4 cm) and number of productive tillers greater than Bako-09 and Urji varieties (Table 3). Urji variety, however, has a white seeded color and a shorter variety (1.0 m) than Bako-09 and Diga-2 varieties. This shows appropriate spacing and plant population $area^{-1}$ could be considered varietal differences in terms of tillering capacity, ear/finger length of finger millet, number of fingers and plant morphology in the case of row planting of finger millet production. Sarawale *et al*. (2016) indicated that the yield difference in finger millet varieties is might be due to the better performance of the varieties in terms of yield attributing characters.

Economic feasibility of seed rate and inter-row spacing on finger millet production at Western Oromia, Ethiopia

The economic feasibility for means of treatment combinations was also assessed. As indicated in table 4, the partial budget analysis due to seed rate and inter-row spacing on finger millet production was varied. The highest net benefit ETB 26221.3, 19814.52, and 13390.70 ha^{-1} with marginal rate of return of 4643.5, 584.4 and 363% was obtained when 12 kg/50cm, 8 kg/50 cm and 15 kg/40 cm was used for Bako-09, Diga-2 and Urji variety of finger millet production, respectively. Hence, it is economically profitable for finger millet production in the study.

Conclusions and Recommendations

Finger millet production by using optimum seeding rate and spacing between rows could improving growth, yield and yield components and make an important contribution in increasing production and productivity of finger millet at house hold level. From the study it was observed that agronomic practices could be one of the important practices to improve productivity of finger millet by using optimum seed rate and inter-row spacing by considering the varietal differences in finger millet in terms of seed color and growth characteristics. It was also observed, the varieties used in the study were varying in their plant height, tillering capacity, number of finger $plant^{-1}$ ear length and dry biomass.

Table 4: The effects of seed rate and inter row spacing on economic profitability for Bako-09, Diga-2 and Urji finger millet varieties production in Bako and Gute during 2019 and 2020 rainy season.

Bako-09 variety						
Trt SD/SP	Gy	Ayd	TC	GB	NB	MRR
12/20	2.4	2.16	701	19440	18739	
8/30	2.3	2.07	703.94	18630	17926.1	D
15/20	2.4	2.16	731.9	19440	18708.1	D
12/30	2.8	2.52	765.14	22680	21914.9	4951.4
15/30	2.8	2.52	796.04	22680	21884.0	D
8/20	2.0	1.8	823.8	16200	15376.2	D
8/40	2.6	2.34	1149.2	21060	19910.8	D
12/40	2.4	2.16	1182.4	19440	18257.6	D
15/40	2.9	2.61	1233.3	23490	22256.7	75
8/50	2.7	2.43	1249.5	21870	20620.5	D
12/50	3.4	3.06	1318.7	27540	26221.3	4643.5
15/50	3.4	3.06	1349.6	27540	26190.4	D

Diga-2 variety						
Trt SD/SP	Gy	Ayd	TC	GB	NB	MRR
8/20	1.4	1.3	635.80	11340.0	10704.20	
8/30	1.7	1.5	679.94	13770.00	13090.06	5405.2
12/20	2.1	1.9	689.00	17010.00	16321.00	35661.6
15/20	1.9	1.7	711.90	15390.00	14678.10	D
12/30	2.1	1.9	737.14	17010.00	16272.86	D
15/30	2.2	2.0	772.04	17820.00	17047.96	875.4
8/40	2.2	2.0	1133.20	17820.00	16686.80	D
12/40	2.1	1.9	1170.40	17010.00	15839.60	D
15/40	2.2	2.0	1205.30	17820.00	16614.70	D
8/50	2.6	2.3	1245.48	21060.00	19814.52	584.4
12/50	2.6	2.3	1286.68	21060.00	19773.32	D
15/50	2.4	2.2	1309.58	19440.00	18130.42	D

Urji finger millet variety						
Treatments SD/SP	Gy	Ayd	TC	GB	NB	MRR
8/20	0.9	0.8	599.80	7290.00	6690.20	
8/30	1.1	1.0	655.94	8910.00	8254.06	2785.6
12/20	1.5	1.4	665.00	12150.00	11485.00	35661.6
15/20	1.2	1.1	683.90	9720.00	9036.10	D
12/30	1.3	1.2	705.14	10530.00	9824.86	D
15/30	1.5	1.4	744.04	12150.00	11405.96	D
8/40	1.4	1.3	1101.20	11340.00	10238.80	D
12/40	1.5	1.4	1146.40	12150.00	11003.60	D
15/40	1.8	1.6	1189.30	14580.00	13390.70	363.5
8/50	1.7	1.5	1209.48	13770.00	12560.52	D
12/50	1.8	1.6	1254.68	14580.00	13325.32	D
15/50	1.8	1.6	1285.58	14580.00	13294.42	D

The result also showed that significantly higher mean grain yield (3.4, 2.6, and 1.8 t^{-1}) was obtained from the use of 12 kg 50 cm and 15kg/50cm, 8kg/50cm and 12kg/50cm, and 15kg/40cm and 15kg/50cm for Bako-09, Diga-2 and Urji variety of finger millet, respectively. However, in the study the highest net benefit ETB 26221.3, 19814.52, and 13390.70 ha^{-1} with acceptable marginal rate of return (4643.5, 584.4 and 363%) was obtained when 12 kg/50cm, 8 kg/50 cm and 15 kg/40 cm was used for Bako-09, Diga-2 and Urji variety, correspondingly. Therefore, seeding rate of 12 kg ha^{-1} with 50 cm inter-row spacing for Bako-09 variety, 8 kg ha^{-1} with 50 cm row spacing for Diga-2 variety, and seed rate of 15 kg ha^{-1} with 40 cm for Urji variety was produced better grain yield and economically feasible and recommended for improved finger millet production in the areas of Bako and Gute, and similar agro-ecologies in the country.

Acknowledgements

First, I would like to thank the almighty God who lives us and lead us to see seed of our work. The authors also thank Oromia Agricultural Research Institute for funding the experiment. I am very grateful to Bako Agricultural Research center for providing all necessary equipment's and logistics during the research work. All the technical and field assistants of Cereal crops technology generation research team are also acknowledged for unreserved effort during executing the experiment.

References

Ali E. A. (2010). Grain yield and Nitrogen use efficiency of pearl millet as affected by plant density, nitrogen rate and splitting in sandy soil. In American-Eurasian J. Agric. and environ. Sci., 7 (3): 327. ISSN 1818-6769. IDOSI publication.

Asfaw Zewdu, Fekede Gemechu and Mideksa Babu (2018). Pre-scaling up of improved finger millet technologies: The case of Daro Lebu and Habro districts of West Hararghe, Oromia, Ethiopia. International Journal of Agricultural Education and Extension, 4(2): 131-139.

Babu B., Senthil, N., Gomez, S., Biji, K.. Rajendraprasad, N., Kumar, S. and Babu, R. (2007). Assessment of genetic diversity among finger millet accessions using molecular markers. *Genetic Resource and Crop Evolution* 54: 399-404.

Barbeau, W.E. and Hilu, K. (1993). Protein, calcium, iron and amino acid content o f selected wild and domesticated cultivars o f Finger millet. Plant Foods & Human Nutrition43:97-104.

Bezaweletaw K.. Sripichit, P., Wongyai, W., Hongtrakul, V. (2006) Genetic variation, heritabi1ity and path-analysis in Ethiopian finger millet (*Eleusine coracana* (L.)Gaertn) landraces. Kasetsart Journal o f Natural Science 40: 322-334.

Bora P. (2013). Nutritional properties of different millet types and their selected products. A thesis presented to the University of Guelph in partial fulfillment of requirements for a master degree in food science. International Journal of Agricultural Education and Extension, 4(2): 131-139.

Central Statistical Agency (CSA)., 2019/20. Area and production of major crops. Agricultural Sample survey 2019/2020 (2012 E.C). V1. Statistical Bulletin 587, Addis Ababa, Ethiopia.

Chekol Niguse and Birhanu Melese (2018). Effect of inter-row spacing and seed rate on finger millet (Eleusine Coracana L.) production in MerbLekhe district-Ethiopia. American Journal of Research Communication, 6(8): 1-10.

CIMMYT (1988). From Agronomic data to farmers recommendations: economics training manual.

Dagnachew Lule, Kebede Dessalegn, Chemeda Birhanu, Girma Mengistu, Gudeta Bededa, Megersa Debela, Girma Chemeda, Geleta Gerema[1], Hailu Feyisa, Megersa Kebede, and Fufa Anbessa (2020). Registration of “Diga-2” finger millet (Eleusine coracana sub. Spp. Coracana) variety. East African Journal of Science, 14(2): 175-180.

Duncan DB (2004). Multiple Range and Multiple F-Test," *Biometrics*, 11: 1-42.

Ekwamu. A. (1991). Influence of head blast infection on seed germination and yield components of finger millet (*Eleusine coracana* L. Gaertn). *Tropical Pest Management* 37: 122-123.

Getahun Dereje, Tigist Adisu and Bekele Anbessa (2016). Influence of Row Spacing and Seed Rate on Yield and Yield Components of Finger Millet at Assosa Zone in Benshagul Gumuze Region of Ethiopia. Journal of Biology, Agriculture and Healthcare 6(5):42-45.

Hailegebriel Kinfe, Yiergalem T, Alem Redda, Redae Weldegebriel, Desalegn Y and Welegerima Gebrelibanos (2017). Yield performance and adaptability of finger millet landrace in North western Tigray, Ethiopia. World News of Natural Science, 15(2017): 98-111.

Hailu Feyis, Chemada Brihanu, Dagnachew Lule and Kebede Dessalegn (2021). On-farm evaluation and pre-scaling up of improved finger millet technologies under rainfed condition in Western Oromia, Ethiopia: A case of East Wollega Zone, Ethiopia. Journal of agricultural extension and rural development 13(3), pp. 165-172.

Hay R. K. M. and Wolker. A. J. (1989). An introduction to the physiology of crop yield, pp. 163-187. Longman scientific and technical group. Harlow, UK.

Kassahun Tesfaye and Solomon Mengistu (2017). Phenotypic characterization of Ethiopian finger millet accessions for their agronomically important traits. ACTA Universitatis Saplentiae, Journal of Agriculture and Enviromental Science, 9(1):107-118.

Kebede Dessalegn, Dagnachew Lule, Girma Chemeda, Girma Mengistu, Kassa Mamo, Megersa Debela and Chemeda Birhanu (2017). Grain Yield Stability and GxE Interaction Study in Black Seeded Finger Millet (Eleusine Coracana Sub Spp. Coracana) Genotypes. Oromia Agricultural Research Institute (IQQO), Crop research Proceeding 2017.

Kebede Dessalegn, Dagnachew Lule, Kassa Mamo, Girma Mengistu, Girma Chemeda, Megersa Debela, Megersa Kebede, Chemeda Birhanu, Hailu Feyisa, Geleta Gerema, Fufa Anbesa and Gudeta Bededa (2020). The release and registration of Bako-09 finger millet variety. Ethiopian Journal of Crop Science 8(2): 101-105.

Kebede Dessalegn, Dagnachew Lule, Megersa Debela, Chemada Birhanu, Girma Mengistu, Geleta Gerema, Gudeta Bededa (2019). Genotype by enviroment interaction and grain yield stability of Ethiopian black seeded finger millt genotypes. Journal of African Crop Science, 27 (2), pp 281-294.

Kebere Bezaweletaw, Prapa Sripichitt, Wasana Wongyai and Vipa Hongtrakul (2006). Genetic Variation, Heritability and Path-Analysis in Ethiopian Finger Millet [Eleusine coracana (L.) Gaertn] Landraces. Kasetsart Journal (Nat. Sci.) 40:322-334.

Kumar A., Metwal M., Kaur S., Gupta A.K., Puranik S., Singh S., Gupta S., Babu B.K., Sood S., Yadav R. (2016). Nutraceutical value of finger millet and their improvement using Omics approaches. Journal of Frontiers in Plant Science, 7:934.

Marshall G. C. and H. W. Ohm. (1987). Yield response s of 16 winter wheat cultivars to row spacing and seeded rate. Agron. J.79: 1027-1030.

Mulatu T., Debclo. A., Gutema, Z. and Degu, E., 1995. Finger millet: A potential crop in Ethiopia. *In*: proceedings of work shop organized to re-establish sorghum and millet in Eastern & Central Africa. Kampala, Uganda 6-9 Nov. 1995.

Sarawale P.P., Rajemahadik V.A., Shendage G.B. and Mane S.V. (2016). Effect of different varieties and establishment methods on growth and yield of finger millet (Eleusine Coracana (L.) Gaertn) under *Konkan* condition. Journal of Indian Society of Costal Agricultural Research, 34(2): 22-26.

Soumya R., Karunkar S., Vivek K. (2016). Millet grain processing, utilization and its role in health promotion: A review. International Journal of Nutrition and Food Science, 5(5): 318-329.

Tekale Yoseph (2014). Determination of Inter Row Spacing and Seed Rate on Productivity of Finger Millet (Eleusine Coracana (L.) Gaertn.), At Jinka, Southern Ethiopia International Journal of Research in Agricultural Sciences 1 (3): 2348–3997.

Upadhyaya H.D., Gowda, C.L. and Gopal Reddy, 2007. Morphological diversity in finger millet germplasm introduced from Southern and Eastern Africa. SAT Journal 3(1).

Variety Registration (2018). Crop variety registers for plant variety release. Protection and Quality control Directorate of Ethiopia, № 21, Addis Ababa.

Wedajo Gebre, Tekle Yoseph, Getachew Gashaw, Mehari G/Mechical, Kebre Bezawuletaw, Zemach Sorsa, Wondewosen Shiferaw and Tibebu Simon (2018). Grain yield stability and adaptability of finger millet genotypes in Southern Ethiopia. International Journal of Research Studies in Science, Engineering and Technology, 5(3): 11-15.

Yilma Kebede and Abebe Menkir (1986). Improvement of finger millet in Ethiopia, pp. 173-176. In: Seetheram, A.. Rilley. K.W. and Upadhyaya, G. (eds.). Small Millet in Global Agriculture: Proceeding of the First International Small Millet Workshop. October 29-November 2. 1986. Bangalore, India.

Determination of Seed and Nitrogen fertilizer rate on yield and yield components of upland Rice (Oryza Sativa L.) in western Oromia, Ethiopia.

Bodena Guddisa *, Hailu Feyisa, Geleta Gerema, Girma Chemeda, Meseret Tola, Fufa Anbessa and Gudeta Bedada.

Bako Agricultural Research Center, Oromia Agricultural Research Institute, P.O.Box: 81265, Addis Ababa, Ethiopia

Abstract

Biotic and abiotic stresses are among the influencing factors that harnessing rice productivity from which inappropriate crop management practices played a greatest role. However, application of optimum Nitrogen fertilizers along with Phosphorus and proper seed rates is the basis to produce more crop yield from the land under cultivation. Thus, a field experiment was conducted in 2019-2020 main cropping season from the end of May to end November at western Oromiya on Bako and Chewaka locations to determine optimum seed and nitrogen rate that maximizes the yield and yield components and to evaluate the economic profitability of seed and N fertilizers rate for rice production. The treatments were factorial combination of five Nitrogen fertilizer rates (35, 46, 58, 69, 81 kg/ha N) and four Seed rates (60, 80, 100, 120 kg/ha) tested on Rice variety (Chewaka) and with uniform application of 125 kg/ha NPS in randomized complete block design replicated three times. The pre soil analysis indicates that the soil of experimental area was acidic (pH = 5.04 at bako and 5.02 at chewaka) and medium (11 mg/kg) in available Phosphorus at Bako and low (5.91 mg/kg) at chewaka. The post soil analysis depicted lower percent increment in total nitrogen and organic matter while decrement in phosphorus. The main and interaction effect of Days to heading, Panicle length, number of effective tiller and Thousand seed weight were not significantly influenced (P>0.05) by Nitrogen (N) and Seed rates but Plant height significantly (P<0.01) different due to the main effect of N both at Bako and Chewaka locations. However, the number of Filled grain, number of unfilled grain, Aboveground biomass, Grain yield and Harvest index were significantly (P<0.01) influenced due to the main and interaction effect of Nitrogen (N) and Seed rates at both tested sites. Thus, economic analysis showed that 58 kg/ha N and 80 kg/ha seed rates on chewaka variety gave better grain yield (4318.2 kg/ha) and net benefit (65684.9 birr/ha) and the highest Marginal Rate of Return (MRR) (3605.6%) were economically feasible alternative to the other treatments. Therefore it is recommended to use 58 kg/ha N and 80 kg/ha seed rates on Chewaka variety since it is economically feasible to the farmers.

Keywords: Economic analysis, Nitrogen rates, seed rates, yield and yield components

Introduction

Rice (*Oryza sativa* L.*)* belongs to the grass family. It is a vital food crop because half the world's population feeds rice as a main part of their diets. It provides more calories per hectare than any other cereal grain. In Ethiopia, rice is a highly valued crop and is primarily grown for its grains. Rice is 2nd in area basis and total production in the world after wheat (FAOSTAT, 2012). In Ethiopia, rice is cultivated on an area of about 85,288.87 hectares (CSA, 2021). In Ethiopia, low soil fertility arose from continuous cropping, overgrazing, high soil erosion and removal of field crops' residues are among the major constraints affecting rice productivity (Kebebew *et al*., 2002). Rice is the high yielding crop in the cultivating countries of the world and stable food in some countries (Mann *et al.,* 2007). Although, low yields of these crops were attributes of several biotic and abiotic factors, inappropriate crop management practices that mainly include; sowing periods, seeding methods, weeding practice, and lack of farmers awareness on uses of cropping systems and different soil fertilization methods are found the key elements that contributed to low crop productivity in the country.

In Ethiopia the productivity is very low than the attainable yield and not exceed 3.5 t/ha due to the challenges of biotic and abiotic factors (Heluf Gebrekidan and Mulugeta Seyoum, 2006). The average national yield of rice is less than 3.15 t/ha (CSA, 2021). The productivity of these crops were by far lower than the potential yields obtained on research stations and on farm verification trials that was 6-8 t/ha for maize, 4-6 t/ha for sorghum and 5-7 t/ha for wheat (Hailu *et al,*. 2002, Mosisa *et al.*, 2004, Desalegn *et al.*, 2006). Even though it was cultivated in all regions of the country, it is cultivated in a few locations of the regions. In the other hand, the growth and yield of rice is influenced by different nutrients management and other factors during their production in a field (Mann *et al.,* 2007). In many crop producing areas lack of available nutrients is frequently the limiting factor next to the soil water as their uptake and liberation of N, P and S from soil organic matter depends upon availability of water (FAO, 2003). Application of balanced fertilizers is the basis to produce more crop output from existing land under cultivation and nutrient needs of crops is according to their physiological requirements and expected yields (Ryan, 2008). Excessive application of fertilizers or manure can contribute to pollution of streams, ground water resources and generally reduce profitability (Mulugeta *etal*., 2011). When commercial fertilizers are applied at rates that exceed the plants' ability to remove the nutrients at a given growth stage, fertilizer run-off can occur. When N is supplied from a fertilizer or other sources (manure, sewage sludge, etc), it should be applied at a rate that does not greatly exceed the expected crop N requirement. It should be applied as near as possible by the time when the plant need to reduce the chance for potential losses and to prevent undue nutrient enrichment of the environment (Taddesse, 2008). However the farmers around the rice growing area apply more Nitrogen rate even more than the rate recommended by research centers for the assumption of increasing yield. Besides different seed rate is utilized across national, regional and individual farmers of rice growing in the vicinity area, resulting sparse population in some places and more dense in the other areas. In other cases, producers suggested when there is sparse population per hectare there is the appearance of termite infestation and normal plant physical structure in relatively densely plant populated areas. Thus the research aimed to investigate different seed and Nitrogen rate fertilizers to the rice crop for determining optimum seed and nitrogen rate that maximizes the yield and yield components and to evaluate the economic profitability of seed and N fertilizers rate for rice production.

Materials and Methods

The trial was conducted at Bako Agricultural research center at Bako on station and sub- station of chewaka site during 2019-2020 main cropping seasons. The treatments were consisted of different seed and Nitrogen fertilizer rate. Four seed rates (60, 80, 100 and 120 Kg/ha) and five rates of Nitrogen (35, 46, 58, 69 and 81 Kg N/ha) were combined factorially, with two time of Nitrogen application 1/2 at plating and the remaining half at tillering was done. One hundred twenty five (125kg/ha) NPS was used uniformly on the experimental plot. Three replications under completely randomized block design was used in the field trial. The land preparation was started at the beginning of the rainy season and soil made loosen before planting. Seed of Rice (Chewaka) variety was sown in six rows with 20cm between rows. The experimental area consisted twenty (20) treatments with the spacing between block and plots 1.5 and 1m, respectively. Gross area ($6m^2$) of the plots with 1.2m width and 5m length was accommodated. A composite soil sample was taken before onset of rainfall from the selected area of the intended site and analyzed for Physico-Chemical property of the soil and available nutrients. After the harvest of the crop, twenty composite samples per treatment bases were collected for nutrient analysis such as phosphorus, Total nitrogen, organic matter, sulfur and exchangeable cations of the soil.

Data Collection and Measurements

Growth, Yield and Yield Component

Plant height was measured at physiological maturity from the ground level to the tip of panicle from five randomly selected plants in each plot and the average was taken. Panicle length was measured from the node where the first panicle branches emerged to the tip of the panicle from five selected plants per plot and the average was calculated. Number of effective tillers per plant was determined by counting the number of tillers from five plants of harvestable rows at maturity and the average was considered. Biomass yield was harvested at maturity at ground level from the whole plant parts, including leaves, stems and seed from the net plot area and the weight of biomass was taken after sun drying for a week when the weight got constant. Finally the total Grain yield was measured by harvesting the crop from the net middle plot area of 5m x 0.8 m (4 m^2).

Results and Discussions

Soil Physico-Chemical Properties of Experimental Site

The soil textural classes consisted the proportion of 38% sand, 54% clay and 8% silt indicating clay at Bako and Clay loam (48% sand, 20% silt and 32% clay) at Chewaka which is ideal for rice production. pH of the soil was 5.04 and 5.02 at Bako and Chewaka respectively, categorized as acidic which is in line with the rating of landon (1991), soils with pH of 5.1-5.5 is acidic. The organic matter of the soil showed medium (3.43 and 4.97%) at chewaka and Bako, respectively which agreed with Berhanu (1980) rating, soil organic matter in the range of 2.6-5.2 categorized as medium. Total N of the soil was medium (0.17 and 0.21%) at chewaka and Bako which coincided with rating of (Ethiosis, 2014). Available phosphorus indicated there was medium (11 mg/kg) phosphorus content of the soil at bako and low (5.91 mg/kg) at Chewaka which was in line with landon (1991) rated as soil phosphorus content below 10 mg/kg is low, 11-20 mg/kg moderate and > 20 mg/kg as high (Table 1). After crop harvest even though some soil nutrients like organic matter, total nitrogen showed small increment trends at both locations of Bako and

Chewaka, available phosphorus indicated decreasing at both locations which might be associated with high nutrient consumption of the rice crops. Similarly, the lower increment of organic matter probably had direct implication with the removal of crop residues (biomass) during

Table 1. Percent change of soil pH, Organic matter content (%), Total nitrogen (%) and available phosphorus (P) after harvest of the crop in response to Nitrogen and seed rate application.

Location	Bako			Chewaka		
Soil chemical analysis	Before planting	After harvest	% change	Before planting	After harvest	% change
pH	5.04	5.4	7.14	5.02	5.3	5.58
Organic matter (%)	4.97	5.04	0.25	3.43	4.24	0.81
Total Nitrogen (%)	0.21	0.25	0.04	0.17	0.21	0.04
Avail. P (mg kg^{-1})	11	7.22	-34.36	5.91	5.39	-8.80

When 58 kg Nitrogen and 81 kg seed rate ha^{-1} applied harvesting of the crop. The result agreed with Mekonnen (2015) and Melese *et al.* (2015) who reported that available soil phosphorus (P) was found to be deficient in most soils of cultivated lands.

Growth, Yield and Yield Components

From the analysis of variance Days to maturity, Panicle length, Number of effective tiller, Thousand seed Weight were not influenced due to the main and interaction effect of Nitrogen and Seed rate ($p>0.05$) at Bako and Chewaka locations. However, Plant height had significant difference due to the main effect of nitrogen only when Days to heading responded positively for both main effect of Nitrogen and Seed rates ($p<0.05$) but non- significantly influenced due their interaction effects ($p>0.05$) (Table 2). Increasing Nitrogen rates from the lowest to the highest rates increased plant height which might be connected with optimum nitrogen demand is met for their growth. On the other hand, Grain yield and Above ground biomass were highly significantly different due to both main and interaction effects of Nitrogen and seed rates($p<0.01$) and the interaction effects of Number of filled and unfilled grain as well as Harvest index of rice (Chewaka) variety at both locations(Appendix Table 2). Number of filled grain showed significant difference due to the main ($p<0.05$) and the interaction ($p<0.01$) effects of Nitrogen and seed rates at both Bako and Chewaka locations. The highest Number of filled grain (104.97) was observed at the combination of 58 kg/ha N and 100 kg/ha seed rates even if statistically par with 58 kg/ha N and 60kg/ha seed rates and 69 kg/ha N and 80 kg/ha seed rates (Table 3). Conversely, the lowest number of filled grain was obtained from the combination of 46 kg/ha N and 100 kg/ha seed rates though similar with 69 kg/ha N and 120 kg/ha seed rates.

Table 2. The main effect of Nitrogen and seed rates on Plant height, Panicle length, Number effective tiller, Days to maturity, Days to heading and thousand seed weight at Bako and Chewaka locations

N rates (kg/ha)	DH	DM	PH	PL	NET	TSW
35	86.54 a	122.15	106.3 c	20.36	5.34	27.09
46	85.98 a	121.72	106.6 c	20.64	5.32	27.38
58	85.85 ab	121.81	108.7 bc	20.46	5.61	27.49
69	85.83 ab	122.14	110.9 ab	20.77	5.38	27.40
81	85.17 b	122.10	112.5 a	20.71	5.37	27.15
LSD (0.05)	0.76	ns	3.250	ns	ns	ns
Seed rates						
60	86.62 a	122.30	107.93	20.71	5.517	27.28
80	85.75 b	121.82	109.23	20.66	5.380	27.54
100	85.60 b	122.03	110.64	20.49	5.330	27.14
120	85.53 b	121.80	108.24	20.48	5.387	27.25
LSD (0.05)	0.69	ns	ns	ns	ns	ns
Cv	2.2	1.2	7.4	5.6	21.7	7.2

LSD (0.05) = Least significance difference at 5% probably level, CV = Coefficient of variation, NS = non-significant at 5% probability level. DM= days to maturity, DH= Heading, PH=Plant height, PL=Panicle length, NEF= number of effective tiller and TSW=thousand seed weight.

The highest Number of filled grain at the combination of 58 kg/ha N and 100 kg/ha seed rates was probably due to adequate supply of nitrogen for sufficient spikelet growth and thereby contributing optimum grain filling of the variety (Chewaka). This result agreed with Noor (2017) who reported source maximum proportion of N source is used to produce maximum spikelets per panicle and grain filling and when more the number of spikeletes produced, less number of filled grains occurred at any rate of nitrogen application.

Number of unfilled grain showed significant difference due to the main effect of nitrogen ($p<0.01$) and their interaction ($p<0.05$) effects of Nitrogen and seed rates at both tested sites. The highest Number of unfilled grain (17.23) was resulted from the combination of 81 kg/ha N and 80 kg/ha seed rates even if statistically similar with 81 kg/ha N and 60kg/ha seed rates and 69 kg/ha N and 100 kg/ha seed rates (Table 4). Unlikely the lowest number of unfilled grain was observed at the lower Nitrogen and seed rates. This might be connected with when increasing seed and nitrogen rates, more number of unfilled grain resulted at the highest rate because of

Table 3. The interaction effect of Nitrogen and seed rates on number of filled grain of rice (Chewaka variety) at Bako and Chewaka locations

Seed rates (kg/ha)	Nitrogen rates (kg/ha)				
	35	46	58	69	81
60	97.03 b-e	97.22 b-e	100.18 ab	96.88 b-e	98.85 bc
80	98.67 b-d	97.63 b-e	98.52 b-d	100.12 ab	93.25 d-f
100	92.38 ef	90.28 f	104.97 a	92.73 ef	93.87 c-f
120	98.28 b-d	94.80 b-f	94.40 c-f	91.82 f	99.83 ab
LSD (0.05)	5.42				
CV	7.0				

LSD (0.05) = Least significance difference at 5% probably level, CV = Coefficient of variation, NS = non-significant at 5% probability level.

Table 4. The interaction effect of rates of Nitrogen and seed on number of unfilled grain of rice (Chewaka variety)at Bako and Chewaka locations

Seed rates (kg/ha)	Nitrogen rates (kg/ha)				
	35	46	58	69	81
60	13.25 c-f	13.10d-f	12.97d-f	14.00 b-f	16.07ab
80	12.20 f	14.65 b-e	13.58 c-f	12.70 ef	17.23 a
100	13.15 d-f	14.43 b-f	14.92 b-e	15.48 a-c	14.47 b-e
120	13.50 c-f	14.87 b-e	12.80 ef	15.18 a-d	14.15 b-f
LSD (0.05)	0.80				
CV	19.6				

LSD (0.05) = Least significance difference at 5% probably level, CV = Coefficient of variation, NS = non-significant at 5% probability level

more number of tillers flushed and probably compete for growth resources. The result agreed with Gewaily *et al.* (2018) who depicted with increased rate of nitrogen application, a significant increase in number of unfilled grains per panicle for all rice genotypes was observed. Similarly, Noor (2017) indicated that the more the number of spikeletes produced, the less will be the number of filled grains at any rate of nitrogen application.

Above ground biomass was significantly responded for Nitrogen and seed rates due to the main and their interaction effects of rice (Chewaka) variety at both test sites. The highest Above ground biomass yield (14350 kg/ha) was recorded from the combination of 81 kg/ha N and 80 kg/ha seed rates on rice variety (Chewaka) even if statistically similar with 69 kg/ha N and 120 kg/ha seed rates as well as when interacting 81 kg/ha N and with all seed rates (Table 5). On the other hand, the lowest (9371 kg/ha) Above ground biomass was obtained from the combination of 46 kg/ha N and 60 kg/ha seed rates. The highest above ground biomass from the highest Nitrogen and seed rates might be because of optimum supply of nutrients for growth led to the flush of more tiller growth. On the other side, lowering both nitrogen and seed rates reduce tiller emergency from individual plants there by decreasing above ground biomass. The result is in line with Javaid *et al.* (2012) who reported increased in biomass production might be attributed to the increased plant population due to higher seeding rate with better nitrogen application. In similar ways, Otteson *et al.* (2007) found that biological yield was increased by increasing nitrogen up to optimum levels.

From analysis of variance in spite of some traits showed non-significant difference, Grain yield was highly significantly affected due the main and interaction($p<0.01$) effects of Nitrogen and seed rates of rice at the test site of bako and chewaka locations (Appendix Table 2). The highest grain yield (4880 kg/ha) was recorded from the combination of 69 kg/ha N and 120 kg/ha seed rates on rice variety (Chewaka) even if statistically par with 69 kg/ha N and 100kg/ha seed rates, 81 kg/ha N and 120 kg/ha seed rates and 58 kg/ha N and 81 kg/ha seed rates (Table 6). However,

Table 5. The interaction effect of Nitrogen and seed rates on Above ground Biomass of rice (Chewaka variety)at Bako and Chewaka locations

Seed rates (kg/ha)	Nitrogen rates (kg/ha)				
	35	46	58	69	81
60	10195 hi	9371 i	11467 f-h	13365 a-d	13644 ab
80	11450 f-h	11478 f-h	13325 a-d	12327 c-f	14350 a
100	10747 gh	12763 b-e	12157 d-f	12221 d-f	13796 ab
120	11056 f-h	12177 d-f	11495e-g	13546a-c	13069a-d
LSD (0.05)	1284.22				
CV	13.1				

LSD (0.05) = Least significance difference at 5% probably level, CV = Coefficient of variation, NS = non-significant at 5% probability level.

the lowest grain yield was observed when the lowest Nitrogen (35 kg/ha N) rate combined with the highest seed (120 kg/ha and 100 kg/ha) rates. The highest grain yield from the highest Nitrogen and seed rates is probably due to application of sufficient nutrient met the plant demand and increasing population of rice may led to the provision of highest yield of rice. In contrary to this, application of less nitrogen with the highest seed rates might increase competition among the rice population and resulted low grain yield. Hameed et al. (2003) and Ijaz et al. (2003) reported that grain yield increased as seed rate increased and the highest grain yield was noted in plots seeded at the rate of 120 kg ha^{-1} on wheat. Similar results were obtained by Pandy *et al.* (2001) and Singh*et al.* (2002) who reported that increasing nitrogen rates increased grain yield.

Harvest Index was significantly influenced due to the main ($P<0.05$) effect of Seed rates and the interaction ($P<0.01$) effects of Nitrogen and seed rates (Appendix Table 2). The highest harvest index (41.13 %) was obtained when 46 kg/ha N and 60 kg/ha seed rates even though statistically par with when of 58 kg/ha N combined with 60 and 100 kg/ha seed rates. On the other hand, the

Table 6. The interaction effect of Nitrogen and seed rates on Grain yield of rice (Chewaka variety) at Bako and Chewaka locations

Seed rates (kg/ha)	Nitrogen rates (kg/ha)				
	35	46	58	69	81
60	3937 g	3851g	4279 d-f	4647a-d	4517 b-d
80	4034 fg	4179 e-g	4798 a-c	4556 b-e	4663 a-c
100	3872g	4432 c-e	4699 a-c	4671 ab	4626 a-c
120	3872 g	4004 fg	3974 fg	4880 a	4840 ab
LSD (0.05)	289.46				
CV	8.2				

LSD (0.05) = Least significance difference at 5% probably level, CV = Coefficient of variation, NS = non-significant at 5% probability level.

Table 7. The interaction effect of rates of Nitrogen and seed on Harvest index of rice (Chewaka variety) at Bako and Chewaka locations

Seed rates (kg/ha)	Nitrogen rates (kg/ha)				
	35	46	58	69	81
60	38.87 a-c	41.13 a	38.14 a-d	35.54 c-f	34.08 f
80	34.42 ef	37.64 b-e	35.85 b-f	37.61 b-e	33.69 f
100	35.96 b-f	34.45ef	39.09 ab	38.10 a-d	34.41 ef
120	34.80 d-f	33.49 f	34.91 d-f	35.84 b-f	36.75b-f
LSD (0.05)	3.36				
CV	11.5				

LSD (0.05) = Least significance difference at 5% probably level, CV = Coefficient of variation, NS = non-significant at 5% probability level.

lowest Harvest index resulted from the highest (81 kg/ha N) Nitrogen and 80 kg/ha seed rates even if statistically similar with when combined with the highest (120 kg/ha seed rates (Table 7). The lowest harvest index at the highest Nitrogen and seed rates probably because of more growth of tillers at the highest nitrogen rates and the expected population competition at the highest seed rates resulted in low economic yield. The result is agreed with Afsana *et al.* (2020) who reported Nitrogen fertilization improved rice vegetative growth in terms of plant height and tiller number leading to increased straw yield of BRRI dhan 58 variety of rice in Boro season.

Economic Analysis

The experiment was conducted with two factor experiment including different Nitrogen (N) level and seed rates combined factorally by keeping uniform application of 125 kg/ha NPS rates. Thus, the partial budget analysis was done on the basis of total variable cost considering the costs of different Nitrogen level, seed rates and transport as well as application costs. The economic analysis was done on the basis of adjusting 10% yield downward for the fact it closest to the farmer yield. The result of partial budget analysis showed that seven Nitrogen and seed rates were non-dominated with an associated MRR greater than 100% (Table 8). An additional income of 36.05 Ethiopian Birr per unit Birr invested was obtained from the combination of 58 kg/ha N and 80 kg/ha seed rates on chewaka variety compared to the other treatments. This analysis revealed that the interaction of 58 kg/ha N and 80 kg/ha seed rates on chewaka variety gave grain yield (4318.2 kg/ha) with the net benefit (65684.9 birr/ha) and the highest marginal rate of return (3605.60%) are economically feasible alternative to the other treatments (Table 8). Therefore it is advisable to use 58 kg/ha N and 80 kg/ha seed rates on chewaka variety since economically feasible to the farmers.

Table 8. Results of partial budget analysis for Nitrogen fertilizer and seed rates on Rice varieties (chewaka).

N rate (kg/ha)	seed rate	TVC	FGy(kg/ha)	adj Gy (10%)	GB	NB	Dominance	MC	MB	MRR (%)
35	60	2258.80	3937	3543.3	56692.8	54434		0	0.00	
35	80	2718.80	4034	3630.6	58089.6	55470.8		460.00	1036.80	225.39
46	60	2755.00	3851	3465.9	55454.4	52799.4	D			
35	100	2978.80	3872	3484.8	55756.8	52778	D			
46	80	3015.00	4179	3761.1	60177.6	57162.6		296.20	1691.80	571.18
58	60	3146.30	4279	3851.1	61617.6	58571.3		131.30	1408.70	1072.85
35	120	3338.80	3872	3484.8	55756.8	52418	D			
46	100	3375.00	4432	3988.8	63820.8	60445.8		228.70	1874.50	819.65
58	80	3520.30	4798	4318.2	69091.2	65684.9		145.30	5239.10	3605.60
69	100	4200.00	4671	4203.9	67262.4	63062.4	D			
81	80	4268.80	4663	4196.7	67147.2	62878.4	D			
69	120	4560.00	4880	4392	70272	65712		1039.70	27.10	2.61
81	100	4628.80	4626	4163.4	66614.4	61985.6	D			
81	120	4988.80	4840	4356	69696	64707.2	D			

GB= gross benefit, TVC= total variable cost, NB= net benefit, D=dominance, MC= marginal cost, MB= marginal benefit and MRR= marginal rate of return

Conclusions and Recommendations

The medium nitrogen and low phosphorus content of the soil reflects the demand for both Nitrogen and Phosphorus application of the soil for Bako and Chewaka sites. Even though farmers believes increasing Nitrogen and seed rates increases rice yield, optimum yield was obtained at certain level of the rates at the tested site. Increasing Nitrogen and seed rates to optimum level resulted in better Grain Yield of rice variety (Chewaka). From different Nitrogen and seed rates tested at Bako and Chewaka locations during cropping season of 2019-2020, the combination of 58 kg/ha N and 80 kg/ha seed rates as well as 69 kg/ha N and 120 kg/ha seed rates gave the highest grain yield compared to the other treatments. Economic analysis revealed that from the tested treatments, 58 kg/ha N and 80 kg/ha seed rates which gave better yield, net benefit and highest marginal rate of return are economically feasible alternative to the other treatments. Therefore, it is advisable to use the combination of 58 kg/ha N and 80 kg/ha seed rates on chewaka variety since economically feasible to the farmers.

References

Afana Jahan, Aminul Islam, Md. Imran Ullah Sarkar, Mosud Iqbal, Md. Nayeem Ahmed & Md. Rafiqul Islam (2020): Nitrogen response of two high yielding rice varietiesas influenced by nitrogen levels and growing seasons, Geology, Ecology, and Landscapes, DOI: 10.1080/24749508.2020.1742509.

Berhanu Debele, 1980. The physical criteria and their rating proposed for land evaluation in the highland region of Ethiopia. Land Use Planning and Regulatory Department, Ministry of Agriculture, Addis Ababa, Ethiopia. CSA (central statistical agency). The federal democratic republic of Ethiopia, agricultural sample survey. Addis ababa, may, 2016.

CSA (Central Statistical Authority), 2021. The Federal Democratic Republic Of Ethiopia Central Statistical Agency Agricultural Sample Surve, Volume I Report on Area and Production of Major Crops Statistical Bulletin 590. Addis Ababa, Ethiopia.

E.E.Gewaily, Adel M. Ghoneim*, Marvet M.A. Osman, 2018.Effects of nitrogen levels on growth, yield and nitrogen use efficiency of some newly released Egyptian rice genotypes. Open Agriculture. 2018; 3: 310–318, https://doi.org/10.1515/opag-2018-0034.

EthioSIS (Ethiopian Soil Information System) (2014). Soil Fertility and Fertilizer recommendation Atlas of Tigray Region. Ministry of Agriculture (MoA) and Agricultural Transformation Agency (ATA).

FAO. 2004. Species description *Oryza sativa* L.

Hameed E, Wajid SA, Shad AA, Bakht J, Muhammad T. Effect of different planting dates, seed rates and nitrogen levels on wheat. Asian Journal of Plant Science. 2003; 2(6):464-474.

Ijaz AK, Bakht J, Wajid SA, Khan NM, Ullah I. Effect of seed rate on the yield and yield components of wheat under irrigated conditions of Peshawar. Asian Journal of Plant Science. 200.

Islam MS, Hasanuzzaman M, Rokonuzzamanc M, Nahar K., 2009. Effect of split application of nitrogen fertilizer on morphophysiological parameters of rice genotypes. International Journal of Plant Production; 3(1):52-61.

Javaid I., Khizer H., Safdar H., Anser A., Muhammad A., Alias H. and Ahmad B., 2012. Effect of Seeding Rates and Nitrogen Levels on Yield and Yield Components of Wheat (*Triticum aestivum* L.). *Pakistan Journal of Nutrition* 11 (7): 531-536, 2012

Kamara AY, Ekeleme F, Omoigui L, Oikeh, OS, Chikoye D, Tegbaru A., 2010. Responses of upland rice cultivars to nitrogen fertilizer in the Savannas of Nigeria Agronomy; 102(1):333-339.

Kebebew Assefa, Hailu Tefera and Arnulf Merker, 2002. Variation and inter-relationships of quantitative traits in rice (*Oryza sativa L.*) germplasm from northern and southern Ethiopia. Hereditas. 136:116.

Maya M, Toshinori M, Makie K., 2009. Growth and yield of new rice for Africa (NERICAs) under different ecosystems and nitrogen levels. Plant Production Science. 2009;12(3):381-389.

Mekonnen, G., 2015. Characterization of agricultural soils in cascape intervention *woredas* of Amhara region. BDU-CASCAPE Working Paper 12.

Melese, A.., GEbrekidan, H., Yli-Halla, M., Yitaferu, B., 2015. Phosphorus status, inorganic phosphorus forms, and other physicochemical properties of acid soils of Farta district, Northwestern Highlands of Ethiopia. *Applied and Environmental Soil Science* Article ID 748390.

Noor M.A., 2017. Nitrogen management and regulation for optimum NUE in maize–A mini review, Soil Crop Sci.,https://www. cogentoa.com/article/10.1080/23311932.2017.1348214.

OECD. 1999. *Consensus document on the biology of Oryza sativa (Rice)*. ENV/JM/MOMO (99) 26. Organization for Economic Co-operation and Development.

Otteson, B.N., M. Mergoum and J.K. Ransom, 2007. Seeding rate and nitrogen management effects on spring wheat yield and yield components. *Agron. J.*, 99: 1615-1621.

Pandy, R.K., J.W. Maranvilla and A. Admou, 2001. Response of durum wheat genotypes to nitrogenous fertilizers. Rastenievdni-Nauki, 38: 203-207.

Singh, C.B., J. Kumar, A.A. Khan, R.A. Katiyar and A.K. Katiyar, 2002. Effect of nitrogen and dates of sowing on yield and quality of wheat (*Triticum aestivum* L.) seeds. Progressive Agric., 2: 92-93 2;1:513-515.

Swain DK, Sandip JS., 2010. Development of SPAD values of medium-and long duration rice variety for site-specific nitrogen management. Agronomy; 9(2):38-44.

Taddesse, D., 2008. Study on genetic variation of landraces of rice (*Oryza sativa L.*) in Ethiopia. Genet. Resource. Crop Evolution. 40. 101-104.

Taddesse, E., 2009. Rice (*Oryza sativa L.*) cultivars: Morphology and Classification part II. Experimental Station Bulletin 66. Addis Ababa University, College of Agriculture, Dire Dawa (Ethiopia). 73p.

Appendices

Appendix Table 1. Mean squares of ANOVA for Days to heading, Days to maturity, Plant height, Number of effective tiller, and Thousand Seed weight of Rice in response to Nitrogen and Seed rate at bako and chewaka.

sources of variation	Mean squres					
		DH	DM	PH	NET	TSW
Rep	2	19.51**	2.15ns	177.09ns	2.82ns	1.45ns
Nitrogen(N)	4	11.51*	1.93ns	347.43**	0.69ns	1.47ns
Seed rate(SR)	3	10560.27**	3.28ns	89.52ns	0.38ns	1.78ns
N*SR	12	4.45ns	2.34ns	61.24ns	0.95ns	2.58*
MSE	158	3.698	2.11	64.97	1.38	3.85
CV (%)		2.2	1.2	7.4	21.7	7.2

Appendix Table 2. Mean squares of ANOVA for Panicle length, Number of filled grain, Number of unfilled Grain, Grain yield, Above ground biomass and Harvest index of Rice (Chewaka) in response to Nitrogen and Seed rate at bako and chewaka.

sources of variation	Df	PL	NFG	NUFG	GY	AGBM	HI
Rep	2	6.99**	59.96ns	2.79ns	8994.ns	2934771 ns	35.74ns
Nitrogen	6	1.439ns	150.42**	39.64**	5397527**	61207140 **	40.48ns
Seed Rate	1	0.82 ns	61088.50**	4.40ns	644877**	10450805 *	61.54*
N*SR	6	1.38 ns	161.85**	16.05*	590823**	9324419**	54.60**
MSE	84	1.31	45.16	7.69	128866	3618020	17.33
CV(%)		5.6	7.0	19.6	8.2	13.1	11.5

Registration of Bread wheat variety named 'Laku'

Geleta Gerema[1], Meseret Tola[1], Hailu Feyisa[1] , Chemeda Birhanu[1] , Girma Chemeda[1], Fufa Anbassa[1], Gudata Badada[1], Kebede Desalegn[1], Bodena Gudisa[1],Girma Mengistu[2] Dagnachew Lule[2].

[1]Bako Agricultural Research Center, P.O.Box 03, Bako, West Showa, Ethiopia,

[2] Oromia Agricultural Research Institute, Addis Ababa, Ethiopia

Abstract

A Bread wheat variety named "Laku" with the pedigree designation of Acc. ETBW8597 has been released by Bako Agricultural Research Center, Ethiopia. The variety is well adapted to altitudes ranging between 2353-2763 m.a.s.l in the western Oromia. Laku is characterized by amber seed color, large seed size, long panicle and high yielder. This variety is a medium maturity & its mean grain yield performance ranged from 4.5 to 6.01tonha^{-1}on research field and 3.4 to 4.2 tonha^{-1} on farmers' field. The grain yield of the variety is 17.2% heavier than the grain weight of the variety used as the standard check 'Liben'. Based on stability parameters, Laku showed relatively better grain yield performance and stable adaptability across locations *and years than the standard check 'Liben'. This variety is moderate resistance to the major wheat diseases such as steam rust, yellow rust, Septoria spp, and head blight and could be cultivated from mid to high altitude areas of western Oromia*

Key words: Genotype, Pedigree, Resistance, Wheat, Variety

Introduction

Ethiopia is one of the main wheat producing country in sub-Saharan Africa (SSA) next to South Africa (Tadesse *et al*., 2018) and ranked fourth next Egypt, Morocco and Algeria in Africa in domestic consumption. Wheat is grown on 1.7 million ha with a total production of 4.2 million tons and ranks fourth after Teff, Maize and Sorghum both in area and production among cereal crops in Ethiopia (CSA, 2019). It is largely grown in the highlands of the country evolved western Oromia and plays a significant role of supplying the production with carbohydrates, proteins and minerals. Still the productivity of the crop in general in Ethiopia is low (2.9 ton ha^{-1}) (CSA, 2020) as compared to the world average yield (3.4 ton ha^{-1}) (FAOSTAT, 2019). The production and productivity of wheat is highly affected by low access of high yielding and diseases resistant varieties that could be adapted to wide range of agro-ecologies. Therefore, developing high yielding varieties with resistance/tolerance to the prevailing pests or diseases and fluctuating weather condition is the major target of wheat improvement program. Therefore, the objective of this activity was to evaluate and release high yielding, diseases resistance for wheat growing areas of western parts of Oromia and similar agro-ecologies

Varietal Origin and Evaluation

Laku and other genotypes were collected from Kulumsa Agricultural Research Center. The genotypes were evaluated along with the standard check, Liben, across two locations (Shambu and Gedo) for three consecutive years (2017-2019). Based on information of combined data analysis of variance from most of traits including grain yield, three genotypes, "Acc.ETBW8603, Acc.ETBW8597 and Acc.ETBW8572" were selected as the most promising candidate varieties and promoted to variety verification trial. Finally, the three candidates were planted along with one best standard check "Galan" on plot size of 10 m x 10 m and evaluated by the national variety release technical committee at three locations during 2020 cropping season. Therefore, Acc.ETBW8597/Laku was recommended for commercial production in western Oromia.

Varietal characteristics

The released variety "Laku" is characterized by amber seed color, large seed size, high tillering capacity, medium maturity. The spike is owned, mid-dense, and tapering. Lakku is relatively medium-tall variety with 89 cm with erected type upright growth habit. The variety could be tolerant to major wheat diseases such as steam rust and septoria tritici. The detailed agronomic characteristics of the variety are indicated in Table 1, 3 and 4 below.

Table 1. Major qualitative and quantitative parameters of the candidate genotypes and check

Traits	Acc.ETBW8603	Acc. ETBW8597	Acc.ETBW8572	Liban
1000 grain weight(gm)	49.8	46.3	49.2	39.7
Seed color	amber	Amber	white	amber
Panicle length	9.5	8.4	9.1	8.8
Spike density	high	dense	dense	dense
Seed size	large	Large	large	Intermediate

Yield Performance

The newly released variety "Laku" produced seed yield ranging between 4.5-6.01 $tonha^{-1}$ over the three years of production at the two locations while "Liban" variety produced seed yield ranging between 2.9 $tonha^{-1}$ and 5.0 ton ha^{-1} (Table 2). The new variety, 'Laku' has a mean seed yield of 4.9 $tonha^{-1}$ which was higher by about 17.2 % than the seed yields obtained from Liban (the check variety) .The newly released variety produced 3.4 to 4.2 ton ha^{-1} seed yield on farmers field as compared to Liban, which produced 2.9 to 3.3ton ha^{-1}. (Table 2 and 3)

Table 2. The mean of grain yield among three bread wheat candidates and one standard check across locations and over years

	Grain yield(Kg/heck)									
	2017			2018			2019			
Genotype	Shambu	Gedo	Mean	Shambu	Gedo	Mean	Shambu	Gedo	Mean	Over all mean
ETBW8597	4374.5	5699.0	5036.8	4641.2	4765.7	4703.5	5799.9	4222.5	5011.2	4917.1
ETBW8603	5123.9	6052.3	5588.1	4890.5	5052.3	4971.4	5945.3	4599.8	5272.6	5277.4
ETBW8572	4535.8	5024.9	4780.4	4869.2	5024.9	4947.1	5101.4	4860.4	4980.9	4902.8
Liben	4306	3347	3827	4173	3681	3927	5059	4605	4832	4195.2

Table 3. Mean agronomic traits of three Bread wheat candidates and one standard check during 2017-2019 cropping seasons

Genotypes	Maturity	Plant height	Spike length	1000 grain weight	Grain yield (Kg/heck)	Yield advantage%
ETBW8597	127.17	89	8.41	46.82	4917.11	17.2
ETBW8603	128.92	82.16	9.53	49.8	5277.4	25.8
ETBW8572	130.08	84.93	9.10	49.15	4902.7	16.9
Liben	131.58	77.97	8.79	39.72	4195.1	-

Table 4: Agronomic and Morphological characteristics of Laku bread wheat variety

Adaptation area:	Western Oromia (from middle to highland ecologies)
Altitude (masl)	2353-2763
Rainfall	> 700mm
Seed rate	150 $kgha^{-1}$
Fertilizer rate	
NPS	100$gkha^{-1}$
UREA	100$kgha^{-1}$
Days to maturity	123.9-133.9

1000 seed weight 42.9-56.6
Plant height 71.5-93
Panicle length 8.9-10.1
Crop pest reaction Tolerant to major wheat diseases
Yield (ton/ha)
Research field 4.5-6.01
Farmers 3.4-4.2
Year of release 2020
Breeder seed maintainer: OARI/BARC

Stability and Adaptability

The variety ‘Laku was released for the mid-to-high altitude agro-ecologies of western part of the country receiving >700mm average annual rainfall. It is well adapted to an altitude range of 2353-2763 meters above sea level western Oromia and similar agro ecologies. GGE biplot analysis revealed that Laku/ Acc. ETBW8597 (G9) variety showed stable adaptability across locations and years. Laku “ETBW8597(G9)” is high yielder and fall relatively close to the ideal environment and in the concentric circle and near to average environment axis, suggested their potential for wider adaptability with better gain yield performances (Fig 1).

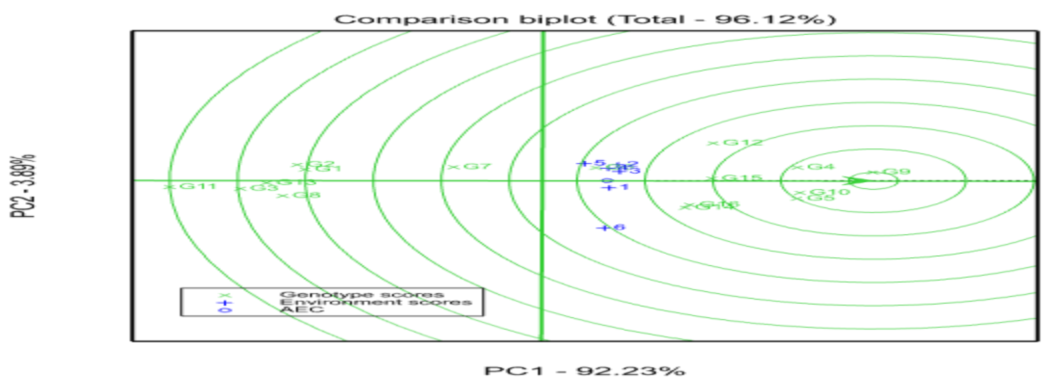


Fig 1: GGE biplot analysis depicting the stability of tested genotypes and test environment. Remark: G4= Acc. ETBW86037, G9= Acc. ETBW8597, and G10= Acc. ETBW8572 and G16=standard check (Liben).

Reaction of Major Diseases: Develop pests/diseases a resistant wheat variety is among the major objectives of the wheat improvement program. Therefore, Laku variety was showed resistance/moderate disease reaction particularly to yellow rust (R-MR) and moderate resistant(R) to steam rust while, the standard check “Liban” was moderate susceptible to steam and yellow rusts (Table 5).

Table 5. Diseases reaction of the candidates and check

Genotypes	Diseases Reaction			
	Yellow rust	Steam rust	Septoria spp(%)	Head blight
Acc.ETBW8603	R	R-MR	9.1	Immune
Acc. ETBW8597	R-MR	MR	8.4	Immune
Acc.ETBW8572	R-MR	MR-MS	7.5	Immune
Liben(St.check)	MR-MS	MS	7.6	Immune

Remark: R=Resistance, MR=Moderately Resistance, S= Susceptible

Conclusion

"Laku" produced high yield, and it had a more stable performance in seed yield over locations and years than the standard check variety. The variety also showed resistance reaction to rusts and Septoria tritici. Therefore, it was released and recommended for cultivation in western Oromia and could be adopted for production in similar agro ecologies in the country

Reference

Tadesse W, Bishaw Z and Assefa S .2019. Wheat production and breeding in Sub -Saharan Africa: Challenges and opportunities in the face of climate change. International Journal of Climate Change Strategies and Management. 11 (5): 696-715

Central statistical agency CSA (2019). Agricultural sample survey 20118/2019 (2009 E.C). Volume I report on area and production of major crops (private peasant holdings, Meher season), Addis Ababa.

CSA. 2020. Agricultural sample survey 2019/20. Report on area and production of major crops for private peasant holdings, main cropping season. Statistical 586 (1), Central statistical agency, Addis Ababa, Ethiopia

Food and Agriculture Organization of the United Nations, Rome .2019. Johnson, H. W., H. F. Robinson and R.W. Comstock, 1955. Estimates of genetic and environment variability in Soybean. Agronomy Journal, 47: 314–318

Genotype by Environment Interaction and Yield Stability of Bread Wheat Genotypes in western Ethiopia

Geleta Gerema[1], Meseret Tola[1], Chemeda Birhanu[1] , Hailu Feyisa[1], Fufa Ambasa[1] , Girma Chemeda[1] , Bodena Gudissa[1] , Gudeta Bedada[1], Girma Mengistu[2], Dagnachew Lule[2]

[1] Bako Agriculture Research Center, Oromia, Ethiopia

[2]Oromia Agriculture Research Institute, Finfinne, Ethiopia

*Corresponding author: geletarabi@gmail.com

Abstract

Investigation of genotype-by-environment interaction and determining representative testing ideal environments are important for propose a new varieties. The study was laid in a randomized complete block design with three replications. Twenty one advanced wheat genotypes were appraised to study their adaptability and stability in six environments of western Oromi. The AMMI analysis of variance revealed that genotypes, genotype-by-environment interaction, and interaction principal component analysis (IPCA-I and IPCA-II IPCA-III and IPCA-IV) had significant effects on grain yield. The first two IPCAs (IPCA-I and IPCA-II) most accurate model that could be predicted for AMMI and explained about 35.9% and 31.5%, of the total sum of squares of genotypes, respectively. Analysis using Eberhart and Russell model showed that genotypes G5, G16 and G11 have regression coefficients closer to unity (bi= 1.05, 1.09 and 1.0) and nearly acceptable deviation from regression (s2di = 0.0.299, 0.058 and 0.048), respectively. AMMI biplot graphical representation was displaying genotype main effect *and interaction effect of the genotype and environment simultaneously. The IPCA-I was plotted on x-axis whereas IPCA-II was plotted on y-axis for grain yield. The more IPCA-II scores approximate to zero, the more stable the genotype is across environments sampled while high magnitude of IPAC scores have specific adaptability. Therefore, G11, G21 and G 5 attain IPCA values relatively close to zero and hence are better stable and widely adaptable genotypes across location. However, G14 was attained IPCA values far away from zero in both sides (either positive or negative), it indicates those genotypes specific location based adaptable. Therefore, both G11 genotypes are proposed for further research because of wider adaptability; the uppermost yielding genotype G5 and G16 is proposed recommended for release at western Oromia.*

***Keywords**: Bread wheat, AMMI model, GxE interaction, genotype, stability*

Introduction

Wheat is one of the food security crops at the global level with an annual volume of production and area coverage of 750 million tons and 220 million ha, respectively in 2017 (FAO, 2017). Sub-Sahara Africa (SSA) produced wheat with an annual production of 7.5 MT on a total area of 2.9 million hectares accounting for 40% and 1.4% of the total in Africa and at global levels, respectively (FAO, 2017). Ethiopia is the second largest wheat producer in sub-Saharan Africa (SSA) next to South Africa having 1.7 million ha of wheat and 4.3 million tons of production volume (Demeke Marcantonio, 2013; CSA, 2019). The crop can grown over wider agro-ecologies of Ethiopia mainly at mid and high land areas, commonly known as the east African wheat-belt (Dawit et al., 2017). Oromia is one of the largest regions in Ethiopia that shares a largest area coverage and production of wheat of the country. It is also known for high production of cereal crops in the country. Among the wheat potential zones in Oromia, Western Oromia is generally receiving reliable rainfall and characterized by extensive bread wheat production. However, the national average yield of wheat production (2.76 $tonha^{-1}$) is very low compared with world average productivity)(CSA, 2019 and FAO, 2016). This yield gap between achieved and potential yield of bread wheat in Ethiopia could be due to genotypes , environmental variability, management practices and their interactions (Gadissa *et al*., 2020) as well as the emerged new disease in particular wheat rusts. Developing high yielder verities with stable in wide agro ecologies and rust diseases resistance genotypes are important in wheat variety development breeding strategy. Genotype-by-environment interaction and determining representative testing environments are important for recommending new varieties. Stability of yield of a cultivar across a range of production environments is very important for variety recommendation. However, the changing environmental conditions of Ethiopia, the expansion of bread wheat to new agro-ecologies coupled with inadequate bread wheat varieties available for the different environments necessitate a rigorous and continuous study of G x E interaction for a dynamic crop improvement program. Several statistical methods have been proposed to investigate genotype by environment interactions. Among these AMMI is commonly used method in plant breeding for the analysis of genotype by environment interaction (Zobel *et al*., 1988). AMMI model is a hybrid model combine's analysis of variance for the genotype and environment main effects and principal components analysis of the genotype by environment interaction. Lack of high yielding varieties adapted to diverse agro- ecological conditions and limitation of information on GEI of bread wheat genotypes in Ethiopia is the major reason of low productivity. Therefore, this study was conducted to determine the magnitude of genotype by environment interaction for yield and yield components and to identify genotypes adapted to a specific or wider adaptation of bread wheat genotypes for grain yield.

Materials and Methods

The experiment was conducted at two locations representing major bread wheat producing areas of western Oromia region for three cropping years (2018 - 2020) in 6 environments. The twenty one genotypes consisting of 20 advanced genotypes and one released varieties were used as experimental (Table 1). The experiment was carried out in a randomized complete block design (RCBD), with three replications. Each plot consisted of six rows of 2.5 meter length and the spacing was 20 cm between rows and 50 cm between plots. Data on seed yield was taken from the middle four rows of each plot. At harvest seed yield was determined for each genotype at each test environments.

Table 1. Bread wheat genotypes evaluated in the six environments

Genotypes	Code	Source
47/NUR	G1	CIMMYT
1179NUR	G2	CIMMYT
ETW17-56/NUR	G3	CIMMYT
6235/NUR	G4	CIMMYT
37ESWYT126/PVT2	G5	CIMMYT
ETW17-56/NUR	G6	CIMMYT
ETW17-143/PVT2	G7	CIMMYT
ETW17-39/NUR	G8	CIMMYT
37ESWYT112/PVT2	G9	CIMMYT
G29/NUR	G10	CIMMYT
ETW17-25NUR	G11	CIMMYT
ETW17-155/PVT2	G12	CIMMYT
1102/PVT	G13	CIMMYT
ETW17-96/NUR	G14	CIMMYT
G55NUR	G15	CIMMYT
LIBEN	G16	CIMMYT
2011/NUR	G17	CIMMYT
ETW17-137/PVT2	G18	CIMMYT
BWIC138/PVT2	G19	CIMMYT
1263/NUR	G20	CIMMYT
ETW17-238	G21	CIMMYT

Data Analyses

Different statistical software packages were used to analyze the data; combined analyses of variance and mean comparison with LSD test were done using the General Linear Model (GLM) procedure of the Statistical Analysis System (SAS) software 9.3 (SAS Institute Inc., 2002). The chi-square test for homogeneity of variances was significant; however no site has a CV value that is greater than 20% so that all six sites are included in the combined analysis of variance. The additive main effect and multiplicative interaction (AMMI) and regression analysis and was performed using PBSTAT-GE software version.

AMMI analysis

The Additive Main effect and Multiplicative Interaction (AMMI) model analysis was performed for grain yield. The AMMI model equation is given as:

$$yij = \mu + Gi + Ej + (\sum Kn\, Vni\, Snj) + Qij + eij$$

yij = is the observed yield of genotype i in environment j, = is the grand mean, Gi= the additive effect of the ith genotype (genotype means minus the grand mean), Ej=is the additive effect of the jth environment (environment mean deviation), Kn= is the eigen values of the PCA axis n,Vni and Snj = are scores for the genotype i and environment j for the PCA axis n, Qij = is the residual for the first n multiplicative components,eij = is the error

Yield stability index: The yield stability index (YSI) was calculated as: $YSI = RASV + RY$ Where, RASV is the rank of the AMMI stability value and RY is the rank of the mean grain yield of genotypes (RY) across environments

Yield Stability Index (YSI) Analysis

The yield stability index was calculated using the following formula: YSI = RASV + R, where RASV is the ranking of the AMMI stability value and RY is the rank of the genotypes based on yield across environments.(Mkumbira *et al*., 2003). YSI incorporates both mean yield and stability in a single criterion. Low values of both parameters show desirable genotypes with high mean yield and stability.

Eberhart and Russell's model

Yield stability was determined following the Eberhart and Russell (1966) model by regressing of the mean grain yield of individual genotypes on environmental index and calculating the deviation from the regression

$$bi = \frac{\sum y\, ijIj}{\sum I\, j^2}$$

Results and Discussions

AMMI analysis of variance for G, E and GxE Interactions

The AMMI analysis of variance of grain yield of bread wheat genotypes evaluated in 6 environments (two locations and three years) is presented in Table 2. The combined analysis of variance (ANOVA) for grain yield of 21 bread wheat genotypes tested in six environments showed significant differences ($p<0.05$) for genotypes, environments by genotypes interaction and IPCAs(IPCA1, IPCA2,IPCA3 and IPCA4) but no significant variation was obtained for IPCA5(Table 2). These results were in agreement with the works of Assefa *et al*., (2020) who reported the significant difference of wheat genotypes and their interactions was attributed to variations in different climatic and edaphic conditions across the locations. This showed that the genotypes responded differently over environments, or genotypes responses were affected by environment, and thus the test environments were highly variable. The presence of GxE interaction was clearly demonstrated by the AMMI model (Table 2) in which four of the principal component axes were significant ($p<0.05$). As a result, 100% of the interaction sum of squares were cumulatively explained, of which 35.9%, 31.5%, 19.6%, 8.6% and 4.4% were explained by IPCA-I, IPCA-II, IPCA-III, IPCA-IV and IPCA-V, respectively (Table 2). Many researchers witnessed that the best accurate AMMI model prediction can be made using the first two IPCA (Yan *et al*., 2000). The remaining interaction principal component axes captured mostly non-predictive random variation and did not fit to predict validation observations (Gauch and Zobel, 1996; Yan and Manjit, 2002). The two principal components (PCA-I and PCA-II) together captured above 50% interaction principal components. Several authors also reported for various crops that significant and greater percentage of GXE interaction (>50) was explained by the first two IPCA score (Gadisa *et al*., 2019 and Assefa *et al*., 2020 , on wheat ; Dangachew *et al*., 2014; on Triticale, Kebede *et al*., 2019, on finger millet).

Table 2. Analysis of variance for grain yield using Additive Mean Effect and Multiple Interactions (AMMI) model

Source of variation	Df	Sum Sq	Mean Sq	F value	Pr(>F)	G x E explained (%)
ENV	5	232722688.74	46544537.74	111.281	0.9	
REP(ENV)	12	5018764.09	418230.34	1.29	0.22	
GEN	20	97477627.42	4873881.37	7.01	0.92	
ENV:GEN	100	694743.40	694743.40	2.14	0.025	
PC1	24	46173519.38	1923896.64	5.93	0.02	35.9
PC2	22	24977070.51	1135321.38	3.5	0.03	31.5
PC3	20	6505284.4	433685.6	0.6	0.034	19.6
PC4	18	3536053.7	272004.1	0.4	0.97	8.6
PC5	16	1498794.4	136254.0	0.2	0.02	4.4
Residuals	240	77803694.39	324182.05			

Regression analysis based on Eberhart and Russell Model

Based on Eberhart and Russel (1966) a stable cultivar had a regression coefficient equal or near the unity and low or near the zero deviation from regression mean square. The coefficient of regression (b) values for twenty one genotypes used in this study ranged from 0.03 (G17) to 1.62 (G4) (Table 3). Regression values of unity are interpreted as average stability. The variations in b values proposed that the response of 21 genotypes is deferred to the various environments. Variability among environments is a prominent factor and mostly determines the usefulness of b values (Mohammadi *et al*., 2012). There was no genotype with b-values equal to unity, while the regression coefficient values for some of genotypes including G11, G5 and G 16 were close to 1. Genotype G 4 had the highest (1.62) regression coefficient, followed by G14 (1.52) (Table 3). The yields of these genotypes were lower than the other genotypes and significantly influenced by varying environmental conditions. However, G11 (1.0), G 5(1.05) and G16 (1.09) showed regression coefficient close to unity and with low deviation from regression value (0.048, 0.299 and 0.058, respectively). Implies that the genotypes are stable and widely adaptable than the other genotypes (Table 3). Patel *et al*., (2014) reported similar result of stability and wide adaptability of bread wheat genotypes tested over locations. Supportive results were also reported by Farshadfar (2008).

Yield Stability Index (YSI) Analysis: Another advance, known as the yield stability index (YSI), is calculated by ranking the mean grain yield of genotypes (RY) across environments. The yield stability index method incorporates both yield and stability into a single index, reducing the problem of using only yield stability as the sole criterion to select genotypes. Genotypes with lower YSI are desirable since they combine high mean yield performance with stability, Based on the YSI rank (Table 3), genotypes G5, G16 , G20 and G7 were selected as the most stable varieties combining high grain yield performance with stability, hence these can be selected to advanced yield trials for wide adaptable variety development. Although genotypes G5 and G16 were high yielding genotypes had high YSI rank scores, however, they can be recommended for all test environments where they performed well.

Table 3. Regression coefficient (bi) and squared deviation from linearity of regression (s2di) by the test genotypes revealed using Eberhart and Russell model.

Genotype	Yi	CVi	bi	P_bi	P_s2di	Wi2	Di	YSI(rank)
G1	3483.91	27.4	1.05	0.645	0.307	531115.3	2049.39	6.5
G10	3143.12	38.05	1.38	0.000	0.859	674759.8	1954.28	14
G11	3241.77	31.76	1.0	0.064	0.048	213773.1	1938	12
G12	2614.52	41.82	1.26	0.013	0.844	397291.8	1956.63	16.5
G13	3372.08	35.29	1.38	0.000	0.917	627148.4	1944.23	10
G14	3219.68	50.03	1.52	0.000	0.000	5500027	2862.99	19
G15	2903.78	36.05	1.21	0.040	0.956	237936.4	1936.14	15
G16	4000.94	29.89	1.09	0.001	0.058	858530.3	2017.77	2
G17	2128.01	2.42	0.03	0.000	0.999	3502049	1920.41	21
G18	3235.68	26.15	0.72	0.007	0.004	1985307	2316.85	16.5
G19	3374.35	23.5	0.86	0.181	0.434	481959.4	2022.14	9
G2	3350.98	21.65	0.82	0.077	0.803	299172.7	1962.96	11
G20	3909.66	21.6	0.98	0.879	1.000	4039.29	1918.4	3
G21	3651.36	27.84	1.18	0.075	0.999	134633.3	1920.06	5
G3	3395.46	18.39	0.71	0.005	0.898	433306.8	1947.57	8
G4	3673.18	38.13	1.62	0.000	0.883	1551146	1950.23	6.5
G5	4238.58	25.28	1.05	0.017	0.299	235485.2	1919.88	1
G6	2276.02	33.4	0.55	0.000	0.003	2533542	2336.89	20
G7	3652.84	27.06	1.13	0.210	0.773	255471	1967.5	4
G8	3196.34	18.52	0.69	0.003	0.999	365144	1919.87	13
G9	3224.64	5.24	0.13	0.000	0.940	2895026	1939.55	18

AMMI biplot analysis

AMMI biplot is displaying genotype main effect and interaction effect of the genotype and environment simultaneously. The closeness between pairs of environments or pairs of genotypes in the biplot is proportional to the response they have to the genotype by environment interaction effects (Crossa et al., 1990). The IPCA1 was plotted on x-axis whereas IPCA2 was plotted on y-axis for grain yield and yield components (Figure 1). The more IPCA scores approximate to zero, the more stable the genotype is across environments sampled (Purchase, 1997; Adugna and Labuschagne, 2002) . While high magnitude of IPAC scores has specific adaptability (Gauch and Zobell, 1996). Therefore, G5, G21 amd G11 attain IPCA values both (from positive and negative) relatively close to zero and hence are better stable and widely adaptable genotypes across location (Figure 1). However, G18, G14 and G9 were attained IPCA values far away from zero in both sides (either positive or negative) (Figure 1).

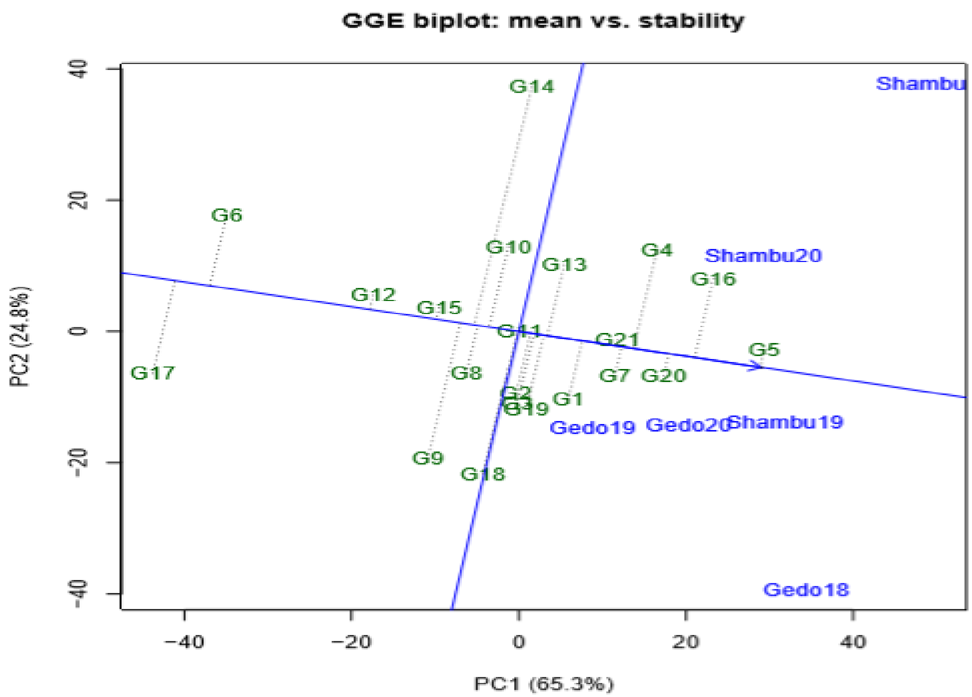


Figure 1."Mean vs Stability" GGE biplot for the wheat trials yield data (kg/ha) with 21 genotypes (G) and 6 environments (E)

Polygon View of GGE biplot analysis /Which Won Where Pattern

The polygon view of GGE biplot is important for studying the possible existence of different mega environments in a region (Gauch and Zobel, 1997; Yan et al., 2000). In the present investigation,the partitioning of GE interaction through GGE biplot analysis showed that PC1 and PC2 accounted for 65.3% and 24.8% of GGE sum of squares, respectively, explained 90.1% of the total variance (Figure 2). The polygon view of GGE biplot was formed by connecting the vertex genotypes with straight lines and the rest of the genotypes were placed within the polygon. In GGE biplot-graph, various lines emanating from the origin and become perpendicular to the line connecting the vertex genotypes are useful to divide the testing environments and genotypes into different sectors. Therefore, the six testing environments were divided into four mega environments while the 21 genotypes were divided into six genotypic groups (Figure 2). The four mega environments consisted of Group-I (no eviroment), Group-II (Shambu 2020 and 18), Group-III (Gedo2018, 2019 and 2020, and Shambu 2019), and Group-IV (no environment). Genotype G 5 was the vertex and highest yielding varieties at three environments namely Gedo 2018, Gedo 2020 and Shambu 2019 (Figure 2). Similarly, G16 was the vertex and highest yielding genotype in the sector where Shambu 2018 and Shambu. The other vertex Genotype G6 , G7 and G14, however, had no corresponding environment and hence are the poorest yielding in all the testing environments. On the other hand, the variety, which was located near the origin, was less responsive than the corner (vertex) varieties. Hence, the G8, G11, G15 and G21 were located apparently near the biplot origin showed moderate and average; respectively performance and these genotypes were less responsive to environments than the vertex varieties. According to the findings of Yan and Tinker (2006), the vertex genotypes were the most responsive genotypes, as they have the longest distance from the origin in their direction. The vertex genotypes were G5 and G16 far from the origin (Figure 2). These genotypes are the best or poorest in some or all environments because they are farthest from the origin of biplot (Yan and Tinker (2006), which were more responsive to environmental change and are considered as specially adapted genotypes.

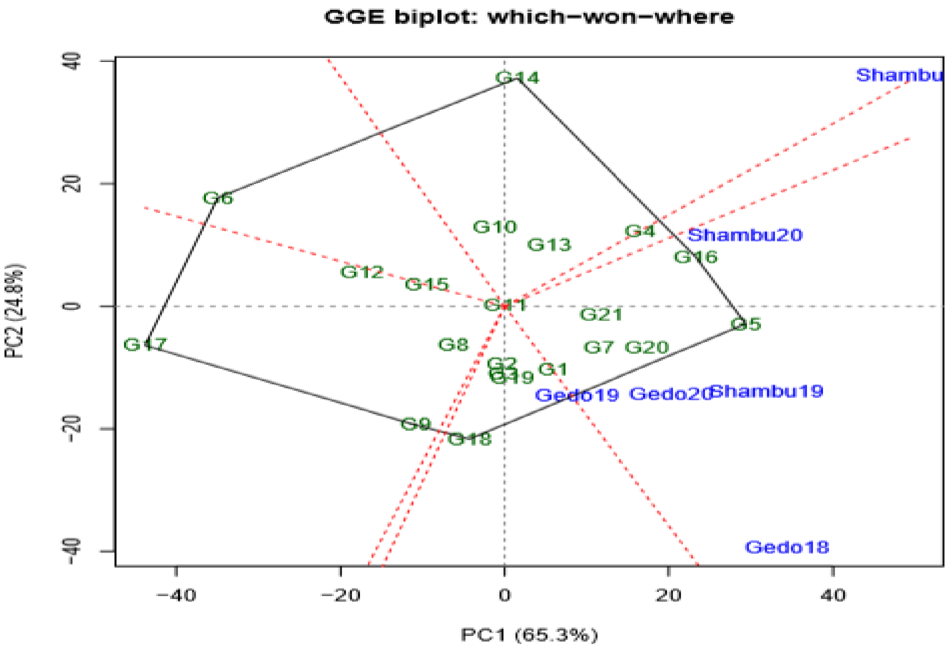


Figure 2. The which-won-where view of the GGE biplot to show which bread wheat genotype performed better in which environment for grain yield

Conclusion

The genotype and environment main effects (genotype and environment) and genotype-by-environment interaction effect were significant for bread wheat genotypes studied in western Oromia, Ethiopia. Both AMMI and Eberhart and Russell models revealed that genotype G11 was widely adaptable and stable, and thus are recommended for further research with wider environmental adaptability. Genotypes G5 and G16 gave the highest mean grain yield and better stable hence is recommended for high yielding environments.

References

Adugna, W., Labuschagne, M.T. 2002. Genotype- environment interactions and phenotypic stability analyses of linseed in Ethiopia. Plant Breeding, 121:.66-71.

Assefa, A., Firew, M., Wuletaw, T & Kindie, T.2020. Genotype X Environment Interaction and Stability of Drought Tolerant Bread Wheat (Triticum Aestivum L.) Genotypes in Ethiopia. International Journal of Research Studies in Agricultural Sciences (IJRSAS) , 6: 26-35

CSA (Central Statistical Authority). (2019). Agricultural sample survey 2018/19. Report on area and production of major crops for private peasant holdings, main cropping season. Statistical 586 (1), Central statistical agency, Addis Ababa, Ethiopia

CSA (Central Statistical Authority) .(2018). Agricultural sample survey 2017/18. Report on area

and production of major crops for private peasant holdings, main cropping season. Statistical 586 (1), Central statistical agency, Addis Ababa, Ethiopia
CSA (Central Statistical Authority). (2019). Agricultural sample survey 2018/19. Report on area and production of major crops for private peasant holdings, main cropping season. Statistical 586 (1), Central statistical agency, Addis Ababa, Ethiopia
Crossa,J., H.G. Gauch, and R.W.Zobel. 1990. Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. Crop Science, 30:493–500
Dagnachew,L., Kassahun, T., Girma, M. 2014. Genotype by environment interaction and grain yield stability analysis for advanced triticale (x. triticosecale wittmack) genotypes in western Oromia. Ethiopian Journal of Science. 37:63–68.
Dawit, A., Zerihun, T., Habtemariam, Z ., Alemayehu A. 2017. Seasonal variablity and genetic response of elite bread wheat lines in drought prone environments of Ethiopia. Journalof Plant Breeding and Genetics. 5:15-21.
Demeke, M and Marcantonio, F. 2013. Analysis of incentives and disincentives for wheat in Ethiopia. Technical notes series, MAFAP, FAO, Rome.
Eberhart SA and Russell WA. 1966. Stability parameters for comparing varieties. CSc. 6:36-
Eticha, F., Berghofer, E., Grausgruber, H. 2008. Utilization of barley (Hordeum vulgare L.) landraces in the highlands of West Shewa, Ethiopia. Plant Genetic Resources: Characterization and Utilization . 7:154-162.
FAO. 2017. FAOSTAT Rome, available at: http://faostat.fao.org.
FAO. 2016. FAOSTAT data. Food and Agriculture Organization of the United Nations. http://faostat.fao.org/ site/339/default.aspx
FAO. 2014a. Rome:FAO.Accessed athttp://faostat.fao.org/site/368/DesktopDefault.aspx?PageID =368#anc
Farshadfar, E .2008 .Incorporation of AMMI stability value and grain yield in a single non-parametric index (GSI) in bread wheat. Pak J Biol Sci. 11(14): 1791-1796
Gadisa et al. (2020).Development of Bread Wheat (Triticum aestivum L.) Varieties for High Moisture areas of Ethiopia: A G x E Interaction and Stability Analysis for Grain Yield. Ethiopian journal of crop science 8 :1
Gauch, H.G., Zobel ,R.W. 1996. AMMI analysis in yield trials. KANG, M. S., GAUCH, H. G. (Ed) Genotype by environment interaction. New York: CRC Press, 416-428.
Mohammadi,M., R. Karimizadeh, N., Sabaghnia and M. K. Shefazadeh. 2012. Genotype× environment interaction and yield stability analysis of new improved bread wheat genotypes. Turkish Journal of Field Crops. 17: 67-73.
Gauch, H.G. and Zobel, R.W. 1997. Identifying mega- environments and targeting genotypes. Crop science, 37:.311-326.
Mkumbira N M., Mahungu and U. Gullberg.2000. “Grouping locations for efficient cassava evaluation in Malawi,” Experimental Agriculture. 39: 167–179.
Kebede, D., Dagnachew, L., Megersa, D., Chemeda, B., Girma, M., Geleta, G., and Gudeta, B. 2019. Genotype by environment interaction and grain yield stability of Ethiopian black

seeded finger millet genotypes. African Crop Science Journal. 27(2): 281-294.
Purchase, J.L. 1997. Parametric analysis to describe GXE interaction and stability in winter wheat. PhD thesis. Department of Agronomy, Faculty of Agriculture, University of the Orange Free State, Bloemfonten, South Africa.
Yan, W., L .A.Hunt, Q. Sheng and Z .Szlavnics. 2000. Cultivar Evaluation and Mega-Environment Investigation Based on the GGE Biplot. Crop Science, 40: 597.
Yan, W., Hunt, A .2002. Biplot analysis of multi-environment trial data. In: Quantitative Genetics, Genomics and Plant Breeding. Kang, M.S., (Ed.), CABI Publishing.
Yan, W. and Tinker, N.A. 2006. Biplot analysis of multi-environment trial data: Principles and applications. Canadian journal of plant science, 86:623-645.
Vavilov NI (1951). The origin, variation, immunity and breeding of cultivated plants. Chron. Bot, 13:1-366.
Zobel RW, Wright MJ and Gauch HG (1988) Statistical analysis of a yield trial. Agronomic Journal, 80:388– 393

Registration of 'Jalqabne' Hulless barley (*Hordeum vulgare L.)* variety

Meseret Tola*[1], Geleta Gerema[1], Kassa Mamo[3], Chemeda Birhanu[1], Bodena Gudisa[1], Girma Chemeda[1], Hailu Feyisa[1] and Gudeta Bedada[1]

[1]Bako Agricultural Research Center, P.O.Box 03, Bako, West Showa, Ethiopia,

[2] Oromia Agricultural Research Institute, Addis Ababa, Ethiopia

[3]Ambo Agricultural Research Center, West Showa, Ethiopia,

Corresponding author email: meserettola342@yahoo.com

Abstract

Hulless (Hordeum vulgare L.) variety named 'Jalqabne' with the pedigree designation of BARC/JED/003/14 has been released by Bako Agricultural Research Center, Ethiopia. The variety is well adapted to altitudes ranging between 2344-2774 meters above sea level in the western Ethiopia. 'Jalqabne' is characterized by amber seed color, high yielder and has longer panicle. The yield advantage of this variety is 31% higher than the grain weight of the variety used as local check 'Qaxe'. Based on stability parameters, 'Jalqabne' showed relatively better grain yield performance and stable adaptability across locations and across years than the standard check 'Qaxe'. This variety is resistant to major barley diseases such as scald, blotches, insects and other hazards (e.g. Cold, heat, drought, salinity) and could be cultivated from mid to high altitude areas of Western Ethiopia.

Key words: Pedigree, Resistance, Hulless barley, Variety

Introduction

Barley (*Hordeum vulgare* L.) is an ancient crop and a very important cereal. It is one of the first domesticated crops and today is ranked fifth according to the dry matter production in the world, following maize, wheat, rice and soybean (Baik & Ullrich, 2008). Barley has both winter and spring, hulled and hulless, and two-row and six-row varieties. Barley grain contains starch (65-68%), proteins (10-17%), β-glucan (4-9%), fats (2-3%) and minerals (1.5-2.5%) (Wang *et al.*, 2015). Hulless barley research and development is now receiving more emphasis with potential for feed, food and industrial uses. This crop is an important source of water-soluble plant fiber essential in human diets to lower serum cholesterol (Bhatty, 1986; Anderson and Berglung, 1990). Compared to hulled barley cultivars, hulless cultivars have lower fiber content and higher amount of starch due to absence of the hull. The crude protein of hulless barley typically exceeds that of comparable hulled types and should be 1-3% greater (Yang *et al*., 1997; Griffey, 1999). Hulless barley also has a major advantage over conventional barley in transportation, processing and storage. Due to its positive effects on human health, in recent years hulless barley has increasingly been used as an alternative type of cereals, in direct nutrition and industrial processing (Oljača *et al*., 2009; Sullivan *et al.*, 2010). Barley-based products can be classified as functional food due to the content of β-glucan, since this polysaccharide helps the regulation of blood glucose and cholesterol levels (Behall *et al*., 2004), reduces the risk of heart disease, prevents type 2 diabetes, eliminates gastrointestinal disorders, and regulates body weight by causing the feeling of satiety (Dodig *et al*., 2007b; Sullivan *et al*., 2010). The grain of hulless barley is much suitable for '*Kolo'* especially for commercial market.

Varietal Origin and Evaluation

Jalqabne (BARC/JED/003/14) and other genotypes were collected from Jeldu district, West Showa zone, Oromia region. The genotypes were evaluated along with the standard check, 'Qaxe' across two locations (Shambu and Gedo) for three consecutive years (2017-2019). Based on information of combined data analysis of variance from most of traits including grain yield, two genotypes "BARC/JED/003/14 and BARC/JED/008/14" were selected as the most promising candidate varieties and promoted to variety verification trial. Finally, candidate varieties were evaluated along with one best standard check on 10 m x 10 m plot area by the national variety release technical committee at three locations Gedo, Shambu and Bilaa. Each site has one on-station and two on-farm fields during the 2019/20 cropping season. As a result BARC/JED/003/14 was recommended for commercial production and named 'Jalqabne'.

Agronomic and Morphological characteristics

The released variety, 'Jalqabne' (BARC/JED/003/14) is characterized by amber seed color, average 1000 seeds weight of 38.6 grams and has an average panicle length 8.2 cm (Table 4). The variety could be resistance to lodging, the ability to withstand high fertility/nitrogen input and wider adaptation. The detailed agronomic characteristics of the variety are indicated in Table 2 and 4 below.

Yield Performance

The released variety 'Jalqabne' is mainly described by high yield over the check and other candidates, which have 3752kgh^{-1} of grain yield (Table 1). The grain yield of this newly released variety has advantages of 31% over the check 'Qaxe'. 'Jalqabne' (BARC/JED/003/14) gave grain yield of 22 and 26.76 Quntal per hectare on a farmer's and on research field respectively (Table 4).

Table 1. Mean of grain yield hulless barley genotypes and one local check in six test environments

Genotype	Grain yield(Kg/heck)						
	2017		2018			2019	
	Shambu	Gedo	Shambu	Gedo	Shambu	Gedo	Mean
BARC/JED/001/14	3749.4	2840.0	3205.0	2450.0	2160.0	2190.2	2765.8
BARC/JED/002/14	3230.5	2318.3	3293.3	2013.3	1840.0	4337.0	2838.7
BARC/JED/003/14	5137.7	2986.7	3243.3	3565.0	4566.7	3012.6	3752.0
BARC/JED/004/14	3175.4	1830.0	2711.7	2758.3	2041.7	4067.2	2764.1
BARC/JED/006/14	3602.2	2450.0	2923.3	2451.7	2338.3	2907.1	2778.8
BARC/JED/008/14	3008.5	1968.3	4441.7	3148.3	3903.3	2405.2	3145.9
BARC/JED/009/14	2916.6	2470.0	3496.7	1380.0	1755.0	4436.3	2742.4
BARC/JED/004-2/14	2984.6	2695.0	3263.3	2216.7	2223.3	2769.7	2692.1
BARC/JED/005-2/14	1925.3	1765.0	2508.3	2023.3	2055.0	3190.0	2244.5
BARC/JED/007-1/14	3436.3	2746.7	3158.3	1893.3	3063.3	2958.9	2876.1
BARC/JED/008-1/14	2344.2	1785.0	2950.0	1593.3	1926.7	3024.6	2270.6
BARC/JED/009-1/14	3438.2	1611.7	3345.0	2338.3	2220.0	3944.2	2816.2
INBYT13-2	4308.9	1946.7	3151.7	2350.0	2631.7	4333.7	3120.5
INBYT13-3	4505.2	2788.3	2428.3	2838.3	3180.0	3685.9	3237.7
INBYT13-4	3818.6	2605.0	1898.3	2111.7	2403.3	3378.0	2702.5
INBYT13-5	1668.3	1673.3	2711.7	1463.3	2295.0	3188.6	2166.7
INBYT13-11	2670.6	1743.3	3920.0	2238.3	2506.7	3697.1	2796.0
INBYT13-12	2940.1	2108.3	3806.7	3128.3	2191.7	2639.6	2802.5
INBYT13-14	2428.4	1950.0	3593.3	2953.3	2105.0	3203.1	2705.5
INBYT13-19	2684.0	1586.7	2473.3	3556.7	2210.0	3632.0	2690.5
INBYT13-20	2456.0	1636.7	3801.7	3315.0	2330.0	2870.7	2735.0
INBYT13-25	2928.8	1543.3	2828.3	3021.7	2528.3	3010.3	2643.5
FCJelduSPS-10	2412.6	2151.7	3010.0	2980.0	1958.3	2532.8	2507.6
FCAmbo-16	3241.7	1828.3	2796.7	3108.3	2401.7	2661.7	2673.1
Qaxe (check)	2691.2	2353.3	2756.7	3493.3	1986.7	3890.5	2862.0
Mean	3108.1	2135.3	3108.7	2575.6	2432.8	3278.6	
CV (%)	12.2	17.8	13.7	12.3	18.2	15.6	
LSD (5%)	1125.7	626.9	1172.2	962.7	754.2	1211.9	
P-value	*	**	*	**	**	**	

Table 2. Mean agronomic traits of 24 hulless barley genotypes and a local check during 2017-2019 cropping seasons

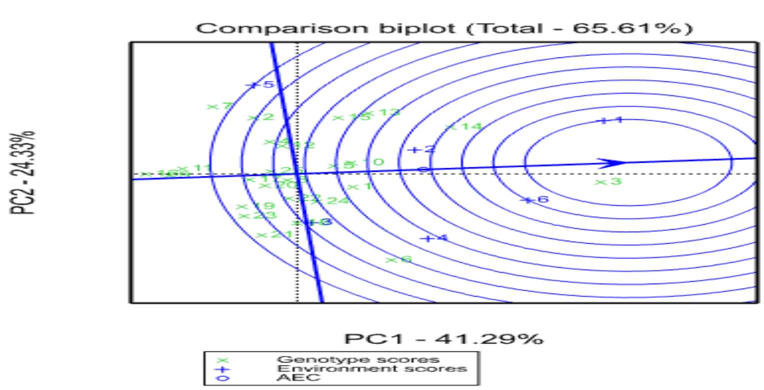
Genotype	DTM	PHT	PTPP	SL	KPS	TSW	Gy(kg/ha)	YA (%)
BARC/JED/001/14	126.7	83.0	5.3	7.7	44.6	39.9	2765.8	
BARC/JED/002/14	129.0	87.1	4.6	8.0	48.7	37.5	2838.8	
BARC/JED/003/14	129.8	89.2	6.5	8.2	50.3	38.6	3752.0	31.1
BARC/JED/004/14	128.5	94.9	5.4	7.6	48.4	35.8	2764.0	
BARC/JED/006/14	129.5	87.1	4.3	6.7	54.5	32.0	2778.8	
BARC/JED/008/14	127.9	90.4	4.8	8.3	53.8	33.1	3145.9	9.9

BARC/JED/009/14	128.1	99.0	4.9	7.7	45.6	36.5	2742.4	
BARC/JED/004-2/14	124.2	74.2	5.9	7.5	50.1	30.6	2692.1	
BARC/JED/005-2/14	126.6	98.7	5.2	7.4	51.1	33.1	2244.5	
BARC/JED/007-1/14	125.2	84.5	4.9	7.8	53.2	33.0	2876.1	
BARC/JED/008-1/14	127.4	88.1	4.8	8.2	50.0	33.6	2270.6	
BARC/JED/009-1/14	128.6	100.4	5.2	8.3	51.7	32.9	2816.2	
INBYT13-2	125.5	104.7	5.3	7.6	53.6	35.3	3120.4	9.0
INBYT13-3	125.9	88.0	4.6	7.7	52.2	33.1	3237.7	13.1
INBYT13-4	126.4	83.1	4.6	7.4	50.4	33.2	2702.5	
INBYT13-5	126.8	73.0	5.1	7.0	49.5	30.9	2166.7	
INBYT13-11	126.89	95.20	5.48	6.26	40.93	35.72	2796.00	
INBYT13-12	125.67	110.66	6.02	8.41	26.01	47.31	2802.50	
INBYT13-14	126.33	96.27	5.32	16.96	42.09	34.89	2705.50	
INBYT13-19	126.50	94.33	5.52	6.19	26.21	46.68	2690.40	
INBYT13-20	129.39	108.18	5.42	8.34	26.56	50.71	2735.00	
INBYT13-25	127.94	112.99	5.02	8.27	27.99	51.14	2643.50	
FCJelduSPS-10	129.33	102.81	5.38	8.39	26.69	51.05	2507.60	
FCAmbo-16	129.56	105.68	5.38	8.44	28.09	52.42	2673.10	
Qaxe(check)	128.50	113.40	5.90	7.50	47.11	32.42	2862.00	-
LSD	2.1	5.5	0.8	4.2	4.8	3.5	412.2	
CV	13	8.9	23	17	16.5	12.6	21.2	

DTM = Days to maturity, PTPP=Number of productive tillers, PHT=plant height, KPS=Kernels per spike, SL= Spike length, PHT=plant height, TSW=Thousand seed weight, Gy=Grain yield in kilogram per hectare, YA= Yield advantage in percentage

Stability and Adaptability Performance

The variety 'Jalqabne' (BARC/JED/003/14) was released for the mid-to-high altitude agro-ecologies of the middle and western part of the country receiving between 1800-2000 average annual rain fall. It is well adapted to an altitude range of 2344-2774 meters above sea level such as Wellega and West Showa, and similar agro ecologies. GGE biplot analysis revealed that the two candidates showed stable adaptability across the two locations and across years. Mainly BARC/JED/003/14 is high yielder than the check and fall relatively close to the ideal environment and in the concentric circle and near to average environment axis, suggested their potential for wider adaptability with better gain yield performances. (Fig 1).



Remark: 3= BARC/JED/003/14, 14= BARC/JED/008/14 and 25= Local check

Fig 1. GGE biplot showing which genotypes performed best in which environment.

Reaction of Major Diseases

Develop resistant hulless barley varieties to major diseases such Scald, Net blotch and Spot blotch, rust and septoria spp is among the major objectives of the breeding program. Particularly, 'Jalqabne' variety was showed relatively tolerant to scald and blotch while the local check was affect by scald. (Table 3).

Table 3: Diseases reaction of the varieties "candidates and check ''.

Diseases/Insects	Acc. BARC/JED/003/14	Acc.BARC/JED/008/14	Qaxe
Scald (%)	11.3	9.2	17.2
Net blotch (%)	9.1	8.4	13.5
Spot blotch (%)	7.8	9.2	10.3

Table 4: Agronomic and Morphological characteristics of 'Jalqabne' Hulless barley variety (BARC/JED/003/14)

Variety name	Jalqabne (BARC/JED/003/14)
Adaptation area:	Gedo, Shambu, Bilaa and similar areas agro ecologies of Ethiopia
Altitude (masl):	2344-2774
Rain fall (mm):	1800-2000
Seed rate:	100 kg per hectare
Planting date:	Mid July
Fertilizer rate (kg/ha):	
NPSB:	125
Urea:	75
Days to heading:	67
Days to maturity:	129.8
1000 grain weight (gm):	38.6
Plant height (cm):	89.2
Growth habit:	Erect type
Panicle length (cm):	8.2
Seed color:	Amber
Ear type:	Compacted Six row type
Crop pest reaction:	Resistant to major barley disease
Grain yield (qt/ha):	
Research field =	26.76
Farmer's field =	22
Year of release:	2021
Breeder seed maintainer:	OARI/BARC

Conclusions and Recommendations

The hulless barley variety 'Jalqabne' was high yielder, showed better adaptability and stable performance than the local check. Also, the variety was showed relatively tolerant to rust and septoria spp. Therefore, it was released and recommended for western and similar agro-ecology in the country.

Acknowledgments

The authors would like to thank Oromia Agricultural Research Institute for funding the research budget. Staff members of Bako Agricultural Research Center in general and Cereal Crops Technology Generation Team in particular are highly acknowledged for their support in field work.

References

Anderson JW, Berglung PT. 1990. Oat-bran cereal lowers serum total and LDL cholesterol in hypercholesterolemic men. American Journal of Clinical Nuture 52, 495-499.

Baik, B.K., & Ullrich, S.E. 2008. Barley for food: Characteristics, improvement, and renewed interest. *Journal of Cereal Science*, 48, 233–242.

Behall, K.M., Scholfield, D.J., & Hallfrisch, J. 2004. Diets containing barley significantly reduce lipids in mildly hypercholesterolemic men and women. *American Journal of Clinical Nutrition*, 80, 1185–1193.

Bhatty RS, 1986. The potential of hull-less barley, a Rev. Cereal Chem. 63, 97-103.

Dodig, D., Ţilić, S., & Milašinović, M. 2007b. Golozrni ječam - značaj i upotreba u ljudskoj ishrani (Hulless barley - importance and use in human nutrition). *Žito-hleb*, 34(3-4), 73-77.

Griffey C. 1999. Hull-less barley as an improved feed crop. In: Small Grain Breeder. pp. 423 430.

Oljača, S., Dolijanović, Ţ., Glamočlija, Đ., Đorđević, S., & Oljača, J. 2009. Produktivnost golozrnog ječma u organskom i konvencionalnom sistemu gajenja (Productivity of hulles barley in organic and conventional cropping system). Poljoprivredna tehnika, (2), 149–154.

Sullivan, P., O'Flaherty, J., Brunton, N., Gee, V. L., Arendt, E., & Gallagher, E., 2010. Chemical composition and microstructure of milled barley fractions. *European Food Research and Technology*, 230(4), 579-595.

Wang, Y., Bamdad, F., & Chen, L. 2015. New Technologies in the Processing of Functional and Nutraceutical Cereals and Extruded Products. *Nutraceutical and Functional Food Processing Technology*, 235–267.

Yang WZ, Beauchemin KA, Ferr BI, Rode LM. 1997. Comparison of barley, hulless barley and corn in the concentrate of dairy cows. J. Dairy Sci. 80, 2885-2895.

Genotype by Environment Interaction and Grain Yield Stability Analysis for Ethiopian Sorghum [Sorghum bicolor (L.) Moench] Genotypes in Western Oromia

Chemeda Birhanu[1]*, Gudeta Bedada[1], Kebede Dessalegn[1], Dagnachew Lule[2], Meseret Tola[1], Girma Chemeda[1], Geleta Gerema[1], Hailu Feyissa[1], Girma Mengistu[2], Tesfaye Mengiste[3]

[1] Bako Agricultural Research Centre, PO Box: 03, Bako, Ethiopia,

[2] Oromia Agricultural Research Institute, P.O Box: 81256, Addis Ababa, Ethiopia

[3] Purdue University, 915 W. State Street, West Lafayette, IN 47907, USA

*Corresponding author email: chemedabirhanu@gmail.com

Abstract

Sorghum is an important cereal crop serving as food securing commodity in Ethiopia. However, its productivity is low resulted from lack of high yielding and stable farmer preferred variety. In the present study, eleven sorghum genotypes including standard checks (Bonsa and Emahoy) were evaluated across three locations (Bako, Gute and Billo) for two consecutive years during

2019-2020 main cropping seasons with the objectives to identify stable, disease resistance and high yielding genotypes for grain yield and other agronomic traits to utilize for future breeding program and also for possible release. The experiment was conducted using randomized completed block design with three replications. Combined analysis of variance showed highly significant ($P<0.01$) differences among tested genotypes for grain yield. The result of AMMI ANOVA showed that genotype (G), environment (E) and genotype-environment interaction (GEI) significantly ($P<0.01$) affected sorghum grain yield. This result indicated that there was a variation among testing environments that genotypes are responded differently across locations. The G×E term was partitioned into five significant Interaction Principal Component Axes (IPCA); where only first and second IPCA captured 69.10 % of the G×E variance. The GGE biplot analysis showed that the first two PCAs explained 73.36 % of the GGE variance. Genotypes named by ACC. 206154 and PML 981488 were the highest-yielding, stable genotypes and significantly out yielded the checks. Regression analysis using Eberhart and Russell model also revealed that these genotypes showed acceptable range of regression coefficients (bi), approaching to one, and deviation from regression closer to zero (s2di). In addition to AMMI, GGE, Eberhart and Russell analysis, based on genotypes to anthracnose and grain mold diseases reaction; the major bottleneck of sorghum production in the study areas, genotype named by PML981488 was proposed for variety verification for possible release and registration in western Oromia and similar agro ecologies.

Key words: AMMI, Genotype, GEI, Sorghum, Stability, Variety

Introduction

Sorghum is the fifth most important cereal crop globally (FAO, 2019). It is a major food crop in Sub-Saharan Africa and South Asia and staple food for the most of food insecure people in the world (Gudu *et al.,* 2013). Sorghum is versatile crop produced for its grain which is used for food, feed, and making sugar and alcohol while its stalk used for fodder, building material and ethanol production (Bibi *et al.,* 2010; Dahlberg *et al.*, 2011). It is the dietary staple for more than 500 million people in over 30 countries, primarily in the developing world (Kumar, 2016). For instance, in Sub-Saharan Africa and South Asia, it serves as major staple food crop for the most food insecure people (Bibi *et al.,* 2010). From Eastern horn of Africa alone, more than 100 million people depend on sorghum as major food and nutritional security crop (FAO, 2019). In Ethiopia, sorghum is very important crop widely grown in the highlands, lowlands and semi-arid regions of especially in moisture stressed parts where other crops can least survive (Tesfaye *et al.,* 2008; EIAR, 2014). Currently, it is a staple crop for millions of subsistence small-scale farmers in Ethiopia that make fourth in total production after maize, tef and wheat, and third after tef and maize in area coverage (FAO, 2020).

Ethiopia is known to be one of the Vavilovian centers of origin, or diversity for many cultivated and wild species of crops including sorghum.

The phenotype performances of the genotype is not necessarily the same under diverse agro-ecological conditions. For instance, quantitative traits are influenced by the environment they often show varied degrees of genotype by environment interactions (GEI). The effect of GxE can be reduced by identifying stable genotypes across environments. As the result, understanding nature GEI is very important so you can respond to it. In general, understanding the structure and nature of GEI is important in plant breeding programs because a significant GEI can seriously impair efforts in selecting superior genotypes relative to new crop introductions and cultivar development programs (Chemeda *et al*, 2021). From this point of view, the present study was conducted with objective is to identify stable, disease resistance and high yielding genotypes for grain yield and other agronomic traits to utilize for future breeding program and also for possible release in the study areas.

Materials and Methods

Eleven Sorghum [*Sorghum bicolor* (L.) Moench] genotypes originally selected from Sorghum and Millets Innovate Lab (SMIL) project core collections and the standard checks (Bonsa and Emahoy) were used for this study (Table 1). The study was conducted for three (2019-2020) main cropping season at Bako, Billo Boshe and Gute research stations. Bako Agricultural Research Center (BARC) is located at 9º6'N latitude and 37º09'E longitude with altitude of 1650 m.a.s.l. Mean and maximum temperature of the last 5 years is 13.1 and 28.4 0 C, respectively. Average 5 years relative humidity of the Bako station is 53.2% (Kebede *et al*., 2019) and the soil is deeply weathered and slightly acidic in reaction. Gute sub-station is also found at west and lies at 96'N and 36.9'E with altitude of 1915 m.a l. The average rain fall of 1431 mm per annum and clay loom soil with slightly acidic property. The minimum and maximum temperature was 12.32 and 320C, respectively (Kebede et al., 2019). Bilo boshe subsite coordinated 8^{o}54'0''N and 37o 0'0''E with altitude 1762 masl. The three research stations have unimodal pattern of rain distribution, with the rainy period running from April to October.

The experiment was laid out in randomized complete block design with three replications and each plot comprised three rows of 5 m long and 75 cm spacing between rows and 15 cm intra rows spacing. Seed rate of 12 kg $ha^{-1}$and fertilizer rate of 100 kg ha^{-1} NPS and 100 kg ha^{-1} Urea were used. Urea was applied in split form; half at planting and the rest half at 35 days after emergence.

Data analysis

Grain yield data was subjected to analysis of variance (ANOVA) using SAS computer software (9.3 SAS version). Grain yield stability analysis was carried out using regression (Eberhart and Russell, 1966), AMMI models and genotype and genotype by environment (GGE) Biplot using GenStat 18th edition software.

Additive main effect and multiplicative interaction (AMMI) model.

The AMMI model equation was used: Yij=μ + gi +ej +Σλk +αikyjk +Rij

Where, Yij is the yield of ith -genotypes in jth environment; μ is the overall mean; gi is the effect of the ith genotype; ej is the effect of the jth environment; λk is the Eigen value of the PCA for axis k. Then αik and yjk are the genotype and environment principal component scores for axis k, respectively, and Rij is the residual term. Environment and genotype PCA scores are expressed as unit vector times the square root of λk.

Eberhart and Russell Regression Model: The Eberhat and Russel model was used and is represented by: Yij = µi +biIj +S2dij; Where: Yij is the mean performance of the ith variety (I = 1, 2, 3…, n) in the ith environment; µi is the mean of the i^{th} variety over all the environments; bi is the regression coefficient which measures the response of i^{th} variety to varying environments; S2dij is the deviation from regression of i^{th} variety in the i^{th} environment; and Ij is the environmental index of the i^{th} environment.

Genotype and genotype by environment interaction (GGE) biplot

To determine genotype by environment interaction and stability analysis, different methods were used. The genotypes and genotype by environment (GGE) biplot analysis is the most common currently utilized (Yan and Tinker 2006; Yan *et al.*, 2007). GGE biplot analysis was carried out using the method proposed by Yan (2002) for multi environment data.

Results and Discussions

The results of the combined analysis of variance across locations revealed there was a significant (P<0.01) differences among sorghum genotypes for grain yield across all testing environments (Table 1) indicating the range of genetic variability among tested genotypes.

Table 1: Combined analysis of Variance for eleven sorghum genotypes tested in western Oromia,

Source	DF	Mean Square	Pr > F
Loc	2	7909822	<.0001
Year	1	2E+07	<.0001
Gen	10	1940734	<.0001
Rep	2	1169346	0.116
Loc*Gen	20	1069331	<.0001

Additive Main Effects and Multiplicative Interaction (AMMI) Model

The AMMI model stands out as the first choice with its high degree of accuracy when the interaction effect with the main effect is important .The combined analysis of variance indicated a significant (P<0.05) variations among genotypes (G) and; highly significant differences for environments (E), genotype by environment interactions (GEI), principal component analysis IPCA-I, IPCA-II, and IPCA-III, IPCA-IV and IPCA-V (Table 3). This result indicated that there was a variation among testing environments that genotypes are responded differently across locations. It also revealed that the potential grain yield variation among genotypes across locations is due to the existence of genotype by environment interaction (GEI). For instance, the mean grain yield of genotypes across location and years ranged 583.40 kg ha^{-1} to 4767.60 kg ha^{-1}, at Bilo 2020 and Gute 2019, respectively. The result clearly

Table 3: Analysis of variance using AMMI stability model for seed yield of sorghum genotypes

Source	Df	SS	MS	% GXE	% cumulative interaction explained
Genotypes	10	19407338.14	1940733.81*		
Environments	5	74912851.89	14982570.38**		
Env x Gen	50	55594516.84	1111890.34**		
IPCA I	14	26129711.21	1866407.94**	47	47
IPCA II	12	12301174.59	1025097.88**	22.1	69.1
IPCA III	10	9816703.81	981670.38**	17.7	86.8
IPCA IV	8	4042766.65	505345.83**	7.3	94.1
IPCA V	6	3304160.59	550693.43**	5.9	100
Residuals	120	18789427.10	156578.56		

indicates, there is the differences in genotypes, environments and years; implying the contribution of environmental in which the experiment was undertaken is different, and the variation observed among genotypes for grain yield is largely due to environmental effects. Similar finding report by Seyoum *et al*. (2019), Worede *et al. (*2020) and Chemeda *et al.* (2021) over locations and years on sorghum genotypes in Ethiopia corroborates the present finding.

In present finding, AMMI analysis identified five principal component axes, in which the first and second interaction principal component analysis only contributed to 69.1 % of the total variation observed among sorghum genotypes for grain yield due to GEI (Table 3). All IPCA (IPCA-I to IPCA-V) showed highly significant (P<0.01). The IPCA scores, which indicates the adaptability over environments and association between genotypes and environments of the present study showed that a significant proportion of main GEI (47 %) was explained by IPCA-I; followed by 22.1 %, 17.7 % , 7.3 % and 5.9 for IPCA-II, IPCA-III, IPCA-IV and IPCA-V, respectively (Table 3). The IPCA scores of genotypes in the AMMI analysis are an indication of the stability or adaptation over environments (Gauch and Zobel, 1996). The greater the IPCA scores, the more specific adapted in genotype to certain environments. The more the IPCA scores approximate to zero, the more stable or adapted the genotype is over all the environments sampled.

Regression analysis based on Eberhart and Russell Model

According to Eberhart and Russell Model, genotype with high yield and regression coefficient (bi) equal to unity (1), and deviation from regression (s2di) approach to zero, would be selected as stable genotypes (Ebrehart and Russell, 1966). In the present study, genotypes ACC.206154, PML981488, ETSL101849 and PI267619 were stable, the most promising candidates and gave high grain yield of 2957.00, 2574.60, 2272.30, 2257.00 kg ha^{-1}, respectively (Table 4 and 5). From the stability point of view, genotypes that fitted to Eberhart and Russell Model are more stable and can be proposed for possible release in breeding program. Accordingly, these pipeline genotypes showed regression coefficients (bi) approaching to one (0.93, 1.06, 1.42, 1.27) and absolute deviation from regression approaching to zero (0.000, 0.001, 0.000, 0.000), respectively.

Table 4: Analysis of variance for grain yield for sorghum genotypes using the Eberhart and Russell Regression model

Source	Df	SS	MS
Total	65	49971568.95	768793.40
Genotype	10	6469112.71	646911.30*
Env + (Gen x Env)	55	43502456.24	790953.70
Env (linear)	1	24970950.63	24970950.60
Gen x Env (linear)	10	3491097.26	349109.70^{ns}
Pooled deviations	44	15040408.35	341827.50

Key: Grand mean = 2220; R^2 = 0.8965; Coefficient of variation (CV) = 17.80 %,*, = Significant at P < 0.05 levels

These result indicates that genotypes are stable, widely adaptable and also gave high yielding than other genotypes. Similar finding report by Seyoum *et al.* (2019); Admas & Tesfaye (2018);

Ndiaye *et al.* (2019); Chemeda *et al.* (2021) on sorghum in their genotype and environment interaction and stability analysis over locations and years. In contrast, genotypes ETSL100496 and ETSL100615 are fitting to Eberhart and Russell Model; showed better stability and, also were widely adaptable over the environments, but gave lower grain yield as compared to other tested genotypes.

Table 5: Regression coefficient (bi) and squared deviation from linearity of regression (s2di) of the tested sorghum genotypes using Eberhart and Russell mode

Genotype	Regression coefficient (bi)	squared deviation from regression (S^2di)	Grain yield (kg ha^{-1})
ACC. 206154	0.93	0.000	2957.00
Bonsa	0.15	0.000	2167.53
Emahoy	1.15	0.000	2120.90
ETSL 100496	0.93	0.000	1867.40
ETSL 100572	0.65	0.281	2303.20
ETSL 100615	1.07	0.005	1754.00
ETSL 101699	1.42	0.000	2272.30
ETSL 101849	0.73	0.007	2097.50
PI 267619	1.27	0.000	2257.00
PI 273967	1.16	0.001	2049.20
PML981488	1.06	0.001	2574.60

The recent standard checks, Bonsa, showed acceptable deviation from regression approaching to zero and, however showed a highly significant regression coefficients (bi) different from unity indicating the variety is less stable and not adaptable over testing environments (Table 5). Genotypes, ETSL100496 and ETSL101699 showed better stability and, also were widely adaptable over the environment; but recorded lower grain yield less than grand mean (Table 6). In the present study, the result obtained using Eberhart and Russell (1966) model is in agreement with that of the AMMI model. Similar result was reported by Worede *et al.* (2021) that significant differences between genotypes for grain yield of twelve sorghum genotypes across locations.

GGE biplot analysis

GGE biplot analysis showed that PCA1 and PCA2 explained 50.80 % and 21.56 % of the GGE variance, respectively (Figures 1 and 2). Figure 1 help visualize grain yield performance and stability of the genotypes. Accordingly, the biplot figure showed that genotype ACC. 206154 was in the first concentric circle, closer to IPCA stability horizontal line followed by PML981488 and PI 267619 and away from the mean vertical line which indicates these genotypes were stable and high yielders among tested genotypes. Among these genotypes, PLM981488 genotypes more close to IPCA stability horizontal line that revealed the more stable genotypes across locations. On other hand, among tested genotypes, genotype ETSL100615, ETSL100496, PI273967 and Emahoy were stable genotypes, however gave grain yield below average (1754.00, 1867.40, 2049.20 and 2120.90 kg ha^{-1}), respectively (Table 6).

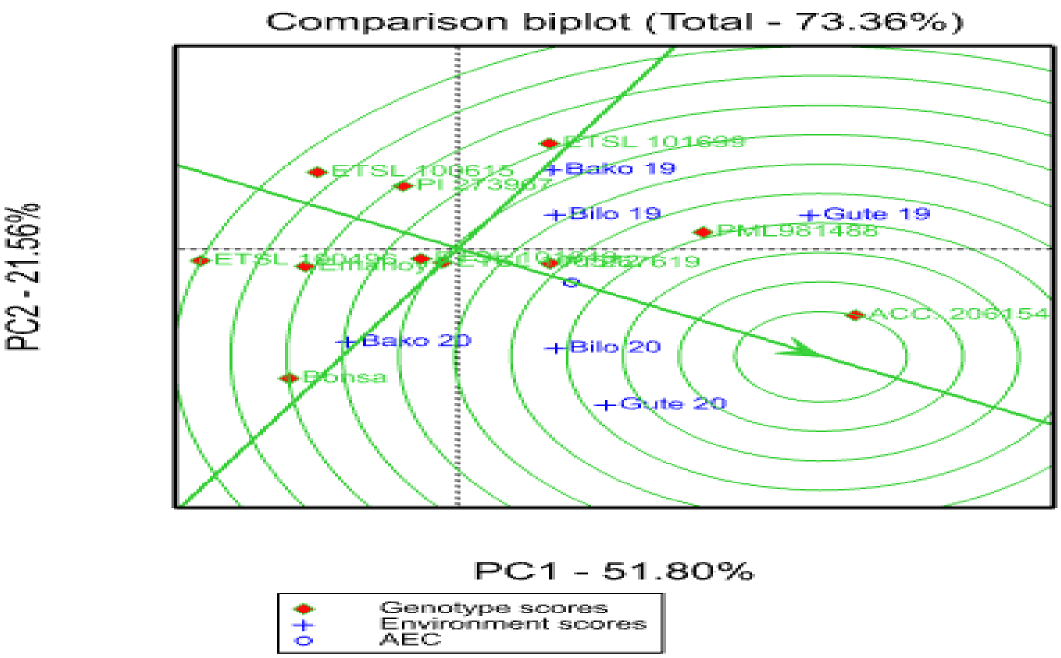
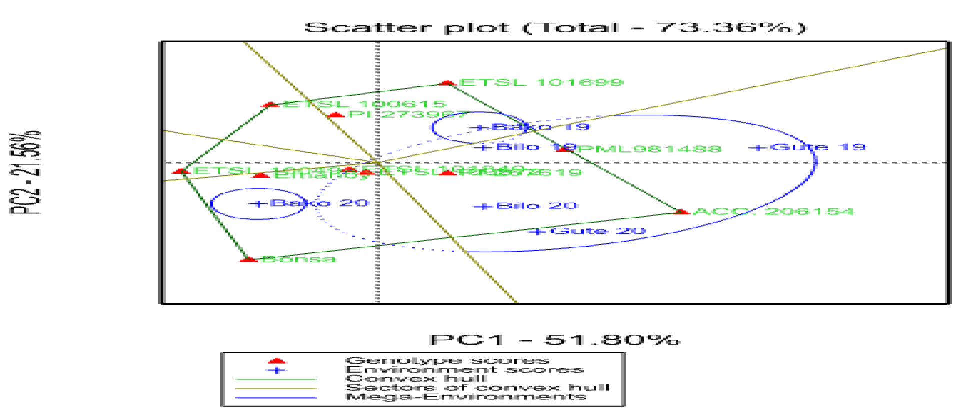


Figure 1. GGE Biplot analysis showing grain yield stability of genotypes and environments in Ethiopia

Furthermore, one of the important features of GGE biplot is the average environment coordinate (AEC) view of ranking genotypes relative to an ideal genotype to identify desirable genotypes. Genotypes proximal to the arrow at the center of the concentric circles (ideal genotype) are assumed to be suitable (Yan and Tinker, 2007). Hence, genotype ACC. 206154 was the most desirable genotype followed by genotype PLM981488 and PI273967. However, ETSL100496 is the least desirable followed by and ETSL100615 are (Figure 1). The result is in concurrence with that of Worede *et al.* (2020, 2021) who identified desirable genotypes for testing environments.



In general, the GGE biplot analysis (Fig 1 and 2) indicates the best performing genotype(s) for specific environment and the group of environments. Biplot divided the plot into five sections and the environments categorized in three mega environments (Fig 2). One of the most important properties of GGE biplot is its ability to show the which-won-where pattern and mega environment differentiation from the genotype by environment interaction and hence is a concise summary of the G × E pattern of a multi environment trials data set (Yan, 2002). According to Yan *et al.* (2007) in biplot analysis, graphical analysis of multi environment trial reveled when different environments fall into different sectors shows different high yielding cultivars for those sectors and also the presence of a cross over interaction.
According, ranking environments relative to the ideal environment (Fig 3) the ideal environment is located in the first concentric circle in the environment focused biplot.

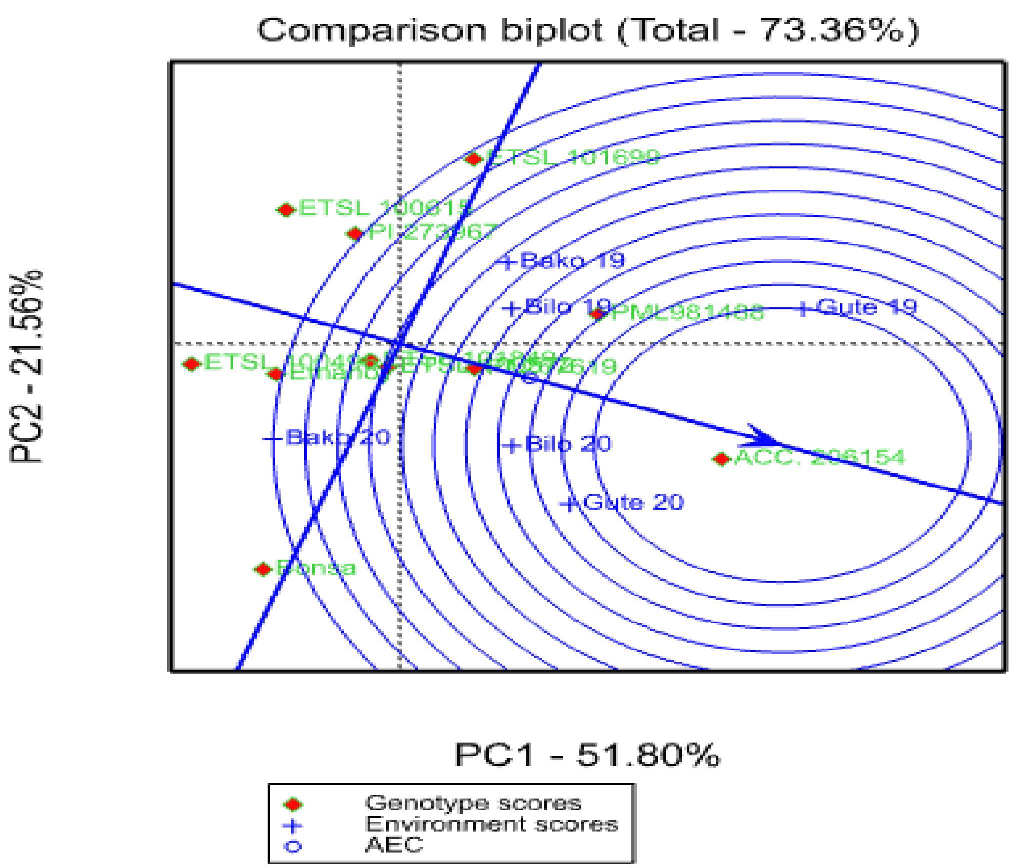


Figure 3. GGE-biplot showing the “ideal” environment

Desirable environments are close to the ideal environment. Accordingly, the nearest to the first concentric circle the environment Gute is the ideal environments to select widely adapted sorghum genotypes. Similar research finding by Belay *et al.* (2020) was corroborated the present finding.

Table 6: Grain yield (kg/ha) of sorghum genotype at Bako, Bilo Boshe and Gute in 2019 and 2020 cropping seasons.

Genotype	Bako		Bilo boshe		Gute		Mean
	2019	2020	2019	2020	2019	2020	
PML981488	2737.10	2489.30	2069.50	1914.50	4746.20	1491.10	2574.60
Emahoy	2438.15	3316.10	1461.00	2184.10	2675.80	650.10	2120.90
ETSL 100615	2864.18	1969.00	1365.90	941.30	2506.70	877.20	1754.00
PI 267619	1863.72	2574.20	1805.80	1989.70	4060.80	1248.80	2257.00
ACC. 206154	3210.10	2053.70	2129.10	2778.70	4767.60	2803.10	2957.00
ETSL 100572	2813.78	2542.90	2231.10	1724.60	2786.60	1721.10	2303.20
PI 273967	2272.15	2452.60	2455.40	583.40	3120.60	1411.00	2049.20
ETSL 101849	2033.46	2158.00	2057.20	2488.00	2861.80	987.60	2097.50
ETSL 101699	3859.32	1739.40	1935.00	1839.50	3454.20	806.60	2272.30
ETSL 100496	2352.76	3192.60	1223.60	1521.1	2084.70	830.70	1867.40
Bonsa	2175.20	3140.30	1309.70	2192.90	1946.80	2240.30	2167.50
Mean	2601.81	2511.60	1822.10	1832.53	3182.90	1369.78	2220.10
LSD	803.80	442.40	635.20	246.30	1094.20	471.30	559.90
CV	18.10	10.30	20.50	7.60	20.20	21.40	17.80
F-Value	**	**	**	**	**	**	

Key: **=highly significant, LSD=least significant differences, CV= coefficient of variation,
Grand mean=2220.10 kg ha^{-1}

Table 7: Mean of major agronomic and disease traits of sorghum genotypes evaluated at Bako,Gute and Bilo Boshe during 2019 and 2020 cropping season.

Genotype	DF	DM	PH	PL	PW	TKW	ANT[a]	GM[b]	Rust[c]	Insect[d]
ACC. 206154	109	155	389	37	7.00	21	4	2	2	2
ETSL 100615	101	149	232	26	7.70	24	3	1	2	1
PI 267619	106	152	343	26	8.62	25	2	2	2	2
PI 273967	92	149	219	19	7.29	27	3	1	2	1
ETSL 101699	89	153	272	20	7.06	29	2	2	1	2
PML981488	88	152	186	30	5.13	27	1	1	1	1
ETSL 100496	79	152	272	31	5.34	34	3	1	1	2
Bonsa	106	156	165	22	6.26	24	4	2	3	4
ETSL 100572	87	149	184	28	5.26	26	2	1	2	2
ETSL 101849	107	154	331	28	8.74	26	2	2	2	2
Emahoy	79	151	268	31	5.63	31	3	2	2	2
Mean	95	152	260	27	6.73	27	2.54	1.54	1.72	1.8
LSD	4.85	4.78	14.83	2.70	0.87	2.27	0.54	0.41	0.45	0.56
CV	7.77	4.77	8.66	15	20	13	10.6	15.4	7.4	8.9
F-test	**	NS	**	**	**	**	*	*	*	**

[a,b],[c,d] =anthracnose, grain mold and rust severity 1-5 scale (1=highly resistant, 2=resistant, 3=moderately resistant, 4=susceptible and 5=highly susceptible), d= bird attack 1-5 scale (1=resistant, 5=susceptible) **=highly significant, ns= non-significant, DF=days to 50% flowering, DM=days to 75 % maturity, PH=plant height(cm), TKW=thousand kernel weight (gm), PL=panicle length(cm), PW=panicle width

(cm), ANT=anthracnose, GM=grain mold, Disease assessment was recorded on 1-5 scale, where 1=resistant and 5= susceptible

Conclusions and Recommendations

In plant breeding program, GEI study is very crucial in diverse environmental conditions in identifying stable cultivar for wider adaptation and recommendations. This enable breeder to save time and amenability of varietal development and recommendations. In the present finding, the combined analysis of variance indicated highly significant (P<0.01) variations among genotypes (G), environments (E), genotype by environment interactions (GEI), principal component analysis IPCA-I through IPCA-V indicating that there is a variation among testing environments and genotypes respond differently over environments, or the existence of GEI that affects the performance grain yield of the genotypes across locations. The AMMI analysis identified five principal component axes, and all contributed to 100 % variations observed among sorghum genotypes for grain yield due to GEI. Stability analysis using by GGE biplot and regression analysis using Eberhart and Russell Model revealed that genotype ACC. 206154 and PML981488 are the most stable and high yielding genotypes. However, in addition to yield potential and stability of genotypes; based on disease reaction to anthracnose and grain mold (major bottleneck of sorghum production in the study areas), genotype PML981488 showed tolerant reaction that selected and proposed for variety verification for further release and registration as sorghum improved variety for western Oromia and similar agro ecologies.

Acknowledgement

The authors acknowledge Oromia agricultural research institute and Sorghum and Millet innovation lab (SMIL) project for funding the research work. We also thank Bako Agricultural Research Center; staff members of the cereal technology generation team for their field management and data collection during conducting the experiment.

References

Admas, S., and Tesfaye, K. 2018. Genotype-byenvironment interaction and yield stability analysis in sorghum (Sorghum bicolor (L.) Moench) genotypes in North Shewa, Ethiopia. Acta Universitatis Sapientiae, Agriculture and Environment, 9:82–94.

Belay, F., Mekbib, F. and Tadesse, T. 2020. Genotype by Environment Interaction and Grain Yield Stability of Striga Resistant Sorghum [*Sorghum bicolor* (L.) Moench] Genotypes in Ethiopia. *Ethiopian Journal of Crop Science*, *8*(2): 79-99

Chemeda, B., Gudeta, B., Kebede, D., Dagnachew, L., Girma, C., Megersa, D., Geleta, G. 2021. Genotype by Environment Interaction and Grain Yield Stability Analysis for Ethiopian Sorghum [Sorghum bicolor (L.) Moench] Genotypes. International Journal of Plant Breeding and Crop Science, 8(1): 975-986.

Eberhart, S.A. and Russell, W.A. 1966. Stability parameters for comparing varieties. Crop Science 6:36– 40

FAO. 2019. Food and Agriculture Organization Statistics [Online]. (Accessed on December, 26, 2020).

Gauch, H.G. and Zobel, R.W. 1996. AMMI analysis of yield trials. pp. 85-122. In: Genotype by environment interaction Kang, M. and Gauch, H. (Eds.). Boca Raton. CRC Press

Kebede, D., Dagnachew, L., Megersa, D., Chemeda, B., Girma, M., Geleta, G. and Gudeta, B. 2019. Genotype by environment interaction and grain yield stability of Ethiopian black seeded finger millet genotypes. African Crop Science Journal, 27: 281- 294.

Ndiaye, M., Adam, M., Ganyo, K.K., Guissé, A., Cissé, N. and Muller, B. 2019. Genotype-Environment Interaction: Trade-Offs between the Agronomic Performance and Stability of Dual-Purpose Sorghum (Sorghum bicolor L. Moench) Genotypes in Senegal. Agronomy, 9: p.867

Seyoum, A., Gebreyohannes, A., Nega, A., Nida, H. and Tadesse, T. 2019. Performance evaluation of sorghum (Sorghum bicolor (L.) Moench) genotypes for grain yield and yield related traits in drought prone areas of Ethiopia. Adv Crop Sci Technol, 7, pp.2.

Worede, F., Mamo, M., Assefa, S., Gebremariam, T. and Beze, Y. 2020. Yield stability and adaptability of lowland sorghum (Sorghum bicolor (L.) Moench) in moisture-deficit areas of Northeast Ethiopia. Cogent Food & Agriculture, 6 :1-13

Worede, F., Tarekegn, F. and Teshome, K. 2021. Simultaneous selection for grain yield and stability of sorghum [*Sorghum bicolo*r (L.) Moench] genotypes in Northeast Ethiopia. *African Journal of Agricultural Research*, *17*(10):1316-1323.

Yan, W. 2002. Singular value partitioning for biplot analysis of multi-environment trial data. Agronomy Journal 4:990–996

Yan, W., Kang, B.M. Woods, S. and Cornelius, P.L. 2007. GGE biplot vs AMMI analysis of genotype by environment data. Crop Science 47:643-655.

Yan, W. and Tinker, N.A. 2006. Biplot analysis of multienvironment trial data: Principles and applications. Canadian Journal of Plant Science 86:623–645

Genotype-by-Environment Interaction and Yield Stability Analysis in Finger Millet Genotypes (Elucine coracana L. Gaertn) in Western Oromiya, Ethiopia

[1]*Girma Chemeda, [1]Chemeda Birhanu, [1]Kebede Desalegn, [1]Gudeta Bedada, [1]Magarsa Dabala,
Bako Agricultural Research Center, P. O, Box 03, Bako, West Shoa, Ethiopi
[1]Oromia Agricultural Research Institute, Addis Ababa, Ethiopia
Corresponding author: girmachemeda@yahoo.com

Abstract

Finger millet (Eleusine coracana (L.) Gaertn) is one of the most important indigenous cereal crop grown largely by small holder farmers. It prized by local farmers for its ability to grow in adverse agro-climatic conditions, where other cereals fail. A field experiment was conducted using eleven finger millet genotypes, including standard checks (Bako 09) at three locations (Bako ,Gute and Bilo) for two years (2019 - 2020). The objective of this study was to identify stable and high yielding finger millet genotypes for grain yield and other agronomic traits, to assess the magnitude of genotype by environment interaction and discriminating ability and representativeness of the testing environments. In this study, Randomized Complete Block Design with three replications was used. Combined analysis of variance revealed highly significant (P<0.01) variations due to genotype, environment and genotype by environment *interaction effects. The additive main effect and multiplicative interaction (AMMI) model analysis of variance revealed highly significant (P<0.01) differences between environments, genotype, and Interaction Principal Component Analysis (IPCA-I), andt significant variations (P<0.01) for G x E interactions. This indicates that the genotypes performed differently over environments and that the test environments are highly variable. Only the first IPCA-I showed high significance (P<0.01) and contributed 84.27% of the total genotype by environment interaction (G x E). Genotypes G7, G3 and G2 which had high grain yield, and with IPCA value close to zero, indicated the wide adaptability/stability. Similarly, analysis using Eberhart and Russell model revealed that these genotypes were within the relatively acceptable range of regression coefficients (bi), approaching to one (0.93, 0.73 and 1.03), and deviation from regression closer to zero (s2di) (0.36, -0.32 and -0.40), respectively. This implied that pipeline genotypes were stable, widely adaptable and high yielders than the other genotypes. Genotype and genotype by environment (GGE bi-plot) analysis also revealed that these candidate genotypes were stable and high yielder. Besides, these genotypes showed resistance to blast disease, which is a threat to finger millet production in the study areas. Therefore, these genotypes were promoted to variety verification trial to be tested at Bako, Gute and Bilo-Boshe sub-sites during 2021/22.*

***Key words**: AMMI; biplot; GGE; stability; Finger millet*

Introduction

In Ethiopia finger millet [Eleusine coracana (L.) Gaertn] is one of the most important indigenous cereal crop grown largely by small holder farmers. It is native to Ethiopian highlands and plays a crucial role in dietary needs and income sources for many rural households of the country (Admassu et al., 2009; Ayalew, 2015; Tesfaye and Mengistu, 2017; Zewdu et al., 2018). Finger millet accounts about 4% of the total area allocated to cereals and the sixth important crop in the country after tef, wheat, maize, sorghum and barley (CSA, 2018). Despite its importance, there are plentiful production and productivity limiting factors, including blast disease caused by Magnaporthe grisea (anamorph Pyricularia grisea); absence of stable, high yielding and disease tolerant finger millet varieties. Genetic variability is a precondition for a breeding programme and provides opportunities to breeders to select high yielding genotypes, or to combine or transfer genes with desirable traits. Phenotypic expression and yield potential of a given genotype is based on its genetics, the environment and the GXE interactions (Yan, 2001; Yan and Hunt, 2001). Genotypes by environment (G x E) interactions are conceived to be among the key factors limiting response to selection and the efficiency of breeding programs. Environment change can affect the performance of a genotypes, and breeders should give due attention to the impact of GXE in genetic exploitation to efficient in selection. Ghaderi et al. (1980) observed that analysis of variance procedure helps to estimate the magnitude of GXE interaction; but is unable to provide information on the contribution of each genotypes and environment to GXE interactions. On the other hand, analytical models like additive main effects and multiplicative interaction (AMMI) can treat both the additive main effect and multiplicative interaction components employing the analysis of variance (ANOVA) and Interaction Principal Components

(IPCA) (Gauch and Zobel, 1996). Besides, AMMI and GG bi-plot analysis are considered to be effective graphical tools to estimate genotype by environment interaction patterns (Gauch and Zobel, 1996; Yuksel et al., 2002). The regression model suggested by Eberhart and Russell (1966) allows for the computation of a complete analysis of variance with individual stability regression coefficient (bi) estimates deviation from regression line (s2di). Based on the model, a stable variety is one with a high mean yield, bi = 1 and s2di = 0. The Eberhart and Russell (1996) model and AMMI stability analysis are preferred tools for identifying stable and high yielding and genotype(s) for varied or specific environments. The objectives of this study, therefore, were: (i) to assess the magnitude of GE interaction and stability; (ii) to examine the possible existence of different mega-environments; and (ii) to determine the discriminating ability and representativeness of the environments.

Materials and Methods

Eleven brown seeded finger millet (Eleusine coracana (L.) Gaertn) genotypes, including standard check (Table 1) were tested at Bako, Gute and Bilo-Bosh research sub-sites in Ethiopia for two cropping seasons (2018/19-2019/20). Bako Agricultural Research Center (BARC) is located at 9º6'N latitude and 37º09'E longitude with altitude of 1650 m.a.s.l. Mean and maximum temperature of the last 5 years is 13.1 and 28.4 0 C, respectively. Average 5 years relative humidity of the Bako station is 53.2% (BARC Agro-Metrology department) and the soil is deeply weathered and slightly acidic in reaction (Wakene, 2000). Gute sub-site is also found at west and lies at 09001.06'N and 036038.196'E with altitude of 1915 m.a s.l. The average rain fall of 1431mm per annum and clay loom soil with slightly acidic property. The min and maximum temperature is 12.32 and 32 0 C, respectively. The two research stations have unimodal pattern of rain distribution, with the rainy period running from April to October. Bilo-Boshe sub site at Western and lies at N:090 01.061' and E:0370 00.165' with altitude of 1645 m.a.s.l. the average rain fall is 1500(mm) per annum and with clay soil slightly acidic property. The experimental materials were planted in a Randomized Complete Block Design (RCBD), with three replications. Each plot comprised of five rows having 5 m length; the middle three rows were harvestable and the spacing between rows was 40 cm. A seed rate of 15 kg ha-1 and fertilizer rate of 100 kg ha-1 DAP and 100 kg ha-1 urea was used. Urea was applied in split form; half at planting and the rest half at 35 days after emergence. Data on grain yield (GY) was recorded on plot basis which was later extrapolated to hectare basis

Grain yield data were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 16th software. Grain yield stability analysis was carried out using regression (Eberhart and Russell, 1966) and AMMI models in Agrobase software (Agrobase, 2000) and genotype and genotype by environment (GGE) Biplot using Genstat15th edition software.

Additive main effect and multiplicative interaction (AMMI) model

The AMMI model equation was used:

Yger =µ+ág+âe+"nënãgnäen+ åger+ñge;

Where: Yger is the observed yield of genotype (g) in environment (e) for replication (r); Additive parameters: µ is the grand mean; ág is the deviation of genotype g from the grand mean, âe is the deviation of the environment e; Multiplicative parameters: ën is the singular value for IPCA, ãgn is the genotype eigenvector for axis n, and äen is the environment eigenvector; åger is error term and ñge is PCA residual.

Eberhart and Russell Regression Model

The Eberhat and Russel model was used and is represented by:

Yij = µi +biIj +S2dij;

Where: Yij is the mean performance of the ith variety (I = 1, 2, 3…, n) in the ith environment; µi is the mean of the ith variety over all the environments; bi is the regression coefficient which measures the response of ith variety to varying environments; S2dij is the deviation from regression of ith variety in the ith environment; and Ij is the environmental index of the ith environment.

Genotype and genotype by environment interaction (GGE) biplot

To determine genotype by environment interaction and stability analysis, different methods were used. The genotypes and genotype by environment (GGE) biplot analysis is the most common currently utilized (Yan and Tinker 2005; Yan et al., 2007). GGE biplot analysis was carried out using the method proposed by Yan (2001) for multi environment data.

Table 1.Description (background information) of finger millet genotypes used for the study:

SN	Genotypes	Source	
		Female	Male
1	Wama X PW-001-022 (P3-2)-2-3	BARC	AA U
2	Wama X PW-001-022 (P3-3)-2-3	BARC	AA U
3	Wama X PW-001-022 (P1-1)-2-3	BARC	AA U
4	PW X P-001-022 X AAUFM-35(p2-1-)-1-2	AAU	
5	PW X P-001-022 X AAUFM-35(p2-1-)-1-2	AAU	
6	Wama X PW-001-022 (P3-1)-1-2	BARC	AA U
7	Wama X PW-001-022 (P1-1)-1-2	BARC	AA U
8	Wama X PW-001-022 (P3-3)-1-2	BARC	AA U
9	Wama X PW-001-022 (P3-1)-2-3	BARC	AA U
10	Wama X PW-001-022 (P3-2)-1-2	BARC	AA U
11	Bako 09	BARC	

BARC=Bako Agricutural Research Center, AAU=Addis Ababa University

Results and Discussions

Analysis of variance: Combined analysis of variance for grain yield of the 11 finger millet genotypes across six testing environments revealed highly significant (P < 0.01) variations due to genotype, environment and genotype by environment interactions (Table 2). The significant GE interaction in the present study indicates the presence of genetic variability among the genotypes in the wide-range of environments and possibility to select high yielding and stable genotypes. The significant variability among the finger millet genotypes in the present study is in line with the previous reports in tef (Kefyalew T., 2017). The mean grain yield of the11 tested genotypes ranged from 1774.66 Kg ha-1 (G1) to 3178.49Kg ha-1 (G7) with a grand mean 2258.49KG ha-1.

Table 2.Combined analysis of variance for grain mean yield of finger millet tested at three locations for two years (2019/20)

	Df	Sum Sq	Mean Sq	F value	Pr(>F)
Environment (E	5	23.524	4.7048	11.5341	0.00
Replication/E	12	4.895	0.4079	4.3946	0.00
Genotype (G)	10	41.012	4.1012	18.3132	0.00
GxE	50	11.197	0.2239	2.4128	0.00
Residuals	120	11.138	0.0928		

Table 3.Mean Grain Yield (t/ha) per location across years

Genotypes	2019 Bilo	BaKo	GUT	mean	2020 Bilo	BaKo	GUT	Mean	Over all mean
7	2.94	3.43	3.04	3.14	3.19	3.45	3.01	3.22	3.18
3	2.16	2.77	2.46	2.46	3.27	3.39	3.42	3.36	2.91
2	2.36	2.67	2.40	2.48	2.78	2.75	2.98	2.84	2.66
6	2.47	2.77	2.40	2.55	2.36	2.75	2.24	2.45	2.50
11	1.94	1.69	1.68	1.77	1.90	3.17	2.22	2.43	2.10
10	1.61	2.07	1.45	1.71	2.35	2.41	2.59	2.45	2.08
5	1.37	1.86	1.57	1.60	2.48	2.28	2.42	2.39	2.00
8	1.32	1.71	1.32	1.45	2.07	2.60	2.35	2.34	1.89
9	1.29	1.25	1.63	1.39	2.36	2.76	2.06	2.39	1.89
4	1.48	1.61	1.22	1.44	2.26	2.40	2.19	2.28	1.86
1	1.29	1.42	1.36	1.36	1.92	2.50	2.16	2.19	1.77
Mean	1.84	2.11	1.87	1.94	2.45	2.77	2.51	2.58	2.26
LSD	0.24	0.44	0.31	0.30	0.60	0.28	0.91	0.41	0.32
CV	7.54	12.20	9.72	10.25	14.50	5.85	21.28	14.83	13.49
F-Test	***	***	***	***	***	***	*	***	***

CV = coefficient of variation, LSD = Least Significant Difference

Stability analysis

Additive Main Effects and Multiplicative Interaction (AMMI) Analysis: The combined analysis of variance revealed highly significant (P<0.01) variations among environments, genotypes, and Principal Component Analysis IPCA-1 and significant difference ((P<0.01) for genotype, genotype x environment interactions (Table 3). This showed that the genotypes responded differently over environments, or genotypes responses were affected by environment, and thus the test environments were highly variable. The mean grain yield across the six environments ranged from 1.84 t ha-1 at Bako in 2019 to 2.58 t ha-1 at Gute in 2020 (Table 3). This implies genotypes and locations differences including seasons'. Environmental conditions during different seasons significantly influenced grain yield, indicating that environments and genotypes were significant variable. Similar results were reported by Ezeaku et al. (2014) in pearl millet and Dagnachew et al. (2014) in Triticale and Kebede *et al.* (2019).

Table 4.AMMI analysis for variance for the effect of genotypes, environment and GE interaction on grain yield (Kgha^{-1}) of finger millet

Source	Df	Sum Sq	Mean Sq	F value	Pr(>F)	Proportion	Accumulated
ENV	5	5,749,583.04	1,149,916.61	64.62	0.00***		
REP(ENV)	12	213,528.20	17,794.02	0.57	0.87		
GEN	17	22,237,238.18	1,308,072.83	41.67	0.00***		
GEN:ENV	85	5,300,100.22	62,354.12	1.99	0.00***		
PC1	21	4,224,403.15	201,162.05	6.41	0.00***	84.27	84.27
PC2	19	490,088.51	25,794.13	0.82	0.68	7.83	92.1
Residuals	204	6,403,928.68	31,391.81				
Total	408	45,204,478.53	110,795.29				

GEI= Genotype by Environment interaction; DF= Degrees of freedom; SS= Sums of square; MS= Means square

Additive Main Effects and Multiplicative Interaction (AMMI) Model: The combined analysis of variance revealed highly significant (P<0.01) variations among environments, genotypes, and Principal Component Analysis IPCA-1; and significant difference (P<0.01) for genotype x environment interactions (Table 4). This showed that the genotypes responded differently over environments, or genotypes responses were affected by environment, and thus the test environments were highly variable. According to AMMI biplot, environments showed high variations in both main effects and interactions (IPCA 1). Environments Bako 2018 and 2020, and Bilo 2019 and Gute 2019 were plotted in the first quadrant for their high mean grain yield, and had positive IPCA 1 scores, which interacted positively with genotypes that had positive IPCA 1 scores; and negatively with genotypes having negative IPCA 1 scores. Bako 2020 gave the higher environmental mean yields (3.45 t ha-1) and was the best performing environment. Similarly, G7 and G3 gave the higher grain yield (3.45 and 3.39 t ha-1, respectively) at Bako location during the 2020 cropping season, than they did at other locations and years. On the other hand, the least mean grain yield was harvested from Gute during 2019 (Table 4). Bako 2020 showed high interactions, while Gute and Bilo 2020 were in the 1st quadrant, but with relatively low interaction (Fig. 1&2). Analysis using Eberhart and Russell regression model confirmed the result obtained by AMMI model. AMMI bi-plot indicated that genotypes G7, G3 and G2 are plotted closer to the horizontal IPCA stability line and far from vertical IPCA mean value. This showed that these genotypes were a stable and high yielding (Fig. 1&2). Regression analysis based on Eberhart and Russell Model. Ebrehart and Russell (1966) model hypothesizes that genotypes with high yield and regression coefficient (bi) equal to unity (1), and deviation from regression (s2di) approach to zero, would be selected as stable genotypes and proposed as potential candidates for possible release. An ideal genotype has the highest grain yield, a regression coefficient (bi) value of approximately one, and a mean square deviation from regression (s2di) value close to zero. Accordingly, pipeline genotypes, G7, G3 and G2, were the most promising candidates and gave grain yield of 3.18, 2.91 and 2.66 t ha-1 , respectively. The regression coefficients (bi) for those genotypes were approaching one (0.93, 0.73 and 1.03) and acceptable deviation from regression (s2di) (0.36, 0.32 and 0.40), respectively; implying that they are stable, widely adaptable and higher yielders than the other genotypes (Table 5). Kebede *et al.* (2019) reported similar result of stability and wide adaptability of finger millet genotypes tested over locations. Genotypes, G1 and G5 and showed better stability and, were widely adaptable over the environment; but were inferior in grain yield.

TABLE 5. Regression coefficient (bi) and squared deviation from linearity of regression (s2di) by the test black seeded finger millet genotypes using Eberhart and Russell model

Genotype	Regression Coefficient (bi)	Squared deviation from regression(s2di)	Grain Yield Over all mean (t/ha)
7	0.93	0.364	3.18
3	0.73	0.317	2.91
2	1.03	0.402	2.66
6	1.24	0.604	2.50
11	1.11	0.169	2.10
10	0.07	0.122	2.08
4	0.30	0.238	2.00
9	1.44	0.021	1.89
8	1.41	0.955	1.89
5	1.12	0.240	1.86
1	1.17	0.001	1.77

In stability analysis, the biplot for grain yield explained 92.1% of the total variation (84.28% and 7.83% by PC1 and PC2, respectively) (Fig. 2). The biplot showed that genotype G7 was in the first concentric circle, closer to IPCA stability horizontal line; followed by G3 and G2 and away from the mean vertical line. This was an indication of the genotypes that were the most stable and high yielders among the tested genotypes. Whereas G1 and G8 were the best stable genotypes, but showed an inferior mean grain yield, even far below the average (1.77 and 1.9 t -1). This result is in agreement with the above two models results. Earlier researchers also identified stable finger millet genotypes for the brown seeded groups (Asfaw Adugna et al., 2011 and Kebede et al., 2019.

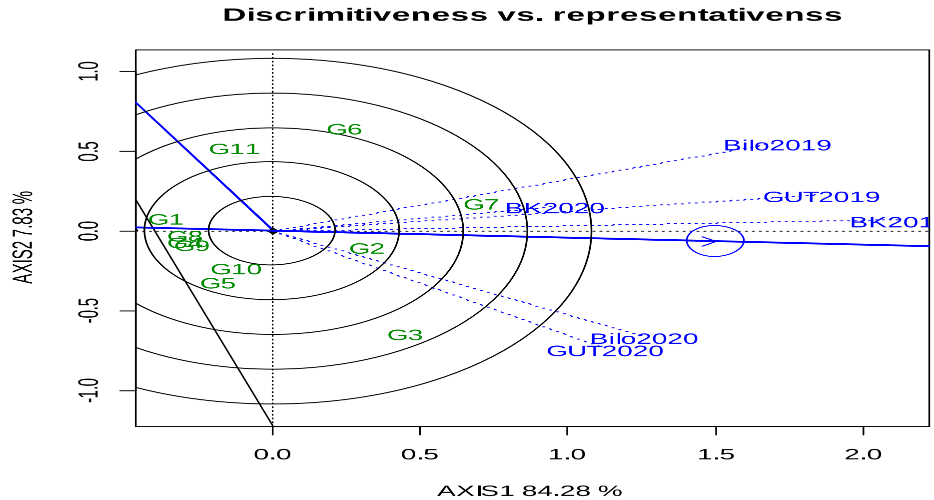


Fig.1. GGE bi-plot showing the ranking of test environment relative to the ideal test environments (a) and relative to the best genotypes (b).

The GGE biplot (Fig. 3) indicates the best performing genotype(s) for specific environment and the group of environments. In general, AMMI, GGE biplot and Eberhart and Russell model analysis results confirmed that G7, G3 and G2 were stable and high yielding genotypes and were therefore, selected and proposed to Variety Verification Trial (VVT) for possible release under wider environmental conditions of the test locations and similar agro-ecologies of the country.

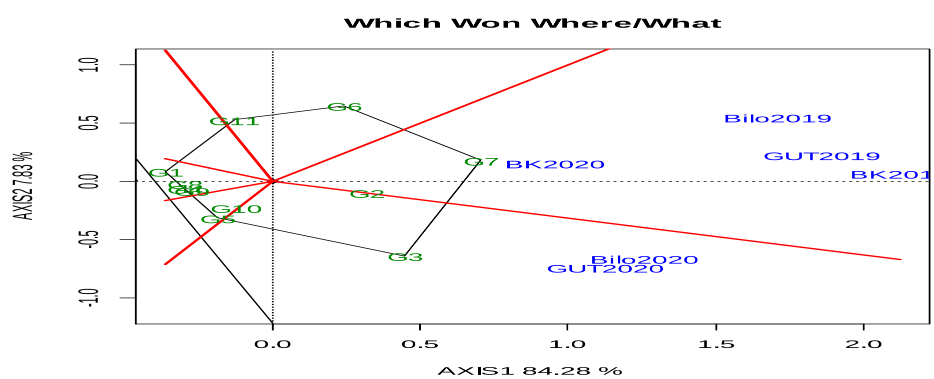


Fig.2.Which performed where view of the GGE bi-plot showing the grouping of genotypes and environments into various sectors

Conclusions and Recommendations

Based on the stability test model result, finger millet genotypes such as G7, G3 and G2 give high grain yield, better adaptability and more stable performance than all tested genotypes. The genotypes are also relatively tolerant to blast disease. A GxE interaction of 92.1% is explained by IPCA-I; followed by 7,83% for IPCA-II. The first IPCA is significant, but the remaining IPCA axes are not significant.

According to Eberhart and Russell regression model, An ideal genotype has the highest grain yield, a regression coefficient (bi) value of approximately one, and a mean square deviation from regression (s2di) value close to zero (Ebrehart and Russell,1966). Accordingly, pipeline genotypes, G7, G3 and G2 showed better stability and were widely adaptable over the environments gave high grain yield and shows a regression coefficient (bi) value of approximately one, and a mean square deviation from regression (s2di) value close to zero (Table 5) are desirable and recommended to be tested in Variety Verification trial for possible release for wider adaptability around Bako and Gute including areas with similar agro-ecology in the country. The biplot showed that G7 was in the first concentric circle, closer to IPCA stability horizontal line; followed by G3 and G2 and away from the mean vertical line. This is an indication these genotypes are the most stable and high yielders among the tested genotypes.

Acknowledgment

We would like to acknowledge Oromia Agricultural Research Institute for funding the activity. The authors are also grateful to Bako Agricultural Research Center for full support of all necessary facilities to undertake the study. Finally our great gratitude goes to all staff members of the Cereal Technology Generation team for data collection and experimental field management during the entire period of the experiment.

References

Asfaw Adugna1, Tesfaye Tesso, Erenso Degu, Taye Tadesse, Feyera Merga, Wasihun Legesse, Alemu Tirfessa, Haileselassie Kidane, Andualem Wole, Chemeda Daba 2011. Genotype-by-environment interaction and yield stability analysis in finger millet (Elucine coracana L. Gaertn) in Ethiopia. American Journal of Plant Sciences 2:408-415.

Ayalew, B. 2015. Trends, growth and instability of finger millet production in Ethiopia. Research Journal of Agriculture and Environmental Management, 4(2): 078-081.

Admassu S, Mulugela T, Dawit A (2009). Chemical composition pf local and improved finger millet (Eleusine coracana L. Gaertn) varieties grown in Ethiopia. Ethiop. J. Health Sci. 19(1): 1-18.

Central Statistical Agency (CSA). 2018. Agricultural survey report on area and production of major crops (1).

Dagnachew Lule, Kassahun Tesfaye, and Girma Mengistu. 2014. Genotype by environment interaction and grain yield stability analysis for advanced triticale (x. triticosecale wittmack) genotypes in western Oromia. Ethiopian Journal of Science 37(1):63–68.

Eberhart, S.A. and Russell, W.A. 1966. Stability parameters for comparing varieties. Crop Science 6:36– 40.

Ezeaku, I.E., Angarowai I.I., Aladele S.E. and Mohammed S.G. 2014. Genotype by Environment interactions and phenotypic stability analysis for yield and yield components in parental lines of pearl millet (pennisetum glaucum [L]R.Br). African Journal of Agricultural Research 9(37): 2827-2833

Gauch, H.G. and Zobel, R.W. 1996. AMMI analysis of yield trials. pp. 85-122. In: Genotype by environment interaction.

Kebede, D., Dagnachew, L., Girma, M., Kassa, M.., Chemeda, B., Girma, Ch. and Gudeta, B. 2019. Genotype by environment interaction and grain yield stability analysis for black seeded finger millet (Eleusine coracana (L.) Gaertn) genotypes from Western Oromia. Ethiopian Journal of Crop Science 6(1):119-133.

Tesfaye K, Mengistu S (2017). Phenotypic characterization of Ethiopian finger millet accessions (Eleusine coracana (L.) Gaertn), for their agronomically important traits. Agric. Env., 9 (2017) 107-118 DOI: 10.1515/ausae-2017-0010

Yan, W. and Tinker, N.A. 2006. Biplot analysis of multi-environment trial data: Principles and applications. Canadian Journal of Plant Science 86:623–645

Yan,W. and Tinker, N.A. 2005. An integrated biplot analysis system for displaying, interpreting, and exploring genotype by environment interaction. Crop Science 45: 1004-1016.

Yan, W. and Hunt, L.A. 2001. Interpretation of genotype x environment interaction for winter wheat yield in Ontario Crop Science 41: 19-25

Yan, W., Kang, B.M. Woods, S. and Cornelius, P.L. 2007. GGE biplot vs AMMI analysis of genotype by environment data. Crop Science 47:643-655.

Yan, W. 2002. Singular value partitioning for biplot analysis of multi-environment trial data. Agronomy Journal 4:990–996.

Yan,W. 2001. GGE Biplot-A Windows application for graphical analysis of multienvironment trial data and other types of two-way data. Agronomy Journal 93:1111- 1118.

Yuksel Kaya, Palta, C. and Taner, S. 2002. Additive main effects and multiplicative interaction ns analysis of yield performances in bread wheat genotypes across environments. Turk Journal of Agriculture and Forestry 26:275–279.

Zewdu A, Fekede G, Mideksa B (2018). Pre-Scaling up of Improved Finger Millet Technologies: The Case of Daro Lebu and Habro Districts of West Hararghe Zone, Oromia National Regional State, Ethiopia. Int. J. Agri. Educ. Exten. 4(2): 131-139.

Registration of "Jarso" Tef [Eragrostis tef (Zucc.)] Variety

[1]*Girma Chemeda, [1]Chemeda Birhanu, [1]Kebede Desalegn, [1]Gudeta Bedada, [1]Magarsa Dabala, [1]HailuFeyisa, [1]Geleta Gerema, [1]Magarsa Kebede, Meseret Tola and [1]Fufa Ambasa
[1]BakoAgricultural Research Center, P.O.Box 3, Bako Ethiopia.
. *Corresponding author: girmachemeda@yahoo.com

Abstract

The name Jarso was given to tef [Eragrostis tef (Zucc.)] variety with the pedigree of RIIL No.76B which was developed by Bako Agricultural Research Center. Jarso was evaluated together with sixteen pipelines genotypes and the standard check (Dursi) and local check in regional variety trial at three locations (Arjo, Gedo and Shambu) for two consecutive years (2018/19 and 2019/20). The combined analysis of variance revealed highly significant ($p<0.01$) difference among genotypes for plant height, panicle length, lodging % and grain yield (kg ha-1) and significant ($p<0.05$) for days to heading. Genotype and Genotype by Environment interaction (GGE) biplot analysis revealed that Jarso (RIIL No.76B) was the most stable and high yielding variety (2278.97 kg ha-1) with 26.62% yield advantage over the standard check, Dursi (1799.81 kg ha-1), tolerant to lodging and thus was released in 2021 for the highlands of Arjo, Gedo, Shambu and similar agro-ecologies.

Keywords:Bi-plot, Genotype and Genotype by Environment Interaction (GGE)

Introduction

Tef is an indigenous Ethiopian cereal, extensively cultivated on about 3 million hectares annually (CSA, 2018), and serving as staple food for over 70 million people. Tef has an attractive nutritional profile, being high in dietary fiber, iron, calcium and carbohydrate (Hager et al., 2012). Besides, it has high level of phosphorus, copper, aluminum, barium, thiamine and excellent composition of amino acids essential for humans (Abebe et al., 2007). The straw (chid) is an important source of feed for livestock. Tef is also a resilient crop adapted to diverse agro ecologies with reasonable tolerance to both low (especially terminal drought) and high (water logging) moisture stresses. Tef, therefore, is useful as a low-risk crop to farmers due to its high potential of adaptation to climate change and fluctuating environmental conditions (Balsamo et al., 2005). Because of its gluten-free proteins and slow release carbohydrate constituents, tef is advocated and promoted as health crop at global level (Spaenij Dekking et al., 2005). Inadequate research investment to improvement of the crop is one among the major tef productivity constraints. Therefore, the objective of this activity was to evaluate and release high yielding, lodging and diseases tolerant variety for tef growing areas of western parts of the country

Varietal origin and evaluation. Initially Jarso was developed through crossing made between mutant tef inbred lines (GA-10-3) and quncho tef variety (DZ-Cr-387) after stringent selections to eight generations as a result, Jarso was developed as a recombinant inbred line through an F2 derived single-seed descent method. A total of 16 tef genotypes originally introduced from Debre Zeit Agricultural Research Center were evaluated at multi location (Shambu, Gedo and Arjo sub-sites) in 2018/19 and 2019/20 to identify stable high yield variety with other desirable traits.

Jarso (RILLNo.76B) gave the highest grain yield (2278.97kg ha-1) followed by RILL No.46 (2155.71 kg ha-1) and RILL No.43A (2028.68 kg ha-1). The standard check Dursi gave 1799.81 kg ha-1. Besides, Jarso showed stable performance over the six environments (year by location). The three genotypes, RILL No.76B (Jarso), RILL No.46 and RILL No.43A gave above 10 percent yield advantage and preferable desirable traits over the standard check and thus selected and evaluated against local & standard checks in variety Verification trial at Shambu, Gedo and Arjo sub site and on farmers field during 2018/19 and 2019/20 (Table 1).

Agronomic and Morphological Characteristics

Jarso variety is well adapted to the highlands of Western Oromia and has an average plant height of 94.28 cm and maturity date of 134.22 days. The variety has high tillering capacity, high shoot biomass (12.74 t ha-1) and grain yield (2278.97 kg ha-1). The caryopsis color of the variety is very white with thousand seed weight of 0.26 gram and It has variegated (yellow + red) lemma color, purple anther color and loose panicle form (Table 1, 2 and 3).

Yield Performance

The average grain yield of Jarso combined over locations and years were 2278.97 kg ha-1 , which is higher than Dursi (standard check),1799.81 kg ha-1 . Under research field, Jarso gave grain yield of 2278.97 kg ha-1 while on farmers' field it ranges from 2242-2571 kg ha-1

Table 1. Mean grain yield across years and Locations

Genoty	Shambu		Gedo		Arjo		mean	%yd	
	2018	2019	2018	2019	2018	2019	GY Kg/ha	advata ge	Ran k
RIL 76	2422.7	2365	2305.8	2288	2112	2180	2278.97	26.62	1
RIL 46	2203.2	2234	2160	2233	2052	2053	2155.71	19.77	2
RIL 43	2112.5	2105	2045.8	2046	1884	1978	2028.68	12.72	3
RIL 66	1955.8	1976	1977.5	2068	1849	1959	1964.29	9.14	4
Dursi	1865.8	1864	1812.2	1762	1746	1749	1799.81		5
RIL 65	1540.8	1568	1874.2	1529	1676	1624	1635.43		6
RIL 80	1813.2	1317	1985.2	1373	1698	1328	1585.62		7
RIL 44	1726.7	1490	1575.8	1423	1718	1520	1575.8		8
RIL53	1637.8	1390	1784.2	1336	1628	1417	1532.19		9
RIL 74	1462.5	1521	1693.3	1418	1606	1428	1521.44		10
RIL72	1525.8	1322	1724.2	1380	1685	1387	1503.97		11
RIL52	1698.3	1142	2079.17	1115	1802	1111	1491.38		12
L.Ck	1607.5	1251	1759.5	1323	1720	1257	1486.15		13
RIL 61	1576.7	1367	1775	1353	1630	1203	1483.99		14
RIL49	1575.8	1231	1864.17	1292	1663	1264	1481.76		15
RIL85	1585.0	1355	1726.67	1332	1583	1276	1476.28		16
RIL91	1693.3	1224	1700	1256	1520	1301	1449		17
RIL 7	1525.8	1154	1908.33	1179	1388	1122	1379.69		18
Mean	1751.6	1549	1875	1539	1720	1508			
LSD	143.5	359.	162.7	361	237.8	377			
CV	4.9	14	5.23	14	8.3	15.07			
F-test	***	***	***	***	***	***			

Note: GY=grain yield, RIL= recombinant inbred line, ***= highly significant, LSD= least significant difference, CV= coefficient of variation

Table 2. Mean Agronomic Traits Across years and Locations									
Genotype	DH	DM	PH	ET	PL	LD	ST	LR	SBM
RIL NO 76B	71.11	134.22	94.28	4.22	36.31	2.51	2.22	1.93	12.74
RIL NO.46	71.11	136.06	94.81	3.97	35.36	2.91	2.67	1.93	7.86
RIL NO.43A	71	135.17	93.24	4.67	34.64	2.7	3.78	1.87	7.76
RIL NO.66	72.5	136.72	99.32	3.9	37.98	3.24	2.67	3.03	7.24
Dursi (check)	72.11	135	102.23	4.49	39.31	2.31	1.67	1.69	7.64
RIL NO.65	70.17	136.56	99.13	4.13	37.44	2.95	2.22	2.67	6.69
RIL NO.80	70.17	135.94	97.87	3.96	35.68	3.03	3	2.53	5.79
RIL NO.44	73.28	134.39	97.98	4.35	36.72	2.83	2.78	2	7.54
RIL NO.53	71.06	136.67	96.57	3.86	35.98	3.17	2	3.37	6.71
RIL NO.74	68.44	137.28	94.9	4.21	35.63	3.67	2.89	2.29	6.29
RIL NO.72	71.28	136.61	98.13	3.66	37.49	3.61	2.67	2.85	6.82
RIL NO.52	71.11	135.17	99.54	3.97	38.11	3.27	2.44	2.43	6.38
Local check	71	134.5	97.48	4.12	37.2	3.52	2.78	2.5	6.82
RIL NO.61	68.11	132.11	87.64	3.89	30.79	2.94	2.67	1.98	6.07
RIL NO.49	71.22	137.5	99.44	3.62	38.58	3.24	2.56	2.29	7.25
RIL NO.85	72.5	134	95.57	4.03	36.79	3	2.89	2.23	6.36
RIL 91A Check	69.5	133.22	90.78	4.16	33.67	2.58	3	2.3	6.39
RIL NO.73	73.44	136.61	94.06	3.69	35.17	3.44	3	3.16	6.36
Grand Mean	71.06	135.43	96.28	4.05	36.27	3.05	2.66	2.39	7.15
LSD	3.19	1.41	3.96	0.41	1.67	0.61	0.39	0.64	3.45
CV	5.44	1.53	5.31	13.18	6.95	14.3	22.03	22.41	69.74
F.test	*	***	***	***	***	***	***	***	ns

Note: *= significant, ***= highly significant, ns= none significant, RILL= recombinant inbred line, DH= days to heading, DM= days to maturity, plant height, ET= effective tiller, PL= panicle length, LD= lodging %, SBM= shoot biomass, ST= Stand %, LR =leaf rust, LSD=least significant difference, CV= coefficient of variation

Stability performance

The GGE biplot explained 97.0% (PC1=91.5 and PC2=5.5 %) of the total variations (Figure 1).In the polygon view, Jarso found farthest away from the origin having the highest grain yield in its respective sector and closer to IPCA stability horizontal line (Figure 1). Jarso gave highest grain yield at Arjo, shambu and Gedo during 2018.

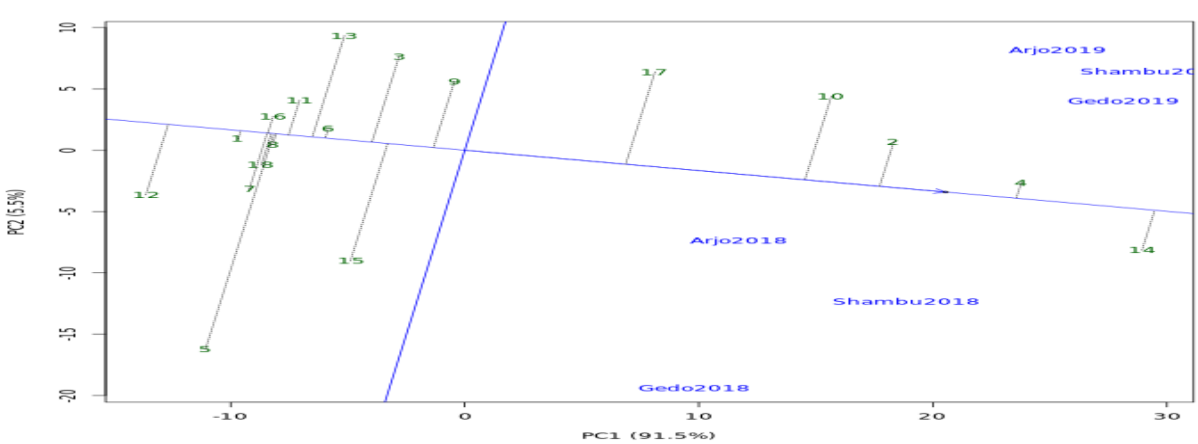


Figure1. GGE bi-plot: mean vs. stability

Table 3.Agronomical & Morphological Characteristics of Jarso tef Variety

Variety name: Jarso (RIL No.76B)

Agronomic and Morphological Characteristics

Adaptation area: Shambu, Gedo, Arjo, and similar agro ecologies of western highlands of Oromia, Ethiopia.

Altitude: (masl) 1750-2250

Rainfall (mm): 1800-2000

Seeding rate (kg/ha): 10 for row & 15 broad casting

Spacing (cm): 20cm between rows

Planting date: Early July

Fertilizer rate: 100 kg ha-1NPS at planting & split application of 50 kg ha-1 UREA

Days to heading: 71.11 days

Days to maturity: 134 days

100 seed weight (g): 0.30(g)

Plant height (cm): 94.28

Panicle color: variegated (yellow + red) lemma color, purple anther color, loose panicle form

Seed color: Very white

Crop pest reaction: Tolerant to major tef diseases and acidic soils of western Oromiya

Grain yield (qt/ha):

On farmers field: 2242-2571 kg/ ha

On-station: 2278.97 kg/ha.

Shoot Bio-mass: 12.74 t/ha

Year of release: 2021

Breeder/ maintainer: BARC/IQQO

Conclusions and recommendations

The new tef variety Jarso was released for its stable high grain yield and other desirable traits, wider adaptability, attractive seed color (very white) and tolerant to tef leaf rust. This new variety was released in 2021 and recommended for production areas of Shambu, Gedo, Arjo and similar agro-ecologies.

Acknowledgment

Oromia Agricultural Research Institute and Bako Agricultural Research Center are acknowledged for fulfilling all the necessary inputs to undertake this investigation. I am also grateful to all research staffs and workers of Bako Agricultural research Center for their great contribution.

References

Abebe Y, Bogale A, Hamgidge, KM, Stoecker BJ, Bailey K, Gibson RS, (2007). Phytate, zinc, iron, and calciumcontent of selected raw and prepared foods consumed in rura Sudama, Southern Ethiopia and implication of bioavailability. J food Compo Anal.20:161-168.

Balsamo R, Willigen C, Boyko W, Farrent L (2005). Retention of mobile water during dehydration in the desiccation-tolerant grass Eragrostis. Physio Planetarium.134:336-342.

Central Statistical Agency (CSA) (2018). The federal Democratic Republic of Ethiopia. Central Statistical Agency Agricultural Sample Survey 2014/15: Report on Area and Production of Major Crops (Private peasant Holdings, Maher Season), Vol III. Addis Ababa.

Hanger AS, Wolter A, JacobF, Zannini E, Arendt EK (2012).National properties and ultera-structure of commercial gluten free flours from different botanical sources compared to wheat flours. J Cereal Sci. 56:239- 247.

Spaenij-Dekking L, Kooy-Winkelaar Y and Koning F. (2005).The Ethiopian cereal tef in celiac disease.N. Engl.J. Med. 353: 16.

Registration of "JIRRAAFI" field pea (pisum sativum L.) variety (kik Type)

Solomon Bekele[1]

[1]Bako Agricultural Research Centre, P.O Box: 03, Bako, Ethiopia, Oromia

Corresponding author: E-mail: slmnbkl092@gmail.com

Abstract

JIRRAAFI (EH05011-2) is a "KIK type" field pea variety released by Oromia Agricultural Research Institute of Bako Agricultural Research Center in 2021 after evaluated at Shambu, Gedo and Arjo in the last five consecutive years (2016-2021) with the objectives of developing good variety in terms of yield, disease resistant and other characters. JIRRAAFI variety was evaluated against fourteen field pea pipe lines and one standard check Jiidhaa in Randomized Complete Block Design with three replications at multi-location evaluations. Variety JIRRAAFI is averagely gave grain yield 2800 - 3700.6 kg ha^{-1} and 2500.4 – 3400 kg ha^{-1} on both research field and farmer's field respectively. The variety had also 10.4% yield advantages than standard check Jiidhaa (2427.3 kg ha^{-1}). The GGE - plot analysis is also showed that, JIRRAAFI field pea variety is high yielder, disease resistant and moderately resistant to major disease (Blotch, Powdery and downy mildews). Therefore, JIRRAAFI variety is officially released for Western Oromia and similar agro -ecologies.

Introduction

Field pea (Pisum sativum L.) is a cool season and an annual climbing, herbaceous plant, showing very considerable variation in form and habit. Field pea is diploid species (2n= 2x=14) belonging to the Leguminosae family, a self-pollinating crop (N. Ben- Ze'ev et al., 1973). Field pea is nutritious food staff when fully matures and they are valuable food legume in different forms particularly in Ethiopia (CSA, 2017). It is the fourth most important legume crop in Ethiopia in terms of both area and total amount of production accounts for 13% of the total grain legume production (CSA, 2017). In 2017/2018 cropping season, 220,508.39 ha of land was covered with field pea and the annual production was estimated at about 3,685,190.65 quintals in Ethiopia (Crop Variety Register, 2018). Because of filed pea production limiting factors in the world and Ethiopia, like: use of local variety, disease, aphids, lodging and shattering, the reported average yield in tha^{-1} were 1.9 tha^{-1} in the world (Rubiales et al. 2019) and 0.85 in Ethiopia (CSA 2015/2016) respectively. In Ethiopia, the annual consumption of pea seeds per person is estimated about 6-7kg. Main dishes include 'Kik wot' (split pea seeds boiled and made in to stew); its cotyledons are properly dissected and don't as sweet as shiro type one. Snacks include 'eshet' (fresh green field pea seeds either eaten raw or roasted), 'nifro' (boiled dry or fresh green pea seeds) and 'endushdush' (seeds soaked first and then roasted). In local markets white and cream colored seeds are preferred for 'kik' making, (Crop Variety Register, 2018). Bako Agricultural Research Center was released four 'kik' type field pea varieties called Gedo 1, Arjo-1, Bariso and Jiidhaa in 22010, 2005, 2005, 2017 respectively and this year (2021), field pea variety called jirraafi going to be registered as fifth in number for kik type field pea varieties with Bako Agricultural Research Center as a maintainer.

Agronomic and Morphological Characteristics

The newly released kik type field pea variety, JIRRAAFI characterized by white smooth shape. The variety has averagely 21.63 gm of hundred seed weight, 62.33 days to flowering, 125.22 days to mature and 167.07 cm of plant height. This variety also has moderately resistant to Blotch (2.66) and powdery and downy mildews (1.55) diseases. The detailed description of JIRRAAFI variety characteristics are indicated in table 1 below.

ANOVA for Kik Type Field Pea Crop Varieties

Table 1. Mean square from ANOVA for field pea kik-Type for phonology and growth traits

Source of variations	DF	Mean Squares		
		DsF %	DsM %	PH
Loc	2	322..7534722**	7270.42014**	30784.50181**
Year	1	8.0000000ns	612.50000**	4166.32347**
Trt	15	8.3027778**	19.72222**	2334.76510**
Rep	2	22.2326389**	96.35764**	877.85056ns
Loc*Trt	30	8.3979167**	5.15347ns	511.55588ns
Trt*Rep	30	8.9993056**	20.72431**	747.70641ns
Loc*Year*Trt	47	7.6453901**	26.37234**	907.98957*
Error		3.726389	3.56806	588.3293
CV (%)		3.13	1.5	14.6

Table 2. Mean squares from ANOVA for field pea Kik-Type in yield and its components.

Source of variations	DF	Mean Squares		
		NPPP	HSW	GYLD
Loc	2	431.2738889**	149.0075347**	47735648.83**
Year	1	244.5734722**	17.6517014**	42860651.81**
Trt	15	7.1169537ns	41.0611829**	867926.57*
Rep	2	14.2693056ns	12.2537847*	1388428.50*
Loc*Trt	30	6.8238148ns	4.6851273ns	441482.46ns
Trt*Rep	30	4.5032315ns	2.8617106ns	567315.01ns
Loc*Year*Trt	47	7.5802807ns	6.2321978**	1200930.29**
Error		5.638111	3.155132	404491.6
CV (%)		24	8.4	16

Yield Performance

The pooled grain yield performance of JIRRAAFI field pea variety is 2680.1 kg ha^{-1} and the variety was comparatively well performed both at Gedo (3106.9 kg ha^{-1}) and Shambu (3177.1 kg ha^{-1}); in contrast, lowly performed at Arjo (1756.4 kg ha^{-1}); the performance of the Arjo location has been raised from poor soil fertility of the test location. Generally, the variety has 10.4% yield advantages than standard check Jiidhaa. The detailed performances of the evaluated genotypes are listed in the following table 3.

Table. 3 Pooled Mean performance of grain yield for Field pea KikType

S.N	Genotypes	Locations			Pooled mean	
		Arjo	Gedo	Shambu	GYLD	Y.Ad.
1	EH07002-1	1373.9a	3206.3ba	2989.5ba	2523.2	4.0
2	EH07006-5	1677.1a	3185.9ba	2778.1bac	2547.0	4.9
3	EH07014-1	1651.7a	2630.7cd	3029.3ba	2437.2	0.4
4	EH07014-2	1322.7a	3355.4a	2484.6bac	2387.6	-1.6
5	EH08037-1	1644.9a	2124.4d	2216.6bac	1995.3	-17.8
6	EH08037-3	1695.6a	2545.5cd	3041.3ba	2427.5	0.0
7	EH08041-1	1445.9a	2948.3bcd	2426.2bac	2273.5	-6.3
8	EH05011-2	1756.4a	3106.9bc	3177.1a	2680.1	10.4
9	EH05030-3	1696.8a	2962.4bcd	3027.2ba	2562.1	5.6
10	EH06001-2	1463.7a	3064.3bc	2683bac	2403.7	-1.0
11	EH06002-4	1771.1a	2935.7bcd	3225.3a	2644.0	8.9
12	EH06003-1	1695.7a	3166.8ba	3116.8a	2659.8	9.6
13	EH06014-1	1627a	2691cd	3115.5a	2477.8	2.1
14	EH06015-1	1407.6a	2840.4c	2048.8c	2098.9	-13.5
15	EH06030-6	1265.7a	2332cd	2492.9bac	2030.2	-16.4
16	Jiidhaa	1788.3a	2923.4bcd	2570.1bac	2427.3	0.0
Grand Means		1580.3	2876.2	2776.4	2411	
Sig. Dif.		Ns	*	**	*	
CV (%)		21	23	20		

Table 4. Over years & Locations Pooled Mean performance for some characters of Field pea

S.N	Genotypes	DsF	DsM	PH	NPPP	HSW
1	EH07002-1	62.11	125.88	174.58	9.34	20.71
2	EH07006-5	60.94	125.72	157.1	9.54	22.15
3	EH07014-1	61.27	123.33	166.67	8.98	23.32
4	EH07014-2	61.88	124.38	142.9	8.92	21.16
5	EH08037-1	62.61	126.11	190.12	9.55	21.83
6	EH08037-3	61.55	125.33	175.63	10.38	21.57
7	EH08041-1	61.27	125.05	165.61	10.24	20.16
8	EH05011-2	62.33	125.22	167.07	9.41	21.63
9	EH05030-3	62.33	125.22	158.51	9.71	17.88
10	EH06001-2	60.55	123.44	152.98	9.93	20.47
11	EH06002-4	61.55	124.61	173.93	9.42	19.62

12	EH06003-1	61.33	125.44	160.82	9.71	21.02
13	EH06014-1	61.05	124.94	165.37	11.25	21.70
14	EH06015-1	61.77	122.55	159.02	9.41	19.62
15	EH06030-6	60.05	123.27	161.88	10.63	23.73
16	Jiidhaa	61.22	124.33	180.22	10.37	19.12
Grand Means		61.49	124.68	165.77	9.80	20.98
LSD		1.27	1.24	15.96	1.56	1.16
Sig.Lev.		*	**	**	*	**
CV (%)		3.13	1.5	14.6	24	8.4

Table 5. Pooled means of field pea Kik type diseases scored in 2019 cropping season in 1-9 scale for Gedo, Shambu and Arjo Locations

	Accessions	Field Pea Diseases		
		Downy Mildews	Powdery Mildews	Blotch
1	EH07002-1	1.77	1.11	2.77
2	EH07006-5	1.66	1.44	2.44
3	EH07014-1	1.66	1.44	2.33
4	EH07014-2	1.33	1.11	2.55
5	EH08037-1	1.77	1.44	2.33
6	EH08037-3	2	1.66	2.33
7	EH08041-1	1.44	1.11	2.44
8	EH05011-2	1.55	1.55	2.66
9	EH05030-3	1.33	1.33	2.05
10	EH06001-2	1.11	1.11	2.11
11	EH06002-4	1.44	1.11	2.55
12	EH06003-1	1.44	1.22	2.22
13	EH06014-1	2	1.55	2.44
14	EH06015-1	1.33	1.33	2
15	EH06030-6	2.22	1.66	2.66
16	Jiidhaa (Ch.)	1.44	1.11	2.66
	Grand mean	1.6	1.3	2.4
	CV (%)	18	23	15
	LSD (5%)	0.57	0.54	0.57
	F - value	**	Ns	Ns

GGE-Biplot Analysis

The Ranking of Genotypes Based on Yield and Stability

The GGE-biplot analysis of kik type field pea tested varieties showed that, eight genotypes : EH05011-2, EH06003-1, EH06002-4, EH05030-3, EH07006-5, EH07002-1, EH06014-1 and EH07014-1 have better yield performance than standard check Jiidhaa with the score of 2680.1 (10.4), 2659.8 (9.6), 2644 (8.9), 2562.1 (5.6), 2547 (4.9), 2523.2 (4), 2477.8 (2.1) and 2437.2 (0.4) in both kg ha^{-1} and percentage respectively. Both PC1 and PC2 were separated based on their scored for sixteen kik type field pea tested varieties in the study area. The primarily use of GGE-biplot is grading the tested genotypes for the locations. PC1 indicated the mean performance of the varieties while PC2 indicated the G X E associated with each genotype which is the measure of stability or instability (Yan et al., 2000; Yan, 2002). Genotypes having PC1 > 0 were recognized as high yielding while those genotypes having PC1 score < 0 were identified as low yielding, (Kaya et al. 2006). A JIRRAAFI variety (EH05011-2) or treatment 8 is more stable than other tested field pea varieties and gives higher yield and environment Gedo-2018 season is the best year for the production of field pea crop.

Grain yield stability of the 16 treatments was evaluated across three environments for two consecutive years. The result showed that, EH05011-2 candidate variety was placed nearest to the first circle of GGE bi plot of the diagram than standard check jiidhaa and other tested genotypes. This showed that, EH05011-2 candidate variety had better stability and high yielder than jiidhaa and the rest of the genotypes. The stability and GGE- biplot diagrams are sketch below.

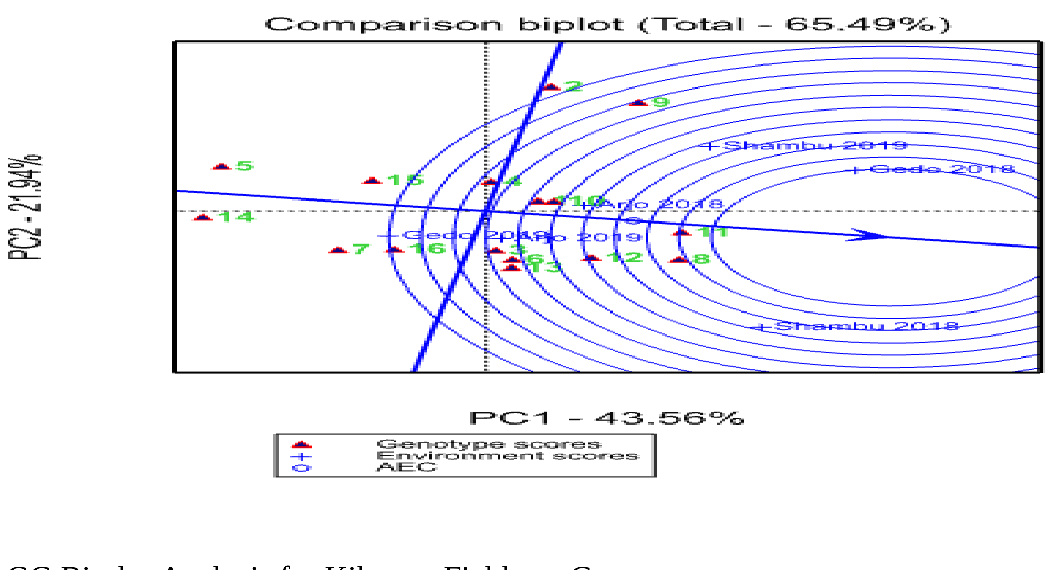


Fig 1. GG Bi-plot Analysis for Kik type Field pea Genotypes

Conclusion

JIRRAAFI field pea variety was widely adapted, stable and showed high yield performance than the standard check and the other tested pipeline field pea genotypes. Generally, GGE biplot analysis results revealed that *JIRRAAFI (*EH05011-2*)* is a stable and high yielding (2680.1 kg ha^{-}

[1]) field pea variety with 10.4% yield advantage over the best standard check, jiidhaa (2427.3 kg ha^{-1}) and also tolerant to major diseases. Therefore, it was officially released for wider production in west Oromia and areas with similar agro ecologies.

Table 6. Agronomic and morphological characteristics of jirraafi Field pea variety

1	Variety	EH05011-2
2	Agronomic & morphological Characters	
	2.1.Adaption area:	Shambu, Gedo, Arjo and similar agro ecologies
	Altitude(ma.s.l	1800-2600
	Rain fall (mm)	- 1000-1300
	2.2. Fertilizer rate (kg/ha):	
	NPS	100 kg ha^{-1}
	2.3.Planting date	Late June
	2.4. Seed rate (kg/ha)	150-180 kg ha^{-1}
	2.5.Spacing (cm)	20 x 5 cm (Inter and Intra row Spacing)
	2.6. Days to flowering	60-66
	2.7. Days to maturity	123-127
	2.8.Plant height (cm)	163-168
	2.9.No. of pods per plant	9-17
	2.10.Seed shape and character	smooth and white
	2.11.Seed color	White
	2.12. Cotyledon color	White
	2.13 Flower color	White
	2.14. 100 seed weight (g)	19-22
	2.15.Crop pest reactions	Moderately Resistant
	2.16.Yield (qt/ha)	
	· Research field	28-37.6
	· Farmers field	25.4-34
3	Year of release	2021
4	Breeder seed maintainer	OARI (BARC)

Acknowledgement

The primary appreciation of the author goes to Oromia Agricultural Research Institute for funding the project. Bako Agricultural Research center was acknowledged for the Coordination of the Research Project and logistic facilitates during field trials at respective locations. Pulse technology generation research team members of Bako Agricultural research center is highly praised for their contribution during field experimentations.

Reference

CSA (Central Statistical Agency), "Report on area and production of major crops (private peasent holdings, meher season),"Statistical Bulletin, vol. 532, pp. 15-17, 2017.

CSA (Central Statistical agency), Agricultural Sample Survey. 2015/2016 Volume I Report on Area and Production of Major Crops, Statistical Bulletin, Addis Ababa, Ethiopia, 2015.

CVR (2018) Crop Variety Register Book

N. Ben-Ze’ev and D. Zohary, "Species relationships in the genus," pp. 321-322, 1973

Rubiales D, González Bernal MJ, Warkentin T, Bueckert T, Vaz Patto MC, McPhee K, McGee R, Smýkal P (2019) Advances in pea breeding. In: Hochmuth G (ed) Achieving.

Registration of "KUULLEE" field pea (pisum sativum L.) variety (Shiro Type)

Solomon Bekele[1]

[1]Bako Agricultural Research Centre, P.O Box: 03, Bako, Ethiopia, Oromia

Corresponding author: E-mail: slmnbkl092@gmail.com

Abstract

KUULLEE (EH08027-2) field pea variety is an improved variety selected from eleven pipe lines including standard check LAMMIIF during the trial was undertaken at three test locations (Gedo, Shambu and Arjo) in randomized Complete Block Design with three replications. The study was conducted with the objectives of releasing the variety which is high yielder, disease resistant and stable than the other competent genotypes from 2016-2020 for five consecutive years. The accessions were originated first from field pea center of Excellence (Holetta Agricultural Research Center). The new variety, KUULLEE (2795.23 kg ha^{-1}) was 10.15% yield advantages than the standard check Lammiif (2537.5 kg ha^{-1}). KUULLEE variety is mainly used for "SHIRO type". The GGE revealed that, EH08027-2 or KUULLEE variety is high yielder, stable and moderately resistant to Blotch, Downy Mildews and Powdery Mildews field pea disease. Therefore, KUULLEE variety was officially released in 2021 for Western Oromia and similar agro-ecologies.

Key Words: Field pea, GGE-biplot, KUULLEE, Registration

Introduction

Field pea (Pisum sativum L.), a legume crop, belongs to the Leguminosae family and contains a high amount of protein including amino acids, especially lysine (Nawab etal, 2008). Field pea (Pisum sativum L.) is one self-pollinated diploid (2n=14, x = 7) annual of the most important annual cool season pulse crop and is valued as high protein food K. McKay., *et al* 2003. It is one of the most important pulse crops produced in the high land of Ethiopia and the world by small holder farmers. Due to field pea rich in protein, significantly used as animal meat products in the most of developing countries including Ethiopia and also used in the cropping systems for soil fertility improvement H. Kandel et al., 2016. In 2017/2018 cropping season, 220,508.39 ha of land was covered with field pea and the annual production was estimated at about 3,685,190.65 quintals in Ethiopia (Crop Variety Register, 2018). Because of filed pea production limiting factors in the world and Ethiopia, like: use of local variety, disease, aphids, lodging and shattering, the reported average yield in tha^{-1} were 1.9 tha^{-1} in the world (Rubiales et al. 2019) and 0.85 in Ethiopia (CSA 2015/2016) respectively. In Ethiopia, the annual consumption of pea seeds per person is estimated about 6-7kg. Main dishes include 'shiro wot' (split pea seeds ground and made in to stew), mainly don't dissected rather disintegrated to the powder and sweets, and Snacks include 'eshet' (fresh green field pea seeds either eaten raw or roasted), 'nifro' (boiled dry or fresh green pea seeds) and 'endushdush' (seeds soaked first and then roasted). In local markets, grey colored field pea seeds preferred for 'shiro' making (Crop Variety Register, 2018). Bako Agricultural Research Center was released one 'shiro' type field pea variety called Lammiif in 2017; and this year, (2021) kuullee variety will be registered as the second shiro type field pea variety with Bako Agricultural Research Center as a maintainer.

Varietal Origin and Evaluation

The source of KUULLEE (EH08027-2) field pea variety was from Holetta Agricultural Research Center. Kuullee variety was evaluated along side with 9 field pea pipe lines and one standard check Lammiif for two consecutive years at RVT stage (2018 and 2019) at Arjo, Gedo and Shambu research stations.

Agronomic and Morphological Characteristics

The newly released shiro type field pea variety, KUULLEE characterized by brown irregular shape. The variety has averagely 17.27 gm of hundred seed weight, 63.16 days to flowering, 122.61 days to mature and 168.53 cm of plant height. This variety also has moderately resistant to Blotch (2.77) and powdery and downy mildews (1.77) diseases. The detailed description of KUULLEE variety characteristics are indicated in table 1 below.

ANOVA for Shiro Type Field Pea Crop Varieties

Table 1. Mean square from ANOVA for field pea Shiro-Type for phonology and growth traits

Source of variations	DF	Mean Squares		
		DsF %	DsM %	PH
Loc	2	4020.954545**	8146.09596**	1726.70470**
Year	1	0.045455ns	165.45960**	22381.04045**
Trt	10	25.492929ns	13.63737**	568.38122ns
Rep	2	32.772727s	6.68687ns	82.51833ns
Loc*Trt	20	30.798990ns	17.15707**	522.21925ns
Trt*Rep	20	38.167172ns	17.14798**	324.75022ns
Loc*Year*Trt	32	16.368371**	8.30335**	1301.51858**
Error	110	19.81616	4.68182	675.3229
CV (%)		7	1.77	15.16

Table 2. Mean square from ANOVA for field pea Shiro-Type for yield and its components.

Source of variations	DF	Mean Squares		
		NPPP	HSW	GYLD
Loc	2	185.9000505**	76.5545960**	31585187.62**
Year	1	11.5879293ns	8.8244444ns	11474775.81**
Trt	10	4.3929394ns	46.2926061**	646661.11**
Rep	2	1.5491414ns	4.5096990ns	421110.63ns
Loc*Trt	20	4.3256061ns	5.7183182ns	421769.88ns
Trt*Rep	20	7.8096970ns	5.4496212ns	175550.18ns
Loc*Year*Trt	32	11.3187626**	9.4221528**	793029.63**
Error		4.990374	3.735404	302861.3
CV (%)		23	9.87	21

Yield Performance

The pooled grain yield performance of KUULLEE field pea variety is 2795.23 kg/ha and the variety was mainly well performed at Gedo (3769 kg/ha) followed by Shambu (2960.5 kg/ha) and finally 1656.2 kg/ha at Arjo; this was primarily raised from soil fertility status difference of the three test locations. Generally, the variety has 10.15% yield advantages than standard check Lammiif.

S.N	Genotypes	Arjo	Gedo	Shambu	GYLD	Y. Adv.
1	EH08013-2	2106.8a	3017.1bc	2958.3a	2694.07	6.17
2	EH08027-1	2009.2ab	2996.7bc	3094.1a	2700.00	6.4
3	EH08027-2	1656.2abc	3769a	2960.5a	2795.23	10.15
4	EH08031-1	1304.4c	2458.4c	2656a	2139.60	-15
5	EH08033-1	1671.1abc	2679.5bc	2919.5a	2423.37	-4.4
6	EH08034-2	1802.7abc	2735.5bc	2507.8a	2348.67	-7.4
7	EH04044-1	1342.9bc	3005.6bc	3062.7a	2470.40	-2.6
8	EH04047-1	1783.2abc	2939bc	3223.7a	2648.63	4.3
9	EH06029-3	1771.1abc	2891.9bc	2797.6a	2486.87	-1.9
10	EH06032-3	2121a	3241.8ab	2623.4a	2662.07	4.9
11	Lammiif	1598abc	3327.7ab	2687a	2537.5	0
Grand Means		1742.4	3005.7	2862.8	2536.9	
Sig.Lev.		*	**	Ns	*	
CV (%)		22	18	20	21	

Table 4. Over years & Locations Pooled Mean performance for some characters of Field pea Shiro Type

S.N	Genotypes	DsF	DsM	PH	NPPP	HSW
1	EH08013-2	64.11	122.16	177.1	9.63	19.1
2	EH08027-1	63.27	121.61	171.65	9.7	18.23
3	EH08027-2	63.16	122.61	168.53	10.18	17.27
4	EH08031-1	62.94	122.55	179.61	9.27	22.6
5	EH08033-1	63.38	121.33	174.17	9.92	19.56
6	EH08034-2	61.16	121.77	168.29	10.27	17.74
7	EH04044-1	62.72	121.44	179.67	9.31	20.7
8	EH04047-1	63.44	123.11	163.33	10.22	20.66
9	EH06029-3	61.55	120.16	170.05	9.17	18.41
10	EH06032-3	60.66	120.83	166.86	10.06	20.03
11	Lammiif	64.38	121.00	165.54	8.8	20.95
Grand Means		62.8	121.69	171.35	9.68	19.57
LSD		2.94	1.42	17.167	1.47	1.27
Sig.Lev.		*	*	Ns	*	**
CV (%)		7	1.77	15.16	23	9.87

Table 5. Pooled means of field pea Shiro type diseases scored in 2019 cropping season in 1-9 scale for Gedo, Shambu and Arjo Locations

Accessions		Field Pea Diseases		
		Downy Mildews	Powdery Mildews	Blotch
1	EH08013-2	1.88	1.55	2.22
2	EH08027-1	2	1.44	2.55
3	EH08027-2	1.77	1.77	2.77
4	EH08031-1	1.88	1.22	2.33
5	EH08033-1	2.44	1.88	2.88
6	EH08034-2	2.22	1.66	2.55
7	EH04044-1	1.88	1.33	2.88
8	EH04047-1	2.11	1.44	2.77
9	EH06029-3	1.55	1.44	2.88
10	EH06032-3	2	1.66	2.33
11	Lammiif (Check)	1.55	1.33	2.55
Grand mean		1.93	1.52	2.6
CV (%)		17	18	16
LSD (5%)		0.64	0.53	0.65
F - value		Ns	Ns	Ns

GGE-Biplot Analysis

The Ranking of Genotypes Based on Yield and Stability

The GGE-biplot analysis of shiro type field pea tested varieties showed that, four genotypes: EH08027-2, EH08027-1, EH08013-2 and EH04047-1 have better yield performance than the standard check, lammiif with 2795.25 (10.15%), 2700 (6.4%), 2694.07 (6.17%) and 2648.63 (4.3%) in both kg ha^{-1} and percentage respectively. Both PC1 and PC2 were separated based on their scored for eleven shiro type field pea tested varieties in the study area.

The primarily use of GGE-biplot is grading the tested genotypes for the locations. PC1 indicated the mean performance of the varieties while PC2 indicated the G X E associated with each genotype which is the measure of stability or instability (Yan et al., 2000; Yan, 2002). Genotypes having PC1 > 0 were recognized as high yielding while those genotypes having PC1 score < 0 were identified as low yielding, (Kaya et al. 2006). A KUULLEE variety (EH8027-2) or treatment 3 is more stable than other tested field pea varieties and gives higher yield and environment Gedo-2018 season is the best year for the production of field pea crop.

Grain yield stability of the 11 treatments was evaluated across three environments for two consecutive years. The result revealed that, EH08027-2 candidate variety was placed nearest to the first circle of GGE bi plot of the diagram than standard check Lammiif and other tested genotypes. This showed that, EH08027-2 candidate variety had better stability and high yielder than Lammiif and the rest of the genotypes. The stability and GGE- biplot diagrams are sketch below.

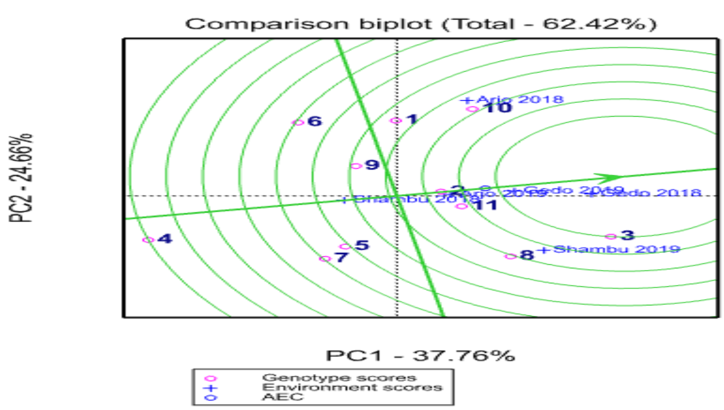


Fig 1. GG Bi-plot Analysis for shiro type field pea genotypes

Conclusions and Recommendations

Classification of field pea varieties depend on purpose of utilization is very use full to boost the satisfaction of the users in one or other case on the same commodity. *KUULLEE* field pea variety was widely adapted, stable and showed high yield performance than the standard check and the other tested pipeline field pea genotypes. Generally, GGE biplot analysis results revealed that *KUULLEE (*EH08027-2*)* is a stable and high yielding (2795.25 kg ha^{-1}) field pea variety with 10.15% yield advantage over the best standard check, Lammiif (2537.5 kg ha^{-1}) and also tolerant to major diseases. Therefore, it was officially released for wider production in west Oromia and areas with similar agro ecologies.

Table 6. Agronomic and morphological characteristics of Kuullee Field pea variety

1	Variety	EH08027-2
2	Agronomic & morphological Characters	
	2.1.Adaption area:	Shambu, Gedo, Arjo and similar agro ecologies
	Altitude(ma.s.l	1800-2600
	Rain fall (mm)	- 1000-1300
	2.2. Fertilizer rate (kg/ha):	
	NPS	100 kg ha^{-1}
	2.3.Planting date	Late June
	2.4. Seed rate (kg/ha)	100-150 kg ha^{-1}
	2.5.Spacing (cm)	20 x 5 cm (Inter and Intra row Spacing)
	2.6. Days to flowering	57-65
	2.7. Days to maturity	120-125
	2.8.Plant height (cm)	160-170
	2.9.No. of pods per plant	10-19
	2.10.Seed shape and character	Irregular and brown
	2.11.Seed color	Brown
	2.12. Cotyledon color	Gray
	2.13 Flower color	Red
	2.14. 100 seed weight (g)	16.5-18.5
	2.15.Crop pest reactions	Moderately Resistant
	2.16.Yield (qt/ha)	
	· Research field	29.2-37.8
	· Farmers field	24.7-36
3	Year of release	2021
4	Breeder seed maintainer	OARI (BARC)

Acknowledgement

The authors acknowledge Oromia Agricultural Research Institute for funding the project. His praise also extended to Bako Agricultural Research center for the Coordination of the Research Project and logistic facilitates during field trials at respective locations. Pulse technology generation research team members of Bako Agricultural research center is highly acknowledged for their contribution during field experimentations.

References

CSA (Central Statistical agency), Agricultural Sample Survey. 2015/2016 Volume I Report on Area and Production of Major Crops, Statistical Bulletin, Addis Ababa, Ethiopia, 2015.

CVR (2018) Crop Variety Register Book

H. Kandel, K. Mcphee, A. Akyüz et al., North Dakota Dry Pea Variety Trial Results for 2016 and Selection Guide, NDSU Extension Service, 2016

K. McKay, B. Schatz, and G. Endres, "Field pea production," In Production, vol. 1166, pp. 1–8, 2003. View at Google Scholar

Kaya, Y., Ackura and M., Taner, S. 2006. GGE-biplot analysis of multi-environment yield trials in bread wheat. Turkish Journal of Agriculture 30: 325-337.

Nawab NN, Subhani GM, Mahmood K, Shakil Q, Saeed A. Genetic variability, correlation and path analysis studies in garden pea (Pisum sativum L.). J Agric Res. 2008.

Rubiales D, González Bernal MJ, Warkentin T, Bueckert T, Vaz Patto MC, McPhee K, McGee R, Smýkal P (2019) Advances in pea breeding. In: Hochmuth G (ed) Achieving sustainable cultivation of vegetables. Burleigh Dodds Science Publishing, Cambridge, ISBN: 9781786762368; www.bdspublishing.com. https://doi.org/10.19103

Yan, W., Hunt, A. L., Sheng, Q. and Szlavnics, Z. 2000. Cultivar evaluation and mega-environment investigation based on GGE- biplot. Crop Science, 40: 596-605

Registration of "Hachalu" (EW006 x EW003 (1)-4-2-1) Sesame (Sesamum indicum L.) Variety

[1]Feyera Takele*, [1]Alemayehu Dabasa and [2]Chemeda Daba

Bako Agricultural Research Center, P.O. Box 3, Bako, West Shoa, Oromia,[2]Oromia Agricultural Research Institute, P.O. Box 81265, Addis Ababa/Finfinne, Ethiopia

**Corresponding author*

Abstract

Hachalu is a name given to a newly released sesame variety developed by Bako Agricultural Research Center and released in June 2021. Selection of this variety was made among recombinant inbred lines of sesame developed through pedigree breeding method. The two parents of the selected variety were collected from western Oromia of Ethiopia. This variety was selected out of fifteen inbred lines that were tested along with standard check Walin at three locations for two consecutive years of 2018 and 2019 main cropping season. Hachalu was the best high yielding variety and the most stable among all lines for its grain yield performance and has resistance to bacterial blight which is very challenging for sesame production in our country. In addition to this, its oil content is high (54.9%) and has white seed color which has a great role in the market class. For these reason, the variety was released for commercial production in major sesame growing areas of western Oromia and other similar agro-ecologies.

Key words: Grain yield stability, Oil content, Recombinant inbred line and Sesame (*Sesamum indicum* L.)

Introduction

Sesame is a self-pollinated crop (Zhang *et al*., 2013). However, 2-48% natural crossing was reported due to insect pollination (Daniel and Parzies, 2011). Domestication of the crop is about 5000 years old in Harappa of India country (Fuller, 2003). Sesame is an oilseed crop grown for its seed, oil for local and export markets, a great source of income for farmers, traders and processers and source of foreign exchange earnings. It is one of the important oilseed crops which is described as the queen of oil crops because of its high oil content. Sesame seed is consumed as a source of calcium, potassium, tryptophan and methionine (Soundharya *et al.*, 2017). In Ethiopia, the production of sesame is both by small and large scale farmers; and it is an important export commodity. Ethiopia is 3rd sesame exporter in the world next to Nigeria and India and sesame is first export (79%) from oil seeds and 2nd (20%) agricultural export next to coffee in Ethiopia (Zerihun, 2012). In spite of its wider importance and huge nutritional value, limited number of adaptable varieties with tolerance to biotic and abiotic factors is one of the major sesame production constraints in Ethiopia. In view of this, study was conducted with the aim of developing adaptable, high yielding, oil content and stable as well as disease resistant sesame variety for commercial production across tested environments and similar agro-ecologies of the country.

Varietal Origin and Evaluation

Hachalu (EW006 x EW003 (1)-4-2-1) sesame variety was developed from parental materials were collected from Western Oromia and developed through hybridization and subsequent pedigree selection at Bako Agricultural Research Center. The variety although tested at multi locations together with sixteen genotypes including one standard check *Walin* during 2018 & 2019 cropping season.

Agronomic and Morphological Characters

This variety has determinate growth type. It has erect growth habit and the stem and leaf are purple in color with stem branching habit. The average 1000 seeds weight was 2.7 grams, and its average plant height was 127.8cm. It has white seed color. The detailed agronomic features of the variety is indicated in the following table (Table 1).

Yield Performance

The released variety *Hachalu* showed higher mean seed yield (634.22 kgh-^{1}) with greater yield advantage of 12.88% over the standard check, *Walin* (Table 2).

Table 1. Agro-morphological characteristics and oil content of *Hachalu* Sesame variety

Variety Name	*Hachalu* (EW006 x EW003 (1)-4-2-1)
Adaption area	Well adapted to major Sesame growing areas of western Oromia and other similar agro ecologies Altitude (m.a.s.l): 1250 - 1650 Rainfall (mm): 800 - 1100
Planting date	End May to Early June
Seed rate (kgha^{-1})	5 (for row planting)
Spacing (cm)	40cm between rows and 10cm between plants
Fertilizer rate (kgha^{-1})	NPS: 100 and UREA: 50
Days to flowering	65.7-70.3
Days to maturity	115-131.7
Growth habit	Intermediate
1000 seed weight (gm.)	2.7
Plant height (cm)	109.3-146.3
Capsule per plant	69.2-91.9
Stem and branching character	Angular and branched
Growth pattern	Erect
Seed color	White
Crop pest reaction	Resistant for bacterial blight and other pests
Oil content (%)	54.9
Seed yield (kgha^{-1})	Research field: 634-929 Farmer's field: 628-870
Year of release	2021
Breeder/ Maintainer	BARC/OARI

Table 2. The mean value of seed yield (kgha^{-1}) among 16 sesame genotypes across six locations

	Yield/ha							
	2018			2019			Pooled	Yield
Genotypes	Bako	Uke	Ose	Bako	Uke	Ose	mean	adv.
EW00 x BG006-7-1-1	268.33	326.00	541.33	264.69	532.61	283.80	369.46	
EW002 x BG006-2-1-1	406.00	357.33	562.33	340.52	619.48	444.69	455.06	
EW006 x EW003 (1)-4-2-1	929.00	830.67	567.00	361.88	596.77	520.00	634.22	12.81
EW006 x EW003 (1)-3-1-1	392.67	747.00	630.67	321.98	398.23	274.17	460.79	
EW006 x EW003 (1)-7-1-1	517.33	631.67	611.00	319.48	698.96	502.97	546.90	
EW003 (1) x Wama -9-1-1	490.33	430.00	692.00	303.23	625.83	419.79	493.53	
Dicho x EW006-1-1-1	703.00	939.67	714.33	325.84	526.67	530.83	623.39	10.88
Dicho x EW006-9-1-1	549.00	480.00	760.00	256.77	378.54	657.08	513.57	
Dicho x Obsa -4-1-1	503.00	345.67	452.00	228.75	622.81	537.08	448.22	
Obsa x BG006-4-1-1	637.67	522.67	620.33	362.29	913.13	375.84	571.99	1.74
EW003(1) x EW002-4-2-1	829.67	529.67	353.00	386.36	541.25	434.06	512.33	
EW003(1) x EW002-5-2-1	632.67	551.67	556.33	394.59	603.34	988.64	621.21	10.50
EW023(2) x BG006-13-1-1	845.67	521.33	594.67	311.67	598.33	316.35	531.34	
Obsa x EW023(2)-3-3-1	495.00	492.67	650.67	318.54	723.75	370.21	508.47	
EW003(1) x EW019-4-2-1	441.00	366.00	694.00	290.42	849.59	619.90	543.48	

Walin	510.33	687.33	681.33	387.71	713.13	393.33	562.20
Mean	571.92	547.46	605.06	323.42	621.40	479.30	524.76
CV%	12.52	9.15	12.43	21.46	14.93	9.75	28.08
P value	**	**	**	Ns	**	**	**
LSD	119.38	83.52	125.41	115.71	154.73	77.94	96.75

*Key: *, ** and ns indicates significant and non-significant at 0.05 and 0.01 probability level, respectively*

Stability and Adaptability Performance

Based on the AMMI result, the new variety, *Hachalu* (G3) ranked first for its stability for seed yield performance (Fig 1) and the GGE biplot confirmed that *Hachalu* (G3) variety fell in the central circle, indicating its high yield potential and relative stability compared to the other genotypes (Fig 2). The new variety, *Hachalu* is adapted to major areas of sesame production of western Oromia and similar agro-ecologies in altitude ranging from 1250 to 1650 meters above sea level. This variety can be grown in high rainfall areas where bacterial blight is a problem for sesame production.

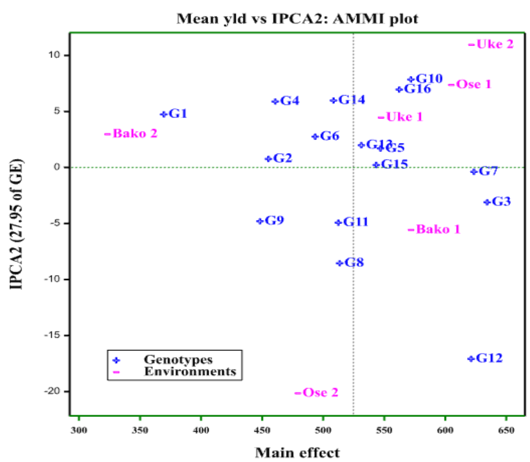


Figure:1. AMMI1bi-plot showing Genotype and Environment means seed yield against IPCA2

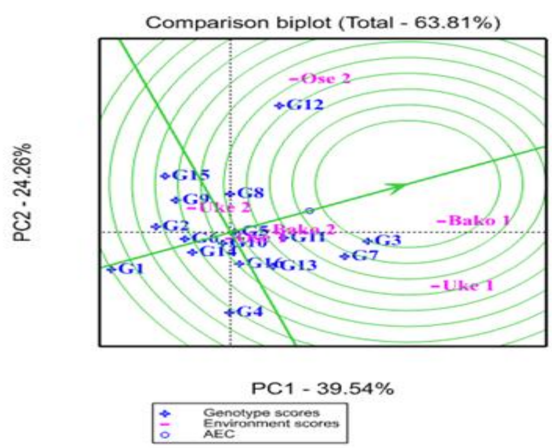


Figure: 2. GGE-bi-plot showing the "ideal" genotype

Disease Reaction

Bacterial blight is the most yield limiting factor for sesame production in western Ethiopia as the disease is favored by the effect of high humidity and rainfall condition in the area. In addition to higher yield, this variety showed better resistance to bacterial blight than the check (Fig 3).

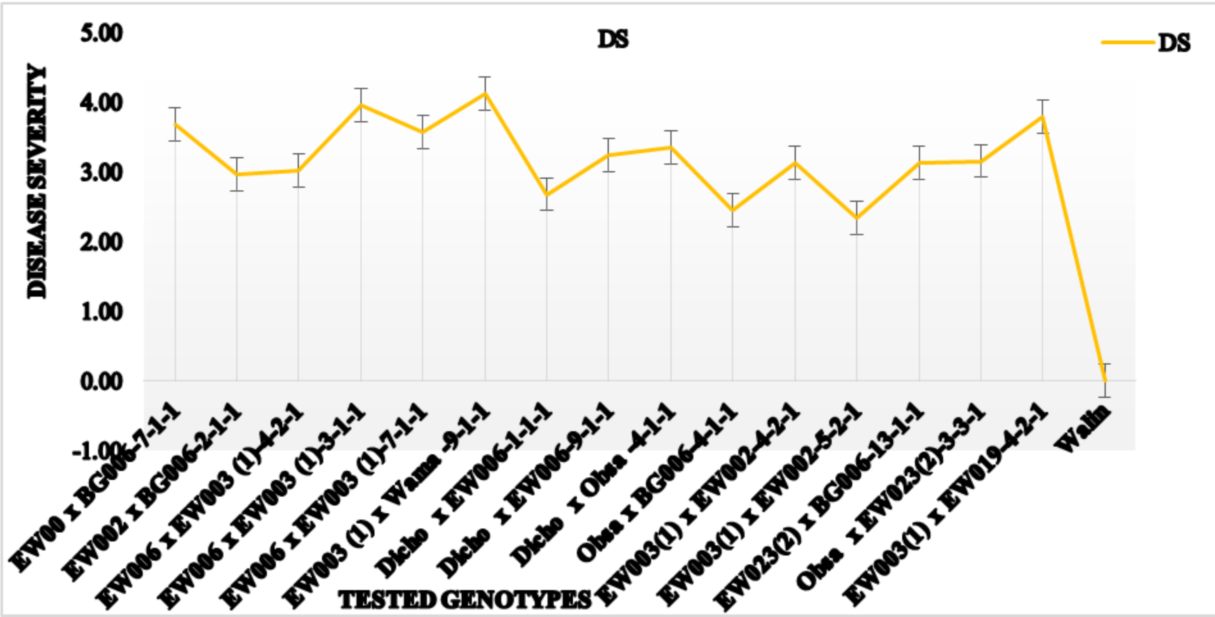


Figure: 3. Performance of tested sesame genotypes against bacterial blight disease at Bako, Uke and Ose during cropping season

Conclusions and Recommendations

Hachalu variety was released in June 2021 for western Oromia and similar agro-ecologies due to its high grain yield, oil content, wider adaptability, resistant to bacterial blight, white seed color and stable performance than the standard check and other tested genotypes. Therefore, smallholder farmers and other sesame commercial producers in western Oromia with similar agro-ecology can grow *Hachalu* variety with its full agronomic and other management recommendations.

Acknowledgement

The authors would like to thank Oromia Agricultural Research Institute for funding the research. Staff members of Bako Agricultural Research Center particularly Pulse and Oil Crops Technology Generation Team members are highly acknowledged for their technical support during field research work.

References

Daniel E.G., and Parzies, H.K., 2011. Genetic variability among landraces of sesame in Ethiopia. *African Crop Science Journal*, 19(1):1-13

Fuller, D.Q., 2003.Further evidence on the prehistory of sesame. *Asian Agri-History*, 7(2):127-137

Soundharya, B., Hemalatha, V., Rani, T.S. and Edukondalu, B., 2017. Trait association and path coefficient analysis for yield and yield attributing traits in sesame (*Sesamum indicum* L.). *Environment and Ecology*, 35(4E):3617-3620

Zerihun, J., 2012. Sesame (*Sesame indicum* L.) crop production in Ethiopia: Trends, challenges and future prospects. *Science, Technology and Arts Research Journal*, *1*(3):01-07

Zhang, H., Miao, H., Wang, L., Qu, L., Liu, H., Wang, Q. and Yue, M., 2013. Genome sequencing of the important oilseed crop (*Sesamum indicum* L.). *Genome biology*, 14(1):401

Registration of "Oda Gibe variety" newly released large pod Hot pepper

Debele Bekele*, Ishetu Mogasa, Tilahun Wondimu , Sheleme Kaba and Abraham Nagera
Oromia Agricultural Research Institute, Bako Agricultural Research Center, P.O. Box 03 , Bako, Ethiopia
*Corresponding Author Email: debto2010@gmail.com

Abstract

Oda Gibe accession name BSEP020/14 is hot pepper variety released by Bako Agricultural Research center. Experiment was conducted at Bako Agricultural Research Center from observation nursery to preliminary yield trial promising hot pepper genotypes were selected from yield base on pod yield and reaction to fusarium wilt. These promising genotypes were evaluated against standard check Marako fana across three location for two years (2017-2018). Oda Gibe variety showed superior pod yielder (Dried pod yield 1.55-2.0t/ha on research field and 1.15- 1.314t/ha on farmer's field. New variety yield advantage about 36.68% over standard check (Marakofana). Finally Oda Gibe was released as new variety for western Oromia around Bako and similar agro-ecologies.

***Key Words**: Pepper (capsicum annuum), Oda Gibe variety, Marakofana variety*

Introduction

Pepper (*Capsicum* spp.) is one of the world's major vegetable and spice crops valued for its aroma, taste, flavor and pungency (Zewdie *et al.,* 2004). It is also the leading spice crop in Ethiopia and the pungent Capsicum type (hot pepper) consumed in various food preparations particularly for flavoring and adding color to the stew. In addition to dietary benefits, Capsicums are also high value crops and can often provide excellent income-generating opportunities for small-scale farmers. Further, the crop is leading industrial raw materials for processing of capsaicin and color oleoresins (Marame, *et al.* 2008). Since hot pepper is a labor-intensive crop, it also creates significant employment opportunities in rural areas of the country. According to Central Statistical Authority (CSA, 2006) production data, on average, about 1.5 million smallholder farmers participated in pepper production during the period 2004 - 2006.

Pepper production in Ethiopia accounted for about 2.5% and 69.31% of the total arable land and land covered by vegetables, respectively (CSA, 2006). According to FAO (2003), the areas under green and dry pod peppers were 6,247 ha and 52,723.3 ha, respectively, with production of 40, 103.4 MT green peppers and 116,000 MT dry pod peppers. The same study showed the productivity of dry and green peppers was 2.2 t/ha and 6.42 t/ha, respectively. However, world average green pepper (bell pepper) productivity stood at 14.05 t/ha compared to 20.07 t/ha in Europe and 26.5 t/ha in North America (FAO, 2004). The low level of hot pepper productivity in Ethiopia is many-sided of which fusarium wilt disease problem is the major one and also low yield hot pepper because of shortage of improved varieties and no germplasm however; Oda Gibe variety with better tolerant to fusarium wilt disease and high pod yield.

Varietal Origin/pedigree and Evaluation

Oda Gibe variety accession name BSFP020/14 was material which collected from landrace Western Oromia and develop through selection. About 10 promising hot pepper genotypes were evaluated with marakofana variety as standard check (2017-2018). Promising candidates and standard check were further evaluated under verification and planted on nine locations by 10m*10m in 2019 and evaluated by technical committee then in 2020 approved by National variety releasing committee. Finally Oda Gibe was released for western Oromia around Bako and similar agro-ecologies.

Morphological and characteristics of Oda Gibe variety

Oda Gibe variety is good natured morphological and agronomic characteristics. It has good branching, pod setting and deep red pod color (table1); and also has uniform field stand with uniform physiological maturity.

Table 1: Mean agronomic traits across years and Locations

Accession	PH(cm)	Np/p	pL	Pd	Pw
BSFP 041/14	43.21	10.71	7.68	2.33	2.82
BSFP 019/14	51.03	12.21	7.40	1.99	2.51
BSFP 016/14	50.58	12.21	8.20	1.85	2.53
BSFP078/14	50.10	11.77	7.29	2.20	2.61
BSFP 072/14	51.0 33	11.09	8.41	1.97	2.82
BSFP 088/14	49.89	12.88	8.75	1.80	2.66
BSFP 032/14	55.40	12.97	7.74	1.91	2.49
BSFP 004/14	51.57	13.99	8.01	2.03	2.53
BSFP 020/14	48.58	10.83	8.01	2.28	3.04
BSFP 010/14	48.01	11..20	7.37	1.92	2.18
Marako Fana	45.54	9.71	7.82	1.77	2.22
Grand Mean	49.53	11.70	7.88	2.00	2.58
CV%	26.38	42.94	22.89	23.55	25.54
Accession	Ns	Ns	**	**	Ns
Location	**	**	**	**	**

PH=plant height, Np/plant=number of pod per plant, Pl=pod length in centimeter, PW=pod weight in gram

Result and discussion

Yield performance

Oda Gibe variety is showed high yielder (Dried pod yield 1.55-2.0t /ha on research field and 1.15- 1.314t/ha on farmers' field). This new variety yield advantage about 36.68% over standard check (Marakofana). Finally *Oda Gibe* was released as new variety for western Oromia around Bako and similar agro-ecologies.

Table 2: Mean pod yield (Qt ha^{-1}) per location over years

Accession	Mean Yield Qt/Ha of two year							
	2017			2018			0ver all mean	Yield adv %
	Bako	Uke	Bilo	Bako	Uke	Bilo		
BSFP 041/14	15.16	1.30	0.92	13.78	1.83	7.38	6.72	25.73
BSFP 019/14	11.47	1.80	1.44	16.66	0.64	7.93	6.65	24.4
BSFP 016/14	9.15	1.30	2.33	13.16	0.33	8.26	5.75	7.49
BSFP078/14	9.74	1.15	2.00	15.56	1.19	6.12	5.98	11.85
BSFP 072/14	7.84	0.71	2.94	13.53	1.43	8.52	5.83	9.01
BSFP 088/14	10.00	1.33	3.73	16.41	2.18	9.63	7.21	34.89
BSFP 032/14	15.56	1.23	2.00	11.76	1.94	10.4	7.15	33.68
BSFP 004/14	10.03	1.50	1.78	13.88	1.72	6.20	5.85	9.42
BSFP 020/14	13.14	1.95	0.88	19.05	2.70	5.95	7.28	36.13
BSFP 010/14	8.74	0.99	1.51	10.61	1.38	5.62	4.81	-10.06
Marako Fana	10.30	0.73	1.08	16.59	0.67	2.72	5.35	
Mean	11.01	1.26	1.89	14.65	1.46	7.16	6.23	
Cv%	51.29	41.16	54.0	34.37	85.8 3	45.29	55.52	
f-value	Ns	ns	*	Ns	Ns	ns	**	

Adaptation and Agronomic recommendation

Hot paper (Capsicum spp)

Variety: Oda Gibe (BSFP020/14)

Adaptation area	Western Oromia around Bako and Nekemte
Altitude (m.a.l.s)	1250-1700
Rain fall (mm)	800-1100
Temp(C)	23-28
Soil type	Nit sols
Planting time:	Early June-early July
Seed rate (kg):	0.8-0.9kgseed /ha for transplanting
Fertilizer rate (kg)	
Urea:	150 (50% during transplanting & 50% at flowering time)
NPS:	100 (at transplanting time)
Days to 50% flower:	70 (days)
Fruity maturity (days):	155
Plant height (cm):	58
Pod color:	Deep red color
Number of pod per plant:	22-30
Pod length: (cm)	10.9
Pod diameter: (cm)	2.7
Pod weight: (g)	35-42
Plant canopy (cm):	40.8-45.3
Yield dry pod (t/ha):	
Research field	1.55-2.0
Farm field	1.17-1.314

Conclusion and recommendation

The newly released hot pepper variety Oda Gibe was found to be superior to marakofana which was used as standard check pod yield. It is tolerant to fusarium wilt . The variety also found to be stable over seasons and locations. thus; concluded that; Oda Gibe hot pepper variety could be cultivated sustainably and profitably by small holder farmers and another investors round western Oromia and similar agro-ecologies.

Acknowledgement

The authors are acknowledged Oromia Agricultural Research Institute, Bako Agricultural Research Center, horticultural research team and all persons supported this research work.

References

CSA, J., 2007. Agricultural Sample Survey 2006-07. *Volume I, Addis Ababa*.

Kuhl, J.C., Cheung, F., Yuan, Q., Martin, W., Zewdie, Y., McCallum, J., Catanach, A., Rutherford, P., Sink, K.C., Jenderek, M. and Prince, J.P., 2004. A unique set of 11,008 onion expressed sequence tags reveals expressed sequence and genomic differences between the monocot orders Asparagales and Poales. *The Plant Cell*, *16*(1), pp.114-125.

Marame, F., Desalegne, L., Singh, H., Fininsa, C. and Sigvald, R., 2008. Genetic components and heritability of yield and yield related traits in hot pepper. *Res. J. Agric. Biol. Sci*, *4*(6), pp.803-809.

Performance of Bread Wheat (*Triticum aestivum* L.) Varieties in Buno Bedele, South West Oromia, Ethiopia

Gebeyehu Chala, Gedefa Sori, Dagne Chimdessa and Garoma Firdisa

Oromia Agricultural Research Institute (IQQO), Bedele Agricultural Research Center (BeARC), Bedele, Ethiopia. P.O. Box, 167.

Corresponding author email: gebeyehuchal@gmail.com

Abstract

Bread wheat is cultivated in a wide range of high and mid-altitude areas of Ethiopia ranking 4th in area coverage and 2nd in productivity. Although many improved bread wheat varieties have been released nationally and regionally, these varieties are not well disseminated and popularized. In Western Ethiopia "Buno Bedele Zone", there is no varieties evaluated by our Research center and farmers are using any variety when they did get which is risky if there would be an occurrence of new diseases and other stresses. To alleviate such a crop's potential challenge, recently released bread wheat varieties were tested for their phenotypic performance to confirm their environmental adaptation using Randomized Complete Block Design in three replications for two consecutive years (2019/2020 to 2020/2021) on two separate Gechi and Choradistricts. Quantitative traits such as plant height, spike length, Biomass, and grain yield were collected and analyzed using RStudio and Genstat 18th edition software's. Qualitative trait *such as days to maturity and days to heading were also collected. The combined analysis of variance indicated that the 12 tested varieties differed significantly for all traits. The highest combined mean grain yield was recorded by the variety "Liben" (*4443*kgha^{-1}) followed by "Ogolcho" (*4268*kgha^{-1}).*

Key words: Bread Wheat, Evaluation, RCBD, Variety.

Introduction

Bread wheat (*Triticum aestivum* L.) is a hexaploid species with (2n=6x=42) having AABBDD with A, B and D genomes) (Sleper and Poehlman, 2006). It is one of one of the oldest domesticated grain crops for 8000 years which native to Middle East. It has been the basic staple food of many regions of the world, while it is grown under both irrigated and rain-fed conditions. It belongs to family Poaceae (formerly Graminae) (Yadawad *et al.*, 2015). World wheat production in 2017 was 743.2 million tons with average yield (3.34 t ha^{-1}) and it accounts for nearly 30% of global cereal (FAO, 2017). The hexaploid bread wheat accounts for 95% of the total wheat production; most of the remaining 5% is from tetraploid durum wheat (T. turgidum subsp. durum, 2n=4x=28, AABB) (Shewry, 2009). It approximately accounts for 20% of nutritional sources of the people around the world (Khabiri *et al*., 2012). It provides nearly 55% of carbohydrates, 20% of the daily protein and 21% calories for about 40% of the global population (Khan and Naqvi, 2011).

Wheat grain is a staple food used to make flour for leavened, flat and steamed breads, biscuits, cookies, breakfast cereal, pasta, noodles, bio-fuel, and for fermentation to make alcoholic beverages such as beer and liquors (Tsegaye and Berg, 2007). In Ethiopia, wheat is one of the major staple and strategic food security crops, and accounts for approximately 11% of the national calorie intake. Wheat is used in the preparation of a wide range of products such as the traditional fermented thin bread ("injera"), regular bread ("dabo"), and local beer ("tella") (GAIN, 2014). Ethiopia is the second largest wheat producer in sub-Saharan Africa after South Africa. It is cultivated on 1.7 million hectares of land and has the production of 4.54 million tons with remain low productivity of 2.67 t ha^{-1} (CSA, 2017) in the country as compared to the world average yield (3.34 t ha^{-1}) (FAO, 2017).

Ethiopia ranks first in wheat production followed by Sudan and Kenya in East Africa, and second in subSaharan Africa after South Africa (FAO, 2015). It is the third largest produced cereal crop after maize and tef (*Eragrostistef*) in Ethiopia. Wheat is grown >1500 m.a.s.l. in mid and highland areas as a rain-fed crop in Ethiopia. Within the country the top wheat producing districts are primarily located in Oromia, Amhara, and Tigray regional states. Oromia accounts for the largest of all with its top producing districts located in the Arsi-Bale areas of the region (Warner *et.al*, 2015). Irrigation contributes 1.1% of the total cultivated land (Girmay, 2017). At mid and highlands between1900 m.a.s.l. and 2700 m.a.s.l., wheat was grown in 1.696907 million hectares during 2017-18 and produced about 46.429657 million tones with average productivity of 27.3 q/ha in Ethiopia (Anonymous, 2018); whereas the world average productivity was 33 q/ha (EIAR, 2020). Bread wheat demand in Ethiopia is increasing because of the preference of people to use it for food as a major source of energy and protein (Hailu, 2003) and it accounts for about 65% of the total wheat area (Alemayehu *et al.,* 2011). The remaining area is under durum and emmer (Aja) wheat. There is a shortage of wheat production in the country for meeting the demand. According to Gebre *et al.* (2017), about 1.0 million tons of wheat is being imported annually since 2008 in Ethiopia at the cost of 500 million US dollars. Lately, Ethiopia imported 1.7 million tons of wheat (EIAR, 2020).

In Buno Bedele Zone, at mid and highland areas, neither genetic variability studies in wheat genotypes nor introduction of improved wheat varieties were attempted. This is due to acidity problem that farmers are not willing to produce bread wheat. But, BeARC had been practicing soil treatment by applying lime on farmer's field by soil sample data taking and graduallyfarmers also followed these practice and appreciated the use of the technology. Beside to this practice, Variety adaptation trial was followed which best fit to the area. To this end, in crop improvement and others technology development and dissemination process with the involvement of the end-users may hasten the process and increase the adaptation and dissemination of the new technology. Therefore, it is necessary to undertake research to develop wheat varieties for the study area in which genetic variability study is the first step. Thus, the study was undertaken with the following objective:-

- To evaluating and select better adapted bread wheat varieties for yield and yield components for the study areas and other similar agro-ecologies.

Materials and Methods

Description of the study area

The experiment was conducted at Chora and Gechi districts on different farmers' fieldduring 2019-2020 main cropping seasons.

Chora District

Chora is one of the districts in Buno Bedele Zone, Oromia Regional State Southwest part of Ethiopia. The district is bordered on the south by Setema, on the west by Yayo and Dorani, on the north by Dega, and on the east by Bedele. The administrative center of this district is Kumbabe. The district is located 519 km away from the capital city of the country and 36 km away from Bedele Town of Buno Bedele Zone. The district is located at an average elevation 1910masl and located at 08^{0}13'33.7" to 08^{0}33'55.0" N latitude and 035^{0}59'59.7" to 036^{0}15'15.8" E longtude. It is generally characterized by warm climate with a mean annual maximum temperature of 25.5°C and a mean annual minimum temperature of 12.5°C. The driest season lasts between December and January, while the coldest month being December. The annual rainfall ranges from 1440 mm. The soil of the area is characterized as an old soil called Nitisoils. The economy of the area is based on mixed cropping system and livestock raring agricultural production system among which dominant crops are maize, tef, sorghum and wheat and also horticultural crops.

Gechi District

Gechi is one of the districts in Buno Bedele Zone, Oromia Regional State Southwest part of Ethiopia. The district is bordered on the south by Didessa, on the west by Didessa river, on the north by Bedele, and on the east by Jimma Zone. The administrative center of this district is

Gechi. The district is located 519 km away from the capital city of the country and 18 km away from Bedele Town of Buno Bedele Zone. The district is located at an average elevation 1787m.a.s.l and located at 08^{0}7’0” N latitude and 036^{0}34’0” E longitude. The soil of the area is characterized as an old soil called Nitisoils. The economy of the area is based on coffee production system among which dominant crops are maize, tef, sorghum and wheat and also horticultural crops.

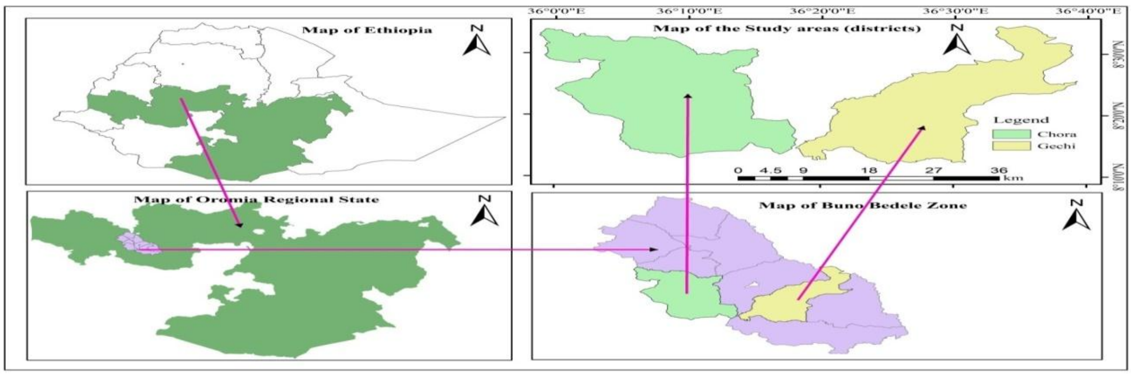


Figure 1. Map of the study areas (Chora and Gechi) districts

Experimental Materials and Design

Twelve (12) bread wheat varieties were brought from Sinana, Kulumsa and Bako Agricultural Research Centers and evaluated as experimental materials. These materials were randomly assigned to the experimental block and the experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The spacing between blocks and plots was 1m and 0.5m, respectively. The gross size of each plot was 2.4m^{2} (2m x 1.2m) having six rows with a row-to-row spacing of 20cm.The total area of the experimental field was165.2m^{2} (29.5m x 5.6m).Planting was done by drilling seeds in rows with a seed rate of 150kg ha^{-1}. NPS fertilizer was applied at the rate of 100kg ha^{-1} (30g per plot) at the time of planting; and Urea was also applied at vegetative stage at the rate of 150 kg ha^{-1}.

Table 1. Description of Bread wheat varieties used in the experiment

No	Variety Names	Altitude ranges (m.a.s.l)	Year of Release	Maintainer
1	Kakaba	2300-2600	2010	KARC/EIAR
2	Danda’a	2000-2600	2010	KARC/EIAR
3	Kingbird	1500-2200	2015	KARC/EIAR
4	Lemu	>2200	2016	KARC/EIAR
5	Liben	2400-2800	2015	BARC/OARI
6	Ogolcho	2400-2800	2012	KARC/EIAR
7	Sanate	NA	2014	SARC/OARI
8	Wane	2100-2700	2016	KARC/EIAR
9	Galan	2200-2500	2019	SARC/OARI
10	Obera	2200-2700	2015	SARC/OARI
11	Sinja	2000-2400	2018	SARC/OARI
12	Sofumar	2300-2800	1999	SARC/OARI

KARC=Kulumsa Agricultural Research Center, SARC= SinanaAgricultural Research Center, BARC= Bako Agricultural Research Center, OARI= Oromia Agricultural Research Institute, EIAR= Ethiopian Institute of Agricultural Research, NA= Non-available.

Data collected: Data were recorded on plot and single plant basis and taken from the central rows of the plot. Individual plant based data were taken from five plants in each plot taken randomly from the central rows of each plot.

Data Collected on Plot Basis: Days to heading (DH), Days to Maturity (DM), Total biomass yield (g/plot), Grain yield (g/plot), Harvest index.

Data collected on plant basis: Plant Height (cm), Spike Length (cm)

Data Analyses

Genstat 18th edition software was used to analyze all the collected data from individual farmers and the combined data over locations. Mean separations was carried out using least significant difference (LSD) at 5% probability level.

Results and Discussions

The combined analysis of variance (ANOVA) over locations and years for grain yield character of 12 bread wheat varieties is presented in Table 2. The analysis of variance (ANOVA) indicated presence of highly significant differences at (P≤0.001) among the evaluated bread wheat varieties for only years and locations interaction only. This indicates presence of effects of year x location effects rather than varietal effects. Therefore, it is an important to do stability analysis for only year x location effects to see which environment is ideal for the tested bread wheat varieties (Table 2).

Table 2. Combined mean ANOVA of 12 bread wheat varieties for grain yield in kg ha^{-1} in 2019-2020 cropping season

Sources of variations	Degree of freedom	Sum of squares	Mean of squares	F value	Pr(>F)
Year	1	27162619	27162619	24.05	1.39e-06 ***
Locations	1	14048653	14048653	12.44	0.0005 ***
Treatments	11	31492797	2862982	2.54	0.004 **
Replications(Env't)	4	437675	109419	0.19	0.83
Year*Locations	1	36721168	36721168	32.52	2.38e-08 ***
Year*Treatments	11	10861479	987407	0.87	0.57
Locations*Treatments	11	15047357	1367942	1.21	0.28
Locations*Replications	4	1078983	269746	0.48	0.62
Year*Locations*Treatments	11	9866041	896913	0.79	0.65
Residuals	44	429122317	9752780		

Grain yield is also a character of prime importance and of special interest to a wheat breeder. Accordingly, highly significant variability was observed among varieties for grain yield kg ha^{-1}, which ranged from 3419 kg ha^{-1} to 4443kg ha^{-1} with the mean value of 3971kg ha^{-1}. Depending on the mean performances, varieties such as Liben, Ogolcho,Kakaba, Danda'a and Sanate had mean performances higher than the grand mean while lower yielder were obtained from genotypes Wane (3663kg ha^{-1}), Obera (3742kg ha^{-1}) and Sinja (3419 kg ha^{-1}) respectively (Table 3). Berhanu *et al.* (2017) conducted genetic variability among 49 bread wheat genotypes at Axum, Northern, Ethiopia and reported a wide range of grain yield from 2.37 to 5.44 t ha^{-1} with a mean of 3.95 t ha^{-1} and the maximum grain yield obtained was 5.44 t ha^{-1}, 5.37 t ha^{-1}, 4.64 t ha^{-1} and 4.56 t ha^{-1} respectively. Gezahegn *et al.* (2015) reported a wide variation of grain yield per hectare which ranged from 2.11 to 5.95t ha^{-1} while Alemu *et al*. (2016) also reported that 2.59 to

4.68 t ha^{-1} and 1.28 to 3.79 tones ha^{-1} at Kulumsa and Tongo site for bread wheat in Ethiopia respectively.

Table 3. Combined mean grain yield (kg ha^{-1}) of Bread wheat varieties tested at Chora and Gechi districts for two years

		Chora District			Gechi District			
Sr. No	Varieties	Year 1	Year 2	Combined	Year 1	Year 2	Combined	Over all
1	Kakaba	4222^{bcd}	4815^{a}	4519^{ab}	4438	2926^{ab}	3934	4226^{ab}
2	Danda'a	4444^{abc}	4321^{ab}	4383^{abc}	4271	3241^{ab}	3927	4155^{abc}
3	Kingbird	4278^{a-d}	4105^{abc}	4191^{a-d}	4021	3079^{ab}	3707	3949^{abc}
4	Limu	3694de	4120^{abc}	3907^{bcd}	4333	3199^{ab}	3955	3931^{a-d}
5	Liben	4694^{ab}	4883^{a}	4789^{a}	4438	3417^{ab}	4097	4443^{a}
6	Ogolcho	5000^{a}	4410^{ab}	4705^{a}	4750	1991^{b}	3830	4268^{ab}
7	Sanate	4028^{b-e}	4333^{ab}	4181^{a-d}	4229	3185^{ab}	3881	4031^{abc}
8	Wane	3889^{cde}	3642^{bc}	3765^{cde}	3979	2722^{ab}	3560	3663^{cd}
9	Galan	4306^{a-d}	3608^{bc}	3957^{bcd}	4000	3611^{a}	3870	3914^{bcd}
10	Obera	3333^{e}	3923^{abc}	3628de	4167	3236^{ab}	3856	3742^{bcd}
11	Sinja	3333^{e}	3213^{c}	3273^{e}	4000	2694^{ab}	3565	3419^{d}
12	Sofumar	4083^{bcd}	3864^{abc}	3974^{bcd}	4229	3060^{ab}	3840	3907^{bcd}
GM		4109	4103	4106	424	3030	3835	3971
LSD(0.05)		729	1053	632	869	1522	847	529
CV%		19.0	27.4	23.4	25.4	38.5	33.6	28.7
P-value		**	*	**	NS	*	NS	*

GM= grand mean, LSD=least significant difference, CV= coefficient of variation, *= significant, **= highly significant, NS= non-significant.

Analysis of variance (ANOVA) revealed significant difference (P< 0.05) among the twelve (12) bread wheat varieties for traits such as days to heading, days to maturity,spike length, plant height and Biomass yields (Table 4).

Table 4. Combined mean of yield related traits of Bread wheat varieties over two years at Gechi and Chora districts

Sr. No	Varieties	DH (days)	DM (days)	PH (cm)	SL (cm)	BMY(kg ha^{-1})	HI(%)
1	Kakaba	61.89^{ab}	96.8^{f}	78.44^{ab}	7.56^{bc}	10915^{ab}	40.12
2	Danda'a	62.17^{a}	108.6^{bcd}	77.80^{ab}	7.66^{bc}	11407^{ab}	38.29
3	Kingbird	60.33^{ab}	104.1^{de}	74.30^{b}	7.41^{bcd}	10428^{b}	39.44
4	Lemu	58.61^{b}	110.3^{abc}	75.21^{ab}	7.78^{bc}	12215^{ab}	39.57
5	Liben	61.28^{ab}	111.1^{ab}	76.00^{ab}	7.74^{bc}	11433^{ab}	39.61
6	Ogolcho	60.94^{ab}	105.3^{de}	79.18^{a}	7.87^{ab}	11714^{ab}	37.62
7	Sanate	60.47^{ab}	106.3^{cd}	77.44^{ab}	7.37^{cd}	10973^{ab}	38.68
8	Wane	61.86^{ab}	101.0^{ef}	75.86^{ab}	7.05^{d}	14630^{a}	35.20
9	Galan	60.19^{ab}	106.6^{cd}	78.49^{a}	8.26^{a}	10303^{b}	39.80
10	Obera	63.25^{a}	113.7^{a}	77.13^{ab}	7.57^{bc}	10647^{b}	36.03
11	Sinja	58.61^{b}	83.9^{g}	77.63^{ab}	7.63^{bc}	9492^{b}	37.87
12	Sofumar	60.36^{ab}	101.0^{ef}	78.35^{ab}	7.86^{ab}	10054^{b}	40.47
GM		60.74	104.05	77.2	7.65	11184	38.56
LSD (0.05)		3.18	4.55	4.18	0.47	3834.2	6.64
CV%		11.3	8.5	11.7	13.2	74.0	37.2
P-value		*	**	*	**	*	NS

DH= days to heading, DM= days to maturity, PH= plant height, SL= spike length, GM= grand mean, BMY= Biomass yield, HI= Harvest Index, LSD=least significant difference, CV= coefficient of variation, *= significant, **= highly significant.

Days to heading: Days to heading Varieties differed significantly (P<0.05) which varied from 58.61 to 63.25 days with the mean of all varieties 60.74 days (Table 4). The earliest heading was recorded in 58.61 days in varietiesLemu and Sinja, which were significantly different from other varieties. Varieties taking more days to heading than the mean of all varieties were Danda'a, Liben, Wane and Obera. The late heading variety wasObera, taking 63.25 days. In line with this resultdifferent authors have been supported significant differences among genotypes of bread wheat for days to heading (Gebre *et al*., 2017; Bayisa *et al*., 2019). Alemu *et al*. (2016) also reported wide range of variation between 48 and 66 days for heading. Days to physiological maturity: Varieties differed significantly (P<0.01) for number of days to physiological maturity ranging from 83.9 to 113.7 days with mean of all varieties 104.05 (Table 4). Variety Sinja was earliest to physiologically mature at 83.9 days changing color of leaves, peduncles and spikes from green to yellow of 90% of the plants from the sowing. At this stage, the grains are fully developed and lose connection for the supply of photosynthetic assimilates, nutrients and water from the tissues of the ovary of the mother plants. The other earlier maturing variety was Kakaba, taking 96.8 days. Varieties with mid maturity period (101-104.1days) around the mean of all varieties were Kingbird, Wane and Sofumar. The late maturing variety wasObera taking 113.7days as compared to other varieties. Alemu *et al*. (2016) also reported wide range of variation between 97 and 108 for days to maturity among 30 bread wheat genotypes. The results in agreement with the findings of Mollasadeghi *et al*. (2012) in which days to heading and days to maturity showing similar parallelism to each other. However, some authors also reported non-significant differences among bread wheat genotypes for days to maturity and number of fertile tillers (Khan, 2013). The differences of different authors report for the performance of bread wheat genotypes for maturity, plant height and number of fertile tillers for varied number of bread wheat genotypes might be due to the differences in the 31 genetic factors carried by the genotypes included in each experiment, growing seasons and environments where the genotypes evaluated. The early maturity, plant height and number fertile tillers were reported as a function of both genetic and environmental factors (Berhanu, 2004; Obsa, 2014; Alemu *et al*., 2016).

Plant height: Varieties differed significantly (P<0.05) for plant height, which varied from 74.30 to 79.18 cm (Table 4). Highest plant height (79.18 cm) was recorded in variety Ogolcho and the lowest plant height was recorded in kingbird (74.30cm) variety. Wheat genotypes/varieties with plant height between 101-and 115 cm are categorized as a single dwarf (Ram, 2011). The plant height in the remaining 24 varieties was less than 85 cm (Ram, 2011).

Discriminating ability and representativeness of environments

According to Yan (2002), discriminating ability and representativeness view of the GGE biplot is the important measure of test environments, which provide valuable and unbiased information about the tested genotypes. Yan and Tinke (2006) also reported that environments with longer vectors had the more discriminating ability of the genotypes, whereas environments with very short vectors had little or no information on the genotype difference. From this study, the test environment Chora was identified as the most discriminating environments which provided much information about differences among genotypes and ideal environment as well.

The ideal test environment is an environment which has more power to discriminate genotypes in terms of the genotypic main effect as well as able to represent the overall environments. It is used for selecting generally adaptable genotypes but obtaining such type of environment is very difficult in real conditions. In such condition, environments which fell near to a small circle located in the center of concentric circles and an arrow pointing on it (ideal environment) is identified as the best desirable testing environments (Yan and Rajcan, 2002). Among the testing environments used in this study, Chorawas identified as an ideal environment in terms of being the most representative of thetwo environments and powerful to discriminate (Fig.2). In harmony, to this, Tariku (2017) in cowpea and Tulu (2018) in common bean have used GGE bi-plot to identify the best desirable testing environment.

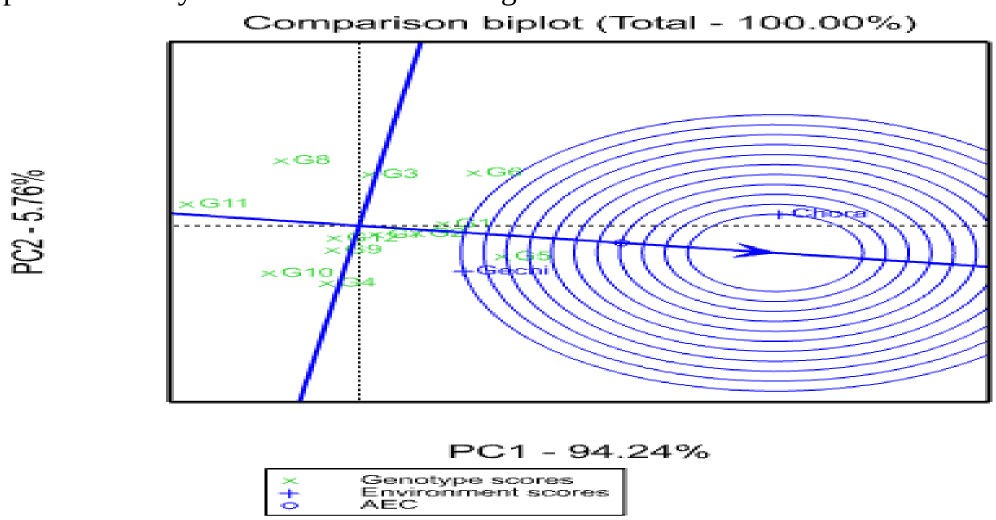


Figure 2: GGE-biplot based on environment-focused scaling for comparison of the environments with the ideal environment

Correlations between yield and yield related traits of bread wheat varieties

Correlation coefficients are useful in finding the degree of overall linear association between any two attributes as suggested by Talebi *et al*. (2009). The pearson correlation coefficients of grain yield under different locations with different years is indicated in (Table 5) showed most grain yield related traits was significantly and positively correlated with grain yield wereDays toheading (DH), plant height (PH), spike length (SL), Days to maturity (DM), number of productive tillers per plant (NT) and Harvest index (HI). There were significant and strong positive associations of grain yield with days to heading (0.12), Plant height (0.35), spike length (0.23), Days to maturity (0.25), number of productive tillers (0.43), and harvest index (0.73). Similar results were reported by Ezatollah *et al*. (2012), Farshadfar *et al*. (2013), Darzi-Ramandi *et al*. (2016) and Sardouie-Nasab *et al*. (2015) for the four induces.

Table 5. Correlation coefficients among morpho-physiological traits evaluated between grain yield and yield related traits of 12 bread wheat varieties tested for two consecutive years.

Traits	DH	PH	SL	DM	NT	BMY	NG/SP	GY	HI (%)
DH	1								
PH	0.17*	1							
SL	0.06^{ns}	0.25*	1						
DM	0.10*	0.08^{ns}	0.14*	1					
NT	0.01^{ns}	0.27*	0.26*	-0.03^{ns}	1				
BMY	-0.01^{ns}	0.13*	-0.04^{ns}	0.02^{ns}	0.13*	1			
NG/SP	0.06^{ns}	-0.01^{ns}	0.15*	0.07^{ns}	0.16*	-0.07^{ns}	1		
GY	0.12*	0.35**	0.23*	0.25*	0.43**	0.06^{ns}	0.25*	1	
HI (%)	0.10*	0.13*	0.17*	-0.04^{ns}	0.17*	-0.29*	0.20*	0.73**	1

DH= days to heading, PH= plant height, SL= spike length, DM= days to maturity, NT= number of productive tillers per plant, BMY=Biomass (kg ha^{-1}), NG/SP= number of grain per spike, GY= grain yield (kg ha^{-1}), HI= Harvest index.

Conclusion and Recommendation

Even though there are different bread wheat varieties released by different organizations, there adaptability and yield performance under different environment is important for boosting bread wheat production and productivity. In this study about 12 bread wheat varieties were used to evaluate their adaptability at Chora and Gechi districts for two consecutive years (2019 to 2020) cropping season. The result of this study showed the presence and the type of Year x locations interactions. From the combined analysis variety Liben was the best for its grain yield (4443 kg ha^{-1}) followed by Ogolcho variety (4268 kg ha^{-1}). Most of the agronomic parameters were positively and significantly correlated with grain yield. Thus, these two varieties were selected to be demonstrated on farmer's field for further scaling up.

References

Alemu Dabi Borena. 2016. Genetic Variability and Association among Grain Yield and Yield Related Traits of Bread Wheat (*Triticum aestivum* L.) Genotypes. MSc Thesis Postgraduate Program Directorate, Haramaya University, Ethiopia.

Berhanu Mamo Andarge. 2004. Genetic variability and character associations in bread wheat (*Triticum aestivum* L.) genotypes developed for semiarid areas. MSc Thesis Presented to the School of Graduate Studies of Alemaya University, Ethiopia.

Birhanu Mecha, Sentayehu Alamerew, Alemayehu Assefa, Ermias Assefa and Dergicho Dutamo. 2017. Correlation and Path Coefficient Studies of Yield and Yield Associated Traits in Bread Wheat (*Triticum aestivum* L.) Genotypes. Advances in Plants & Agriculture Research, 6(5): 00226. DOI: 10.15406/apar.2017.06.00226.

CSA (Central Statistical Agency). 2017. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Agricultural Sample Survey 2016/2017. Central Statistics Agency, Addis Ababa, Ethiopia.

FAO (Food and Agriculture Organization) (2015). Food Balance Sheets: FAOSTAT. Rome. (http://faostat3.fao.org/download/FB/FBS/E).

FAO. 2017. Food and Agricultural Organization. CROP PROSPECTS and FOOD SITUATION. Quarterly Global Report. March 2018.

GAIN (Global Agricultural Information Network). 2014. Report: ET1401, Addiss Ababa.

GezahegnFikre, SentayehuAlamerew, ZerihunTadesse. 2015. Genetic Variability Studies in Bread Wheat (*Triticum aestivum* L.) Genotypes at Kulumsa Agricultural Research Center, South East Ethiopia. *Journal of Biology, Agriculture and Healthcare*. 5(7) 2224-3208.

Khabiri, E., Imani, A.A., and Shahbazi H., 2012. Studying the grain yield and yield components in advanced rain fed wheat genotypes. Scholars Research Library. *Annals of Biological Research*, 3 (12):5647-5650.

Khan, N. and Naqvi, F.N. 2011. Heritability of Morphological Traits in Bread Wheat Advanced Lines Under Irrigated and Non-Irrigated Conditions. *Asian Journal of Agricultural Sciences*, 3(3): 215-222.

Khan, S.A. 2013. Genetic Variability and Heritability Estimates in F2 wheat Genotypes. *International Journal of Agriculture and Crop Sciences*, 5(9):983-986.

Mollasadeghi, V., Elyasi S., and Mirzamasoumzadeh, B. 2012. Genetic variation of 12 bread wheat genotypes based on number of phonological and morphological traits. *Annals of Biological Research*, 3 (10):4734-4740.

ObsaChimdesa. 2014. Genetic Variability among Bread Wheat (Triticum Aestivum L.) Genotypes For Growth Characters, Yield And Yield Components In Bore District, Oromia Regional State. MSc thesis Postgraduate Program Directorate, Haramaya University, Ethiopia.

Shewry, PR. 2009. Wheat. Journal of Experimental Botany 60, 1537-1553.

Sleper, D.A. and Poehlman, J.M. 2006. Breeding Field Crops. 5th edition. Blackwell Publishing, Professional, Ames, Iowa.

Tsegaye B. & Berg, T. 2007. Utilization of durum wheat landraces in East Shewa, central Ethiopia: Are home uses an incentive for on-farm conservation? Agriculture and Human Values. 24, 219- 230.

Performance of Tef [*Eragrostis tef* (Zucc.)Trotter] Varieties atChora District, Buno Bedele Zone

Gebeyehu Chala, Gedefa Sori, Dagne Chimdessa and Garoma Firdisa
Oromia Agricultural Research Institute (IQQO), Bedele Agricultural Research Center (BeARC), Bedele, Ethiopia. P. O. Box, 167.
Corresponding author email: gebeyehuchal@gmail.com

Abstract

Tef is the most important staple cereal crop in Ethiopia. However, its productivity is low due to several biotic and abiotic constraints. The diverse and dynamic environmental condition of Ethiopia needs detailed and sustainable study of under different environment for developed tef varieties. The objective of this study was to evaluate and select better performed tef varieties for the study area and similar agro ecologies. Ten (10) improved tef varieties were tested at Chora district during the 2019-2020 main cropping seasons using Randomized Complete Block Design (RCBD) with three replications.An important data like Days to heading, Plant height, Panicle length, Total productive tillers per plant, Biomass yield and Grain yield were recorded and mean performances of these traits were evaluated using Genstat 18th edition software. The results showed significant differences among tef varieties for grain yield and yield related traits. Combined mean grain yield of the tef varieties varied from 1733kg ha^{-1} for variety Dega-tef, to 2217kg ha^{-1} for variety Dursi. The maximum yield was obtained from Dursi variety (2217kg ha^{-1}) followed by Dukem variety (2171kg ha^{-1}). The results from this study gave valuable information and input for researchers who were interested to examine the effect of environment on the performance of tef varieties for future breeding program in the Southwest Ethiopian condition (Buno Bedele Zone). Therefore, these two varieties were recommended to be demonstrated under farmers' field for further scaling up.

Keywords: Adaptability, Eragrostis tef, Varieties, Yield related

Introduction

Eragrostis tef (Zucc.) Trotter is a member of the grass family Poaceae and genus Eragrostis. The genus Eragrostis constitutes about 350 species of which only tef is cultivated for human consumption (Watson & Dallwitz, 1992). Fifty-four Eragrostis species are found in Ethiopia, out of which fourteen are known to be endemic. Worldwide, Africa contributes 43% of the genus, while South America contributes 18%. Likewise, 12%, 10%, 9%, 6% and 2% of the genus Eragrostisis from Asia, Australia, Central America, North America, and Europe, respectively (Costanza *et al*.,1979).Tef is an allotetraploid species with a base chromosome number of 10 (2n=4x=40) with genome size of 730 Mbp (Mulu *et al*.,1996). It is self-pollinated with chasmogamous and hermaphroditic flowers. It has very low degree of out-crossing, that ranges from 0.2% -1.0% (Seyfu, 1997).

Tef is a crop for which Ethiopia is the center of origin and diversity (Vavilov, 1951). Tef is endemic to Ethiopia and its major diversity is found only in that country. As with several other crops, the exact date and location for the domestication of tef is unknown. However, there is no doubt that it is a very ancient crop in Ethiopia, where domestication took place before the birth of Christ (Seyfu, 1997). It was probably cultivated in Ethiopia even before the ancient introduction of wheat and barley (Shaw, 1976). According to Ethiopian flora, tef grows up to 2500 m.a.s.l. However, the Ethiopian biodiversity institute expedition and collection database indicates that tef is collected from the altitudinal range of 800 to 3200 m.a.s.l. (Alganesh,2013). Maximum production occurs at altitudes between 1800 and 2100 m, annual rainfall of 750 to 850 mm with growing season rainfall of 450 to 550 mm and a temperature range of 10 to 27°C. A very good result can also be obtained at an altitude range of 1700 to 2200 m and growing season rainfall of 300 mm (Seyfu, 1993). The temperature range of 10 to 27°C is most suitable to avoid frost (Seyfu, 1997), and soil temperature range of 18 to 27°C and above was recommended in US (Miller, 2008).

Tef is the most preferred crop as source of food and feed in Ethiopia. Besides, it is tolerant to drought, water logging and pests particularly against storage pests. Now a day, tef has become a globally popular crop for its gluten free property that makes it conducive for people suffering from celiac disease and diabetic because of its slow release of carbohydrates. Hence, it is regarded as a promising alternative food replacing gluten containing cereals like wheat, barley and rye in products such as pasta, bread, beer, cookies and pancakes (Spaenij *et al.,* 2005). Recently, Gina *et al*., (2014) supported this fact with results from the genome sequence initiative. Tef has high iron content that makes it appropriate for pregnancy related anemia (Alaunyte *et al.*, 2012). The iron content mainly seems to play an essential role in Ethiopia, as there is absence of anemia in areas of tef consumption (BoSTID, 1996). It is the major cereal crop in Ethiopia where it is staple food for about 50 million people (Kebebew *et al.,* 2015). Its resilience to extreme environmental conditions and high in nutrition makes tef the preferred crop among both farmers and consumers (Plaza *et al*., 2015). Among the food crops grown in Ethiopia, tef is cultivated on about 3 million hectare producing 5.02 million tons (CSA, 2017). In spite of the low productivity, tef is widely cultivated by over six million small-scale farmers' households in Ethiopia. It is considered to be an orphan crop because it has benefited little from international agricultural research system (Kebebew *et al*., 2015).

The low national tef productivity is mainly attributed to susceptibility to lodging, low yield potential of landraces under widespread cultivation, poor agronomic management practices, biotic and abiotic stresses (Kebebew *et al*.,2011).Nevertheless, it is possible to increase the yield up to 4.5ton per hectare by using improved varieties and proper management practices (Likyelesh, 2013).Determining the magnitude and nature of the production environment is also the most important strategy to maximize grain yield and ensure stable performance of tef varieties across varying environments (Tiruneh,2000).

Even if tef is the most important staple food and enrich with different mineral elements and vitamins, the production and productivity of the crop is below average because of different production constraints (lack of farmer's awareness, lack of improved variety(s) that adapted to their environment, inadequate supply of seed and other agricultural input). For that reason, this study was initiated to improve the production and productivity of tef by evaluating and selecting high yield tef variety (s) for tef growing district of Buno Bedele Zone. Therefore, the study was initiated with the objective to evaluate and select best adapted tef varieties for high yielder and diseases and insect tolerant for the study areas of Chora district and other similar agro ecologies.

Materials and Methods

Description of the study area

The experiment was conducted at Chora district on different farmers' fieldduring 2019-2020 main cropping seasons.

Chora District: Chora is one of the districts in BunoBedele Zone, Oromia Regional State Southwest part of Ethiopia. The district is bordered on the south by Setema, on the west by Yayo and Dorani, on the north by Dega, and on the east by Bedele. The administrative center of this district is Kumbabe. The district is located 519 km away from the capital city of the country and 36 km away from Bedele Town of Buno Bedele Zone. The district is located at an average elevation 2000 masl and located at $08^0$13'33.7" to $08^0$33'55.0" N latitude and $035^0$59'59.7" to $036^0$15'15.8" E longtude. It is generally characterized by warm climate with a mean annual maximum temperature of 25.5°C and a mean annual minimum temperature of 12.5°C. The driest season lasts between December and January, while the coldest month being December. The annual rainfall ranges from 1440 mm. The soil of the area is characterized as an old soil called Nitosols. The economy of the area is based on mixed cropping system and livestock raring agricultural production system among which dominant crops are maize, tef, sorghum and wheat and also horticultural crops.

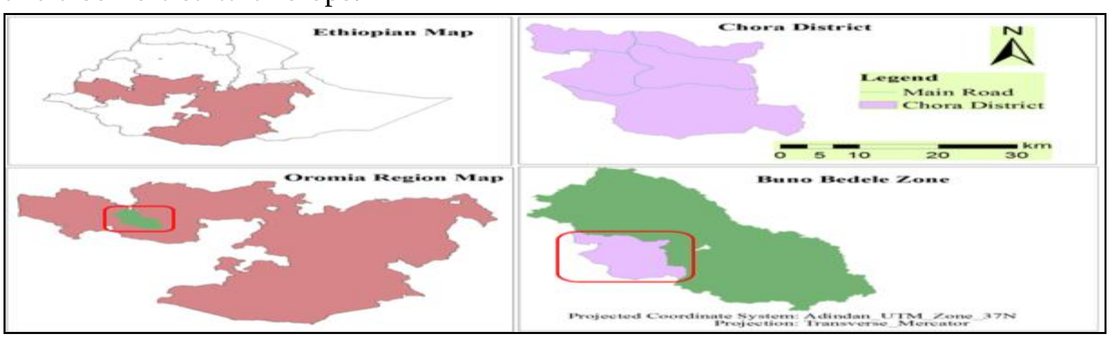


Figure 1. Map of the study area (Chora) district

Experimental Materials and Design

Ten (10) improved tef varieties were brought from Debrezeit and Bako Agricultural Research Centers and evaluated as experimental materials. These materials were randomly assigned to the experimental block and the experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The spacing between blocks and plots was 1m and 0.5m, respectively. The gross size of each plot was $4m^2$ (2m x 2m) having ten rows with a row-to-row spacing of 20cm.The total area of the experimental field was $196m^2$ (24.5m x 8m).Planting was done by drilling seeds in rows with a seed rate of 25kg ha^{-1}. NPS fertilizer was applied at the rate of 100kg ha^{-1} (30g per plot) at the time of planting; and Urea was also applied at vegetative stage at the rate of 100 kg ha^{-1}.

Table 1. Description of the Tef varieties used in the experiment

No	Variety Names	Altitude ranges (m.a.s.l)	Year of Release	Maintainer
1	Dagem	NA	2016	DZARC
2	Dega-teff	1400-2400	2005	DZARC
3	Gimbichu	1400-2400	2005	DZARC
4	Dukem	1400-2400	1995	DZARC
5	Dursi	1850-2500	2018	BARC
6	Flagot	NA	2017	DZARC
7	Kena	1850-2400	2008	BARC
8	Kora	NA	2014	DZARC
9	Quncho	1500-2500	2006	DZARC
10	Guduru	1850-2500	2006	BARC

NA=Non-available

Data collected: Data were recorded on plot and single plant basis and taken from the central eight rows of the plot. Individual plant based data were taken from five plants in each plot taken randomly from the central eight rows of each plot.

Data Collected on Plot Basis

Days to heading (DH): The number of days from 50% of the plots showing emergence of seedlings up to the emergence of the tips of the panicles from the flag leaf sheath in 50% of the plot stands

Total biomass yield (g/plot): The weight of all the central row plants including tillers harvested at the level of the ground

Grain yield (g/plot): The weight of grain for all the central row plants including tillers harvested at the level of the ground

Harvest index (%): The value computed as the ratio of grain yield to the total (grain plus straw) biomass multiplied by 100

Data collected on plant basis: Plant Height (cm): Measured as the distance from the base of the stem of the main tiller to the tip of the panicle at maturity

Panicle Length (cm): The length from the node where the first panicle branch starts up to the tip of the main panicle at maturity

Data Analyses

Genstat 18th Edition was used to analyze all the collected data from individual farmers and the combined data over locations. Mean separations was carried out using least significant difference (LSD) at 5% probability level.

Results and Discussions

The overall combined analysis of variance across the two years for grain yield revealed highly significant (P<0.01) difference among varieties due to the main effect of varieties and years (Table 2). This suggests the existence of genetic variation among the tasted tef varieties with differential response's across years.

Table 2. Combined mean ANOVA of 10 tef varieties for grain yield in kg ha^{-1} in 2019-2020 cropping season

Sources of variation	Degree of freedom	Sum of squares	Mean of squares	F value	Pr (>F)
Year	1	101757815	101757815	518.62	<0.001 ***
Treatments	9	5175805	575089	2.93	0.003 **
Replications	2	384786	192393	0.98	0.04*
Years*Treatments	9	1725180	191687	0.98	0.460
Residuals	36	42773599	196209		

Table 3. Combined mean grain yield (kg ha^{-1}), BMY (kg ha^{-1}), and HI of tef varieties tested at Chora district for two years

Sr. No	Varieties	Year 1 combined	Year 2 combined	Over all Combined	BMY	HI (%)
1	Dagem	2729^{ab}	1308^{abc}	2019^{ab}	12417^{a}	16.26^{e}
2	Dega-tef	2438^{c}	1029^{c}	1733^{b}	7833^{de}	22.12^{bcd}
3	Gimbichu	2646^{abc}	1171^{bc}	1908^{ab}	7083^{e}	26.94^{ab}
4	Dukem	2688^{abc}	1654^{a}	2171^{ab}	8958^{b-e}	24.24^{abc}
5	Dursi	2750^{a}	1683^{a}	2217^{a}	11083^{ab}	20.00^{cde}
6	Flagot	2479^{bc}	1029^{c}	1754b	8750^{cde}	20.05^{cde}
7	Kena	2729^{ab}	1258^{abc}	1994^{ab}	10167^{bc}	19.61^{cde}
8	Kora	2688^{abc}	1373^{abc}	2030^{ab}	8917^{b-e}	22.77^{a-d}
9	Quncho	2625^{abc}	1317^{abc}	1971^{ab}	9917^{bcd}	19.87^{cde}
10	Guduru	2604^{abc}	1529^{ab}	2067^{ab}	11000^{ab}	18.79^{de}
GM		264	1335	199	9612	21.07
LSD(0.05		269	431	455	2234	4.76
CV%		12.6	36.9	35.3	13.5	22.5
P-value		*	*	*	**	**

BMY= Biomass yield, HI= Harvest Index, GM= grand mean, LSD=least significant difference, CV= coefficient of variation.

The combined analysis of variance across the two years revealed highly significant (P<0.01) difference among varieties for almost all traits (Table 3). Dursi variety gave the highest grain yield (2217kg ha^{-1}) followed by Dukem variety (2171kg ha^{-1}) which is within the yield potential (20-24 qt ha^{-1}) during its release in crop variety registration (crop variety registration, 2018). In agreement with this finding; previous studies of Genotype x environment interaction on 22 tef genotypes at four locations in Southern regions of Ethiopia have indicated significant variations in grain yield for the tested genotypes (Ashamo and Belay, 2012). Similar study on phenotypic diversity in tef germplasm in a pot experiment using 124 single panicle sample collection showed substantial variability for traits such as plant height, panicle length, maturity, seed color, seed yield, lodging and panicle type (Malak*et al*., 1965).

Table 4. Combined mean of yield related traits of tef varieties over two years

Sr. No	varieties	DH (days)	PH (cm)	PL (cm)	NTP	BMY (kg ha^{-1})
1	Dagem	52.46^{a}	88.63^{a}	38.51^{ab}	3.67^{a}	12417^{a}
2	Dega-tef	49.29^{bc}	86.07^{ab}	36.01^{bc}	3.33^{abc}	7833^{de}
3	Gimbichu	48.88^{c}	86.56^{ab}	35.47^{bc}	3.33^{abc}	7083^{e}
4	Dukem	51.04^{abc}	91.36^{a}	37.32^{b}	3.67^{a}	8958^{b-e}
5	Dursi	52.75^{a}	93.92^{a}	42.36^{a}	3.50^{ab}	11083^{ab}
6	Flagot	43.62^{d}	76.98^{b}	32.29^{c}	3.00^{c}	8750^{cde}
7	Kena	51.62^{abc}	86.65^{ab}	35.65^{bc}	3.17^{bc}	10167^{bc}
8	Kora	52.04^{ab}	92.52^{a}	38.08^{b}	3.33^{abc}	8917^{b-e}
9	Quncho	51.29^{abc}	90.92^{a}	36.88^{b}	3.25^{bc}	9917^{bcd}
10	Guduru	51.96^{abc}	95.68^{a}	42.26^{a}	3.50^{ab}	11000^{ab}
GM		50.50	88.9	37.48	3.38	9612
LSD (0.05)		3.16	11.42	3.97	0.39	2234.1
CV%		11.0	22.6	18.6	14.2	13.5
P-value		**	*	**	*	**

DH= days to heading, PH= plant height, PL= panicle length, NTP= total number of tillers per plant BMY= Biomass yield, GM= grand mean, LSD=least significant difference, CV= coefficient of variation

Analysis of variance (ANOVA) revealed highly significant difference ($P< 0.001$) among the ten (10) tef varieties in phenological traits such as days to heading, panicle length and Biomass yields and significantly difference ($P<0.05$) for plant height and total productive tillers per plant. The combined analysis of variance for biomass depicted significant ($P<0.05$) difference among the tested varieties. Dagem variety gave the highest shoot biomass (12417 kg ha^{-1}) followed by Dursi (11083 kg ha^{-1}) (Table 4). Many studies have indicated the presence of substantial variation among tef genotypes for different traits of tef. Habte *et al*., (2011) reported highly significant genotype variation for days to panicle emergence and maturity, plant height, culm and panicle length, shoot biomass, grain yield, harvest index, lodging index and thousand seed weight. Similarly, highly significant ($P<0.01$) genotype differences for days to panicle emergence, lodging percentage, thousands kernel weight, grain yield per plant and grain yield per hectare were also reported by Ayalneh *et al*.,(2012).

Guduru followed by Dursi exhibited longest plant height with the respective values of 95.68cm, 93.92cm respectively. The mean plant height was ranged from 76.98cm to 95.68cm. Flagot showed the shortest plant height (76.98cm) (Table 4).

From the combined data analysis, Panicle length ranged from 42.26cm to 42.36cm. Variety Dursi had longest panicle (42.36cm) followed by Guduru (42.26cm), while the shortest panicle length was recorded from Flagot (32.29cm).Number of tillers per plant (NTP) refers to the number of shoots that emerge at the base of the main stem excluding the main shoot. Number of fertile tillers per plant ranged from 3 to 3.67 (Table 4).

Pearson Correlation Coefficient: Correlation coefficient analysis helps to determine the nature and degree of relationship between any two measurable characters. It resolves the complex relations between the events into simple form of association. But measure of correlation does not consider dependence of one variable over the other (Falconer and Mackay, 1996). To know the nature and magnitude of relationship existing between yield and its component characters as well as the association among the components character themselves, the phenotypic correlations among the eight characters were computed and presented in table5.

Grain yield showed positive and highly significant phenotypic association with panicle length (0.38**), plant height (0.74**), days to heading (0.45**), biomass yield (0.31*) and harvest index (0.58**). Therefore, any improvement of these characters would result a substantial increment on grain yield. Similar finding has been reported by Solomon *et al*. (2009) and Ayalneh*et al*. (2012) that day to heading and plant height were significantly correlated and biomass yield and harvest index is highly and positively correlated with grain yield but; inconsistent with this finding, days to maturity indicated that highly and negatively correlated with grain yield. According to Habtamu *et al.* (2011), biomass yield but harvest index had positive and highly significant association with grain yield and also positively and significantly correlated with day to heading. On the other hand, previous research reports showed that association between traits varied with location and years (Abebe, 1985). Kebebew *et al*. (2002) reported that yield and yield component associations showed differences in different locations, which is signified by the variation of association observed between grain yield and component traits.

Table 5. Correlation coefficients among morpho-physiological traits evaluated between grain yield and yield related traits of 10 tef varieties tested for two consecutive years.

Traits	DH	PH	PL	DM	NTPP	BMY	GY	HI (%)
DH	1							
PH	0.36*	1						
PL	0.07^{ns}	-0.27*	1					
DM	0.43**	0.19^{ns}	0.26*	1				
NTPP	0.17^{ns}	0.14^{ns}	0.14*	0.24*	1			
BMY	0.28*	0.27*	0.09^{ns}	0.32*	0.25*	1		
GY	0.45**	0.74**	0.38*	0.19*	0.14*	0.31*	1	
HI (%)	0.23*	0.37*	-0.26*	0.05^{ns}	0.06^{ns}	-0.31*	0.58**	1

DH= days to heading, PH= plant height, PL= panicle length, DM= days to maturity, NTPP= Number of tiller per plant, BMY= Biomass yield (kg ha^{-1}), GY= Grain yield (kg ha^{-1}), HI= harvest index.

Conclusions and Recommendations

Studying varietal response to different environment is crucial for plant breeding programmes where there is a diverse natural, environmental, climatic and soil variability is existing. In line with this, a total of 10 tef varieties were studied at Chora district on different farmers during 2019-2020 main cropping seasons with the objective to select the best adaptive tef varieties with high yield and good agronomic trait to the area. The result of the experiment showed that tef varieties were showed a significant difference both at individual farmers' level and combined mean effects. Varieties were highly affected due to the main effect of years and varieties which show year dynamics with soil and environment. Varieties were affected due to the main effect varieties and years. All the collected agronomic data were positively and significantly correlated with grain yield. Generally, Dursi and Dukem were the best varieties that showed the stability of these varieties as well as higher yielder than other improved varieties tested across two years.

Therefore; these two varieties are recommended as improved varieties and demonstrated on farmers' field for further scaling up.

References

AbebeTullu, 1985. Correlation and Variation Studies on Yield and Some Plant Character in Some Indigenes and Exotic Chickpea Varieties. M.Sc. thesis submitted to Addis Ababa University, Addis Ababa, Ethiopia. PP 89.

Alaunyte, I., Stojceska, V., Plunkett, A., Ainsworth, P. and Derbyshire, E., 2012. Improving the quality of nutrient-rich Tef (*Eragrostis tef*) breads by combination of enzymes in straight dough and sourdough bread making. *Journal of Cereal Science*, 55(1):22-30.

Alganesh, T., 2013. Genetic resources of tef in Ethiopia. In: Kebebew A., Solomon C. and Zerihun T. (eds.). *Achievements and Prospects of Tef Improvement, Proceedings of the Second International Worksho*p. pp 15-19. November 7-9, 2011, Debre Zeit, Ethiopia.

Ayalneh T., Habtamu Z., and Amsalu A.,2012.Genetic variability, heritability and genetic advance in tef [*Eragrostis tef* (Zucc.)Trotter] lines in Sinana and Adaba. *Inter. J. of Plant Breed. & Genet.*6(1): 40-6.

Board on science and Technology for International Development, National Research Council 1996.Lost crops of Africa; Volume I; grains, National Academy press, Washington, D.C, USA

Costanza, S.H., Dewet, J.M.J. and Harlan, J., 1979. Literature review and numerical taxonomy of *Eragrostis tef* (Tef). Economic Botany, 33(4):413-424.

CSA (Central Statistical Agency), 2017.Agricultural Sample Survey 2016/17 (2009 E.C.), Vol. I. Report on Area and Production of Major Crops, (Private Peasant Holdings, Meher Season), Statistical Bulletin 584, Addis Ababa, Ethiopia.

Farshadfar, E., Mohammadi, R., Aghaee M., Vaisi, Z. 2012. GGE biplot analysis of genotype x Environment interaction in wheat-barley disomic addition lines. *Australian Journal of Crop Science* (6):1074–1079.

Gina, C.,Sonia Plaza-W., Korinna E., Stéphanie L., Yi Song W., Dejene G., Edouard de C., Solomon C., Regula B. , Laurent F. , Eric L. , Michel S. , Laurent F., Cris K. , Kebebew A. and Zerihun, T.,2014. Genome and transcriptome sequencing identifies breeding targets in the orphan crop tef (*Eragrostis tef*). BMC Genomics 15.

Habtamu Ayalew, 2012. Phenotypic variability in tef [*Eragrostis tef* (Zucc.)Trotter] landraces from Amhara region, Ethiopia. *Intercontinental Journal of Agricultural Science*, 1(1): 01-06.

Habte, J., Endashaw, B and Kebebew, A., 2011.Genetic variability in released tef [*Eragrostis tef* (Zucc.) Trotter] varieties of Ethiopia. Crop Science Society of Ethiopia (CSSE). Sebil Vol. 13. *Proceedings of the Thirteenth Biennial Conferences*, 31st Dec. 2008 to 2nd Jan. 2009. Addis Ababa, Ethiopia.

Kaya, Y., Akçura, M. and Taner, S., 2006.GGE-biplot analysis of multi-environment yields trials in bread wheat.*Turkish Journal of Agriculture and Forestry*, 30 (5): 325-337.

Kebebew, A., Yu, J.K., Zeid, M., Getachew B., Hailu T. and Sorrells, M.E., 2011.Breeding tef [*Eragrostis tef* (Zucc.)Trotter]; Conventional and molecular approaches. *Plant Breeding*,130:1- 9.

Kebebew A., Gina C., Dejene G., Rizqah K., Solomon C., Sonia Pl., Regula Blösch, Abiel R., Suhail R. and Zerihun T., 2015. Genetic diversity in tef [*Eragrostis tef* (Zucc.) Trotter].*Frontiers in Plant Science,* 6(177):1-13.

Likyelesh, G. and Loerz, H., 2013. Male sterility and gametoclonal variations from gynogenically derived polyploids of tef (*Eragrostis tef*), Zucc. Trotter. *African Journal of Plant Science*, 7(2):53-60.

Miller, D., 2008. Tef as Alternative summer crop. PhD thesis, University of California, U.S.A

Mulu, A., Dolezel, J., van Duren, M., Brunner, H, and Zapata-Arias, F.J., 1996. Flow cytometric analysis of nuclear genome of the Ethiopian cereal tef [*Eragrostis tef* (Zucc.) Trotter].*Genetica* 98: 211–5.

Plaza W., S., Blösch, R. and Tadele, Z., 2015. Efficiency of in Vitro Regeneration is Dependent on the Genotype and Size of Explant in Tef [*Eragrostis tef* (Zucc.) Trotter]. Advances in *Crop Science and Technology,* 3(3): 1-7. doi: 10.4172/2329- 8863.1000179.

Seyfu,K.,1993.Tef (*Eragrostis tef*): Breeding, Genetic Resources, Agronomy, Utilization and Role in Ethiopian Agriculture. Institute of Agricultural Research, Addis Ababa, Ethiopia

Seyfu, K., 1997. Tef (*Eragrostis tef* (Zucc.) Trotter Promoting the Conservation and Use of Underutilized and Neglected Crops. Institute of Plant Genetics and Crop Plant Research, Gatersleben (*International Plant Genetic Resources Institute*), Rome, Italy

Shaw, T., 1976. Early crops in Africa. A review of the evidence. In: J. R. Harlan J. M. J. DeWet and A. B. L. Stemler (Eds.) Origins of African plant Domestication. Mouton Publishers. The Hague, Paris. PP. 107-153.

Solomon Chanyalew, HailuTefera and Harjit-Singh, 2009. Genetic variability, heritability and trait relationships in recombinant inbred lines of tef [*Eragrostis Tef* (Zucc.) Trotter]. Research Journal of Agriculture and Biological Sciences, 5(4): 474-479.

Spaenij, L, Yvonne Kooy-Winkelaar and Frits Koning. 2005. The Ethiopian Cereal tef in celiac disease, *The New England Journal of Medicine*, 353: 1748-1749.

Tiruneh, K.,2000. Genotype × Environment Interaction in tef [*Eragrostis tef* (Zucc.) Trotter].In: Tef Research and Development.Proceeding of the international workshop on tef genetics and improvement.145- 156. October 16-19, 2000, Addis Ababa, Ethiopia

Vavilov, I., 1951.The origin, variation, immunity and breeding of cultivated plants. Translated from the Russian by K. Starrchester Ronald Press, New York.

Watson L, Dallawitz MJ, 1992. The Grass Genus of the World. CAB International, Wallingford, Oxon, UK.

Determination of NPS and N Requirements of Barley (*Hordeum vulgare* L) under Limed Conditions of Acid soils at Guji highland, Southern Ethiopia

Seyoum Alemu, Yared Tesfaye, Aliyi K., Kuma K.

Bore Agricultural Research Center, P O Box 21, Bore, Ethiopia

*Corresponding author: Seyoum Alemu, Bore Agricultural Research Center, P O Box 21, Bore, Ethiopia, Email: seyoum23@gmail.com, Tel:+251-09-10-31-63-84

Abstract

Barley is one of the major staple crops in Ethiopia in terms of both production and consumption. Even though it is such an important cereal crops in Ethiopia, it is giving low yield due to many production constraints such as lack of improved varieties, poor agronomic practice, Soil acidity, diseases, weeds and low soil fertility in Ethiopia in general and in Guji zone in particular. Therefore, field experiment was conducted during the 2019 -2021 main cropping season at Bore to assess the effect of NPS and N fertilizer rates on yield components and yield of Food Barley; under limed condition of acidic soil for highland. The experiment was laid out in split plot design with three replications using a Food Barley variety known as 'HB 1307' as a test crop. The treatments consisted of four levels of NPS (0, 50, 100 and 150 kg ha^{-1}) and four levels of N (0, 50, 100 and 150 kg ha^{-1}) consisting a total of 16 treatment under limed and unlimed condions. Analysis of the results revealed that all parameters were significantly (P<0.05) affected by the interaction of the factors (NPS, N and liming) as well as the main effects except date to 50% heading and days to maturity which did not significantly (P<0.05) affected. The highest grain yield (3862 kg/ha) were obtained from combination of 100 kg/ha NPS and 23 kg/ha. Therefore, use of 100 kg/ha NPS and 23 kg/ha N can be recommended for production of food barley for the study area and other areas with similar agro ecologies.

***Keywords**: Liming, Interaction, Interaction effect, Main effect, Acidic soil*

Introduction

Soil acidity is among the major land degradation problem worldwide. It is estimated that over 11 million ha of land and 32% of arable land is exposed to soil acidity around the world (Eswaran *et al* 1997) which are caused by high rainfall, topographic factors, morphological factors and severe soil erosion (Mesfin Abebe, 1998. Which lead to high rate of weathering of the soil, high rate of leaching nutrients from soils, very rapid destruction of soil physical structure and texture, quick and severe erosion of the top soil and acute drought stress are signals of severe soil acidity (Pearson, 1975; 1989; Eswaran *et al*. 1997). In Ethiopia, huge surface areas of highlands located at almost all regional states of the country are affected by soil acidity, which cover 40.9 % of the Ethiopian total land is affected by soil acidity Schlede (1989). Of these about 27.7 % of these soils are dominated by moderate to weak acid soils (pH in KCl) 4.5 -5.5, and around 13.2 % by strong acid soils (pH in KCl) <4.5) including highland of Guji zone which has pH of 5.1. In such acidic soil deficiencies of N. P, K, Ca, Mg and micronutrients are common. Because of these circumstances a number of adverse effects are observed such as loss of crop diversity, decline in the yield of existing crops/reduced yield, lack of response to ammonium phosphate and urea fertilizers, complete failure of cropping, poor plant vigor, uneven pasture and crop growth, poor nodulation of legumes, stunted root growth, persistence of acid-tolerant weeds, increased incidence of diseases, poor plant growth, nutrient deficiencies and imbalance, and abnormal leaf colors are major symptoms which indicate soil acidity problem (Kang and Juo, 1986).

A recent study on the two important plant growth-limiting nutrients (Nitrogen and Phosphorus) shows that acid soils dominate most of the southern and southwestern parts of the country and generally have low P content. Soils in the south (in which Guji is located) and southwestern part including Sidamo, Ilubabor and Keffa have high N_2 content and low P content (NFIA, 1993). This is due to fixation of P in acidic soil. Thus, enhancing soil organic N and P mineralization in acid soils and speeds up the uptake efficiency of applied NPS fertilizers through liming is very important. In addition, sulfur fertilization helps in enhancing the uptake of N, P, K and Zn in the plant (Fairhurst, 2000). Due to its synergistic effect, the efficiency of these elements is enhanced which results in increased crop productivity. Even though this is the problem in our area, no research was done on liming and other acid soil management practice. Therefore it is important to determine optimum rate of NPS and N with liming for production of barley at acidic soil.

Objective: -To assess the optimum rate of NPS and N for Food Barley under limed and un-limed condition and to give proper fertilizer recommendation after liming

Materials and methods: The experiment was conducted at Bore districts for two years (2019-2021) during the main cropping season. The experiment will be laid out in split plot design (limed and unlimed as main plot and combination of NPS and N (4x4) in sub plot on the plot size of 2.4m x 2.5m. The spacing was 20cm, 1m and 1.5m paths between the row, plots and the blocks respectively. Food Barley, HB-1307 variety was used as seed source with 150kg/ha seeding rate. Management of non-treatment routines was similar for all experimental units including the control. Lime requirement of the soil was calculated based on its exchangeable acidity (Al^{3+} plus H^{1+}). The lime was evenly spread and incorporated up to 20cm depth by using hand hoe one month before planting at equal rate for all treatment for limed condition.

Data Collection and Measurement

Crop phenology and growth parameters

Days to 50% heading (DTH): days to spike heading was determined as the number of days taken from the date of sowing to the date of 50% heading of the plants from each plot by visual observation.

Days to 90% physiological maturity (DTM): days to physiological maturity was determined as the number of days from sowing to the date when 90% of the peduncle turned to yellow straw color. It was recorded when no green color remained on glumes and peduncles of the plants, *i.e.*when grains are difficult to break with thumb nail.

Plant height (cm): plant height was measured from the soil surface to the tip of the spike (awns excluded) of 10 randomly tagged plants from the net plot area at physiological maturity.

Spike length (cm): It was measured from the bottom of the spike to the tip of the spike excluding the awns from 10 randomly tagged spikes from the net plot.

Yield components and yield

Number of tillers per plant: number of tillers per plant was determined from 10 tagged plants per net plot at physiological maturity by counting the number of tillers after removing soils surrounded the tillers.

Thousand kernels weight (g): thousand kernels weight was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using electronic seed counter and weighed with electronic sensitive balance. Then the weight was adjusted to 12.5% moisture content.

Grain yield (kg ha^{-1}): grain yield was taken by harvesting and threshing the seed yield from net plot area. The yield was adjusted to 12.5% moisture content as:

$$\textbf{Adjusted grain yield} = \frac{(100 - MC) \times \text{unadjusted grain yield}}{100 - 12.5}$$

Statistical Data Analysis: All data collected were subjected to analysis of variance (ANOVA) procedure using GenStat (18th edition) software [12]. Comparisons among treatment means with significant difference for measured characters were done by using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

Results and discussion

Days to 50% heading: The analysis of variance revealed that the interaction of the factors (NPS x N x Liming) and main effects did not significantly ($P < 0.05$) effect days to 50% heading of Food barley (Table 1). Lack of significance might be heading of the crop is mainly controlled by the genetic makeup of a genotype. This result is in line with the findings of Haji *et al*.,2017 who reported non significant heading on different blended fertilizer rates.

Days to 90% physiological maturity: The analysis of variance revealed that the interaction of the factors (NPS x N x Liming) and main effects did not significantly ($P < 0.05$) effect days to 50% heading of Food barley (Table 1). Lack of significance might be maturity of the crop is mainly controlled by the genetic makeup of a genotype.

Table 5. Interaction effect of NPS, N & lime on DTM

		N rate(kg/ha)			
Limed	NPS Rate (kg/ha)	0	23	46	69
	0	136.1	134.5	136.5	135.1
	50	137.2	134.6	135.9	134.6
	100	135.8	135.1	135.8	135.5
	150	135.1	135.7	135.1	136.4
Un limed	0	137.1	135.1	135.8	134.1
	50	134.7	135.7	135.7	136.1
	100	134.5	135.5	136.5	135.8
	150	136.1	135.4	136.7	134.1
	Mean	135.56			
	LSD (5%)	NS			
	CV (%)	1.5			

Plant height: The analysis of variance revealed that the interaction of the factors (NPS. N and liming) significantly ($P < 0.05$) affect plant height of Food barley as well as the main effects (Table 2). This might be due to the vital role of N fertilizer in vegetative growth and resulted for significant influence on plant height as acidity is decreased. This result is consistent with Wubshet *et al*. (2017) who reported significance difference of plant height barley though integrated application of blended NPSB, Lime and compost.

Table 6. Interaction effect of NPS, N and liming on plant height of Food barley

		N rate(kg/ha)			
Limed	NPS Rate (kg/ha)	0	23	46	69
	0	100 hi	104.9 a-h	108.6 a-e	108.5 a-e
	50	106.5 a-h	101.6 d-i	107.2 a-h	107.2 a-h
	100	103.6 b-i	105.9 a-h	109.8 ab	112 a
	150	103.6 b-h	103.4 b-i	109.2 abc	109.9 ab
Un limed	0	96.2 i	108.4 a-e	105.5 a-h	108.2 a-f
	50	100.8 f-i	103.4 b-i	106.3 a-h	107.6 a-g
	100	101.3 e-i	106.3 a-h	102.4 c-i	109.1 abc
	150	108.8 a-d	100.6 ghi	105.7 a-h	108.1 a-f
	Mean	105.64			
	LSD (5%)	7.397			
	CV (%)	8.4			

Spike length: The analysis of variance revealed significant ($P < 0.05$) effect of the factors (NPS, N and liming) and the main effect on this parameter. The longest spikes (8.75 cm) were obtained at 100kg/ha NPS and 69 kg N ha^{-1} under limed condition whereas the shortest spikes (6.44cm) were produced at control/0 NPS and 0 N kg ha^{-1} under unlimed (Table 2). The increase in spike length at the highest NPS and N rates might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to interaction/synergetic effect of the three nutrients at the highest rate. This result agrees with the findings of Muluneh and Nebyou (2016) who reported the highest spike length (7.7cm) for Food barley at the rate of 50/150 kg N/P_2O_5 ha^{-1}.

Yield Component and Yield

Number of tillers per plant

The main effect of NPS was significant ($P < 0.05$) on tiller number produced per plant (Table 3) whereas the main effect N rate and the interaction of the factors did not.

The maximum number of tillers per plant (4.39) was produced by plants treated with the application of the highest NPS rate (150kg ha^{-1}) whereas the minimum number of tillers per plant (3.4) was produced at the control treatment. The improvement in number of tillers with NPS application might be due to the role of P found in NPS in emerging radical and seminal roots during seedling establishment in wheat (Cook and Veseth, 1991). In line with this result, Yared *et al*. (2020) reported significant effect of NPS on the number of tiller per plant and the number of fertile tillers. But the result did not agree with that of Wubshet *et al*. (2017) who reported interaction effect of blended NPSB, lime and compost on number of tiller of Food barley.

Table 7. effect of NPS rate on number of tillers Food barley at Bore

NPS Rate (kg/ha)	NFT	
0	3.44 b	
50	3.941 ab	
100	3.722 b	
150	4.399 a	
N Rate (kg/ha)		
0	3.59	
23	4.008	
46	3.912	
69	3.991	
Mean	3.88	
LSD (5%)	0.52	
CV (%)	10.9	

Means with the same letter(s) in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, LSD= Least Significant Difference at 5% level

Thousand Kernels weight: The interaction effect of NPS rates and liming, as well as the main effects significantly ($P< 0.05$) influenced thousand kernels weight of barley. The highest thousand kernels weight (42.67 g) was recorded at combination of 150kg ha^{-1} NPS rate with liming. On the other hand, the minimum thousand kernel weight (36.16 g) was observed at control/ 0 kg NPS ha^{-1} under unlimed condition. Thousand kernels weight obtained from the overall limed plots was significantly higher than thousand seed weight from the unlimed plot/control. This might be due to the improvement of seed quality and size due to due to the three nutrients.

Table 8. Interaction effect of NPS, N and liming on TKW of Food barley

NPS Rate (kg/ha)	Limed	Un limed
0	37.37 bc	36.16 c
50	40.47 ab	37.22 bc
100	42.04 a	40.78 ab
150	42.67 a	39.47 abc
Mean	39.52	
LSD (5%)	3.98	
CV (%)	15.8	

Grain yield: The interaction effect of the three factors (NPS and N rate, and liming) and their main effects significantly ($P< 0.05$) influenced grain yield of Food barley. Increasing NPS and N rates across the liming significantly increased grain yield. Thus, the highest grain yield (3862 kg ha^{-1}) was obtained at combined rates of 100 kg ha^{-1} NPS and 23 kg ha^{-} whereas the lowest grain yield (2045 kg ha^{-1}) was recorded at the combinations of 0 kg NPS ha^{-1} and 0 kg ha^{-1} or at the control treatment (Table 5). The highest grain yield at the highest NPS and N rates might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to interaction/ synergetic effect of the three nutrients which enhanced yield components and yield. In line with this, Shiferaw and Anteneh (2014) reported highest barley grain yield from combined application of NPK and liming. Similarly Hailu and Getachew (2006) reported triple yield increases of barley by applying 3 t ha^{-1}. Wubshet et al ., 2017 also reported the highest grain yield of barley (5386 kg ha^{-1}) by combined application of 611kg lime + 5 t compost + 150 kg NPSB + 100 kg KCl +72 kg N ha^{-1}

Table 9. Interaction effect of NPS, N and Liming on Grain yield of food barley at Bore

		N rate(kg/ha)			
Limed	NPS Rate (kg/ha)	0	23	46	69
	0	2871 de	3226 a-e	3253 a-e	3274 a-e
	50	3264 a-e	3520 abcd	3193 a-e	3384 a-e
	100	2802 e	3862 a	3795 ab	3568 abc
	150	2961 cde	3502 a-d	3333 a-e	3125 b-e
Un limed	0	2045 f	3058 cde	3255 a-e	3321 a-e
	50	2979 cde	3158 b-e	3209 a-e	3552 a-d
	100	3145 b-e	3476 a-e	2983 cde	3196 a-e
	150	3078 cde	3496 a-d	3200 a-e	3103 cde
	Mean	3224.62			
	LSD (5%)	689.58			
	CV (%)	13.00			

Summary and conclusions

Field experiment was conducted during the 2019-2021 main cropping season at Bore to assess the effect of NPS, N and Liming on yield components and yield of food barley. The experiment will be laid out in split plot design (limed and unlimed as main plot and combination of NPS and N (4x4) in sub plot on the plot size of 2.4m x 2.5m using a food barley variety known as 'HB-1307' as a test crop. Analysis of the results revealed that all parameters were significantly ($P<0.05$) affected by the interaction of the factors as well as the main effects except date to 50% heading and date to maturity which did not significantly ($P<0.05$) affected. T his indicates that how the factors are important in production and productivity of food barley. The highest grain yield (3862 kg/ha) were obtained from combination of 100 kg ha^{-1} NPS rate and 23 kg N ha^{-1} with liming. Therefore, use of 100 kg NPS ha^{-1} and 23 kg N ha^{-1} under limed condition can be recommended for production of food barley for the study area and other areas with similar agro ecologies. In addition to this, liming and other acidic soil management should also be done for the future since acidity of highland Guji is ranged from acidic to strongly acidic.

References

Cook R.J. and Veseth, R.J.1991. Wheat health management. The American Phytopathological Society, USA. 152.

Crawford, J. T. W, Singh, U. and Breman, H. 2008. Solving problems related to soil acidity in Central Africa's Geat Lakes Region. International Center for Soil Fertility and Agricultural Development (IFDC) - USA.

Dercon S and Hill RV (2009) Growth from agriculture in Ethiopia. Identifying key Constraints. Paper prepared as part of a study on agriculture and growth in Ethiopia. DFID, UK.Food and Agriculture Organization. Ethiopian Highland Reclamation Study, Ethiopia. Final Report (Volume I and II). Food and Agricultural Organization of the United Nations,2005, Rome, Italy.

Getachew A and Chilot Y (2009) Integrated Nutrient Management in Faba Bean and Wheat on Nitisols of central Ethiopian Highlands. Research Report No. 72. Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia, pp. 24.

Getachew Agegnehu, Angaw T and Agajie T (2012) Evaluation of Crop Residue Retention , Compost and Inorganic Fertilizer Application on barley productivity and Soil Chemical properties in the Central Ethiopian Highlands. Ethiopia.J.Agric.Sci.22:45-61.

Hailu T; Getachew B. 2006. Eragrostis tef (*Zuccagni*) Trotter. In Plant Resources of Tropical Africa 1. Cereals and pulses.. (Eds M. Brink and G. Belay). Prota Foundation, Wageningen/ Backhuys Publishers, Leiden/ CTA, Wageningen, Netherlands. pp 68-72.

Haji Jewaro Beketa, Demelash Kefale and Tarekegn Yoseph.2017. Effect of Blended Fertilizer Types and Rates on Growth, Yield and Yield Components of Bread Wheat (*Triticum aestivum* L.) in Wondo District, Southern Ethiopia. *International Journal of Agriculture Innovations and Research.* 8(4), 2319-1473

Mesfin Abebe, 2007. Nature and Management of Acid Soils in Ethiopia. (http:// www.eiar.gov.et/ Soil/ soils acid.pdf). Accessed on June 21, 2014.

Schlede, H., 1989. Distribution of acid soils and liming materials in Ethiopia. Ethiopian Institute of Geological Surveys, Ministry of Mines and Energy, Addis Ababa, Ethiopia.

Shiferaw Boke; Anteneh Fekadu. 2014. Lime and NPK effect on soil acidity and yield of barley in different acid soils of southern region, Ethiopia. International Journal of Natural Sciences Research, 2(7):113-122.

Taye Bekele, 2008. Estimation of Lime Requirement. Training Manual for Regional Soil Testing Laboratory Heads and Technicians. National soil Testing Center, Ministry of Agriculture and Rural Development.

Taye B (2007). An overview of acid soils and their management in Ethiopia. Paper presented in the third International W0rkshop on water management (Wterman) project, September, 19-21, 2007, Haromaya, Ethiopia.

Tisdale, S. T., Nelson, W. L. and J. D. Beaton, J. D. 1985. Soil Fertility and Fertilizers. 4th ed. Macmillan Publishing Company, New York. 499p.

Wang, J., Raman, H., Zhang, G. Mendham, N. and Zou, M. 2006. Aluminum tolerance in barely (*Horidium vulgarie* L.): Physiological mechanisms, genetics and screening methods. *Journal of Zhejiang University Science*. 7: 769-787. Marschner, H. (1995). *Mineral nutrition of higher plants II* (2^{nd} ed.). London, New York: Academic Press.

Wubshet Demissie, Selamyihun Kidanu, Tolera Abera and Cherukuri V Raghavaiah2017. Effects of Lime, Blended Fertilizer (NPSB) and Compost on Yield and Yield Attributes of Barley (*Hordium Vulgare* L.) on Acid Soils of Wolmera District, West Showa, Ethiopia. *Ethiop.J.Appl.Sci. Technol.* Vol.8 (2): 84-100

Yared Tesfaye, Seyoum Alemu, Kabna Asefa, Girma Teshome and, Obsa Chimdesa.2020. Effect of Blended NPS Fertilizer Levels and Row Spacing on Yield Components and Yield of Food Barley (*Hordeum Vulgare* L.) at High Land of Guji Zone, Southern Ethiopia. *Academic Research Journal of Agricultural Science and Research.8(6): 609-618*

Participatory Variety Selection of Bread Wheat Varieties at High Land Guji Zone, Southern Ethiopia

Yared Tesfaye, Seyoum Alemu, Aliyi Kedir, Kuma Kebede

Bore Agricultural Research Center, P O Box 21, Bore, Ethiopia

Abstract

Many improved bread wheat varieties have been tested for their adaptability and recommended for high land agro-ecologies of Guji Zone. However, some of these varieties were not under production. This is due to the appearance of new rust races and breakdown of resistivity of the crop as highland of Guji is hotspot of wheat rusts. As a result, evaluating newly released wheat varieties by participating farmers to select according to the user's desires. Therefore, study was conducted in 2020 cropping season at two high land districts of Guji Zone(Bore and Ana Sora) to select and recommend high yielding, early maturing and diseases resistant improved bread wheat varieties through Participatory variety selection. Five improved bread wheat varieties with one local check were used as treatments. The treatments were arranged in randomized completed block design with three replications for mother trial and farmers were used as replication for baby trials. The analyzed result of agronomic data indicates presence of significant variance among the tested varieties for most of the characters studied except days to number of tiller per plant. Varieties Sinja, Wane and Lemu were highest yielding and relatively resistant to diseases than the local check. Farmers were also involved in selecting the varieties using their own criteria. Accordingly, two varieties (Sinja and Wane) were selected by farmers. From the two ways studies, it's observed that there is similar result. Therefore, to conclude the result of the study, it's requisite to consider and accept the farmers' decision instead of considering the trial finding. Thus, based on both ways finding varieties Sinja and Wane were recommended for the studied areas and similar agro-ecologies of Guji Zone.

Keywords: Rust, Participatory variety selection, Bread wheat

Introduction

Population growth phenomenon in developing countries, diversity of foods, and their high consumption in the advanced countries have led to an increase in the global demand for food to an unprecedented level in the history (Khabiri *et.al.*, 2012). With this regard, the use of more productive, profitable agricultural production in fostering food security, generating local employment, raising local incomes, and thus alleviating poverty particularly in developing world, where it serve as an economic source is incomparable (Reeves *et al.*,1999). In view of this, increasing cereal crops productivity plays a great role as they are an important source of human nutrition since pre-historic times, dating back to 8000 B.C (Curtis,2002). Cereals account for approximately two-thirds of all human energy intake and are grown on roughly half of the world's crop land USAID (2013). Today, eight cereal crops viz., wheat, rice, maize, barley, oat, rye sorghum and millets collectively accounts 99% of the world cereal production (FAO, 2011).This also true for Ethiopia where the major cereal crops; tef, maize, wheat, sorghum and barley have the largest share of cultivated land and production(CSA,2020/21). In 2012/2013 cropping season, out of the total grain crop area, 81.39% (10.5 million hectares) was under cereals. In terms of production, cereals contributed 88.36% which is about 302.05 million quintals of the grain production. This may be due to the significant importance of these crops in sustaining food security. Because, the lively hoods of the Ethiopian people are directly or indirectly dependant on these crops. Among cereals, wheat accounts 16.91% (57.8 million quintals) grain (CSA, 2020/21). The productivity of the crop remains low (1.8 ton ha^{-1}) in the country as compared the world average yield (3.19 ton/ha) (FAO, 2011).

In Ethiopia, efforts have been made to develop and popularize various improved crop varieties across different locations through PVS (Getachew *et al*., 2008, Asaye *et al.*, 2013; Tesfaye Tadesse, 2013, Tafere *et al*., 2012. However, the farmers' selection criteria for these crops were not adequately assessed and well documented from all parts of the country especially in the Guji Zone of Oromia region. For the last 3-4 years, adaptation trial of various improved bread wheat varieties have been conducted at Bore Agricultural Research Center. From the conducted activities, several technologies were promoted to the users after testing their adaptation at multi-location both on station and farmers field. In addition, this process take time which lead to break of resistivity of the variety before farmers need addressed. Feed backs on the prominence and draw backs of the promoted technologies are raised from the farmers that didn't address their preference which could serve as a basic tool for research. From these out puts, it was observed that gap was made while conducting these activities. Because, in previously conducted research activities, farmers of the area were not majorly participated in selecting and recommending technologies for their specific area through providing their indigenous knowledge. In that time, technologies are taken to demonstration after evaluated by researchers alone. As a result, it's observed that some recommended technologies didn't get acceptance by farmers from various point of view. This shows the gaps made by not participating farmers in selecting and recommending varieties, that means it's a conventional research method that limit farmers interaction in research at certain stages. Rigid release requirements and unrepresentative testing conditions lead to mismatches between what is offered by breeders and what is desired by farmers (Witcombe and Virk 1997). Thus, to solve such problems, it's obvious that farmer's participation has a significant place in selecting and promoting improved agricultural technologies. Only participatory varietal selection was done in Guji zone. But these varieties were not performing good due to break of disease resistivity and yield decrease since highland of Guji is hot spot for wheat rusts. Thus it is important to introduce, evaluate and select by participating farmers newly released varieties.

Participatory varietal selection in agriculture of developing-country is the existence of important cropping systems in marginal regions of the countries where the adoption of modern improved varieties is low or negligible (Walker,2006). So, participating farmers in research especially, in convectional research is the pre- eminent method to meticulously work with farmers through integrating their indigenous knowledge in variety selection. Therefore, this activity was conducted to address the following objectives.

Objectives

To improve production and productivity of the study area through selecting and promoting improved bread wheat varieties

To evaluate and recommend high yielding, early maturing and diseases resistant improved bread wheat varieties through PVS and to identify the most important criteria for future bread wheat improvement work in the area.

Materials and Methods

Description of the study area

The experiment was conducted at two high land districts of Guji Zone (Bore and Anna Sora) to select and recommend high yielding, early maturing and diseases resistant improved bread wheat varieties through PVS. The climatic condition of both districts comprises an annual rain fall of 1250mm and 1750mm/annual, mean temperature of 15-24 and 17.5-28 ^{O}c respectively. The two districts are selected for this experiment based on their potentiality for the production of bread wheat. Five improved bread wheat varieties with one local check were used as treatments.

The treatments were arranged in randomized completed block design with three replications for mother trial (planted on station) and farmers were used as replication for baby trials. For this purpose, one farmer field was used as replication for baby trials in which selected farmers plant materials in one replication and the other host farmers were planted the two non-replicated trials. At both trial sites, the materials were planted on a plot size of 2.5mX1.2m with 20 cm between rows consisting 6 rows. In puts (seeds, fertilizers) and management practices were applied as recommended for wheat production. Data was collected in two ways: agronomic data & farmers data. For agronomic data phenological, Growth, yield and it's component were collected following their own principles. Data collected from mother trials was subjected to ''GenStat' 'software (18th) to evaluate the variability of the tested varieties. This was done through computing analysis of variance for all characters studied according to the method given by Gomez and Gomez (1984). For data's collected from baby trials, matrix ranking suggested by De Boef *et al*.,(2007) was employed.

Results and Discussions

Days to maturity: The analyzed result of agronomic data indicates presence of significant variance among the tested varieties for most of the characters studied except number of tiller per plant. As the study result indicated, early maturity was revealed by variety Sinja (149.7days) and Wane (155days) whereas late maturity was depicted by Lemu (160.3 days).

Plant height: Among the tested varieties, Wane showed the longest height (84.17) where as shortest height (69.16) was from variety Obora. Asaye *et al*.,(2013) was also reported significance difference among the tested varieties for plant height. Considering this character for variety evaluation is very crucial as it help for selecting varieties able to withstand lodging problems. Spike length: From the study result, significant difference was observed among the tested varieties for spike length which was ranged from 6.27 to 7.66 Accordingly, variety

Dambal followed by Wane showed maximum spike length whereas variety Obora followed by Lemu showed minimum spike length.

Tillers per plant*:* As the study result indicates, there was no significant difference observed among the tested variety for number of tillers per plant. Even though there was no statistical difference between the varieties, the highest tiller/plant was revealed by Wane where as the lowest was showed by variety Lemu (Table 1)

Grain yield (GY): significant variability was observed among the tested varieties for grain yield kg/ha, which was ranged from 2542 to 5569 kg/ha with the mean value of 3887 kg/ha. The highest grain yield (5569) was recorded for Sinja followed by Wane (4972 kg/ha). But, low yield of 2542 kg/ha was obtained from Dambal followed by Huluka/local (2611 kg/ha) (table1). Highly significant difference for grain yield among bread wheat varieties under grandmother trial was also reported by Asaye *et al.*, (2013).

Thousand kernels weight: The analysis of variance revealed that the main effect of variety significantly ($P < 0.05$) affect thousand kernels weight of wheat. The thousand kernels weight (40.52 g) was recorded from Sinja whereas the lowest kernels weight (27.6g) obtained from Huluka (table 1).

Table 1. Mean separation of different agronomic characters for six BWV evaluated in mother trial (Bore on station

Variety	GY(kg/ha)	DTH	TKW(g)	DTH	DTM	PH	SL	NTPP	YR	SR
Wane	4972 a	74.7c	37.7 ab	74.67 c	155 ab	84.2 a	6.77 b	2.5	15R	10MS
Lemu	4264 ab	82.7 a	39.1 ab	82.67 a	160 a	75.7 bc	6.33 b	1.9	20MS	25S
Dambal	2542 c	76.3 b	31.6 bc	76.33 b	155 a	77.2 b	7.66 a	2.3	40S	10MS
Huluka	2611 c	81.7 a	27.6 c	81.67 a	156a	73.2 bc	6.6 b	2.2	55S	10MS
Sinja	5569 a	69 d	40.5 a	69 d	150b	79.3 ab	6.3 b	2.2	10M	5R
Obora	3361 bc	82.3 a	36.8 ab	82.33 a	158 a	69.2 c	6.27 b	2.2	30MS	40S
Mean	3887	77.8	35.6	77.78	155.7	76.5	6.67	2.2		
LSD	1396.90	1.5	7.8	1.54	5.35	6.0	0.85	NS		
CV (%)	19.80	1.1	12.1	1.1	1.9	4.8	7.0	17.7		

Keys: DTH: Days to heading, DTM: Days to maturity, PH: plant height, SL: spike length, NTPP: number of tillers per plant, TSW: thousand seed weight, Gy: grain yield,YR-yellow rust, SR-stem rust

Farmers' variety selection criteria

Farmers were allowed to evaluate the varieties using their own criteria. Before selecting varieties, they were informed to set criteria for selecting best bread wheat according to their area. This was done by making group discussion among the farmers which comprises elders, women and men. After setting the criteria they were informed to prioritize the criteria according to their interest. By doing this, farmers were allowed to select varieties by giving their own value. The following table 2 indicated the results obtained from farmers' evaluation. Accordingly, variety Wane and Sinja were selected by farmers due to their best performance for their own criteria.

Table 2. Farmers' preference scores and ranking on baby trial

Variety name	Farmers selection criteria										
	1	2	3	4	5	6	7	8	Total	Average	Rank
Wane	165	65	137	125	154	156	110	164	1076	134.5	1
Lemu	156	106	88	134	140	104	113	124	965	120.6	3
Dambal	66	69	72	131	90	124	164	62	778	97.25	4
Sinja	159	163	166	137	53	114	128	103	1023	127.9	2
Obora	94	39	56	100	160	100	62	55	666	83.25	5
Huluka	34	33	33	54	69	83	88	35	429	53.63	6

Key: 1=grain yield, 2=disease, 3=seed color, 4=spike length, 5=tiller, 6=uniformity, 7=plant height, 8=seed size

Conclusion

Released technologies are not immediately reach farmer in remote areas like Guji Zone of Southern Oromia. This due to lack of setting appropriate research method; like farmer participation and long extension process. In such case, Participatory variety selection is an effective tool in facilitating the adoption and fast extension of the improved technologies. Because, the users are allowed to participate in selecting appropriate technologies by employing their own indigenous knowledge. As the result, the current study was also verified that farmers were able to participate in selecting improved bread wheat varieties through employing their own selection criteria. Thereby, two improved bread wheat varieties (Wane and Sinja) were selected by the farmers and recommended for the study areas and similar agro-ecologies.

References

Asaye Demelash, Tadesse Desalegn, Getachew Alemayehu, 2013. Participatory Varietal Selection of Bread Wheat (Triticum aestivum L.)Genotypes at Marwold Kebele, Womberma Woreda, West Gojam, Ethiopia. *International Journal of Agronomy and Plant Production.* Vol., 4 (S), Pp 3543-3550

Central Statistical Agency ,2020/21. Crop production forecast sample survey. Report on Area and Crop Production forecast for Major Crops. December 2012, Addis Ababa.

Curtis, B.C., 2002. Wheat in the world. Bread wheat production and improvement .*FAO Plant Production and Protection Series No*. 30.

De Boef WS, Thijssen MH (2007). Participatory tools working with crops, varieties and seeds. A guide for professionals applying participatory approaches in agro-biodiversity management, crop improvement and seed sector development. Wageningen International, 83p.

Getachew Belay, HailuTefera, Anteneh Getachew, Kebebew Assefa and Gizaw Metaferia, 2008. Highly client- oriented breeding with farmer participation in the Ethiopian cereal tef [Eragrostistef(Zucc.) Trotter].African Journal of Agricultural Research Vol. 3 (1), pp. 022-028

Khabiri E., Imani A.A., and Shahbazi H., 2012. Studying the grain yield and yield components in advanced rain fed wheat genotypes. Scholars Research Library. *Annals of Biological Research* 3 (12):5647-5650.

Reeves, T.G., S. Rajaram, M. van Ginkel, R. Trethowan, H.J. Braun and K. Cassaday, 1999. *New Wheat's for a Secure, Sustainable Future.* Mexico, D.F. CIMMYT

Tafere Mulualem, Tadesse Dessalegn, and Yigzaw Dessalegn, 2012. Participatory varietal selection of faba bean (*Vicia faba* L.) for yield and yield components in Dabat district, Ethiopia.Wudpecker Journal of Agricultural Research Vol. 1(7), pp. 270 – 274

Tesfaye Tadesse, 2013. Participatory variety selection of Potato (*Solaniumtuberosum* L) in Southern Ethiopia. Journal of Agri-Food and Applied Sciences Vol. 1(1), pp. 1-4

USAID (United States Agency for International Development), 2013.Feed the future food security innovation center. Accessed on March, 2014. Web site: http://www.feedthefuture.gov/research

Walker, T.S. 2006. Participatory Varietal Selection, Participatory Plant Breeding, and Varietal Change.

Witcombe, J.R. and D.S. Virk. 1997. New directions for public sector variety testing. In: Tripp, R. (ed.). New Seed and Old Laws. Regulatory reform and the diversification of national seed systems. ITP on behalf of Overseas Development Institute. p. 59-87

Genotype x Environment interaction for grain yield of bread wheat (*Triticum aestivum* L.) Genotypes in SouthEstern Oromia

Aliyi Kedir, Seyoum Alemu, Yared Tesfaye, Kabna Asefa, Girma Teshome and Kuma Kebeda
Bore Agricultural Research Center, P.O.Box 21, Bore, Ethiopia
Corresponding Author Email: aliobsinan@gmail.com

Abstract

The activity of this regional variety trial exprement was held for two consiquetive years at three high land areas of guji zone of southern Oromia with the objective of screening the best preformed genotypes for the targeted areas. RCBD experimental design with three repilications was used. 17 advanced genotypes with two checks were used. Information on the nature and magnitude of the GxE interaction (GEI) that affects performance of genotypes is essential to enhance the improvement of wheat. This study was conducted across locations to evaluate the nature and magnitude of Genotype x Environment interaction and its effect on grain yield and yield components of bread wheat genotypes and to release widely adapted gonotypes. The combined analysis of variance revealed that, there were very highly significant differences among environments ($p<0.001$) and among genotypes ($p<0.001$) indicating the presence of variability in genotypes as well as diversity of growing conditions at different locations. Environments explained 49.9%, genotypes 15.19% and GxE 17.99% of the variability in grin yield. Bore was the highest yielding (5.13tonha^{-1}) while abayi was the lowest yielding (2.01tonha^{-1}) location. The highest mean grain yield was obtained from ETBW7082 (4.85tonha^{-1}), while ETBW7108 gave the lowest mean grain yield (21.1kgha^{-1}). GGE-II explained 77.18% of G+GEI and from GGE bi-plot, ETBW7082 gave high yield than remaining genotype and at the same time stable across tested location. There for, this advanced genotype were recommended and requested for release as new variety for high land acroecology of southern Oromia and similar agroecology of Ethiopia. The classification of wheat growing areas in to homogenous groups and the recommendation of varieties to these group of environments requires the repetition of similar experiments over years due to the year-to-year variation in factors such as rainfall and temperature of the growing season.

Key words: bread wheat, advanced genotype, Stable ,high land, AMMI, GGE-biplot

Introduction

Bread wheat *(Triticum aestivum* L.*)* is believed to be originated in South Western Asia where it has been grown for morethan 10,000 years. Related wild species are stillbeinggrown in Lebanon, Syria, Northern Israel, Iraq, and eastern Turkey (Peterson 1965; Quisenberry.,1967; Poehlman and Sleper.,1995).The modern hexaploid bread wheat (*T. aestivum*L. em.Thell.)evolved later and became abundant about 8,000 years ago (Curtis BC, 2002). Bread wheat is a self-pollinating annual plant in the true grass family (*Poaceae*), is extensively grown as staple food source in the world. The genetic origin of wheat is of interest since it is a classical example of how closely related species may be combined in nature into a polyploid series. The species of *Triticum*(T.) and their close relatives can be divided into diploid, tetraploid and hexaploid groups, with chromosome numbers of 2n = 14, 28 and 42, respectively, in which the basic chromosome number of wheatis x = 7. *Triticum durum* originated thousands of years ago from a hybridization between the wild diploid *T. monococcum* L. (A genome donor) and the donor of the B genome, which according to morphological, geographical and cytological evidence, has been recognized as *T. speltoides* (Tausch) Gren or a closely related species (Abu T., 2012).

Wheat is grown at an altitude ranging from 1500 to 3000 m.a.s.l, between 6-16^0 N latitude and 35-42^0*E longitude in Ethioia(Abu T., 2012). The most suitable agro-ecological zones, however, fall between 1900 and 2700m.a.s.l (Abu T., 2012).* It is exclusively produced under rain fed conditions, meher and belg (long and short rainy seasons), respectively. Today, wheat is among the most important crops grown in Ethiopia, both as a source of food for consumers and as a source of income for farmers.

Wheat and wheat products represent 14% of the total caloric intake in Ethiopia (ATA, 2019). This makes wheat is the second-most important food, next to maize (19%) and ahead of teff, sorghum, and enset (10-12% each) (FAO, 2014).

Wheat is an annual cool season cereal crop but it can grow in a wide range of environments around the world, but its production is highly concentrated between the latitudes and longitudes of 30^o and 60^o N, and 27^o to 40^o S (Heyne, 1987), and within the temperature range of 3^{o}C to 32^{o}C. In ethiopia, wheat ranks fourth in total area coverage next to teff, maize and sorghum accounting 13.49% (1,696,082.59 hectares) of the grain crop area; and thrirdin total production next to maize and teff holding 15.63% (45,378,523.39 quintals)of the grain production (CSA, 2019). Oromia, Amhara, SNNP and Tigray are the major wheat producing regions in the country with area coverage of 898,455.57, 554,284.49, 127,211.62 and 107,724.17 ha respectively (CSA, 2019).

Ethiopia is known for its diverse/heterogeneous agro-ecology. As a result the performance of genotypes differs within and across environments (ISSA,2009). When environmental differences are large like in Ethiopia, it may be expected that the interaction of genotypes with the environment will also be higher. This interaction may result in one cultivar having the highest yield in some environments while a second cultivar excels in others(ISSA, 2009). Studies on GxE interaction may help determine whether or not a genotype is stable in performance over a range of environments. Genotype x Enviromental Interaction (GEI) is useful to breeders as it can help determine if there is a need to develop cultivars for all environments or specific cultivars for specific target environments (Bridges, 1989). GEI is said to occur when different genotypes respond differently to diverse environments. Analysis of GEI and their influence on performance of bread wheat cultivars can help wheat breeders improve performance stability of cultivars across environments.

Interaction of genotypes with the environment (G × E) is an important component in genetic variance analysis for quantitative traits in crops. Significant G × E interaction component reduces correlations between genotypic and phenotypic values (Kang, 1998) and affects genetic improvement of quantitative traits. G x E interaction is one of the main complications in the selection of genotypes for broad adaptation. The phenotype of an organism is determined by the combined effect of the environment and the genotype which interact with one another. Numerous studies have shown that a proper understanding of the environmental and genetic factors causing the interaction as well as an assessment of their importance in the relevant G x E system could have a large impact on plant breeding (Magari and Kang, 1993; Basford and Cooper, 1998). G x E interaction occurs universally when genotypes are evaluated in several different environments (Becker and Léon, 1988; Magari, 1989; Kang, 1990).

Presence of significantGenotypes x Environment interactions indicates the inconsistency of relative performance of genotypes over environments. Assessment of the stability of a genotype across different environments is useful for recommending cultivars for known conditions of cultivation (ISSA, 2009).

A number of methods have been used for measuring these interactions. These methods include the combined analysis of variance (ANOVA), linear regression analysis (joint regression) and Additive Main Effects and Multiplicative Interaction (AMMI) analysis. Cultivar-superiority measure is another univariate stability parameter used in analyzing multi-environment trials for the selection of high yielding, stable and reliable genotypes. Genotype plus genotype by environment interaction (GGE) bi-plot isanothermulti-variate analytical tools that aid breeders assessing the performance of genotypes in the tested environments. The main purpose of evaluating genotypes across environments is to estimate or predict genotype performance in future years, based on past performance data, and to develop and recommend superior and stablegenotypes. In almost all multi-location trials, there exists interaction and noise (Purchase, 1997). If there were no interactions, one variety would have been good enough for all environments and variety trials would have been conducted only at one location to provide universal results. If there was no noise, results would be exact and there would be no need for replications. But since the reality is quite different, two options are available to deal with these problems. The first one targets the genotypes while the second aims at the environment. The first option is to search for high yielding and widely adapted cultivars that are stableacross the growing environments of interest. The second alternative is to sub-divide the target regions into several relatively homogeneous macro-environments, then to develop and recommend suitable genotypes for specific regions.

Various studies have been conducted at national and regional agricultural research centers to find the best bread wheat genotypes to overcome the challenging factors of bread wheat production at different agroecology of the country to substitute the old varieties. Currently, the rust is the major challenging for bread wheat production globaly. Therefore, to overcome thisproble, the need for screening of best preformed (resistance to major rusts and high yielding) genotypes a crucial for breeders.

Thus, it is necessary to evaluate wheat lines for the intended growing areas since those varieties which were recommended as high yielding after evaluating at few nationally representative wheat growing areas will not always perform the same in areas where they were not evaluated.

Materials and methods

Descriptions of Study Locations

Table1. Description of the locations used to evaluate bread wheat genotypes

location	Altitude (masl)	Lat/long.	Average annual rainfall (ml)*	Average annualTemperature (ºC)	Soil type*
Bore	2775	5º57'N/38º25'E	>1227	15	Nitosols
AnnaSora	2575	5º52'N/38º29'E	1000	20	OrthicAcrosol
Abayi	2701	5º55'N/38º27'E	>1225	15	Nitosols

Entries*:* Ninty bread wheat genotypes (17 advanced lines and 2 standard checks)

Table 2. Lists of bread wheat genotypes and enviroments included in the study

S.N.	Genotype	Category	S.N	Environments	Env. code
1	Danda'a	Lo.check	1	Bore2018	bore
2	ETBW6892	Advaced breeding line	2	Yirba2018	yirba
3	ETBW6929	Advaced breeding line	3	Abayi2018	abayi
4	ETBW6940	Advaced breeding line	4	Bore2019	bore2
5	ETBW7008	Advaced breeding line	5	Yirba2019	yirba2
6	ETBW7037	Advaced breeding line	6	Abayi2019	abayi2
7	ETBW7038	Advaced breeding line			
8	ETBW7042	Advaced breeding line			
9	ETBW7049	Advaced breeding line			
10	ETBW7074	Advaced breeding line			
11	ETBW7081	Advaced breeding line			
12	ETBW7082	Advaced breeding line			
13	ETBW7087	Advaced breeding line			
14	ETBW7098	Advaced breeding line			
15	ETBW7103	Advaced breeding line			
16	ETBW7108	Advaced breeding line			
17	ETBW7120	Advaced breeding line			
18	ETBW7131	Advaced breeding line			
19	Hidase	S.check			

Experimental Design and Field Management

The experimental materials were grown under rain fed condition during the main cropping season in the year 2018-2020 at three locations. The experimental materials at each location were sown with row planting method (drill) using Randomized Complete Block Design with three replications. The gross plot size of each experimental unit was $3m^2$ with six rows of 2.5 m length and 1.2 m width with 0.2 m spacing between rows. The seed *was* drilled by hand at seed rate of 125 kg $ha^{-}1$ which is equivalent to $45g/3m^2$. Planting *was* carried out at appropriate time for each location and 100kg/ha NPS and 50kg/ha. NPS was applied at planting while nitrogen, in the form of urea,*was* applied half at planting and the remaining half at tillering stage of crop development. Weeding *was* conducted based on its appriance, twice to three time .

Collected Data

All agronomic,yield and yield related data *were* recorded from the middle four rows of each experimental unit.

Days to heading:The number of days from date of emergence to the stage where 50% of the spikes have fully emerged from the flag leaf.

Days to maturity:The number of days from emergenceto the stage when 90% of the plants in a plot have reached physiological maturity(is stages at which the crop stops physiological activities, green parts of the plant turned to yellow and grainbecomes hard/ dough stage of grain development).

Grain yield (gm): Grainyield obtained from the central four rows of each plot and converted to kilograms per hectare at 12.5% moisture content.Moisture content of the grain *was*measured by using moisture tester at harvest.

1000-kernel weight: Weightof1000 seeds in gram at moisture content of 12.5% (standard moisture level for bread wheat).

Plant height: Theaverageheight in cm from ground level to the tip of the spike excluding the awns.

Spike length: The average spike length in cm from its base to the tip excluding awns.

Statistical Analysis

Analysis of Variance

All measured parameters *were* subjected to the analysis of variance (ANOVA) using GenStat 18th edition and R software to assess the difference among the tested genotypes. This was carried out to determine the effect of genotype, location and their interaction on various traits, assuming the location effects as random and genotype effects as fixed.

The following ANOVA model *was*used for data of each location:

$Yij = \mu + G_i + B_j + e_{ij}$

Where, Yij = observed value of genotype i in block j μ = grand mean of the experiment, Gi = the effect of genotype i, Bj = the effect of block j eij = error effect of genotype i in block j.

ANOVA model for data combined over locations will be as follows

$Yijk = \mu + G_i + E_j + GE_{ij} + Bk(j) + e_{ijk}$.

Where, Yijk = observed value of genotype i in block k of environment j, μ = grand mean of the experiment, Gi = the effect of genotype i, Ej = environment or location effect, GEij = the interaction effect of genotype i with environment j, Bk(j) = the effect of block k in location j, eijk = error (residual) effect of genotype i in block k of environment j.

Results and discussion

Combined Analysis of Variance for grain yield and Agronomic Traits

Results of combined analysis of variance for all agronomic (Phenology, growth character, yield and yield components) traits are presented in Table 3. The combined analysis of variance (Table 3) revealed that, there were very highly significant differences ($p<0.001$) among environments, genotypes and their interactins for most of the triats included in this study except for TKW, SL and PH significant difference ($p<0.05$) and highly significant ($p<0.01$) respectively for GxE interaction. This siginificance difference indicats, the presence of variability in genotypes as well as diversity of growing conditions at different locations and reflects the differential response of genotypes in various environments.

Table 3. Combined analysis of variance for all 14 agronomic traits across locations

Traits	Source of variation E(5)	Rep (E)(12)	G (18)	GxE(90)	Error(223)	Mean	CV%
HD	201.8836***	1.1082	23.4464***	5.5021***	0.5241	72.48	1.15
MD	5456.992***	0.784	223.660***	95.204***	2.813	145.5	1.00
PH	1839.51***	128.16**	219.64***	40.07**	26.15	85.27	6.00
SL	24.1484***	0.5713	3.5024***	0.8077**	0.5294	8.61	8.46
GY	9498.41***	191.73	803.30***	190.31***	69.50	31.40	26.55
TKW	3998.41***	13.33	286.66***	87.56*	60.81	45.65	17.08

***very highly significant p<0.001, ** highly significant (p<0.01), * significant p<0.05 and ns non-significant: HD=days to heading, MD=days to maturity, PH = plant height, SL= spike length, TKW= thousand kernel weight, GY= grain yield and CV= coefficient of variation.

Combined ANOVA depicted very highly significant differences among environments, genotypes and their interactions except for TKW which was significant for the genotypes (Table 3). This result is in line with the finding of Aliyi K. (2019) who reported that the combined analysis of variance over five locations showed highly significant variations among the genotypes in all studied traits. This indicated that agronomic traits of bread wheat were highly influenced by environmental factors.These results were in agreement with the works of Aliyi 92019), Desalegn (2012) and Demelsah*et al*. (2013) who reported high environmental variance for the agronomic traits of bread wheat. Mohamed and Ahmed (2013.) and Melkamu *et al*. (2015) reported that bread wheat grain yield was significantly affected by environment. Our results also showed the presence of high genetic variability among the tested genotypes and the inconsistency of their performance over the six locations. This agrees with findings of Temesgen *et al*. (2015) who reported that the difference between genotypes was highly significant for grain yield. Similarly Melkamu *et al*. (2015) reported that the bread wheat genotypes they studied had wider genetic variability for all traits investigated.

Mean Comparison of the Genotypes over Locations

Mean performance of the genotypes for agronomic (phenology, growth, yield and yield components) traits across locations are discussed below.

Mean comparison of genotypes in Phenology

Genotypes showed variation for days to heading that ranged from 71.17to 74.83 while days to maturity ranged from 140.1to 153.8 (table 4). The genptypes those late in maturity is preferred for these location where this study were conducted. This due to prelonged high rain fall that excetend to late maturityof the crop. Mean comparison of genotypes in growth characters: Tested genotype showed variation for growth character (plant height and spike length). Plant height ranged from 79.94 to 94.40cm, and spike length ranged from 7.847 to 9.577 cm across environments. Mean comparison in grain yield and yield components: High grain yield from combined data across environments was harvested from genotype ETBW7082 (4.85ton/ha) followed by the genotype ETBW7042 (3.9ton/ha) and ETBW6940 (3.84ton/ha). The lowest yield was obtained from the genotype ETBW7108 (2.11ton/ha). The checks used in this study were gave 2.94ton/ha (Hidase) and 2.34ton/ha (Danda,a) of grain yield (Table 4). Most of the time we did adaptation trial for recently released bread wheat varieties by birringng form both nationa and regional agricultural research centers. But, none of them not adapted the this Guji Zone high land areas mostly. This why we used Danda'a and Hidase as checks those adapted well to this high land areas. The advanced genotype ETBW7082 is under evaluantion at VVT along recently released standard and local check and supposed to be released this year. The studied genotype showed high variability in grain yield. This result was in agreement with those obtained by Aliyi K. (2019), Ali *et al*., (2008) and Zecevic*et al*., (2010) who reported that genotypes showed high variability in grain yield cross environments.

Table 4. Means value of grain yield and agronomic traits of bread wheat genotypes tested across six environments (three locations for two years).

SN	Genotypes	GY(ton/ha)	GYR	DH	DM	PH(cm)	SL(cm)	TKW(gm)
1	Danda'a	2.34	18	72.56	142.0	87.87	8.322	40.11
2	ETBW6892	3.35	7	72.11	150.1	84.71	8.783	51.51
3	ETBW6929	3.65	5	71.17	150.1	86.66	8.528	53.18
4	ETBW6940	3.84	3	74.44	143.8	83.53	8.294	47.04
5	ETBW7008	2.93	12	71.94	153.8	86.94	8.549	42.58
6	ETBW7037	3.19	9	71.39	142.0	88.33	9.292	45.17
7	ETBW7038	2.53	15	70.94	140.1	80.76	8.141	42.11
8	ETBW7042	3.90	2	73.00	147.9	94.40	9.009	49.87
9	ETBW7049	3.35	7	73.00	146.5	82.52	8.619	46.66
10	ETBW7074	2.46	16	71.89	142.1	83.68	8.398	41.16
11	ETBW7081	2.74	14	70.67	140.5	82.32	7.885	43.81
12	ETBW7082	4.85	1	73.61	145.2	86.94	8.976	47.99
13	ETBW7087	3.42	6	72.39	143.5	85.34	8.917	51.47
14	ETBW7098	2.88	13	71.94	147.7	82.89	8.520	44.16
15	ETBW7103	2.44	17	72.11	146.4	83.83	8.355	40.56
16	ETBW7108	2.11	19	73.94	146.4	79.94	8.692	42.02
17	ETBW7131	3.08	10	72.94	145.4	85.61	8.804	49.39
18	ETBW7120	2.94	11	72.17	146.8	90.67	9.577	44.00
19	Hidase	3.66	4	74.83	144.1	83.10	7.847	44.60
	Means	3.14		72.48	145.49	85.27	8.61	45.65
	LSD%	5.476		0.4755	1.102	3.359	0.4779	5.122
	CV%	26.55		1.00	1.15	6.00	8.46	17.08

Where; GY = Grain yield, DE = Days to emergence, DH = Days to heading, DM = Days to maturity, PH = Plant hieght, SL = Spike length, TKW = Thousand kernel weight

Mean of Genotypes for Grain Yield across three location for two years

The relative performance of genotypes based on the mean grain yield over environments is presented in Table5. The first three genotypes with highest mean grain yield were, respectively. Genotypes with the lowest mean grain yield were. Means across environments are adequate indicators of genotypic performance only in the absence of GxE. If GxE is present, means across environments do not tell us how genotypes differ in relative performance over environments.

Table 5. Mean grain yield (ton/ha) performance of 19 bread wheat genotypes tested at three locations for two years (six environments).

TRT	Danda'a	ETBW6892	ETBW6929	ETBW6940	ETBW7008
Loc					
abayi	12.93	25.13	23.87	29.67	14.67
abayi2	9.47	23.33	26.60	11.67	22.73
bore	39.33	60.17	62.08	70.08	51.50
bore2	37.67	38.73	42.27	52.40	28.27
yirba	28.83	34.08	37.50	49.17	31.67
yirba2	12.33	19.80	26.67	17.53	27.13
means	23.43	33.54	36.50	38.42	29.33
TRT	ETBW7037	ETBW7038	ETBW7042	ETBW7049	ETBW7074
Loc					
abayi	22.00	16.20	22.13	25.53	14.40
abayi2	25.60	11.00	23.53	11.60	7.33
bore	45.00	51.58	54.75	62.33	40.83
bore2	34.07	29.07	53.00	30.47	42.47
yirba	40.67	36.33	47.75	50.50	31.57
yirba2	23.93	7.47	32.80	20.27	11.20
means	31.88	25.28	38.99	33.45	24.63
TRT	ETBW7081	ETBW7082	ETBW7087	ETBW7098	ETBW7103
Loc					
abayi	17.93	40.27	22.67	17.73	15.87
abayi2	10.73	52.77	26.53	14.27	10.53
bore	54.00	53.92	51.50	57.00	51.42
bore2	25.27	60.33	44.13	26.13	18.60
yirba	46.00	46.75	29.42	42.58	38.25
yirba2	10.17	36.87	31.20	15.00	11.87
means	27.35	48.49	34.24	28.79	24.42
TRT	ETBW7108	ETBW7120	ETBW7131	Hidase	
Loc					
abayi	10.87	14.80	13.27	20.87	
abayi2	9.20	40.13	48.56	11.93	
bore	30.08	48.83	45.00	46.00	
bore2	38.87	28.53	46.87	48.87	
yirba	26.33	26.08	35.33	29.42	
yirba2	11.13	26.67	30.80	19.13	
means	21.08	30.84	36.64	29.37	

The ranking of genotypes according to their yield performance indicated that there were varied across environmets (table 5). For example, advanced genotype ETBW7082 ranked 1st at abayi, abayi2, bore2 and yirba2. But not ranked 1st at remaining enviroments. This indicate that, GxE interaction is cross-over type interaction. Cross-over GxE interaction is the case when significant change in rank occurs from one environment to another (Matus et al., 1997).

The high percentage variation due to the environment is an indication that the major factor that influence yield performance of bread wheat genotypes in southern Oromiya is the environment. The relatively large proportion of Genotype x Environment variance, when compared to that of genotypes, is a very important consequence. The large sum of squares for environment showed that the environment was diverse with large differences among environmental means caused variation in performance of the genotypes and this could be attributed due to the unequal distribution of rain fall in the growing season, heterogeneity of locations in soil type, altitude range and diseases in discriminating the performance of genotypes across locations. This was in agreement with the findings reported by different researchers (Zerhun et al., 2016;Melkamu Temesgen *et al*., 2015; Roostaei et al., 2014; Mohamed 2013; Farshadfar *et al*., 2012; Kaya *et al*., 2006; Gauch and Zobel,1996, 1997). These imply that, genotypes respond differently over environments as the test environments are highly variable.

Presence of significance GEI indicates that the phenotypic expression of one genotype might be superior to another genotype in one environment but inferior in a different environment. In other words, when significant GxE interactions are present, the effects of genotypes and environments are statistically non additive (or the differences between genotypes depend on the environment). The presence of a significant GxE interaction complicates interpretation of the results. That means, it is difficult to identify superior genotypes across environments when GxE interaction is highly significant. From the combined ANOVA in Table 3, GxE interaction is highly significant and hence superiority of genotypes across environments cannot be identified by considering their mean yield performance (Table 5). Furthermore, the traditional analysis of variance determines the values of each variance source and the significance of the contribution of each component, but it does not partition the interaction in to several components and thus other types of analyses should be performed. Hence, such multi-location trial data along with a highly significant GxE interaction requires measures of stability analysis.

Grain Yield Stability Using Different Stability Parameters

Univariate stability parameters

Wricke's Ecovalence Analysis (Wi)

Wricke (1962) defined the concept of ecovalence, to describe the stability of a genotype, as the contribution of genotype to the genotype x environment interaction sum of squares.

The ecovalence (Wi) or the stability of the i^{th} genotype is its interaction with environments, squared and summed across environments. Genotypes with low ecovalence values have smaller fluctuations across environments and therefore, are stable. Wricke's ecovalence was determined for each of the 19 genotypes evaluated at three location for two years. The amount of interaction (ecovalence) contributed by each genotypes given in (Table 6). The most uninteractive genotype was ETBW6929 followed by genotypes Danda'a and ETBW6929. From this stability concept, genotype ETBW7120 and ETBW67131 was most interactive.

Finlay and Wilkinson Linear Regression Model

According to the joint linear regression model which was developed by Finlay and Wilkinson (1963) and modified by Eberhart and Russel (1966), a stable variety is one with a high mean yield, regression coefficient equals to one (bi=1) and deviation from regression equals to zero ($S^2di=0$). A genotype with bi value less than 1.0 has above average stability and is especially adaptable to low-performing environments. A genotype with bi value greater than 1.0 has below average stability and especially adaptable to high performing environments and a genotype with bi value equal to 1.0 has average stability and is well or poorly adaptable to all environments depending on high or low mean performance (Finlay and Wilkinson, 1963). A cultivar with bi =1 and $S^2di=0$ may be defined as stable. However, in most cases, S^2di is considered as stability parameter rather than bi which is more about responsiveness of genotypes (Eberhart and Russel, 1966; Becker and Le'on, 1988).

According to the S^2di values, genotypes such as ETBW7082, ETBW7120 and ETBW7131 are more stable genotypes. Of these three stable genotypes, ETBW7120 and ETBW7131 were among those poor yielding genotype and ranked 10^th^ and 11^th^ (Table 6).

Cultivar Superiority Measure (Pi) of Lin and Binns Model: The ranks of the Pi measure for mean grain yield are given in Table 6. According to the (Pi) results, genotypes such as ETBW7082, ETBW7042 and ETBW6929 were ranked 1st, 2nd and 3rd respectively which was the same result for mean grain yield rank too (table).

Static Stability Coefficient: From this stability coefficient, genotypes with smaller value is more stable than those having larger value of stability coefficient. Thus, gonotypes ETBW7082, ETBW7037 and ETBW7087 were ranked 1st, 2nd and 3rd respectevily (table 6).

Table 6. Mean grain yield, univariate stability analysis and the ranks of 19 genotypes

SN	Genotype	Yield	R	Pi	R	Wi	R	S^2di	R	Static S.C	Rank
1	Danda'a	2.34	18	429.4	(17)	84.6	(2)	0.9880	8	182.6	(8)
2	ETBW6892	3.35	7	185.1	(6)	93.4	(3)	1.0961	12	220.0	(11)
3	ETBW6929	3.65	5	134.8	(3)	59.6	(1)	1.0726	11	208.6	(9)
4	ETBW6940	3.84	3	186.7	(7)	586.6	(17)	1.6969	19	508.4	(19)
5	ETBW7008	2.93	12	281.7	(11)	179.0	(7)	0.8318	7	152.3	(5)
6	ETBW7037	3.19	9	221.2	(8)	104.1	(4)	0.7071	4	90.9	(2)
7	ETBW7038	2.53	15	392.4	(15)	145.7	(5)	1.2847	16	286.4	(15)
8	ETBW7042	3.90	2	124.7	(2)	153.6	(6)	1.0419	10	216.6	(10)
9	ETBW7049	3.35	7	261.6	(10)	447.8	(15)	1.3848	18	369.5	(18)
10	ETBW7074	2.46	16	410.4	(16)	191.5	(8)	1.1081	13	242.6	(13)
11	ETBW7081	2.74	14	373.9	(14)	369.9	(14)	1.3445	17	344.5	(17)
12	ETBW7082	4.85	1	23.0	(1)	522.1	(16)	0.3800	1	78.8	(1)
13	ETBW7087	3.42	6	173.5	(5)	198.6	(9)	0.7234	5	124.3	(3)
14	ETBW7098	2.88	13	322.6	(13)	246.3	(11)	1.2822	15	303.3	(16)
15	ETBW7103	2.44	17	437.0	(18)	295.3	(13)	1.1777	14	275.5	(14)
16	ETBW7108	2.11	19	505.8	(19)	244.4	(10)	0.7990	6	153.9	(6)
17	ETBW7131	3.08	10	247.6	(9)	656.3	(18)	0.4768	3	142.6	(4)
18	ETBW7120	2.94	11	152.0	(4)	867.6	(19)	0.4310	2	179.7	(7)
19	Hidase	3.66	4	292.8	(12)	262.7	(12)	1.0138	9	227.6	(12)

Where R= rank, Wricke's Ecovalence Analysis, S^2di = Standared Deviation, Pi= Cultiver superiorty major.

Multivariate Stability Parameters

Additive Main Effects and Multiplicative Interaction (AMMI) Analysis and Biplot Representation

AMMI is essentially effective where the assumption of linearity of responses of genotype to a change in environment is not fulfilled, which is important in stability analysis. The results can be graphed in a useful biplot that shows both main and interaction effects for both genotypes and environments (Gauch and Zobel, 1996). The combined analysis of variance (ANOVA) of the 19 genotypes of bread wheat over six environments according to the AMMI-2 model is presented in Table 7. The ANOVA indicated very highly significant differences ($p<0.001$) for environments, genotypes and for the genotype environment interaction (GEI). The IPCA are ordered according to decreasing importance.

Table 7. ANOVA table for AMMI model

Source	D.F.	S.S.	M.S.	Total variation Explained (%)	GXE Explained (%)	Cumulative (%)
Total	341	95170	279			
Genotypes	18	14459	803***	15.19		
Environments	5	47492	9498***	49.9		
Block	12	817	68ns			
Interactions	90	17128	190***	17.99		
IPCA 1	22	9849	448***		57.5	57.5
IPCA 2	20	4684	234***		27.35	84.85
Error	216	15273	71			

***$p<0.001$; IPCA=Interaction Principal Component Axis, DF=degree of freedom, SS=sum of squares, M.S=mean squares.

The Gollob F-test used to measure significant of the GxE interaction components at 0.01 probability level recommended inclusion of the first two interactions PCA axes in the model. Hence, the best fit AMMI model for this multi-environment yield trial data was AMMI-2. Other interaction principal component axes captured mostly non-predictive random variation (noise) and did not fit to predict validation observations. Therefore, the interaction of the 20 bread wheat genotypes with five environments was predicted by the first two interaction principal components of genotypes and environments. In general, the model chosen by predictive criterion consists of two interaction principal components (Kaya et al., 2002).

Out of the total IPCA, the first two IPCA axes explained 84.85% of the GxE interaction sum of squares. In particular, the first IPCA captured 57.5% of the total interaction sum of squares while the second IPCA explained 27.35% of the interaction sum of squares.

The IPCA scores of a genotype from AMMI analysis indicate the stability or adaptation of a genotype across environments. The closer the IPCA scores to zero, either positive or negative, as it is a relative value,the more stable or adapted a genotype is over all test environments. Environment scores from AMMI analysis relating to interaction also have meaningful interpretation. Environments with large IPCA scores are more discriminating of genotypes, while environments with IPCA scores near zero exhibit little interaction across genotypes and have low discrimination power among genotypes.

Table 8. Grain yield, IPCA1 and IPCA2 scores, ASV, YSI and their ranks for the 19 bread wheat genotypes

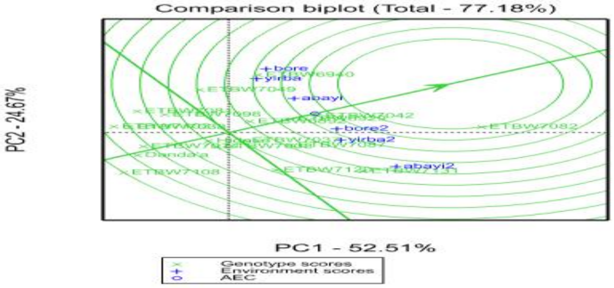
SN	Genotype	Yield	R	IPCAg[1]	IPCAg[2]	ASV	RASV	YSI
1	Danda'a	2.34	18	0.12476	-1.44001	1.440051	5	10
2	ETBW6892	3.35	7	-0.30293	0.36838	0.444701	2	3
3	ETBW6929	3.65	5	0.01881	0.40291	0.402911	1	1
4	ETBW6940	3.84	3	-2.70271	-1.67011	4.681767	15	7
5	ETBW7008	2.93	12	0.60816	1.56042	1.578319	6	7
6	ETBW7037	3.19	9	0.58371	0.65634	0.836818	3	4
7	ETBW7038	2.53	15	-1.42059	0.35773	5.652669	17	19
8	ETBW7042	3.90	2	0.1305	-1.28855	1.288618	4	1
9	ETBW7049	3.35	7	-2.61203	1.00474	6.864443	18	14
10	ETBW7074	2.46	16	-0.27992	-2.15502	2.155327	8	12
11	ETBW7081	2.74	14	-2.20034	1.12188	4.458961	14	17
12	ETBW7082	4.85	1	-0.50016	2.66162	2.663278	12	5
13	ETBW7087	3.42	6	1.40028	-0.36832	5.336315	16	9
14	ETBW7098	2.88	13	-1.68275	1.42487	2.445327	11	12
15	ETBW7103	2.44	17	-1.64145	1.81582	2.344981	9	15
16	ETBW7108	2.11	19	0.87097	-2.07502	2.106978	7	15
17	ETBW7131	3.08	10	2.59917	2.5098	3.680281	13	10
18	ETBW7120	2.94	11	3.64296	0.7152	18.56965	19	18
19	Hidase	3.66	4	0.20176	-2.4409	2.440957	10	6

Where; ASV= AMMI stability value, RASV= rank ASV, YSI= yield stability index

GGE Bi-plot for Evaluation of Environments and Genotypes

Evaluation of genotypes relative to ideal genotypes

From concept of stability parameter, genotypes nearest concentric of the circle supposed to be satable and as the same time high yielder. Based on this concept, ETBW7082 is the nearest to the arrow and is considered to be the "ideal" genotype and the highest yielding genotype followed by ETBW7042. A genotype is more desirable (higher yielding) if it is located closer to the ideal genotype along PCA1 and undesirable (lower yielding) if it is located far from the ideal genotype. Genotypes above PCA1=0 give above-average yield while those below PCA1=0 give below-average yield. ETBW7108 and Danda,a from low yielding genotype , and ETBW7131 from hiegh yielding genotype was most unstable genotypes as they are far from ideal genotype (figure 1). Similar result was reported by (Aliyi K., 2019, Kaya et al., 2006; Mitrovic et al., 2012; Farshadfar et al., 2012).



Evaluation of environments relative to the ideal environments

From GGE-biplot comparison for environment under this study, bore2 and yirba2 had the longest vector with small PCA2, and fell into the center of the concentric circles and is considered as an ideal environment in terms of being the most representative of the overall environments and the most powerful to discriminate genotypes (Figure 2).

From figure 2, it show that, abayi was closer to the ideal environments and is considered as suitable to selecte widely adapted genotypes respectively. Yirba and bore were far from the ideal environment and are considered to be unsuitable environments to select desirable genotypes (Figure 2). This results are in line with the findings of Yan *et al*. (2000), Yan and Rajcan (2002) and Yan *et al*. (2007) and Fiseha *et al*. (2015).

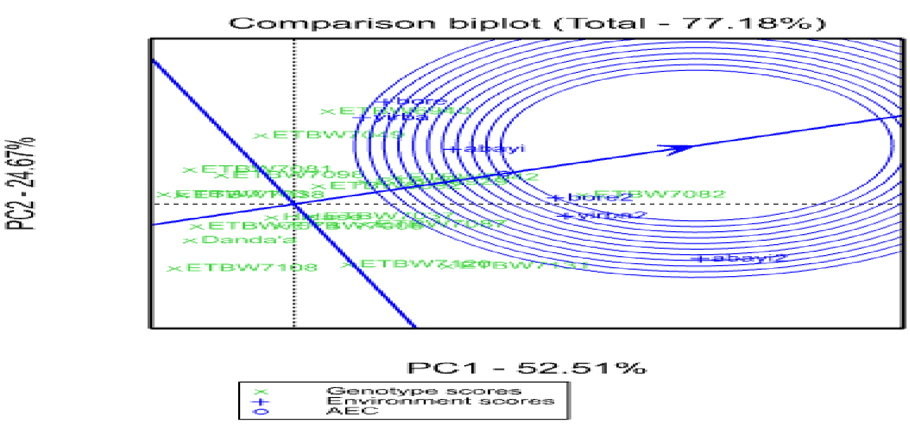


Figure 2. GGE-biplot based on the ranking of environments relative to an ideal environment

'Which-Won-Where' Pattern and Mega-environment Identification

The polygon view of GGE biplot is the best way for the identification of winning genotypes with visualizing the interaction patterns between genotypes and environments in MET data analysis(Yan and Kang, 2007), which is helpful in estimating the possible existence of different mega environments (Yan and Tinker, 2006). The polygon view of a GGE biplot indicates the presence or absence of crossover or non-crossover GE interactions involving the most responsive genotypes, and is suggestive of the existence or absence of different mega-environments among the test environments (Yan and Rajcan, 2002). In this biplot, a polygon is formed by connecting the vertex genotypes with straight lines so that the rest of the genotypes are placed within the polygon. GGE biplot is constructed by plotting the first two principal components, PC1 and PC2, derived from subjecting environment centered yield data to singular value decomposition (Yan *et al*., 2000). These genotypes are the best or worst in some or all environments because they are farthest from the origin of the biplot (Yan and Kang, 2003) and are more responsive to environmental change and are considered as specifically adapted genotypes. They are best in the environments lying within their respective sector in the polygon view of the GGE-biplot (Yan *et al*., 2000; Yan and Tinker, 2006).

The polygon view of the GGE biplot was constructed to show which genotypes performed best in which environment (Figure5). PC1 and PC2 accounted for 77.18% (52.51% and 24.67%) of the G + GE variation for grain yield of the genotypes evaluated at six environments. The vertices of the polygon were the genotype markers located farthest away from the biplot origin in various directions, such that all genotype markers were contained within the resulting polygon. Based on this, seven genotypes were identified as the markers farthest away from the biplot origin and the remaining tweleve genotypes lied within this polygon. The vertex genotype were the best or the poorest genotypes in the test environments since they had the shortest or longest distance from the origin of the biplot on the opposite side of the environments. For example, from marker genotypes ETBW7082, ETBW7131, and ETBW6940 were the best genotypes as they have the shorst distance to the origin of biplot on the same side of all enviroments and genotypes like ETBW7108 and ETBW7083 were the poorest as they have the longest distance from the origin of biplot on the opposite side of all enviroments (figure 3).

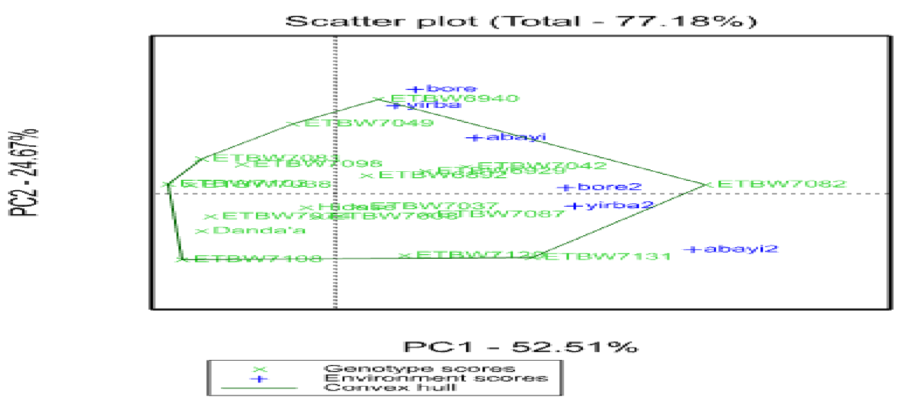


Figure 3. Which-Won-Where View of GGE bi-plot genotypes and environments of yield.

Conclusion and recommendation

Today, wheat is among the most important crops grown in Ethiopia, both as a source of food for consumers and as a source of income for farmers. Wheat and wheat products represent 14% of the total caloric intake in Ethiopia (ATA, 2015). However, the productivity and production is low due to environmental factors, genotypes and GEI. Therefore, the experiment was carried out to evaluate GEI for grain yield and to identify stable and/or high yielding genotypes and assess their performance across locations to release desireable genotypes as new varieties for high land of southern and similar agro ecology. Therefore, ninty bread wheat genotypes were tested at three locations for two years in southern oromia during 2018-2020 main cropping seasons. The experiment was laid out in Randomized Complete Block Designs (RCBD) with three replications From the combined analysis of variance, the effects environment, genotype and genotype x environment were highly significant for grain yield and accounted for 49.9%, 15.19% and 17.99% of the variability in grin yield of the total sum of squares respectively. The high percentage of the environment is an indication that the major factor that influence yield performance of bread wheat in Ethiopia is the environment. In particular, the GEI is highly significant (p<0.001) accounting for 17.99% of the total sum of squares implying the need for investigating the nature of differential response of the genotypes to environments. The presence of the GEI indicates that the phenotypic expression of one genotype might be superior to another genotype in one environment but inferior in a different environment. In other words, presence of GEI does not permit to define an overall ranking of varieties across environments. All of the variance components were highly significant (p<0.001), and indicates that factors such as soil fertility, rainfall, temperature, and disease incidence can result in conditions unique to each location combination and that the genotypes respond differently to these conditions.

As combined means of five locations showed, among 19 genotypes tested, genotypes ETBW7082, ETBW7042 and ETBW6940 were high yielding genotypes while ETBW7108 and Danda'a were low yielding genotypes. The large occurrence of GXE interactions causes the relative rankings of genotypes to change from location to location. Hence, it is imperative to have a proper understanding of the effects of GXE interactions on variety evaluation, which will help to apply appropriate analytical methods and wise application of resources.

GGE biplot showed that PC1 and PC2 accounted for 77.18% (52.51% and 24.67%) of the G + GE variation for grain yield of the genotypes evaluated at six environments. The vertices of the polygon were the genotype markers located farthest away from the biplot origin in various directions, such that all genotype markers were contained within the resulting polygon. Based on this, seven genotypes were identified as the markers farthest away from the biplot origin and the remaining tweleve genotypes lied within this polygon. The vertex genotype were the best or the poorest genotypes in the test environments since they had the shortest or longest distance from the origin of the biplot on the opposite side of the environments. For example, from marker genotypes ETBW7082, ETBW7131, and ETBW6940 were the best genotypes as they have the shorst distance to the origin of biplot on the same side of all environments and genotypes like ETBW7108 and ETBW7083 were the poorest as they have the longest distance from the origin of biplot on the opposite side of all environments. From those genotypes included in study, ilite genotype like ETBW7082 and ETBW7042 were the most disereable genotypes across tested environments and ETBW7082 was advanced and supposed to release and registed as new variety, while the other advanced stable and high yielding geotypes were not selected due to disease reaction and together, with those genotypes specifically adapted to specific enviroments were recommended to include in breeding programs.

References

Abu T (2012). Grain and feed annual report. Grain report number: ET1201, Addis Ababa, Ethiopia (*triticum aestivum L*.). Research in Plant Biology, 3 (1): 33-36.

Ali Y, Atta B.M, Akhter J, Monneveux P. &, Lateef. Z. 2008. Genetic variability, association and diversity studies in wheat (*Triticum aestivum L*.) germplasm. Pak. J. Bot.,40:2087-2097.

Aliyi Kedir, Hussein Mohammed and Tesfaye Letta. 2019. Genotype X Environment Interaction and Stability of Bread Wheat (*Triticum Aestivum* L.) Genotypes in Southern Oromia.

2019. An MSc Thesis Presented to the Postgraduate Program Directorate of Hawassa University.

ATA (Agricultural Transformation Agency),2019.Wheat in Ethiopia, Production, marketing, and consumption report.

Becker, H.C. and Léon, J., 1988. Stability analysis in plant breeding. Plant Breeding 101: 1-23.

Bridges.W.C. 1989. Analysis of plant breeding experiment with heterogeneous

CSA (Central Statistical Agency (2019).Agricultural Sample Survey.Report on Area, Production and Yield of Meher Season Crops for Private Peasant Holdings. Statistical Bulletin 584, CSA, Addis Ababa, Ethiopia, April, 2017, Volume 1.

CSA (Central Statistical Agency), 2014/15.Federal Democratic Republic of Ethiopia.Central Statistics Agency Crop.Agricultural sample survey. Crop and livestock utilization volume 2

Eberhart, S. A., and W. A. Russell, 1966.Stability parameters for comparing varieties.

FAO (Food and Agriculture Organization of the United Nations). 2015. FAOSTAT [Online]. Available at http://www.fao.org/faostat [cited 24 Feb. 2015; verified 14 Oct. 2015].

Farshadfar, E., &Sutka, J. (2006).Biplot analysis of genotype-environment interaction in durum wheat using the AMMI model. ActaAgronomicaHungarica, 54(4), 459-467.

Finlay, K. W., and G. N. Wilkinson, 1963.The analysis of adaptation in a plant breeding programmer. J. Agric. Res. 14: 742-754

Fiseha Baraki, YemaneTsehaye, and FetienAbay. 2015. AMMI analysis of Genotype x Environment interaction and stability analysis of sesame genotypes in northern Ethiopia. Asian J. Plant Sci, 13(4-8):178-183.

Gauch HG, Zobel RW (1997) Identifying mega-environments and targeting genotypes. Crop Sci 37: 311-326

Kang, M.S., 1990. Genotype-by-environment interaction and plant breeding.Louisiana State University, Baton Rouge, LA, USA.

Kang, M.S., 1998. Using genotype by environment interaction for crop cultivar development. Advances in Agronomy 62: 199-246.

Kaya, Y., M. Akçura and S. Taner, 2006. GGE-biplot analysis of multi-environment yield trials in bread wheat. Turkish journal of agriculture and forestry, 30(5): 325-337.

Magari, R. and Kang, M.S., 1993. Genotype selection via a new yield-stability statistics in maize yield trials. Euphytica 70: 105-111.

Magari, R., 1989. Stability of some Albanian maize local varieties and hybrids (in Albania). Bull Agric. Sci. 4: 123-129.

Melkamu T., Sentayehu A., Firdissa E., and Muez M.,(2015). Genotype X Environment Interaction and Yield Stability of Bread Wheat Genotypes in South East Ethiopia. World J. Agri Sci. 11 (3):123

Melkamu Temesgen,2015: Genotype X Environment Interaction and Yield Stability of Bread Wheat Genotypes in South East Ethiopia, pp123

Mohamed, N. E. (2013). Genotype by environment interactions for grain yield in bread wheat (*Triticum aestivum L*.). Journal of Plant Breeding and Crop Science, 7(5), 150-157.

Peterson RF (1965). Wheat Botany, Cultivation, and Utilization. Interscience Publishers Inc. New York.

Poehlman JM, Sleper DA (1995). Breeding Field Crops. 4th ed. Iowa State UniversityPress, Ames, Iowa 50014, USA.

Purchase, J.L., 1997. Parametric analysis to describe Genotype x Environment interaction and yield stability in winter wheat.Ph.D.Thesis, Department of Agronomy, Faculty of Agriculture, University of the Free State, Bloemfontein, South Africa.

Quisenberry KS (1967). Wheat and Wheat Improvement. American Society of Agronomy, Inc. USA.

Yan, W. and Rajcan, I. 2002. Biplot analysis of test sites and trait relations of soybean in Ontario, Crop Science, 42:11-20

Yan, W., Hunt, L.A., Sheng, Q. and Szlavnics, Z. 2000.Cultivar evaluation and mega environment investigation based on GGE bi-plot. Crop Science, 40: 596–605.

Yan, W., Kang, M.S., Ma, B., Woods, S. and Cornelius, P.L. 2007. GGE Biplot vs. AMMI analysis of genotype by environment data. Crop Science, 47: 643-655.

Zecevic. V, Knezevic. D, Boskovic. J, Micanovic. D & Dozet. G. 2010. Effect of N fertilization on winter wheat quality.Cereal Res. Commun.38(2).244-250.

Participatory Varietal Evaluation and Selection of Shiro-type Field Pea in Highland Districts of Guji zone

DeresaShumi[*], TekalignAfeta and Rehoboth Nuguse

Oromia Agricultural Research Institute, Bore Agricultural Research Center, P. O. Box 21, Bore, Ethiopia

Introduction

Field pea is one of the few oldest crops of the world. The first cultivation of the crop took place about 9000 years ago alongside cereals like barley and wheat (Saxesena*et al*., 2013). It is an annual herbaceous legume adapted to cool moist climate with moderate temperatures found in various regions of Ethiopia (Yasin Goa and MathewosAshamo, 2014). The crop is the third legume crop in Ethiopia, headed only by faba bean (*Viciafaba*) and chickpea (*Cicerarietinum*) in terms of both area coverage and total national production (GemechuKeneni*et al*., 2013). According to HaddisYirga*et al.* (2013), there are two botanical varieties of *Pisumsativum*L known to grow in Ethiopia, namely *P. sativum*var*sativum*and *P. sativum*var*abyssinicum*, while much of the production in our country is on *P. sativum*var*sativum*. In Ethiopia, the crop is widely grown in mid to high altitude and ranks fourth in area coverage reaching 312,890 ha with an annual production of 3,632,663.87 tons (t) (FAOSTAT, 2019). It is widely grown in the highlands of Ethiopia. It performs well at an altitude of 1800 – 3000 meter above sea level. In addition, the crop also better adapted under low rainfall environments as compared to other highland pulses such as Faba bean, lentil, and chickpea (Mohammed et al., 2016). It is the major food legumes with a valuable and cheap source of protein having essential amino acids (23 to 25%) that have high nutritional values for resource poor households (Nawab et al., 2008). The crop has important ecological and economical advantages in the highlands of Ethiopia, as it plays a significant role in soil fertility restoration and also serves as a break crop suitable for rotation to minimize the negative impact of cereal based mono-cropping (Angaw and Asnakew, 1994). It is also used as a source of income for the farmers and foreign currency for the country (Girma, 2003). Having all these multiple benefits in the economic lives of the farming communities, however, the average yield of the crop is only 1.24 t ha^{-1} in Ethiopia (FAOSTAT, 2019) which is far below the potential 40 to 50 t ha^{-1} traditionally achieved in Europe (Netherlands, France and Belgium) and the worldwide average yield of 1.7 t ha^{-1} (Petr et al., 2012). Limited availability of adaptable high yielding improved varieties resistance to diseases, insects and abiotic calamities for wider/specific location and absence of appropriate agronomic recommendations can be cited as a major reason for this low productivity (Asfaw*et al.* (1994). Field pea is one of the major pulse crops in the highlands of Guji zone next to faba bean. Currently, over 80 improved field pea varieties have been released to be grown under high altitude areas of the country. However, almost all farmers in Guji Zone were used to produce field peas of local varieties for a long period of time. Participatory variety selection (PVS) has been proposed as an option to provide farmers analternative technology to that can fit to their target environments and identify theirpreferences (Caccarelli*et. al*., 1996). Most released field pea varieties were not considering thepreference of the farmers, they were released based on the interest of the researchers.However, farmers were not taking part in selecting varieties according to their own criteria & thus they were not satisfied with the result. Many recently released varieties are also available. Therefore, it is essential to evaluate with farmers the adaptability and yield performance of released field pea varieties to the agro-ecologies of highland districts of zone, and identify farmers' preferred varieties through farmer's participation in decision making during the selection process for further production in the area.

Materials and Methods: The experimented was conducted in 2013 maincropping seasons at Bore, Dama and Anna Sora districts of Guji Zone. Ten improved varieties were tested (Table 1). A randomized completeblock design with three replications was used. Researches were conducted at one potential site as mother trial (MT) and baby trials (BT) at three f farmers' fields only with one replication. Mother trials were designed by researchers and quantitative data were also taken by the researchers.The plot size was 3m x 2.4m with 6 rows and 10cm spacing between plants, while the net harvested area $6m^2$. To reduce border effect, data was taken from the central four rows. Weeding and other management practices were done as required. The fertilizer rate of 100 $N/P_2O_5/S$ kg/ha was applied at time of planting. All agronomic practices were done as per therecommendation for field pea.

Data on agronomic traits such as number of pods per plant,number of seeds per pod, plant height, seed yield, and 100 seed weight wererecorded. Data for number of pod per plant, number ofseeds per pod and plant height were collected from theaverage value of randomly selected ten plants per plot.Whereas data on seed yield, total biomass and thousandseed weight were collected on plot basis. Analysis ofvariance was performed using Statistical Analysis Software. Least Significant Difference (LSD) test at 5%probability level was used for mean comparison when theANOVA showed significant difference.

Data Collection and Analysis

Agronomic data: Data on agronomic traits such as number of pods per plant,number of seeds per pod, plant height, seed yield, and 100 seed weight wererecorded. Data for number of pod per plant, number ofseeds per pod and plant height were collected from theaverage value of randomly selected ten plants per plot.Whereas data on seed yield, total biomass and thousandseed weight were collected on plot basis. Analysis ofvariance was performed using Statistical Analysis Software. Least Significant Difference (LSD) test at 5%probability level was used for mean comparison when theANOVA showed significant difference.

Farmer's Data: Farmer's preferences were identified using focus group discussions held with 43 households of 27 male and 16 female households through actively encouraging female participation. The households were randomly selected from each kebeles' in the districts. Farmers participated in evaluation and selection of improved varieties at maturity from mothers' trials through farmer research group. Field visit were arranged at maturity to collect the data using agreed criteria by research participant. Farmers discussed and agreed on criteria they thought to be important for selecting a given variety. They set their own selection criteria and ranking of varieties according to their setting criteria.

The participant farmers categorized traits such as plant establishment, lodging, earliness and synchrony to maturity, free of disease and insect pest, drought tolerance, shattering, seed size, seed color, market value (high market demand) and overall performance. The rank sum method each trait for each variety was used to rank varieties based on farmers' selection criteria. The value of each trait has equal weight. The ranking procedure was explained for participant farmers and each selection criterion was ranked from 1 to 5 (1 = Very poor, 2 = Poor, 3 = Average, 4 = Good and 5 = Very good) for each varieties. Simple ranking is a tool often used to identify promising varieties based on farmers' preferences (De Boef and Thijssen, 2007).

Results and discussions

Plant height: significant variation ($P<0.05$) was observed among the studied varieties for plant height. Thevariety Bursa (222.1cm) was the longest variety while the variety Bilalo (190.9 cm) was the shortest variety (Table 1).

Number of pods per plant: Significant differences ($P<0.05$) were exhibited among varieties for number of pods per plant. More numbers of pods/plant were recorded from Tulu Shenen variety (52.33). On the other hand, Megeri and Wayitu had the lowest number of pods per plant with a respective 36 and 36.67.

Number of seeds per pod: varieties wereexhibited variation ($P<0.05$) for number of seeds per pod.The variety Megeri produces more number of seeds perpod (6.08) compared to the other varieties. On the other Tulu Shenen produces the lowest number of seeds per pod(4.71) (Table 1).

Hundred Seed Weight (HSW)

The field pea varieties testedhad a significant variation ($p<0.05$) among each other forhundred seed weight. The variety Bilalo producesthe highest seed weight (24.77 gm). The variety Megeriwas the least in seed weight (18.67 gm) (Table 1).

Grain yield: A significant variation ($p<0.05$) was observedamong field pea varieties in their response to grainyield. The highest yield was recorded from the varietiesBursa and Wayitu with the values of 4463 and 4410kg ha^{-1}, respectively. Tulushenen on the other hand was the lowestyielder with the value of 3630 kg ha^{-1} (Table 1).

Table1: Mean values of growth, yield components and yield at mother trial

Variety	Parameters							
	DF	DM	PH (cm)	NPPP	NBPP	NSPP	HSW (g)	GY (Kg ha^{-1})
Bursa	76.67	146.7	222.1	46.67	1.67	5.46	20.30	4493
Weib	75.33	146.7	198.3	36.00	1.58	5.92	20.07	4410
Megeri	74.67	147.0	210.0	36.67	1.75	6.08	18.67	4361
Bilalo	75.67	148.7	190.9	37.92	1.33	5.25	24.77	3896
Tulu Shenen	75.67	150	193.8	52.33	1.58	5.71	20.13	3630
LSD (0.05)	Ns	ns	40.21(*)	38.2(*)	32.48(*)	0.956(*)	7.058(*)	1240.8(*)
CV (%)	2.4	1.1	10.5	1.14	29.2	8.9	18.0	15.8

Keys: DF= days to flowering, DM= days to maturity, PH= plant height, NPPP=number of pod per plant, NBPP= Number of branch per plant, NSPP= number of seed per pod, HSW= hundred seed weight, GY= Grain yield

Variety Evaluation and Selection Criteria

This diversity during selection is an indication of the complexity of users' preference. Mulu et al., 2016, reported that, when there is more diversity in selection criteria, there is better chance of maintaining on farm diversity since positive traits are seldom found on single variety. However, the result from farmers' evaluation revealed that large seed size, and attractive seed color for high market demand (market value) and Free of Disease and Insect Pest (FDP) & Frost Tolerant (FT) were the major decisive criteria in retaining and rejecting the variety.Seed color and size are important characters of consumers' preference. Similar findings were reported for pure red and red mottled seed color and high yielding variety were the major decisive criteria to accept or reject common bean in Southern Ethiopia (Asrat, 2008 and Mulu*et al*., 2016).

Farmers' evaluation was conducted in the three baby trials and selection had diversified selection criteria to accept and reject bean variety (Table 2). The evaluations mean score value for each variety ranged from 10.89 to 13.87 (Table 2). Bilalo) scored the highest value (13.87 and the lowest was scored by Megeri (10.89), Bursa (13.44) Tulushenen (11.69) and Weib (11.53) were ranked second, third and fourth best varieties by farmers, respectively.

Table 2. Mean value of each selection traits and ranking of varieties in baby trialsduring 2021.

Farmer's Traits	Varieties				
	Tullu-shenen	Megeri	Bursa	Weib	Bilalo
Pod Bearing(PB)	10.6	10.9	12.9	9.1	13.0
Earliness (EL)	9.7	9.0	9.3	9.7	9.0
Synchrony of Maturity (SM)	11.7	12.2	13.9	14.0	14.7
Free of Disease and Insect Pest (FDP) & Frost Tolerant (FT)	10.9	11.4	13.2	11.8	13.8
Shattering (SH)	13.4	13.9	14	12.7	14.9
Seed size (SS)	12.7	9.9	14.9	13.1	15
Seed color (SC)	11.6	9.0	14.9	11.2	15
Market value (MV)	11.4	10.8	14.9	11.7	14.9
Overall performance (OAP)	13.2	10.9	13.0	10.5	14.5
Total	105.2	98	121	103.8	124.8
Mean preference rating	11.69	10.89	13.44	11.53	13.87
Rank	3	5	2	4	1

Key: PE = Plant establishment, EL = Earliness, SM = Synchrony to maturity, FDP = Free of disease and insect pest, DT = Drought tolerance, SH = Shattering, SS = Seed size, SC = Seed color, MV = Market value and OFP = Overall field performance.

Farmers and the researcher used different parameters and methods to evaluate the tested varieties. A range of improved varieties should be available for selection under their participation. Generally, the varieties should have tolerance to biotic and abiotic stresses and have good marketability and consumer preferences.

Conclusion and recommendation

Introducing new varieties through participatory varietal selection help the farmers to choose the variety that possesses the character preferred by customer on market and meets their interest. Researchers must consider farmers selection traits in their varietal development including seed yield, seed size, and seed color, market value and overall field performance. Besides, the training given during participatory variety selection process enhances capacity of the farmers for identifying varieties and managing varietal diversity. According to agronomic data and farmers' selection traits, the variety Bilalo was selected as the first top ranking according to farmers' perception at all three farmer sites. Therefore, Bilalo and Bursa were recommended for production for highland areas of Guji zone and similar agro-ecologies. The identified varieties were promoted to the scaling-up trials as per their adaptability and farmers preferences.

References

Caccarelli, S., Grando S., Booth, R.H. (1996). International breeding programs and resource–poor farmers: Crop improvement in difficult environments. In: Eyzaguirre P, Iwanga M (eds.) Participatory plant breeding proceeding of a workshop on participatory plant breeding, 26 – 29 July 1995, Wageningen, The Netherlands. IPGRI, pp 99 – 116

GemechuKeneni, FassilAssefa, Imtiaz M., and Endashaw Bekele (2013). Genetic diversity for attributes of biological nitrogen fixation in Abyssinian field pea (*Pisumsativum*var. *Abyssinicum*) germplasm accessions. *Ethiopian Journal of Applied Science and Technology*, 4(2): 1-20.

GemechuKeneni, FassilAssefa, M. Imtiaz, and Endashaw Bekele (2013). Genetic diversity for attributes of biological nitrogen fixation in Abyssinian field pea (*Pisumsativum*var*abyssinicum*) germplasm accessions. *Ethiopian journal applied science technology* 4(2): 1-20.

HaddisYirga, Hussein Mohammed and Berhanu Abate (2013). Characterization and preliminary evaluation of DEKOKO (*Pisumsativum*var. *abyssinicum*) accessions using quantitative traits in Southern Tigray, Ethiopia. *International journal of technology enhancements and emerging engineering research* 1(4): 86-93

Mohammed A., Asefie S., Dagnachew W., and Seyum N., 2016.Participatory evaluations of field pea (*Pisumsativum L.*) varieties in Wollo, Ethiopia.*Excellent Word Journal of Agricultural Science*, 1 (2), 1-6.

Saxesena, R.R; Lal, G.M.; Yadav, P.S. and Vishwakarma, M.K. (2013). Diversity analysis and identification of promising lines for hybridization in field pea (*Pisumsativum* L.).*The bioscan journal of life science* 8(4): 1437-1440

Yasin Goa and MathewosAshamo. (2014). Evaluation of Field Pea (*Pisumsativum*L.) genotypes performance for yield and yield components at five growingenvironments of southern Ethiopia. *Current research in agricultural sciences* 1(3):65-76

Participatory Varietal Evaluation and Selection of *Kik*-type Field Pea in Highland Districts of Guji zone

DeresaShumi,[*],TekalignAfetaand Rehoboth Nuguse

Oromia Agricultural Research Institute, Bore Agricultural Research Center, P. O. Box 21, Bore, Ethiopia

Introduction

Field pea is one of the few oldest crops of the world. The first cultivation of the crop took place about 9000 years ago alongside cereals like barley and wheat (Saxesena*et al*., 2013). It is an annual herbaceous legume adapted to cool moist climate with moderate temperatures found in various regions of Ethiopia (Yasin Goa and MathewosAshamo, 2014). The crop is the third legume crop in Ethiopia, headed only by faba bean (*Viciafaba*) and chickpea (*Ciceraritienum*) in terms of both area coverage and total national production (GemechuKeneni*et al*., 2013). According to HaddisYirga*et al.* (2013), there are two botanical varieties of *Pisumsativum*L known to grow in Ethiopia, namely *P. sativum*var*sativum*and *P. sativum*var*abyssinicum*, while much of the production in our country is on *P. sativum*var*sativum*.

In Ethiopia, the crop is widely grown in mid to high altitude and ranks fourth in area coverage reaching 312,890 ha with an annual production of3,632,663.87 tons (t) (FAOSTAT, 2019). It is widely grown in the highlands of Ethiopia. It performs well at an altitude of 1800 – 3000 meter above sea level. In addition, the crop also better adapted under low rainfall environments as compared to other highland pulses such as Faba bean, lentil, and chickpea (Mohammed et al., 2016). It is the major food legumes with a valuable and cheap source of protein having essential amino acids (23 to 25%) that have high nutritional values for resource poor households (Nawab et al., 2008). The crop has important ecological and economical advantages in the highlands of Ethiopia, as it plays a significant role in soil fertility restoration and also serves as a break crop suitable for rotation to minimize the negative impact of cereal based mono-cropping (Angaw and Asnakew, 1994). It is also used as a source of income for the farmers and foreign currency for the country (Girma, 2003).Having all these multiple benefits in the economic lives of the farming communities, however, the average yield of the crop is only 1.24 t ha^{-1} in Ethiopia (FAOSTAT, 2012) which is far below the potential 40 to 50 t ha^{-1} traditionally achieved in Europe (Netherlands, France and Belgium) and the worldwide average yield of 1.7 t ha^{-1} (Petr et al., 2012). Limited availability of adaptable high yielding improved varieties resistance to diseases, insects and abiotic calamities for wider/specific location and absence of appropriate agronomic recommendations can be cited as a major reason for this low productivity.

Field pea is one of the major pulse crops in the highlands of Guji zone next to faba bean. Currently, over 80 improved field pea varieties have been released to be grown under high altitude areas of the country. However, almost all farmers in Guji Zone were used to produce field peas of local varieties for a long period of time. Participatory variety selection (PVS) has been proposed as an option to provide farmers analternative technology to that can fit to their target environments and identify theirpreferences (Caccarelli*et. al*., 1996). Most released field pea varieties were not considering thepreference of the farmers, they were released based on the interest of the researchers.However, farmers were not taking part in selecting varieties according to their own criteria & thus they were not satisfied with the result. Many recently released varieties are also available. Therefore, it is essential to evaluate with farmers the adaptability and yield performance of released field pea varieties to the agro-ecologies of highland districts of zone, and identify farmers' preferred varieties through farmer's participation in decision making during the selection process for further production in the area.

Materials and Methods

Experimental materials and Design

The experimented was conducted in 2013 maincropping seasons at Bore, Dama and Anna Sora districts ofGuji Zone. Ten improved varieties were tested (Table 1). A randomized completeblock design with three replications was used. Researches were conducted at one potential site as mother trial (MT) and baby trials (BT) at three f farmers' fields only with one replication. Mother trials were designed by researchers and quantitative data were also taken by the researchers.The plot size was 3m x 2.4m with 6 rows and 10cm spacing between plants, while the net harvested area $6m^2$. To reduce border effect, data was taken from the central four rows. Weeding and other management practices were done as required. The fertilizer rate of 100

$N/P_2O_5/S$ kg/ha was applied at time of planting. All agronomic practices were done as per therecommendation for field pea.

Data Collection and Analysis: Data on agronomic traits such as number of pods per plant,number of seeds per pod, plant height, seed yield, and 100 seed weight wererecorded. Data for number of pod per plant, number ofseeds per pod and plant height were collected from theaverage value of randomly selected ten plants per plot.Whereas data on seed yield, total biomass and thousandseed weight were collected on plot basis. Analysis ofvariance was performed using Statistical Analysis Software. Least Significant Difference (LSD) test at 5%probability level was used for mean comparison when theANOVA showed significant difference. Farmer's preferences were identified using focus group discussions held with 43 households of 27 male and 16 female households through actively encouraging female participation. The households were randomly selected from each kebeles' in the districts. Farmers participated in evaluation and selection of improved varieties at maturity from mothers' trials through farmer research group. Field visit were arranged at maturity to collect the data using agreed criteria by research participant. Farmers discussed and agreed on criteria they thought to be important for selecting a given variety. They set their own selection criteria and ranking of varieties according to their setting criteria. The participant farmers categorized traits such as plant establishment, lodging, earliness and synchrony to maturity, free of disease and insect pest, drought tolerance, shattering, seed size, seed color, market value (high market demand) and overall performance. The rank sum method each trait for each variety was used to rank varieties based on farmers' selection criteria. The value of each trait has equal weight. The ranking procedure was explained for participant farmers and each selection criterion was ranked from 1 to 5 (1 = Very poor, 2 = Poor, 3 = Average, 4 = Good and 5 = Very good) for each varieties. Simple ranking is a tool often used to identify promising varieties based on farmers' preferences (De Boef and Thijssen, 2007).

Results and discussions

Plant height: significant variation ($P<0.05$) was observed among the studied varieties for plant height. The variety Arjo (229.3cm) was the longest variety while the variety Burkitu (182.1 cm) was the shortest variety (Table 1).

Number of pods per plant: Significant differences ($P<0.05$) were exhibited among varieties for number of pods per plant. More numbers of pods/plant were recorded from Dadimos variety (49.58). On the other hand, Urji variety had the lowest number of pods per plant with a 26.58

Hundred Seed Weight (HSW)

The field pea varieties testedhad a significant variation ($p<0.05$) among each other for hundred seed weight. The variety Markos producesthe highest seed weight (21.63gm). The variety Bamowas the least in seed weight (17.73gm) (Table 1).

Grain yield:A significant variation ($p<0.05$) was observedamong field pea varieties in their response to grainyield. The highest yield was recorded from the varietiesDadimos with the value of 4167 kg ha^{-1} which is statistically at par with Burkitu (3720 kg ha^{-1}) and TulluDimtu (3537 kg ha^{-1}). Tulushenen on the other hand was the lowestyielder with the value of 3630 kg ha^{-1} (Table 1).

Table 1: Mean values of growth, yield components and yield @ Mother Trial

Variety	Parameters							
	DF	DM	PH (cm)	NPPP	NBPP	NSPP	HSW (g)	GY (Kg ha^{-1})
Burkitu	80.67	153	182.1	47.92^{ab}	0.58	5.42	21.20^{ab}	3720^{ab}
Tulu-Dimtu	79.67	150.3	197.8	31.92^{ab}	1.42	5.13	20.03^{abc}	3537^{ab}
Adi	81.33	149.7	201.8	34.17^{ab}	0.83	5.33	19.20^{abc}	3104^{bc}
Gume	79.67	150.7	202.4	36.42^{ab}	1.0	5.75	18.97^{abc}	3326^{bc}
Tegegnech	79.67	149.0	209.2	35.33^{ab}	1.08	5.58	20.83^{abc}	3021^{bc}
Urji	80.33	149.0	201.7	26.58^{c}	1.08	5.67	19.33^{abc}	3275^{bc}
Markos	80.67	147.7	203.4	44.42^{ab}	1.50	5.83	21.63^{a}	3113^{bc}
Arjo	80.00	146.7	229.3	29.08^{ab}	1.08	6.08	18.13^{bc}	2940^{c}
Bamo	79.67	150.0	208.3	40.75^{ab}	1.66	5.17	17.73^{c}	3312^{bc}
Dadimos	80.33	149.3	194.0	49.58^{a}	1.83	5.25	21.0^{abc}	4167^{a}
LSD (0.05)	Ns	ns	30.18(*)	22.44(*)	0.708(*)	0.68(*)	3.46(*)	1261.55(*)
CV (%)	1.1	2.0	11.5	24.8	24.2	7.2	10.2	21.9

Keys: P H= plant height, NPPP=number of pod per plant, NBPP= Number of branch per plant, NSPP= number of seed per pod, HSW= hundred seed weight, GY= Grain yield

Variety Evaluation and Selection Criteria

This diversity during selection is an indication of the complexity of users' preference. Mulu et al., 2016, reported that, when there is more diversity in selection criteria, there is better chance of maintaining on farm diversity since positive traits are seldom found on single variety. However, the result from farmers' evaluation revealed that large seed size, and attractive seed color for high market demand (market value) and Free of Disease and Insect Pest (FDP) & Frost Tolerant (FT) were the major decisive criteria in retaining and rejecting the variety.Seed color and size are important characters of consumers' preference. Similar findings were reported for pure red and red mottled seed color and high yielding variety were the major decisive criteria to accept or reject common bean in Southern Ethiopia (Asrat, 2008 and Mulu*et al*., 2016).

Farmers' evaluation was conducted in the three baby trials and selection had diversified selection criteria to accept and reject bean variety (Table 2). The evaluations mean score value for each variety ranged from 8.43to 13.29 (Table 2). Burkituscored the highest value (13.29 and the lowest was scored by Markos (8.43). The rest varieties were ranked 2 to 8 by farmers, respectively.

Table 2. Mean value of each selection traits and ranking of varieties of baby trial

Farmers Trait	Varieties									
	Burkitu	Gume	Adi	Tegegnech	Tullu-dimtu	Urji	Markos	Bamo	Arjo	Dadimos
Pod Bearing	12.6	7.9	9.9	9.0	7.3	9.3	5.6	10.4	12.7	7.1
Earliness	10.5	9.4	9.1	11.4	11.9	11.4	8.3	12.4	6.2	11.2
Synchrony of Maturity	15.0	9.8	8.5	13.9	13.7	9.9	8.4	13.8	9.6	8.3
Free of Disease and Insect Pest	13.5	6.1	12.4	9.7	8.4	6.7	6.5	11.2	10.2	5.4
Shattering	13.3	9.2	11.2	11.1	8.6	9.0	11.1	12.4	14.4	10.6
Seed size	14.9	10.1	11.8	9.6	9.1	11	10.3	12.5	12.3	11.2
Seed color	13.0	10.3	13.6	9.3	10.9	13.1	9.0	13.6	12.8	11.1
Market value	13.9	9.6	13.5	9.7	10.2	12.1	9.5	13.0	13.2	10.4
Overall performance	12.9	9.1	10.8	9.5	8.4	9.8	7.2	11.0	11.0	7.1
Total	119.6	81.5	100.8	93.2	88.5	92.3	75.9	110.3	102.4	82.4
Mean	13.29	9.06	11.20	10.36	9.83	10.26	8.43	12.26	11.38	9.16
Rank	1	8	3	5	7	6	9	2	4	10

Conclusions and Recommendations

Farmers' participation in evaluating and selecting new crop varieties has substantial advantage to exploit their potential knowledge in identifying adapted varieties which can support the researchers to decide and select the best one that fits the environment and the preference of farmers. According to agronomic data and farmers' selection traits, Burkitu and Dadimos are best performed varieties. Both the varieties have white color which has goodmarketability. Therefore, these two varieties were recommended for Guji and similar agro ecologies for production and scaling up programs

Performance Evaluation of Groundnut (*Arachishypogaea L.*) varieties for yield and yield components in Guji Zone, Southern Ethiopia

DeresaShumi,*,TekalignAfeta, BelachewDebelo and Rehoboth Nuguse
Oromia Agricultural Research Institute, Bore Agricultural Research Center, P. O. Box 21, Bore, Ethiopia

Introduction

Groundnut (ArachishypogaeaL.), also known as peanut is one of the world's most popular crops cultivated throughout the tropical, sub-tropical and warm temperate areas where annual precipitation is between 1000-1200 mm for optimum growth of the crop. The crop is native to South America, Mexico and Central America. Dissemination of groundnut to the old World most probably occurred in the sixteen and seventeen centuries with the discovery voyages of Spanish, Portuguese, British and duchess (Hammons, 1994; Isleibet al., 1994). Groundnut has high economic and nutritional value andis an important cash crop for peasants in poor tropical countries.Groundnut is ranked fifth among oilseed crops in the world after oil palm, soybean, rapeseed, and sunflower in terms of volume of production and is widely grown in more than 100 countries of tropical, subtropical, and warm temperate regions of the globe (FAOSTAT, 2016). It contains 48-50% oil and 26-28% protein, and a rich source of dietary fiber, minerals, and vitamins (Janilaet al., 2013). FAOSTAT (2019) estimated that, annual unshelled groundnut production was around 60.5 million tons from about 31.2 million hectares of land and productivity of 1.9 tons per hectare in 2018 cropping season under rain fed conditions. Groundnut is an important crop from the perspective of food and nutrition security of poor smallholder farmers in developing countries, where it is grown widely. It is grown extensively in the developing countries of Asia, Africa and Latin America. About 62% of the production comes from South, East and Central Asia. Africa and Asia produced 91% of the world's total groundnut production (Nedumaranet al., 2015).

The lowland areas of Ethiopia have considerable potential for increased oil crop production including groundnut. The estimated annual groundnut production in Ethiopia was about 103, 062.38 tons from 64,649.34 hectares of production area. The average national yield was about 1.6 tons per hectare (CSA, 2015). It is mainly produced by smallholder farmers in the lowland area of Ethiopia. Currently, the production is concentrated in some areas of Oromia, Benishangul-Gumuz, Amhara, SNNP, Harari and Gambela regions. Eastern Hararghe zone of Oromia region hold primary position in producing and supplying groundnut both to domestic and export markets as compared to other parts of the country (Wijnandset al., 2009). Production and productivity of groundnut is increasing from year to year in Southern Oromia.However, the improved varieties are not yet exposed to farmers in moisture stress areas particularly in Guji Zone. Therefore, this activity was conducted with objective of evaluating adaptability of improved ground nut varieties and selects the best performing adapted variety for the target areas.

Materials and methods

The experiment was conducted at three districts characterized by different climatic condition using randomized complete block design with three replications at each location. Ten varieties were tested on plot size 4.8m^2 with row spacing of 60cm between rows and 10 cm between plants respectively. A distance of 1.0 m and 1.5 m were left between plots and blocks, respectively. Two seeds per hole were sown at a row spacing of 0.60 m and 0.20 m between plants. Thinning was carried out after 15 days from sowing. Blended NPS fertilizer at 100 kg ha^{-1} was applied at planting time. Required Agronomic and Plant Protection practices were followed during crop growth period to raise a good crop. During harvest time, five representative plants were collected in net plot randomly from each plot. Plot base data such as days to heading and thousand seed weight, stand count at harvest to adjust yield, and grain yield (dry weight of grain harvested from central row. The collected data was subjected to analysis by using SAS software version 9.1.

Results and discussions

The analysis of variance revealed that there was significant between varieties for grain yield at threelocations. So varieties performed differently across each location and they are genetically different.Similar result was reported by Tuloleetal.(2008), FikreHagosetal (2012) andFantahunWoldesenbet (2014).

Table 1. Combined Analysis of Variance

Source of variation	d.f	Mean Squares							
		DF	DM	PH	NB	NMPO	NSPO	HSW(g)	KY
Replication	2	0.07	6.06	10.64	5.55	64.0	0.24	6.40	631277
Variety	9	156.76**	19.13**	3.29ns	91.29*	176.0ns	0.77**	1084.39**	2320765**
Residual	138	1.26	1.52	13.40	39.62	102.7	0.10	8.25	378003
Total	149								

Days to maturity: Table 1 showed that there was statistically significantdifference ($p < 0.05$) among groundnut varieties in daysto maturity in both years. The highest days tomaturity () was recorded in ---- which wasstatistically at par with ------. (Table 1). The lowest days to maturity in both years was obtained from Werer- 961. Generally, ---- was late matured while Werer- 961 was early matured varieties. Next to Werer-961, Sedi had low poled mean of days to maturity. Werer-961 matured 15-30 days earlier than lote-05. Earliness or lateness in the days to maturity might have been due to their inherited characters, early acclimatization to the growing area to enhance their growth and developments. This agrees with the report of Alemayehuet al. (2014) which indicated that Lote-05 matured in 128 days while Sedi took 100 days to mature in eastern and southernEthiopia.

Pods number per plant: Varietal difference causes significant difference in podnumber per plant in both years. In 2013 cropping season,Sedi produced the highest (18.21) numerical data whilethe lowest (12.47) was gained from Werer-963 which,however, did not significantly differ from Mangifer andLote-05 (Table 1). Nevertheless, Werer-961, Lote-05, Werer-963, Werer-964 and Mangifer gave less number of pods and were statistically similar ($p < 0.05$). The highest pod number in Sedi variety in both years was most likely due to the pod bearing capacity of the variety and more branch formation nature which leads to contain high number of pods per plant. Similarly, Sibhatuet al. (2017) reported that variety sedi produced significantly more pods per plant than other at Tanqua-Abergelle, Tigray. It was also in agreement with the findings of Caliskan et al. (2008)

Seed number per pod: According to Table 1, number of seeds per pod ofgroundnut was not significantly influenced due to varietaldifference in both years. The pod of the varieties has thecapacity of producing statistically similar number ofseeds. Though non-significant, the highest numerical pooled mean number of seeds per pod was incurred in Babile-1variety. In general, the seed number pod of groundnutranged from two to three.

Hundred seed weight: Hundred seed weight significantly ($p < 0.05$) affected dueto varieties in both years. During both cropping season,Mangifer had numerically the highest seed weight (51.67g) though significantly at par with Sedi. However, thelowest data (40.07g) was shown in Werer-961 whichhowever, did not significantly different from Werer-963,Werer-964 and Lote-05 varieties. In addition, The highest seed weight in Mangifercould be most probably due to its efficient utilization ofenvironmental growth resources so as to stimulate andenhance the photosynthetic and metabolic activities ofthe plant which resulted on the formation of healthy andwell-structured seed. This result confirms the finding ofBale et al. (2011) who pointed out that weight of dry podsplant-1 was significantly affected by variety x sowing dateinteraction. Moreover, Caliskan et al. (2008) reported thatboth sowing date and cultivars significantly influenced100-seed weight of groundnut

Table 2. Mean values of yield components of Ground nut varieties during 2020 cropping season

No	Variety	Parameters						
		DF (50%)	DM (90%)	PH (cm)	NB	NMPO	NSPP	HSW(g)
1	Roba	55.00a	165.0b	26.80	16.92a	21.25	2.08d	61.00c
2	Baha-gudo	46.67b	164.7b	24.92	12.14a-c	20.64	2.00d	85.33a
3	Werer-961	44.00d	161.7c	24.64	7.14bc	32.94	2.50bc	44.00d
4	Babile-1	45.67bc	164.3b	25.61	8.61a-c	31.00	2.08d	79.00b
5	Babile-2	55.00a	165.0b	25.53	16.16a	25.22	2.00d	78.33b
6	Baha-gidu	55.00a	166.7a	24.95	14.81a-c	25.44	2.00d	59.00c
7	Sedi	43.67d	161.0c	24.72	6.53c	22.39	3.08a	33.00e
8	Tole-1	55.00a	166.0ab	26.03	15.08ab	14.94	2.17cd	83.67a
9	Fayo	45.00cd	165.0b	26.30	8.47a-c	23.75	2.50bc	48.33d
10	Nc-4x	46.67b	165.3ab	24.92	12.86a-c	18.58	2.58b	45.33d
Mean	49.17	164.47	25.44	11.87	23.62	2.30	61.80	
LSD (0.05)		1.359	1.493	4.249	7.307	11.762	0.363	4.928
CV (%)		2.3	0.7	14.4	53.0	42.9	13.6	4.6

Shelled seed yield: The most promising variety is ultimately determined by the level of grain yield per unit area which is cumulative behavior of the yield components. Data presented in Table 2 revealed that varieties caused significant differences on seed yield in both years. The maximum yield (2317 kg ha^{-1}) was obtained from Babile-1 variety. It was statistically similar with the other varieties like Baha-gudo, Werer-96 and Baha-gidu. The lower (1211 & 1248 kg ha^{-1}) numerical yield were obtained from Fayo and Nc-4x and statistically inferior to the other varieties respectively. The variation in marketable yield of these varieties could be due to their differences in genetic characteristics and agro ecological adaptability nature which is in line with the findings of Bale et al. (2011) who pointed out that grain yield difference among varieties is attributed to more efficiency in the manufacture and partitioning of assimilates to the reproductive sink, which in turn led to more grain yield formation. In contrast to this result, Alemayehu*et al*. (2014) reported that Sedi variety gave a shelled seed yield of 20.42 to 29.44 qt ha^{-1} in eastern and southern Ethiopia which related to the current finding.

Table 3. Mean Kernel yield (kg ha^{-1}) of Groundnut varieties during 2019 and 2020

Variety	2019			2020		Overall Mean
	OdoShakkiso		GoroDola	AdolaRede		
	Diba Bate	BantiKorbo	Sirba	Dole	KiltuSorsa	
Roba	1580 $^{a-c}$	1449 $^{b-d}$	931	1174^{cd}	1625^{c}	1352^{cd}
Baha-gudo	2051 ^{a}	2104 ^{ab}	1826	1319^{c}	3000^{ab}	2060^{ab}
Werer-96	1906 ^{ab}	2521^{a}	1340	2444^{b}	2139^{bc}	2070^{ab}
Babile-1	2198 ^{a}	1806 $^{a-c}$	1764	2444^{b}	3375^{a}	2317^{a}
Babile-2	2149 ^{a}	2097 ^{ab}	1531	1035^{cd}	2007^{c}	1764^{bc}
Baha-gidu	1851 ^{ab}	2292 ^{ab}	1427	1417^{c}	2146^{bc}	1826^{a-c}
Sedi	927 ^{cd}	1917 ^{ab}	913	3090^{a}	1528^{c}	1675^{b-d}
Tole-1	1118 $^{b-d}$	1410 $^{b-d}$	1288	757^{d}	1729^{c}	1260^{d}
Fayo	892 ^{cd}	615 ^{d}	1264	1500^{c}	1785^{c}	1211^{d}
Nc-4x	587 ^{d}	868 ^{cd}	1403	1208^{cd}	2174^{bc}	1248^{d}
Mean	1525.97	1707.78	1368.75	1638.89	2150.69	1678.417
P-value	0.007	0.012	0.303	<0.001	0.006	<.001
LSD(0.05)	900.15	984.42	784.18	552.19	892.72	491.99
CV(%)	34.40	33.60	33.40	19.6	24.2	40.6

Conclusions and recommendations

Productivity of groundnut can be enhanced by selectinggenetically improved varieties. The results of thisexperiment showed that Babile-1 variety was early maturedand produced the highest pods per plant, hundred seedweight and good performance in other parameters. Moreover, it gave the highest seed yield as compared to the other varieties. Therefore, it canbe concluded that Babile-1 variety well performed and can berecommended for the growers in the study area toimprove groundnut productivity. Moreover, it canrecommend from this finding that further investigation ondifferent varieties along with different fertilizer levels, soiltypes and

Integrated Pest Management (IPM) techniquescan be a step forward to identify more realistic effect ofdifferent varieties on the growth and yield improvementsof groundnut

References

Hammons, R.O. 1994. The origin and history of the groundnut, The Groundnut Crop, J.Smartt (ed.) Chapman and Hall, London, UK., pp. 24-42

Isleib, T.G., Wynne, J.C., and Nigam, S.N. 1994. Groundnut breeding, In: the groundnut crop. J.Smartt (ed.) Chapman and Hall, London, U.K., pp. 552-623

FAOSTAT (Food and Agriculture Organization of the United Nations). 2016. Available at: http:// faostat. fao.org/site/339/default.aspx. (Accessed on March /23/2017)

Janila, P., Nigam, S.N., Pandey, M.K., Nagesh, P. and Varshney, R.K. 2013. Groundnut improvement: use of genetic and genomic tools. Front. Plant Science, 4: 1-16.

Wijnands, J.H.M., Biersteker, J. and Van Loo, E.N. 2009. Oilseed business opportunity in Ethiopia, Oil Seed Research Report, Addis Ababa, Ethiopia

BerhaneSibhatu, Melesse Harfe1 and GueshTekle (2017) Groundnut (Arachishypogaea L.) varieties evaluationfor yield and yield components at Tanqua-Abergelledistrict, Northern Ethiopia. *Sky Journal of Agricultural Research Vol. 6(3), pp. 057 - 061*

Caliskan S, Caliskan ME, Arslan M, and Arioglu H (2008). Effects of sowing date and growth duration on growth and yield of groundnut in a Mediterranean type environment in Turkey. Field Crops Res., 105:131-140.

Bale HMB, Ogunlela VN, Kuchinda NC, Tanimuu B (2011). Response of Two Groundnut (*Arachishypogaea*L) Varieties to Sowing Date and NPK Fertilizer Rate in a Semi-Arid Environment: Yield and Yield Attributes. *Asian J. of Crop Sci.*, 3(3):130-140

Alemayehu C, Berhanu A, Mulugeta T, Abdi M, Tameru A and Helge S (2014). Opportunities and constraints of groundnut production in selected drylands of Ethiopia. Drylands Coordination Group Report No. 74, Drylands Coordination Group c/o Miljøhuset, Norway. http://drylands-group.org/publications/groundnut-production-in drylands-of-ethiopia.

Genotype by Environment Interaction and Grain Yield Stability of Food-type Common Bean (*Phaseolus vulgaris* L.) Genotypes in Southern Oromia

DeresaShumi,[*],TekalignAfeta, BelachewDebelo and Rehoboth Nuguse

Oromia Agricultural Research Institute, Bore Agricultural Research Center, P. O. Box 21, Bore, Ethiopia

Abstract

Twelve common bean genotypes including the standard checks were evaluated at eight locations during 2019/20 and 2020/21, to determine the magnitude of G x E interaction and to identify high yielding and stable or specifically performed genotypes for target environment(s). The genotypes were arranged in Randomized Complete Block Design and replicated three times. Combined ANOVA and GGE bi-plot models were used to analyze the data. GGE biplot analysis revealed the presence of three mega environments and identified that genotype (NSEA515-11-1) was declared as widely adapted genotypes with greater grain yield of 2.90 tons ha^{-1} and 2.78 *tons ha^{-1}, respectively. So that genotypes (NSEA515-11-1)was stable and high yielder across all locations and recommended to be verified for possible release.*

Introduction

Common bean (*Phaseolus vulgaris* L.) is one of the principal grain legumes of eastern and southern Africa, occupying more than 4 million hectare annually. It provides food for more than 100 million people (Wortmann et al.,1998). In Ethiopia, common bean has been known as an export crop, contributing to foreign exchange earnings. Hence, in 2008 Ethiopia earned 36.2 million United States dollars from common bean export (Ethiopia Custom Authority, 2009, unpublished). Genetic-environment interactions (GEIs) are great interest when evaluating the stability of breeding plants under different environmental conditions. The reliability of genotype performance across different environmental conditions can be an important consideration in plant breeding. Breeders are primarily concerned with high yielding and stable cultivars as much possible as since cultivar development is a time consuming endeavor. A successfully developed new cultivar should have a stable performance and broad adaptation over a wide range of environments in addition to high yielding potential. Evaluating stability of performance and range of adaptation has become increasingly important for breeding programs. Hence, if cultivars are being selected for a large group of environments, stability and mean yield across all environments are important than yield for specific environments (Piepho, 1996).

Knowledge of the presence and magnitude of genotype x environment interactions (GEI) is very important to plant breeders in making decisions regarding the development and release of new cultivars (Chakroun et al., 1990). Genotype x environment interactions have been defined as the failure of genotypes to achieve the same relative performance in different environments (Baker, 1988). Moldovan et al. (2000) indicated that genotype-environment interactions are of major importance; because they provide information about the effects of different environments on cultivar performance and play a key role for the assessment of performance stability of the breeding materials germplasm. Plant breeders perform multi-environment trials (MET) to evaluate new improved genotypes across test environments (several locations), before a specific genotype is released for production to supply growers.

Crop improvement programs usually tests the performance of genotypes across a wide range of environments to partition the effect of genotype (G), environment (E) and their interaction (G x E) and to ensure that the released varieties have a high yield and stable performance across several environments or to the specific environments. The objectives of the present study were to estimate genotypes by environment interactions and to determine the stable and high yielder common bean genotypes fitting for optimum environments of Guji and West Guji zones and similar agro-ecologies of Southern Ethiopia.

Materials and Methods

Plant Materials and Field Management

Field experiments were conducted during the 2019/20 and 2020/21 main cropping seasons for consecutive two years at eight potential common bean producing locations of Guji zones of Southern Oromia. A total of 12 common bean genotypes including two released varieties and one local cultivar were evaluated.Randomized Complete Block Design (RCBD) with three replications was used across all locations. Each variety were sown in 6 rows; 3m length with 40cm inter-row spacing and 10cm between plants and fertilizer rates of 121 NPS Kg ha^{-1} was applied at planting time. All pertinent management practices were carried out at all sites following standard recommendation. Harvesting was done by hand. The central four rows were used as net plot for data collection including yield.

Statistical Analysis: The homogeneity of error variance was tested using the F-max test method of Hartley (1950) prior to pooled analysis over locations. Different statistical software packages were used to analyze the data. The analysis of variance for each location and combined analysis of variance over locations were computed using the SAS program (SAS institute, 2011) versions 9.3. AMMI biplots were analyzed using GEA-R version 2.0 (CIMMYT, 2015). GenStat 18th edition (2012) was used to draw GGE biplots.

AMMI Analysis: Grain yield data was analyzed using AMMI model so as to partitions the interaction sum of squares into IPC axes. The AMMI model is:

$$Y_{ij} = \mu + G_i + E_j + \sum_{k=1}^{N} \lambda_k \alpha_{ik} \gamma_{jk} + \theta_{ij} + \varepsilon_{ij}$$

where, Y_{ij} = the yield of the ith genotype in the jth environment, μ = the grand mean, G_i and E_j= the genotype and environment deviations from the grand mean respectively, λ_k = the eigen value for IPCA analysis axis k,$\alpha_{ik}$and γ_{jk}= the genotype and environment principal component scores for axis k,the summation handles N number of principal components retained in the model,θ_{ij} =the AMMI residual and ε_{ij} = the error (Zobel*et al*., 1988).The degrees of freedom (DF) for the IPCA axes were calculated according to Zobel*et al*. (1988)with the following formula.

DF = G + E – 1 – 2n where, G = the number of genotypes E = the number of environments n = the n^{th} axis of IPCA.

In order to show a clear insight of the interaction and the general pattern of adaptation of varieties, a biplot of varieties and environments (Kempton, 1984) were done. In the biplots the first IPCA was used as the ordinate (Y-axis) and the main effects (mean of the genotype and environment) represent abscissa (X-axis). Similarly, the IPCA1 as abscissa and IPCA2 as ordinate was used to further explore stability.

AMMI Stability Value: AMMI stability value was calculated in the excel spread sheet using the formula developed by Purchase et al. (1997).

$$ASV = \sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1\ Score)\right]^2 + [IPCA2\ Score]^2}$$

where, $\frac{SSIPCA1}{SSIPCA2}$ is the weight given to the IPCA value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares.

Genotype Selection Index

Genotype selection index was also calculated by the formula suggested by Farshadfar*et al.* (2008). Here it is calculated by taking the rank of mean grain yield of genotypes (RY_i) across environments and rank of AMMI Stability Value ($RASV_i$) a selection index GSI was calculated for each genotype which incorporate both mean grain yield and stability index in a single criteria (GSI_i) as:

$$GSI_i = RASV_i + RY_i$$

where, RASV is the rank value of genotypes for AMMI stability value and RY is the rank value of genotypes for grain yield. A genotype with the least GSI is considered as the most stable (Farshadfar, 2008).

GGE Biplot Analysis: The most recent method, GGE biplot model, provides breeders a more complete and visual evaluation of all aspects of the data by creating a biplot that simultaneously represents mean performance and stability, as well as identifying mega-environments (Yan and Kang, 2003; Ding et al., 2007).

To analysis stability and identify superior genotype across environment, GGE bi-plot analysis were conducted. GGE biplot best identifies GxE interaction pattern of data and clearly shows which variety performs best in which environment. The GGE biplot model of *t* principal components is given as follows:

$$\bar{Y}ij - \mu_i - \beta_j = \sum_{k=1}^{t} \lambda_k \alpha_{ik} \gamma_{jk} + \varepsilon_{ij}$$

where; $\bar{Y}ij$= the performance of genotype i in environment j, □= the grand mean, □□$_j$= the main effect of environment j, k = the number of principal components (PC); □$_k$ = singular value of the k^{th} PC; and □$_{ik}$ and □$_{jk}$ = the scores of i^{th} genotype and j^{th}environment, respectively for PC $_k$; □$_{ij}$ = the residual associated with genotype i in the environment j. Usually only the first two PCs are used especially if they account for the major portion of the GxE interaction.

Results and Discussion

Analysis of variance and Mean performances: The result of pooled analysis of variance revealed statistically highly significant differences ($p<0.001$) for days to flowering, plant height, number of pods and hundred seed weight while non-significant was recorded for remaining agronomic traits. The highest pooled mean performance of grain yield was recorded for the genotypes NSEA515-11-1 (2.900 tons ha^{-1}) followed byNSEA515-11-34 (2.823 tons ha^{-1}) whereas the lowest mean was obtained from the local cultivar. In addition both genotypes showed highest number of seeds and moderately resistant to common bean diseases such as common bean blight, angular leaf spot, anthracnose and common bean rust (Table).

Additive main effect and Multiplicative interaction (AMMI): AMMI analysis of variance for grain yield revealed highly significant ($p<0.001$) differences for genotype, environments and genotype by environment interactions (Table 1). The ANOVA using the AMMI model accounted about 6.81% of the total sum square (SS) was attributable to the genotypes (G), 43.50% to the environments (E), and importantly 18.50% to G x E interaction effects (Table1). A large total variation due to E indicated the overwhelming influence of environments on grain yield performance of common bean genotypes. Similar results were reported for various crop such as soybean (Asrat et al., 2009), field pea (Tamene et al., 2013), cowpea (Nunes et al., 2014) and durum wheat (Shitaye, 2015; Temesgen et al., 2015; Tekalign et al., 2018). Likewise, Yan and Kang (2003) in which environment showed predominant effect on varietal performance. AMMI analysis also showed that IPCA1 and IPCA2 captured 40.79% and 29.62% of the genotype by environment interaction sum of squares and this two PCA's accurately predict the AMMI model. Yan and Rajcan (2002) reported that the best accurate model of AMMI can be predicted by using the first two PCA's.

Table 1: The AMMI analysis of variance for grain yield (tons ha^{-1}) of 12 common bean genotypes tested in 8 environments

Source of variation	Df	SS	MS	Total variation explained(%)	GxE explained (%)	GxE cumulative (%)	P-value
Total	287	121.20	0.422				
Genotype	11	8.25	0.750**	6.81			<0.001
Environment	7	52.72	7.531**	43.50			<0.001
Reps (Env.)	16	6.21	0.388**	5.12			0.0079
GxE Interaction	77	22.42	0.291**	18.50			0.0048
IPCA1	17	9.15	0.538**		40.79		<0.001
IPCA2	15	6.64	0.443**		29.62	70.41	0.0026
Residual	46	6.64	0.147ns				0.7785
Pooled error	176	31.60	0.180				

Table 2. Mean grain yield (tons/ha) of 12 common bean genotypes at 8 environments during the 2019 and 2020 main cropping season.

Genotypes	Test locations								Over all Mean	(%)Yield advantage
	2019				2020					
	Adola-woyu(E1)	Kiltu-sorsa(E3)	Gobicha(E5)	Wodera(E7)	Adola-woyu(E2)	Kiltu-sorsa(E4)	Gobicha(E6)	Wodera(E8)		
NSEA515-11-34	2.674^{a}	2.549	3.100^{ab}	2.889^{ab}	3.031^{a}	23.89	3.539	2.417	2.823^{ab}	
NSEA515-11-1	2.781^{a}	2.872	3.392^{a}	2.625^{a-d}	2.528^{a-c}	2.375	4.206	2.147	2.900^{a}	16.00
NSEA515-11-30	2.250^{ab}	2.146	2.628^{bc}	2.111^{de}	2.514^{a-c}	2.444	3.800	2.244	2.517^{cd}	
NSEA515-11-31	2.790^{a}	2.111	2.768^{bc}	3.147^{a}	2.997^{ab}	2.626	3.622	2.280	2.768^{a-c}	11.20
NSEA515-11-42	2.837^{a}	2.174	2.729^{bc}	2.198^{c-e}	2.507^{a-c}	2.542	3.117	1.644	2.468^{d}	
NSEA515-11-46	1.910^{ab}	1.826	2.552^{bc}	2.819^{a-c}	2.583^{a-c}	1.885	3.375	2.003	2.369^{d}	
NSEA515-11-52	2.948^{a}	2.590	2.684^{bc}	2.031^{de}	2.628^{a-c}	3.163	3.336	1.756	2.642^{a-d}	
NSEA515-11-63	2.431^{ab}	3.052	2.542^{bc}	2.285^{b-e}	2.024^{c}	2.622	3.714	2.025	2.587^{b-d}	
NSEA515-11-65	2.274^{ab}	2.396	2.576^{bc}	2.208^{b-e}	1.972^{c}	2.663	3.683	2.028	2.475^{d}	
SER-119	2.111^{ab}	2.417	2.774^{bc}	2.632^{a-d}	2.285^{bc}	2.795	3.536	2.192	2.502^{cd}	
IBADO	2.125^{ab}	1.878	2.587^{bc}	2.358^{b-e}	2.517^{a-c}	1.958	3.678	1.914	2.377^{d}	
LOCAL CULTIVAR	1.382^{b}	1.917	2.483^{c}	1.885^{e}	2.264^{bc}	2.184	3.561	2.092	2.362^{d}	
Means		2.376	2.344	2.735	2.432	2.488	2.471	3.597	2.062	2.563
LSD(5%)		0.732	0.809	0.580	0.680	0.648	1.119	0.637	0.657	0.696
CV(%)		18.2	20.4	12.6	16.5	15.4	26.7	10.5	18.8	16.9

Table 3. Combined mean performances of agronomic traits and disease reactions of 12 genotypes at eight locations during 2019 and 2020 main cropping season.

Genotypes	Agronomic traits							Diseases score (1-9 scale)			
	DF	DM	PH (cm)	NB	NPO	NS	100SW (g)	CBB	ALS	Leaf Rust	Anthracnose
NSEA515-11-34	42.8d	91.8	70.81[c]	1.2	14.2	5.6[ab]	24.4[cd]	3	3	1	2
NSEA515-11-1	44.2[bc]	91.1	90.62[b]	1.6	16.6	5.4[b-d]	23.4[cd]	3	3	1	2
NSEA515-11	44[b-d]	91.3	77.6[c]	1.3	13.5	6[b-d]	25.5[c]	4	3	1	2
NSEA515-11-31	43.5[b-d]	92.3	74.38[c]	1.2	12.3	5.6[bc]	31.4[b]	3	2	1	2
NSEA515-11-42	43.4[b-d]	90.5	50.61[d]	1.1	13.6	5.2[cd]	25.5[c]	3	3	1	2
NSEA515-11-46	42.83[d]	89.9	54.06[d]	1.0	12.9	5.4[b-d]	25.3[c]	4	3	1	2
NSEA515-11-52	43.0[cd]	87.5	78.28[c]	1.1	11.9	5.6[ab]	29.4[b]	3	4	2	3
NSEA515-11-63	43.9[b-d]	91.2	71.25[c]	1.4	15.9	5.4[b-d]	23.8[cd]	3	3	2	2
NSEA515-11-65	44.54[b]	92.2	69.07[c]	1.4	15.6	5.2[d]	24.6[cd]	3	4	2	2
SER-119	46.25[a]	92.4	69.73[c]	1.4	15.7	5.9[a]	22.3[d]	3	3	1	3
Ibado	43[b-d]	89.1	70.1[c]	1.3	10.9	3.8[e]	44.7[a]	4	2	1	2
Local Cultivar	45.9[a]	94.3	122.1[a]	1.3	15.4	5.4[b-d]	21.6[e]	4	4	2	2
MEANS	44.00	91.1	74.89	1.3	14.0	5.34	26.65	3	3	2	2
(5%) LSD	1.10	3.92	9.21	0.3	2.11	0.33	2.80	0.54	0.5	0.41	0.42
CV(%)	4.6	7.6	21.6	47.	26.5	10.8	18.5	30.2	29	31.1	36.7

AMMI Stability Value (ASV): In ASV, the genotypes with least ASV score is the most stable where as those which have highest ASV are considered as unstable (Purchase, 1997). However, stability needs to be considered in combination with yield (Farshadfar, 2008). Thus,genotype (NSEA515-11-1) was considered as the most stable and high yielder across all environments (Table 3)

Genotype Selection Index (GSI): Stable genotypes would not inevitably provide the best yield performance and hence identifying genotypes with high grain yield coupled with consistent stability across growing environments has paramount importance. In this regard, genotype selection index was utilized to further identify stable genotypes with better yield performance. Accordingly, NSEA515-11-1 and NSEA515-11-34 were considered as the two most stable genotypes with high grain yield.

Table 3. The grain yield, AMMI stability value (ASV), Genotype selection index (GSI)and principal component axis (IPCA)

Genotypes	Yield tons ha^{-1}	Rank	IPCA1 score	IPCA2 Score	ASV	Rank	GSI	Rank
NSEA515-11-34	2.823	2	0.30066	-0.17941	0.452	4	6	2
NSEA515-11-1	2.866	1	-0.12030	0.13835	0.216	2	3	1
NSEA515-11-30	2.517	6	0.00718	0.10488	0.105	1	7	3
NSEA515-11-31	2.768	3	0.50950	-0.42576	0.823	10	13	4
NSEA515-11-42	2.468	8	-0.21352	-0.58757	0.657	7	15	6
NSEA515-11-46	2.369	11	0.65157	0.04257	0.900	11	22	8
NSEA515-11-52	2.642	4	-0.61176	-0.49898	0.981	12	16	7
NSEA515-11-63	2.587	5	-0.53778	0.30709	0.803	9	14	5
NSEA515-11-65	2.475	9	-0.30952	0.22458	0.482	6	15	6
SER-119	2.502	7	0.12821	0.68512	0.708	8	15	6
Ibado	2.377	10	0.33924	0.00469	0.468	5	15	6
Local Cultivar	2.362	12	-0.14349	0.18445	0.271	3	15	6

Stability analysis based on GGE Biplot: GGE biplot was the best way to visualize the interaction patterns between genotypes and environments to effectively interpret a biplot (Yan and kang, 2003). In this study, the polygon view of a GGE biplot clearly displays the which-won-where pattern, and hence it arranged the genotypes in such a way that some of them were on the vertices while the rest were inside the polygon.Accordingly, the bi-plot showed that seven vertex genotypes (figure 1). The vertex genotypes for each quadrant (sector) are the one that gave the highest yield for the environment that fall within that quadrant. The falling of all environments into a single sector indicates that a single genotype has the highest yield in all environments which means a genotype consistently performed best in a group of environments.

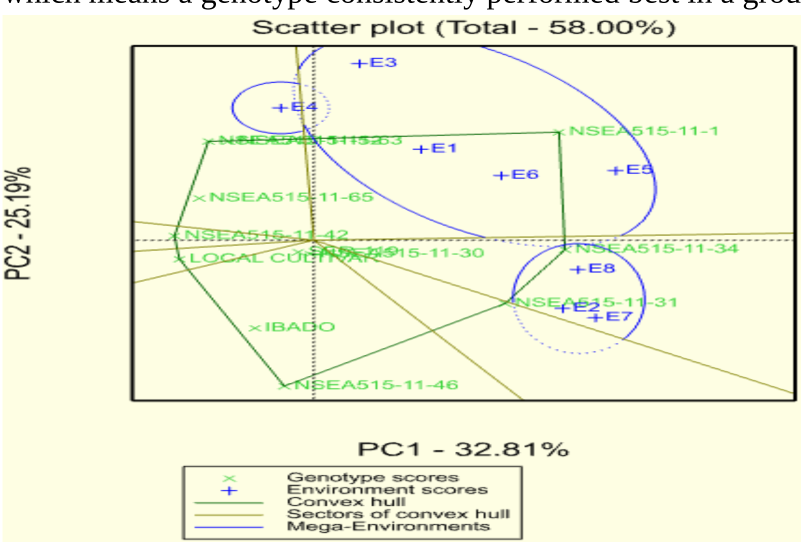


Fig.1. The GGE- biplot for which -won -where pattern for genotypes and environments.

In genotype focusing scaled comparison of GGE biplot, a genotype located nearest to the central concentric circles is both high grain yielding and most stable. Figure 2 depicts that genotype NSEA515-11-1, which fell in the first concentric circle, was the ideal genotype in terms of higher yielding ability and stable. Genotype NSEA515-11-34 was located closer to the ideal genotype, it becomes more desirable.

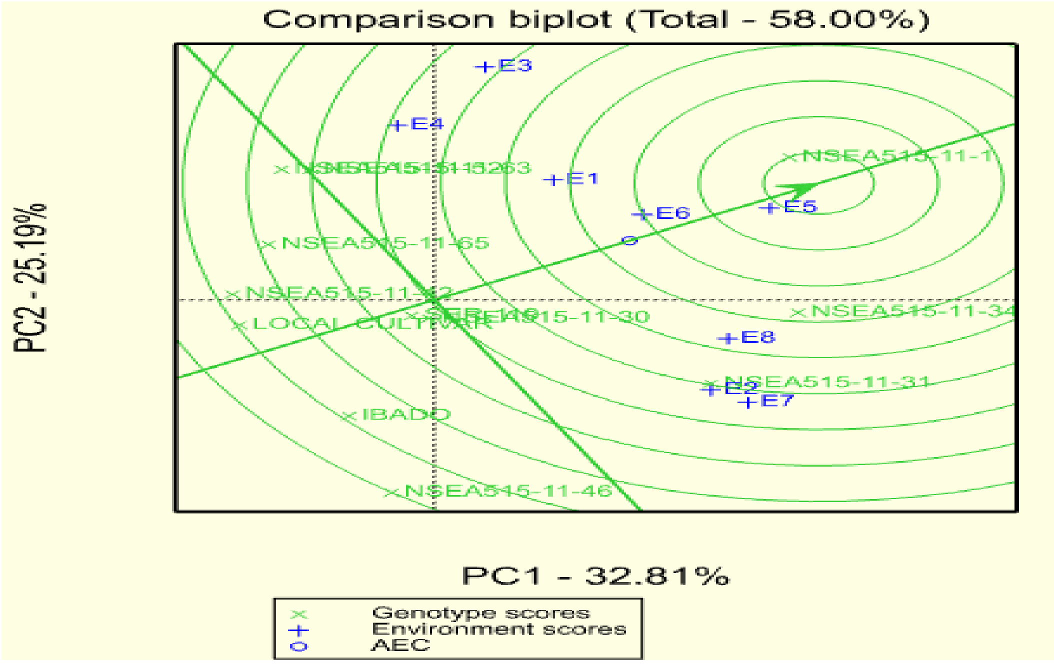


Fig.2. GGE–biplot based on genotype focused scaling for comparison of the genotypes

Mean Performance and Stability of Genotypes: A genotype which has shorter absolute length of projection in either of the two directions of AEC ordinate (located closer to AEC abscissa), represents a smaller tendency of G x E interaction, which means it is the most stable genotype across different environments. The mean performance and stability of these 12 genotypes in 8 locations shows NSEA515-11-1 was relatively high yielding and stable genotype.

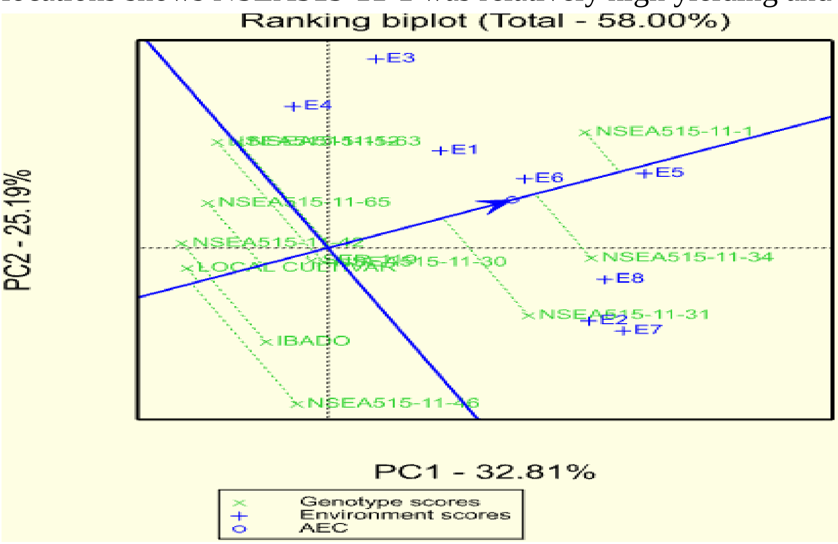


Fig. 3. GGE ranking biplot shows means performance vs stability

Conclusion and Recommendation: Genotype by environment interaction and stability measuring trials helps to identify genotypes with both high performance and grain yield stability.The significant G x E interaction and the changes in the rank of genotypes across environments suggest a breeding strategy for specifically adapted genotypes in homogenously grouped environments, as well as for high yielding stable genotypes suggesting for wider adaptation. As a result, one genotype showed 16.00% grain yield advantage over the standard check, tolerant/resistant to major faba bean diseases, stable and also possessed other desirable agronomic characteristics. Accordingly, genotypes (NSEA-11-1) was identified as the most stable high yielding across environments and promoted to VVT for eventual varietal release to the set of tested environments and similar agro-ecologies.

References

Abbas, G., Atta, B.M., Shah, T.M., Sadiq, M.S. and Haq, M.A. 2008. Stability analysis for seed yield in mungbean (Vignaradiata L.). *Journal of Agricultural Research*,46 (3): 223-228.

Abdelmula, A.A. and Abuanja, I.K. 2007. Genotypic responses, yield stability, and association between variability, correlation and path coefficient analysis of yield and some yield components in faba bean (Viciafaba L.) populations. *Journal of Damascus University for Agricultural Sciences*,27 (1): 83-95.

Acikgoz, E., Ustun, A., Gul, I., Anlarsal, E., Tekeli, A.S., Nizam, I., Avcioglu, R., Geren, H., Cakmakci, S., Aydinoglu, B., Yucel, C., Avci, M., Acar, Z., Ayan, I., Uzun, A., Bilgili, U., Sincik, M. and Yavuz, M. 2009. Genotype x environment interaction and stability analysis for dry matter and seed yield in field pea (Pisumsativum L.). *Spanish Journal of Agricultural Research*,7 (1): 96-106.

Ahmad, J., Choudhry, M.H., Salah-Ud-Din, S., and Ali, M.A. 1996. Stability for grain yield in wheat. *Pakistan Journal of Botany*, 28: 61-65.

Akcura, M., Kaya, Y., Taner,S. and Ayranci, R. 2006. Parametric stability analysis for grain yield of durum wheat. *Plant Soil Environ*., 52: 254-261.

Arshad, M., Bakhsh, A., Haqqani, M. and Bashir, M. 2003. Genotype-environment interaction for grain yield in chickpea (*Cicer arietinum* L.). *Pakistan Journal of Botany*, 35: 181-186.

Baker, R.J. 1988. Test for crossover genotype-environment interaction. Can. *J. Plant Sci*., 68: 405-410.

Bjornsson, J. 2002. Stability analysis towards understanding genotype-environment interaction. www.genfys. Slue. Se/staff/deg/nova 02.

Chakroun, M., Taliaferro, C.M. and McNew, R.W. 1990. Genotype-environment interactions of bermudagrass forage yields. *Crop Science*, 6: 36-40.

Dehghani, H., Sabaghpour, S.H. and Sabaghnia, N. 2008. Genotype x environment interaction for grain yield of some lentil genotypes and relationship among univariate stability statistics. *Spanish Journal of Agricultural Research*, 6 (3): 385-394.

Kalia, P. and Sood, S. 2004. Genetic variation and association analyses for pod yield and other agronomic and quality characters in an Indian Himalayan collection of broad bean (Viciafaba L.). *SABRAO Journal of Breeding and Genetics*, 36: 55-61.

Kang, M.S. 1998. Using genotype-environment interaction for crop cultivar development. *Adv. Agron*.,35: 199-240.

Karadavut, U., Palta, C., Kavuramci, Z. and Bolek, Y. 2010. Some grain yield parameters of multi-environmental trials in faba bean (Viciafaba L.) genotypes. *International Journal of Agriculture and Biology*,12 (2): 217-220.

Moldovan, V., Moldovan, M. and Kadar, R. 2000. Phenotypic stability for yield in chickpea. *Pakistan of Science Research*, 30: 455-465.

Piepho, H.P. 1996. Analysis of genotype environment interaction and phenotypic stability. In: M.S. Kang, and H.G. Zobel Jr (Eds), pp. 151-174. Genotype by Environment Interaction. CRC Press, Boca Raton.

Wamatu, J.N., and Thomas, E. 2002. The influence of genotype-environment interaction on the grain yields of 10 pigeon pea cultivars grown in Kenya. *Crop Science*, 188: 25-33.

Wortmann, C.S, Kirby, R.A., Eledu, C.A. and Allen, D.J. 1998. Atlas of common bean (phseolusvoulgarirsL.) production in Africa. CIAT Pan-Africa Bean Research Alliance, CIAT, Cali, Colombia.

Genotype by Environment Interaction and Grain Yield Stability of Faba Bean (*Viciafaba* L.) Genotypes in Southern Oromia

DeresaShumi,[*],TekalignAfeta, BelachewDebelo and Rehoboth Nuguse

Oromia Agricultural Research Institute, Bore Agricultural Research Center, P. O. Box 21, Bore, Ethiopia

Abstract

A total of 14 faba bean genotypes including the standard and local checks were evaluated at eight locations during 2019/20 and 2020/21, to determine the magnitude of G x E interaction and to identify high yielding and stable or specifically performed genotypes for target environment(s). The genotypes were arranged in Randomized Complete Block Design and replicated three times. Combined ANOVA and GGE bi-plot models were used to analyze the data. Both AMMI and GGE biplot analyses result identified that genotypes (EH03071-1-2006) and (EH99005-2-2005) were declared as widely adapted genotypes with greater grain yield of 4.96 tons/ha and 4.90 tons/ha, respectively. So that genotypes EH03071-1-2006 and EH99005-2-2005 were stable and superior to the standard checks in grain yield and stability and they were recommended as candidate variety for possible release.

Introduction

Faba bean (*Viciafaba* L.) popularly known as the poor's meat plays an important role in the world agriculture; owning to its high protein content, ability to fix atmospheric nitrogen, and capacity to grow and yield well even on marginal lands and at high altitudes (Kalia and Sood, 2004).Genetic-environment interactions (GEIs) are great interest when evaluating the stability of breeding plants under different environmental conditions. The reliability of genotype performance across different environmental conditions can be an important consideration in plant breeding. Breeders are primarily concerned with high yielding and stable cultivars as much possible as since cultivar development is a time consuming endeavor. A successfully developed new cultivar should have a stable performance and broad adaptation over a wide range of environments in addition to high yielding potential. Evaluating stability of performance and range of adaptation has become increasingly important for breeding programs. Hence, if cultivars are being selected for a large group of environments, stability and mean yield across all environments are important than yield for specific environments (Piepho, 1996).

Knowledge of the presence and magnitude of genotype x environment interactions (GEI) is very important to plant breeders in making decisions regarding the development and release of new cultivars (Chakroun et al., 1990). Genotype x environment interactions have been defined as the failure of genotypes to achieve the same relative performance in different environments (Baker, 1988). Moldovan et al. (2000) indicated that genotype-environment interactions are of major importance; because they provide information about the effects of different environments on cultivar performance and play a key role for the assessment of performance stability of the breeding materials germplasm. Plant breeders perform multi-environment trials (MET) to evaluate new improved genotypes across test environments (several locations), before a specific genotype is released for production to supply growers.

Crop improvement programs usually tests the performance of genotypes across a wide range of environments to partition the effect of genotype (G), environment (E) and their interaction (G x E) and to ensure that the released varieties have a high yield and stable performance across several environments or to the specific environments. The objectives of the present study were to estimate genotypes by environment interactions and to determine the stable and high yielder faba bean genotypes fitting for optimum environments of Guji and West Guji zones and similar agro-ecologies in Ethiopia.

Materials and Methods

Plant Materials and Field Management: Field experiments were conducted during the 2019/20 and 2020/21 main cropping seasons for consecutive two years from July to January at eight potential fababean producing areas of Guji zones of Southern Oromia. A total of 14 faba bean genotypes including two released varieties and one local cultivar were evaluated.Randomized Complete Block Design (RCBD) with three replications was used across all locations. Each variety were sown in 4 rows; 4m length with 40cm inter-row spacing and 10cm between plants. Fertilizer rates of 121 NPS Kg ha^{-1} was applied at planting time. All pertinent management practices were carried out at all sites following standard recommendation. Harvesting was done by hand. The central two rows were used as net plot for data collection including yield.

Statistical Analysis: The homogeneity of error variance was tested using the F-max test method of Hartley (1950) prior to pooled analysis over locations. Different statistical software packages were used to analyze the data. The analysis of variance for each location and combined analysis of variance over locations were computed using the SAS program (SAS institute, 2011) versions 9.3. AMMI biplots were analyzed using GEA-R version 2.0 (CIMMYT, 2015). GenStat 18th edition (2012) was used to draw GGE biplots.

AMMI Analysis: Grain yield data was analyzed using AMMI model so as to partitions the interaction sum of squares into IPC axes. The AMMI model is:

$$Y_{ij} = \mu + G_i + E_j + \sum_{k=1}^{N} \lambda_k \alpha_{ik} \gamma_{jk} + \theta_{ij} + \varepsilon_{ij}$$

where, Y_{ij} = the yield of the i^{th} genotype in the j^{th} environment, μ = the grand mean, G_i and E_j= the genotype and environment deviations from the grand mean respectively, λ_k = the eigen value for IPCA analysis axis k,$\alpha_{ik}$and γ_{jk}= the genotype and environment principal component scores for axis k, the summation handles N number of principal components retained in the model,θ_{ij} =the AMMI residual and ε_{ij} = the error (Zobel*et al*., 1988). The degrees of freedom (DF) for the IPCA axes were calculated according to Zobel*et al*. (1988)with the following formula.DF = G + E – 1 – 2n where, G = the number of genotypes E = the number of environments n = the n^{th} axis of IPCA. In order to show a clear insight of the interaction and the general pattern of adaptation of varieties, a biplot of varieties and environments (Kempton, 1984) were done. In the biplots the first IPCA was used as the ordinate (Y-axis) and the main effects (mean of the genotype and environment) represent abscissa (X-axis). Similarly, the IPCA1 as abscissa and IPCA2 as ordinate was used to further explore stability.

AMMI Stability Value: AMMI stability value was calculated in the excel spread sheet using the formula developed by Purchase et al. (1997).

$$ASV = \sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1\ Score)\right]^2 + [IPCA2\ Score]^2}$$

where, $\frac{SSIPCA1}{SSIPCA2}$is the weight given to the IPCA value by dividing the IPCA1 sum of squares by the IPCA2 sum of square.

Genotype Selection Index: Genotype selection index was also calculated by the formula suggested by Farshadfaret al. (2008). Here it is calculated by taking the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI Stability Value (RASVi) a selection index GSI was calculated for each genotype which incorporate both mean grain yield and stability index in a single criteria (GSIi) as:

$$GSI_i = RASV_i + RY_i$$

where, RASV is the rank value of genotypes for AMMI stability value and RY is the rank value of genotypes for grain yield. A genotype with the least GSI is considered as the most stable (Farshadfar, 2008).

GGE Biplot Analysis*:* The most recent method, GGE biplot model, provides breeders a more complete and visual evaluation of all aspects of the data by creating a biplot that simultaneously represents mean performance and stability, as well as identifying mega-environments (Yan and Kang, 2003; Ding *et al*., 2007). To analysis stability and identify superior genotype across environment, GGE bi-plot analysis were conducted. GGE biplot best identifies GxE interaction pattern of data and clearly shows which variety performs best in which environment. The GGE biplot model of *t* principal components is given as follows:

$$\overline{Y}ij - \mu_i - \beta_j = \sum_{k=1}^{t} \lambda_k \alpha_{ik} \gamma_{jk} + \varepsilon_{ij}$$

where; $\bar{Y}ij$= the performance of genotype i in environment j, □= the grand mean, □□$_j$= the main effect of environment j, k = the number of principal components (PC); □$_k$ = singular value of the kth PC; and □$_{ik}$ and □$_{jk}$ = the scores of ith genotype and jthenvironment, respectively for PC $_k$; □$_{ij}$ = the residual associated with genotype i in the environment j. Usually only the first two PCs are used especially if they account for the major portion of the G x E interaction.

Results and Discussion

Analysis of variance and Mean performances: The result of pooled analysis of variance revealed highly significant differences (p<0.001) for grain yield, number of branches, number of pods and hundred seed weight while non-significant was recorded for remaining agronomic traits (Table 1). The highest pooled mean performance of grain yield was recorded for the genotypes EH03071-1-2006 (4.96 tons ha^{-1}) andEH99005-2-2005 (4.90 tons ha^{-1}) whereas the lowest mean was obtained from the local cultivar. Data on the hundred seed weight (an important quality attribute for export market) and important diseases in the region are presented in Table 2.Regarding the hundred seed weight (HSW), genotype (EH03071-1-2006) had the highest (82.83 g) that is comparable or higher than the check variety (Gebelcho) that was nationally released as large seeded faba bean a few years ago. The second candidate genotype (EH99005-2-2005) also had good HSW(75.25g). In terms of disease reaction across the tested environments the most common faba bean diseases for chocolate spot, Ascochyta blight and faba bean rust were detected in the eight locations in two years. All the genotypes being characterized as moderate resistance to the three diseases with no significant differences (Table 2).

Table 1: The AMMI analysis of variance for grain yield (tons ha^{-1}) of 14 faba bean genotypes tested in 8 environments

Source of variation	d.f	SS	MS	Total variation explained(%)	GxE explained (%)	GxE cumulative (%)	P-value
Environments	7	85.5	12.214**	18.85			<0.001
Reps with E	16	18.2	1.138	4.01			0.109
Genotype	13	104.0	7.997**	22.93			<0.001
GxE Interaction	91	85.8	0.943*	18.92			0.012
IPCA1	19	36.3	1.911**		42.32	42.32	0.001
IPCA2	17	18.6	1.097ns		21.74	64.06	0.127
Residual	55	30.8	0.561ns				0.918

Additive main effect and Multiplicative interaction (AMMI)

AMMI analysis of variance for grain yield revealed highly significant (p<0.001) differences for genotype, locations and genotype by locations interactions (Table). The ANOVA using the AMMI model accounted about 22.93% of the total sum square (SS) was attributable to the genotypes (G), 18.85% to the location (L), and 18.92% importantly to G x L interaction effects (Table1). A large total variation due to G indicated that genotypes are diverse and the environment also found variable Similar results were reported for crop such as rice (Anowara et al., 2014). AMMI analysis also showed that IPCA1 and IPCA2 captured 42.32% and 21.74% of the genotype by environment interaction sum of squares and this two PCA's accurately predict the AMMI model (Table). Since the first two interaction principal component axes (IPCA) were significant, they were selected to describe genotype by environment interaction and placement on the biplots. Yan and Rajcan (2002) reported that the best accurate model of AMMI can be predicted by using the first two PCA's. Similar report was also suggested by Sintayehu and Kassahun, 2017 on sorghum.

Table 2. Grain yield (tons/ha) performances of 14 faba bean genotypes at each environments during the 2019 and 2020 main cropping season

Code	Test locations								Overall Mean	(%)Yield advantage
	2019/20			2020/21						
	Bore-songo	Alleyo	Ana Sorra	Bore-songo	Alleyo	AbayiKuture	Ana Sorra	Dama		
G1	5.25^{a}	3.82^{ab}	4.01	6.19^{a}	2.92^{cd}	6.66	4.12^{a}	3.75^{ab}	4.96^{a}	18.66%
G2	3.32^{c}	2.80^{ab}	2.62	$4.75^{b\text{-}f}$	1.75^{d}	5.04	$3.60^{a\text{-}c}$	$3.50^{a\text{-}c}$	$3.80^{b\text{-}d}$	
G3	3.53^{c}	3.67^{ab}	3.95	$4.96^{b\text{-}e}$	$3.67^{a\text{-}c}$	5.47	$3.47^{a\text{-}c}$	$3.55^{a\text{-}c}$	4.41^{ab}	
G4	3.77^{b}c	4.08^{a}	3.75	$4.11^{e\text{-}f}$	4.90^{a}	5.73	3.73^{ab}	4.10^{ab}	4.65^{ab}	11.24%
G5	3.75^{bc}	3.92^{ab}	3.54	$4.71^{b\text{-}f}$	4.49^{ab}	4.23	$3.52^{a\text{-}c}$	3.96^{ab}	$4.39^{a\text{-}c}$	
G6	3.89^{bc}	2.91^{ab}	4.24	5.56^{ab}	2.23^{cd}	5.07	$3.53^{a\text{-}c}$	4.06^{ab}	$4.31^{a\text{-}c}$	
G7	3.84^{bc}	3.46^{ab}	3.79	$5.35^{a\text{-}c}$	$3.69^{a\text{-}c}$	5.57	$2.87^{a\text{-}c}$	4.57^{a}	4.52^{ab}	
G8	3.63bc	3.43^{ab}	3.47	$4.68^{b\text{-}f}$	2.79^{cd}	4.38	2.40^{bc}	3.75^{ab}	$3.94^{b\text{-}d}$	
G9	4.90^{ab}	4.27^{a}	4.67	$5.37^{a\text{-}c}$	2.64^{cd}	6.29	3.67^{ab}	4.42^{a}	4.90^{a}	17.22%
G10	3.41^{c}	2.64^{ab}	2.99	3.77^{f}	2.26^{cd}	3.15	$3.32^{a\text{-}c}$	3.18^{bc}	$3.47^{c\text{-}d}$	
G11	3.05^{c}	2.85^{ab}	3.65	$4.52^{c\text{-}f}$	$3.02^{b\text{-}d}$	4.31	$3.51^{a\text{-}c}$	3.04^{bc}	$3.87^{b\text{-}d}$	
G12	3.58^{bc}	3.24^{ab}	3.96	$3.94^{e\text{-}f}$	2.32^{cd}	4.28	$2.95^{a\text{-}c}$	3.06^{bc}	$3.79^{b\text{-}d}$	
G13	3.94^{bc}	2.77^{ab}	3.92	$5.20^{a\text{-}d}$	$3.53^{a\text{-}c}$	4.79	$3.34^{a\text{-}c}$	3.59^{ab}	$4.18^{a\text{-}c}$	
G14	2.93^{c}	2.21^{b}	2.58	$4.22^{d\text{-}f}$	2.17^{cd}	3.41	2.312^{c}	2.40^{c}	3.15^{d}	
3.77	3.29	3.65	4.81	3.03	4.88	3.31	3.64	4.17		
1.18	1.57	1.83	0.90	1.35	2.77	1.13	1.03	0.94		
18.6	28.4	29.9	11.2	26.6	33.8	20.30	16.9	39.5		

AMMI Stability Value (ASV)

In ASV method, a genotype with high pooled mean, small IPCA1 score and least ASV score is the most stable. Accordingly, the genotype (EH99005-2-2005) was considered as the most stable across all environments (Table 4). In contrast, EH97011-2-2005 and EH00014-1-2004 found to have large ASV and high mean performance. These genotypes are generally suited to specific environments.

Genotype Selection Index (GSI)

Genotype selection index (GSI) was utilized to further identify stable genotypes with better yield performance. Genotypes EH99005-2-2005 and EH03071-1-2006 were considered as the two stable genotypes with high grain yield.

Table 4. The grain yield, AMMI stability value (ASV), Genotype selection index (GSI)and principal component axis (IPCA)

Genotypes	Means (tonsha-1)	Rank	IPCA1 score	IPCA2 score	ASV	Rank	GSI	Rank
EH03071-1-2006	4.964	1	-0.86395	0.14423	1.691	13	14	4
EH98064-2-2004	3.733	11	0.67647	0.56531	1.435	11	22	9
EH03007-3-2006	4.285	5	-0.24449	-0.16549	0.505	6	11	2
EH00014-1-2004	4.646	3	-0.70848	0.77887	1.586	12	15	5
EH97011-2-2005	4.266	6	-0.89751	0.08575	1.752	14	20	8
EH01045-1-2004	4.186	7	0.49931	-0.59490	1.141	9	16	6
EH00228-1-2005	4.391	4	-0.29972	-0.73224	0.937	8	12	3
EH03069-4-2006	3.753	10	-0.26876	-0.61217	0.806	7	17	7
EH99005-2-2005	4.904	2	0.63807	-0.05439	1.245	10	12	3
EH95104-1-2001	3.278	13	-0.13623	0.22390	0.347	3	16	6
EH99002-1-2004	3.680	12	-0.16884	0.12631	0.353	4	16	6
Alloshe	3.792	9	0.16271	0.30511	0.440	5	14	4
Gebelcho	4.178	8	0.00872	0.16741	0.168	1	9	1
Local Cultivar	2.966	14	-0.12522	-0.23770	0.341	2	16	6

Stability analysis based on GGE Biplot

GGE biplot was the best way to visualize the interaction patterns between genotypes and environments to effectively interpret a biplot (Yan and kang, 2003). In this study, the ‘which won where’ feature of the biplot identified the winning genotypes.The application of the biplot for partitioning through GGE biplot analysis showed that PC1 and PC2 accounted for 59.82% and 15.86% of GGE sum of squares, respectively (Figure 3).

'Which-Won-Where' Patterns of Genotypes and Environments

The polygon view of a GGE biplot clearly displays the which-won-where pattern, and hence it arranged the genotypes in such a way that some of them were on the vertices while the rest were inside the polygon.Genotype (EH03071-1-2006) was the vertex (winning genotype) in the sector where environments E1 (Bore-songo-19), E2 (Bore-songo-20) and E5(A-sorra-19),E6(A-sorra-20) and E7(Abayi-20) sites fell.Environments within the same sector share the same winning genotypes, and environments in different sectors have different winning varieties.Another interesting feature of the GGE biplot is the identification of mega-environments.The current test locations could be grouped into three different faba bean growing mega-environments.

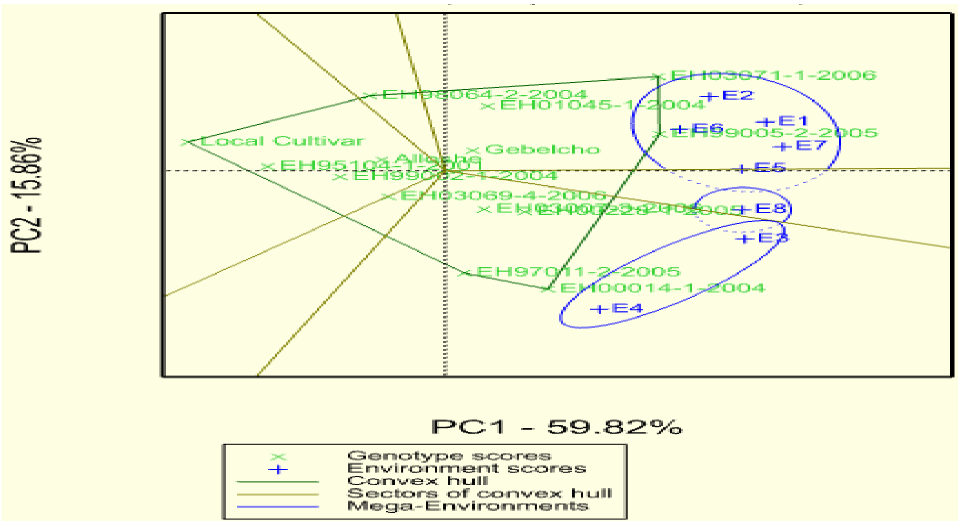


Fig.1. The GGE-biplot for which -won -where pattern for genotypes and environments.

In genotype focusing scaled comparison of GGE biplot, a genotype located nearest to the central concentric circles is both high grain yielding and most stable.The GGE bi-plot analysis for grain yield of faba bean genotypes based on genotype-focused scaling comparison is presented in Figure 2. An ideal genotype is defined as the genotype having the greatest PC1 score (high mean performance) and with zero G x E interaction, as represented by an arrow pointing to it (Figure 2).Figure 2 depicts that genotype EH99005-2-2005, which fell in the first concentric circle, was the ideal genotype in terms of higher yielding ability and stable. Genotype EH03071-1-2006 was located closer to the ideal genotype, it becomes more desirable.

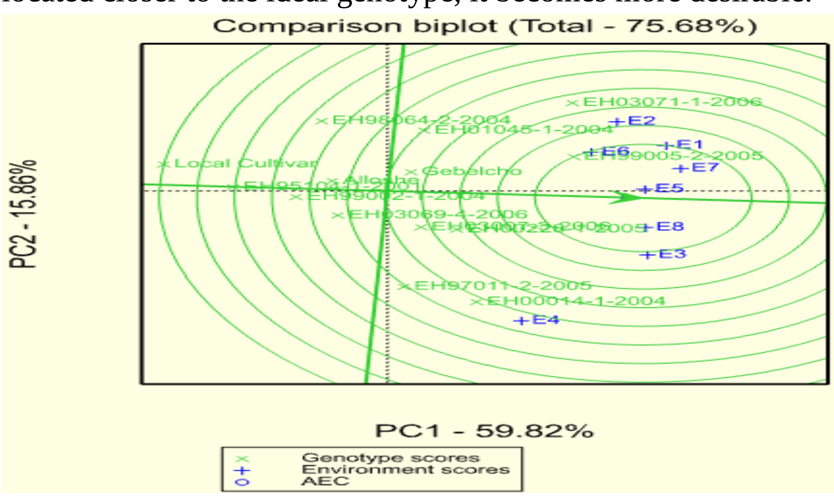


Figure 2. GGE bi-plot based on genotype-focused scaling for comparison of faba bean genotypes for their yield potential and stability.

Mean Performance and Stability of Genotypes

The Average-Environment Axis (AEA) or Average-Tester-Axis (ATA) is the line that passes through the average environment and the biplot origin (Yan, 2002). The average environment coordinates (AEC X-axis) or the performance line passes through the biplot origin with an arrow indicating the positive end of the axis (Figure 3). The AEC Y-axis or the stability axis passes through the plot origin with double arrow head and is perpendicular to the AEC X-axis. The mean performance and stability of these 14 genotypes in 8 locations shows genotype(EH99005-2-2005) was high yielding and stable genotype.

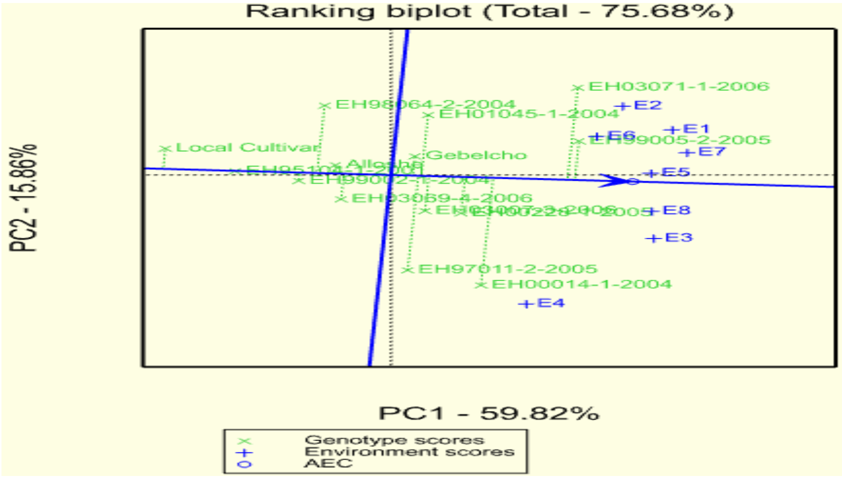


Figure 3. GGE ranking bi-plot shows means performance and stability of 14 faba bean genotypes

Conclusion and Recommendation

Genotype by environment interaction and stability measuring trials helps to identify genotypes with both high performance and grain yield stability.The significant G x E interaction and the changes in the rank of genotypes across environments suggest a breeding strategy for specifically adapted genotypes in homogenously grouped environments, as well as for high yielding stable genotypes suggesting for wider adaptation

As a result, two genotypes showed 18.66% and 17.22% grain yield advantage over the standard check, tolerant/resistant to major faba bean diseases, stable and also possessed other desirable agronomic characteristics. Accordingly, genotypes (EH03071-1-2006) and (EH99005-2-2005) were identified as the most stable high yielding across environments and promoted to VVT for eventual varietal release to the set of tested environments and similar agro-ecologies.

References

Abbas, G., Atta, B.M., Shah, T.M., Sadiq, M.S. and Haq, M.A. 2008. Stability analysis for seed yield in mungbean (Vignaradiata L.). *Journal of Agricultural Research*,46 (3): 223-228.

Abdelmula, A.A. and Abuanja, I.K. 2007. Genotypic responses, yield stability, and association between variability, correlation and path coefficient analysis of yield and some yield components in faba bean (Viciafaba L.) populations. *Journal of Damascus University for Agricultural Sciences*,27 (1): 83-95.

Acikgoz, E., Ustun, A., Gul, I., Anlarsal, E., Tekeli, A.S., Nizam, I., Avcioglu, R., Geren, H., Cakmakci, S., Aydinoglu, B., Yucel, C., Avci, M., Acar, Z., Ayan, I., Uzun, A., Bilgili, U., Sincik, M. and Yavuz, M. 2009. Genotype x environment interaction and stability analysis for dry matter and seed yield in field pea (Pisumsativum L.). *Spanish Journal of Agricultural Research*,7 (1): 96-106.

Ahmad, J., Choudhry, M.H., Salah-Ud-Din, S., and Ali, M.A. 1996. Stability for grain yield in wheat. *Pakistan Journal of Botany*, 28: 61-65.

Akcura, M., Kaya, Y., Taner,S. and Ayranci, R. 2006. Parametric stability analysis for grain yield of durum wheat. *Plant Soil Environ*., 52: 254-261.

Arshad, M., Bakhsh, A., Haqqani, M. and Bashir, M. 2003. Genotype-environment interaction for grain yield in chickpea (*Cicer arietinum* L.). *Pakistan Journal of Botany*, 35: 181-186.

Baker, R.J. 1988. Test for crossover genotype-environment interaction. Can. *J. Plant Sci*., 68: 405-410.

Bjornsson, J. 2002. Stability analysis towards understanding genotype-environment interaction. www.genfys. Slue. Se/staff/deg/nova 02.

Chakroun, M., Taliaferro, C.M. and McNew, R.W. 1990. Genotype-environment interactions of bermudagrass forage yields. *Crop Science*, 6: 36-40.

Dehghani, H., Sabaghpour, S.H. and Sabaghnia, N. 2008. Genotype x environment interaction for grain yield of some lentil genotypes and relationship among univariate stability statistics. *Spanish Journal of Agricultural Research*, 6 (3): 385-394.

Kalia, P. and Sood, S. 2004. Genetic variation and association analyses for pod yield and other agronomic and quality characters in an Indian Himalayan collection of broad bean (Viciafaba L.). *SABRAO Journal of Breeding and Genetics*, 36: 55-61.

Kang, M.S. 1998. Using genotype-environment interaction for crop cultivar development. *Adv. Agron*.,35: 199-240.

Karadavut, U., Palta, C., Kavuramci, Z. and Bolek, Y. 2010. Some grain yield parameters of multi-environmental trials in faba bean (Viciafaba L.) genotypes. *International Journal of Agriculture and Biology*,12 (2): 217-220.

Moldovan, V., Moldovan, M. and Kadar, R. 2000. Phenotypic stability for yield in chickpea. *Pakistan of Science Research*, 30: 455-465.

Piepho, H.P. 1996. Analysis of genotype environment interaction and phenotypic stability. In: M.S. Kang, and H.G. Zobel Jr (Eds), pp. 151-174. Genotype by Environment Interaction. CRC Press, Boca Raton.

SintayehuAdmas and KassahunTesfaye 2017. Genotype-by-Environment interaction and yield stability analysis in sorghum genotypes in North Shewa, Ethiopia; *Agriculture and Environment* (9) 82-94.

Wamatu, J.N., and Thomas, E. 2002. The influence of genotype-environment interaction on the grain yields of 10 pigeon pea cultivars grown in Kenya. *Crop Science*, 188: 25-33.

Effect of Spacing and Pruning Methods on Root Yield and Yield Parameters of Cassava (*Mahinot esculenta* Crantz) in Fedis District, East Harerghe Zone, Ethiopia

*Gebisa Benti, Gezu Degefa, Fikadu Tadesse,Girma Waqgari and Mohammed Jafar
Horticulture Research Team, Fedis Agricultural Research Center, Oromia, Ethiopia
Corresponding author e-mail: bantiig@gmail.com

Abstract

The determination of cassava plant spacing and effect of pruning on root yield and yield parameters has many advantages to cassava producing farmers. Farmers can use cassava top prune to feed their cattle beside root production for their food. The study was to determine the effects of different plant spacing and pruning methods on root yield and root yield parameters of cassava grown in Eastern part of Ethiopia. Cassava variety 'Kello' was used for the experiment as a test crop. Five cassava plant intra-row spacing (0.60, 0.80, 1.00, 1.20 and 1.40 m) were assigned to main plots while pruning methods (cutback, debranching and no pruning) were assigned to sub plots. The experiment was laid out in randomized complete block design (RCBD) in a factorial arrangement with three replications. The result revealed that there were highly significant differences for number of roots per plant, root length, average root weight and unmarketable due to the effect of pruning, while significant differences was observed for total root yields due to intra-row spacing. There was also highly significant interaction effects for marketable and total root yields due to the effects of intra-row spacing and pruning. Cassava with no pruning recorded about, 21.9 and 25.7%, 10 and 26.4%, 17.2 and 19.9%, 43.5 and 58.7% over cassava with debranching and cutback for number of roots per plant, root diameter, root length and root weights, respectively. Cassava pruning and intra-row spacing also interacted and the highest root yield was recorded at 80cm with cassava no pruning. Averagely, cassava with no pruning provided the highest marketable and total root yield by about 39.3 and 44.7%, 35.8 and 41.6% over cassava with debranching and cutback, respectively. Cassava with no pruning and intra-row spacing were also interacted and recorded the highest marketable and total root yields. Therefore, considering the land scarcity of the area intra-row plant spacing of 80cm and cassava with no pruning was recommended for the study area and similar agro-ecology for land economy in eastern Harerghe zone.

Keywords: Cassava, Cutback, Debrancing, Pruning and Spacing

Introduction

Cassava is a perennial crop native to tropical America with its center of origin in north-eastern and central Brazil (Allem, 2002). It is cultivated mainly for its enlarged starchy roots and one of the most important food staples in the tropics, where it is the fourth most important energy source. Given the crop's tolerance to poor soil and harsh climatic conditions, it is generally cultivated by small-scale farmers as a subsistence crop in a diverse range of agricultural and food systems (Alves, 2002). Roots can be left in the ground without harvesting for a long period of time, making it a useful crop as security against famine. The success of cassava production in Africa, as food security crop, is largely because of its ability and capacity to yield well in drought prone, marginal wasteland under poor management conditions where other crops would fail. Cassava is a tropical root crop, requiring at least eight months of warm weather to produce a crop. It takes 18 or more months to produce a crop under adverse conditions such as cool or dry weather. Cassava does not tolerate freezing conditions. It tolerates a wide range of soil pH 4.0 to 8.0 and is most productive in full sun.

In Ethiopia, cassava grows in some areas of southern regions including Amaro, Gamogofa, Sidama, Wolaita, Gedeo and Konso. Cassava was introduced to drought prone areas of Southern part of the country primarily to fill food gap for subsistence farmers due to the failure of other food crops as the result of drought (Feleke, 1997). The average total area planted to the crop and production of cassava per annum in Southern region of Ethiopia is 4,942 ha and 53,036.2 tones, with productivity of 10.73 tons per hectare, respectively (SNNPR(BoA), 2000). Gebisa Benti and Gazu Degefa (2017) also reported that about 26.8 tons per hectare of cassava root yield was recorded around eastern part of Ethiopia. As cassava plant develop large canopy, it can affect nearby or undergrown crops and may reduce the productivity of the undergrown crop as it covers and compete light interception. However, the available sunlight, water and nutrients between rows can be profitably utilized for short duration intercrops (Legese Hidoto and Gobeze Loha, 2013). Gebisa *et al*. (2020) stated that cassava-soybean intercropping was increased cassava root yield by 41.7 and 21.3% as compared to cassava-cowpea and cassava-haricot bean, respectively.

Plant spacing is important agronomic factor in crop productivity and production that can limit yield and agronomic performance of plants. Plant spacing may depend on the soil type, moisture content of the soil, plant growing habit. Large/spread canopy plants need wider spacing than narrower/compact canopy plants. Cassava plant needs wider spacing as it is tree shrubs and large number of branches. According to Legese Hidoto and Gobeze Loha (2013), cassava is planted at intra and inter row spacing of 80-120 × 60-100 cm in the southern part of Ethiopia and takes more than 3 to 4 months to develop enough canopies. However, there is no literature review that state about the plant spacing of cassava in eastern part of Ethiopia including Harerghe area. As cassava is important root crop in tackling food insecurity in lowland areas, determination of plant spacing is important issue to optimize root yield and agronomic performance of the crop. Most studies have quantified the effect of plant spacing on the production of tuberous roots (Aguiar *et al*., 2011), but are lacking studies, especially in Eastern part of Ethiopia including Harerghe Zones, investigation of different spacing on growth and development, which are determinants of root yield in cassava.

Generally, determination of cassava plant spacing and effect of pruning on root yield and yield parameters has many advantages to cassava producing farmers. More than half of Harerghe farmers work on fattening of oxen in addition to crop production. Shortage of cattle feed is also the main problem of the area. In such case they can use cassava top prune to feed their cattle beside root production for their food. Pruning has many advantages to cassava producing farmers: cassava top prune is used for cattle feed beside root production, its canopy can also be pruned to open the space for the under growing and intercropping crops. Cassava plant need wider spacing because of its large canopy with a number of branches, so that it need to determine the spacing and pruning to reduce canopy for the under growing crops if it is not adversely affect root yields. In this context, the objective of this study was to determine the effects of different plant spacing and pruning methods on root yield and root yield parameters of cassava grown in Eastern part of Ethiopia.

Materials and Methods

Description of the Experimental Site

The study was conducted under rain fed conditions at Fedis Agricultural Research Center of Oromia Agricultural Research Institute (OARI) at Boko sub-site, which is located at the latitude of 9°07' north and longitude of 42°04' east, in the middle and lowland areas and at the altitude of 1702 meter above sea level, with a prevalence of lowlands. The soil of the experimental site is black with surface soil texture of sand clay loam that contains 8.20% organic matter; 0.13% total nitrogen, available phosphorus of 4.99 ppm, soil exchangeable potassium of 1.68 cmol(+)/kg and a pH value of 8.26 (Table 1). The experimental area is characterized as lowland climate. The mean rainfall is about 859.8 mm for the last ten years. The rainfall has a bimodal distribution pattern with heavy rains from April to June and long and erratic rains from August to October. The mean maximum and minimum annual temperature are 27.7 and 11.3°C, respectively, for the last five years (Fedis Agriculture Research Center Metrological Station, unpublished).

Treatments and Design

The experiment was conducted at Fedis research station in the main cropping season. Cassava variety 'Kello' was used for the experiment as a test crop. Five cassava plant intra-row spacing (0.60, 0.80, 1.00, 1.20 and 1.40 m) were assigned to main plots while pruning methods (cutback, debranching and no pruning) were assigned to sub plots. The experiment was laid out in randomized complete block design (RCBD) in a factorial arrangement with three replications. Spacing between rows was 1.5 m. For the spacing of 0.60, 0.80, 1.00, 1.20 and 1.40 m, the plant population were 11111, 8333, 6667, 5556 and 4762 plants/ha, respectively.

Table 1. Cassava plant spacing range and pruning methods as treatments

Intra-row spacing	Pruning methods
S1 = 0.60 m	CB = Cutback=removing all shoots
S2 = 0.80 m	DB = De-branching=removing all branches, except main stem
S3 = 1.00 m	NP = No pruning
S4 = 1.20 m	
S5 = 1.40 m	

Data Management and Statistical Analysis

All quantitative data like root length, root diameter, number of root per plant, average root weight, marketable root yield, unmarketable root yield and total root yield will be collected. Root yield of cassava will be weighed using digital balance after harvest. The collected data will be subjected to ANOVA using GenSTAT computer software (GenSTAT Software 18th edition). Differences between means were compared using the least significance difference (LSD) test at $p \leq 0.05$.

Results and Discussion

Number of roots and root weight

The result also revealed that there were highly significant (P<0.01) differences for number of roots per plant and average root weight due to the effect of pruning. The highest number of roots per plant was recorded for cassava with no pruning plots as compared cassava with debranching and cutback. The number of roots per plant with no pruning cassava plant were obtained about 21.9 and 25.7% over the cassava plant debranching and cutback, respectively. In line with this study Ayoola and Agboola (2004) were reported that the highest average number of roots per plant were obtained from the unpruned plants, while no definite trend was observed under the two pruning methods. Moreover, increased number of storage roots per plant with wider root appeared to be responsible for good storage root yield per plant in cassava. Even though the intra-row spacing did not significant differences, the number of roots per plant was advanced linear increase as intra-row spacing increased. The highest root weight was also recorded for cassava with no pruning as compared to cassava with debranching and cutback. Averagely, cassava with no pruning recorded 43.5 and 58.7% root weights over cassava with debranching and cutback treatments, respectively. Ayoola and Agboola (2004) were also stated that the biggest storage roots were recorded for unpruned cassava plants.

Root diameter and length

The result also revealed that there were highly significant (P<0.01) differences for root length due to the effect of pruning. Root diameter and length were significantly affected by pruning treatments regardless of the range of intra-row spacing. The highest root diameter was recorded for with no pruning among the three pruning treatments. Typically, cassava with no pruning was provided about 10 and 26.4% root diameter more than cassava with debranching and cutback, respectively. However, intra-row spacing did no significant differences on root diameter.

Root length also significantly affected by pruning treatments. Cassava pruning treatments from cassava with no pruning, debranching and cutback were reduced root length accordingly. The longest root was recorded for cassava with no pruning among the three pruning treatments. Cassava with no pruning was provided about 17.3 and 19.9% root length over cassava with debranching and cutback, respectively. Fakir et al. (2011) reported that control plants had higher storage root number, root length, root fresh and dry weights than 1-branch and 2-branch removal. However, the range of intra-row spacing did no significant differences for root diameter and length.

Marketable, unmarketable and total root yields

The analysis of variance showed there were highly significant (P<0.01) differences for unmarketable and significant (P<0.05) differences for total root yields due to intra-row spacing. There was also highly significant (P<0.01) interaction effects for marketable and total root yields due to intra-row spacing and pruning. Averagely, cassava with no pruning provided the highest marketable root yield by about 44.7 and 39.3% over cassava with cutback and debranching, respectively, while cassava with no pruning recorded total root yield by about 41.6 and 35.8%

over cutback and debranching, respectively regardless of intra-row spacing. Cutback and debranching were decreased root yield and were not economical as compared to no pruning. This study was supported with the findings of Fakir *et al*. (2011) who stated that storage root yield (both fresh and dry weights) decreased with increasing debranching.

Table 2: Analysis of variances for yield and yield parameters of cassava as influenced by intra-row spacing and pruning

Agronomic and root yield parameters	Replication (2)	Intra-row Spacing(4)	Pruning (2)	Intra-row spacing * Pruning(8)	Error (73)
Number of roots per plant	0.066	3.403	55.65**	2.041	3.935
Root diameter (mm)	83.07	33.15	1974.79	83.09	65.5
Root length(cm)	72.34	36.84	938.87**	52.66	66.11
Average root weight(kg)	0.51	0.02	5.40**	0.10	0.06
Marketable root yield (t ha^{-1})	2.89	57.84	3911.53**	132.86**	29.28
Unmarketable root yield(t ha^{-1})	12.18	15.26**	1.61	2.08	2.66
Total root yield(t ha^{-1})	22.21	120.81*	3829.87**	136.16**	34.58

Table 3: Combined mean of yield components of cassava as affected by intra-row spacing and pruning

Intra-spacing (cm)	Root weight (kg)	Root diameter (mm)	Root length (cm)	Root per plant	Unmarketable root(t ha^{-1})
60	0.86	53.16	43.30	7.79	4.84a
80	0.90	52.22	46.03	7.97	3.86ab
100	0.93	53.58	46.73	8.15	3.06bc
120	0.92	55.32	46.60	8.46	3.11bc
140	0.94	51.88	44.92	8.89	2.44c
LSD (0.05)	NS	NS	NS	NS	1.065
Pruning methods					
Cutback	0.57c	44.54c	41.61b	7.29b	3.37
Debranching	0.78b	54.55b	43.02b	7.66b	3.73
No pruning	1.38a	60.61a	51.93a	9.81a	3.30
LSD (0.05)	0.13	4.159	4.09	0.992	NS
CV (%)	27.9	15.2	17.5	23.4	51.6

The reduction in root yield is due to the cassava plant consuming the reserves stored in the tuberous roots for recovering and leaf growth, always when the plant has environment conditions to develop (Andrade *et al*., 2011; Oliveira *et al*., 2010). This might be due to cut away of cassava plant shoots that lead to limit sink capacity to feedback the photosynthetic process, reducing the photosynthetic rates.

Table 4: Interaction effect of intra-row spacing and pruning on marketable and total root yield.

	Marketable root yield (t ha^{-1})			Total root yield (t ha^{-1})		
	Pruning			Pruning		
Spacing(m)	Cutback	De-branching	No pruning	Cutback	De-branching	No pruning
S1(0.6)	25.70[c]	39.71[b]	43.27[ab]	30.62[c]	45.04[b]	47.55[ab]
S2(0.8)	29.29[c]	24.96[c]	49.19[a]	32.56[c]	29.40[c]	53.07[a]
S3(1.0)	25.60[c]	28.25[c]	46.11[ab]	29.28[c]	30.70[c]	49.17[ab]
S4(1.2)	22.45[c]	23.45[c]	48.19[a]	24.94[c]	27.47[c]	51.02[ab]
S5(1.4)	26.43[c]	25.79[c]	47.33[a]	28.90[c]	28.20[c]	49.78[ab]
LSD (0.01)		6.226			6.767	
CV (%)		16.0			15.8	

Pruning treatments were also interacted with intra-row spacing for marketable and total root yields. Intra-row spacing at 0.8, 1.2 and 1.4m were provided the highest marketable root yield, while highest total root yield was recorded at intra-row spacing of 0.8m under cassava with no pruning. However, all intra-row spacing were statistically parity for marketable root and significantly different for total root yields with no pruning. It is important to consider the resources of the community around when presenting this study due to the scarcity of cultivation land in eastern Harerghe, so that 0.8m intra-row spacing is preferable.

Conclusion and Recommendation

Among pruning treatments, cassava with no pruning recorded the highest value in all parameters while pruning cassava with debranching and cutback adversely affected all parameters as compared to cassava with no pruning. Root yield and yield components of cassava reduced when it was pruned irrespective of pruning methods. The growth of unpruned cassava was never disturbed, while the pruned plots had to recover by developing new shoots. When the plant is pruned it needs some conversion process; use stored foods at an expense of root enlargement while it reduces marketable root yield. The general trend of cassava storage root yield under pruning treatments were cassava with no pruning > cassava with debranching > cassava with cutback. Pruning treatments and intra-row spacing were also interacted for marketable and total root yields. Intra-row spacing was also minimized from 100cm to 80cm without the influence of root yield that could advance about 0.2ha of land under cassava with no pruning. Therefore, the combination of intra-row plant spacing of 80cm and cassava with no pruning were recommended for the study area and similar agro-ecology for land economy as there is a land scarcity in east Harerghe zone.

Acknowledgements

The authors would like to acknowledge the Oromia Agricultural Research Institute for the financial support to this work, and all staff of Fedis Agricultural Research Center for their contribution to this work.

References

Aguiar, E.B.; Valle, T.L.; Lorenzi, J.O.; Kanthack, R.A.D.; Miranda Filho, H.; Granja, N.P. 2011. Efeito da densidade populacional e época de colheita na produção de raízes de mandioca de mesa. Bragantia, v.70, p.561-569.

Allem, A.C. 2002. The origin and taxonomy of cassava. *In*: R.J. Hillocks, J.M. Thresh and A.C. Belloti (Eds.). Cassava: Biology, Production and Utilization, CABI Publishing, New York, pp. 1–16.

Alves, A. A. C. 2002. Cassava botany and physiology. In *Cassava: Biology, production and* 360 *utilization*, 67-90 (Eds). R. J. Hillocks, J.M. Thresh and A. Bellotti). CABI, Wallingford,

Andrade, J.S, Viana A.E.S., Cardoso, A.D., Matsumoto, S.N. and Novaes, Q.S. 2011. Epocas de poda em mandioca. Rev. Cienc. Agron. 42:693 – 701.

Ayoola, O.T. and Agboola, A.A. 2004. Influence of cassava planting patterns and pruning methods on crop yield in a cassava – based cropping system. *African Crop Science Journal*, Vol. 12, No. 2, 1021 – 9730, pp. 115-122.

Fakir, M.S.A., Talukder, M.H.R., Mostafa, M.G. and Rahman, M.S. 2011. Debranching effect on growth and yield in Cassava. *J. Agrofor. Environ.* 5 (1), 1995-6983, pp: 1-5

Feleke, A. 1997. Participatory Rapid Rural Appraisal of Abaya district, North Omo, FARM Africa, Addis Ababa, Ethiopia.

Gebisa Benti and Gezu Degefa. 2017. Performance Evaluation and Palatability Taste of Cassava (*Manihot esculenta* Crantz) Varieties in Fedis and Babile(Erer) Districts, Ethiopia. *International Journal of Current Research*, 9, (04), 48570-48575. Available at: *http://www.journalcra.com*

Gebisa Benti, Gezu Degefa, Mohammed Jafar, Habte Birhanua. Effect of Cassava Intercropping with Legume Crops Followed by Sorghum on Growth, Yield and Yield Parameters of Cassava-Based Double Cropping System. *Plant*. Vol. 8, No. 2, 2020, pp. 37- 42. doi: 10.11648/j.plant.20200802.13

Legese Hidoto and Gobeze Loha. 2013. Identification of suitable legumes in cassava *(Manihot esculenta* Crantz)-Legumes intercropping. Southern Agricultural Research Institute, Ethiopia. *African Journal of Agricultural Research*, Vol. 8(21), pp: 2559 – 2562.

Oliveira, S.P. 2010. Efeito da poda e de epocas de colheita sobre caracteristicas agronomicas da mandioca. Acta Scie., 32:99 – 108.

Southern Nations Nationalities and People Region, Bureau of Agriculture (SNNPR, BoA). 2000. Basic Agricultural Information Planning and Programming Service, Awassa, Ethiopia.

Registration of "Erer" Newly Released Early Maturing Sorghum Variety

Zeleke Legesse*[1], Fikadu Tadesse[1], Birhanu Diribsa[1] and Alemayehu Biri[2]
Oromia Agricultural Research Institute (IQQO), [1]Fadis Agricultural Research Center, P.O Box 904, Harar, Ethiopia, [2]Fiche Agricultural Research Center, P.O Box --, Fiche, Ethiopia
Corresponding Author: Email:-zalelegesse12@gmail.com

Abstract

Erer (3443-2- OP X P9403) is sorghum variety was released in 2021 for Eastern part of Oromia specifically, Fadis and Babile districts and other similar agro-ecologies of Ethiopia. The variety was developed and released by Oromia Agricultural Research institute, Fadis Agricultural Research Center. Originally it was obtained from Melkasa Agricultural Research Center of Sorghum Research Program which was crossed material followed by screening method. The regional variety trial was done at two locations of Fadis research station and Erer sub-station for three years (2016-2019). From the genotypes evaluated Erer variety recorded high grain yield, large biomass and stay green traits than the standard check Dekeba and other genotypes. Mean grain yield of Erer ranged from 49 to 51 Qt ha^{-1} on research field, and 34 to 40Qt ha^{-1} on farmers field. Finally 'Erer' released as superior sorghum variety East Hararghe low lands and similar agro ecologies in 2021.

***Key Words**: Sorghum, Erer, Variety verification.*

Introduction

Sorghum (Sorghum bicolor (L.) Moench) is a diploid C4 cereal crop which was domesticated in Africa. It has 2n=20 chromosome and genome size of 750 Mb (Paterson *et al.,* 2009). Sorghum is predominantly self-pollinated short day plant with the degree of spontaneous cross pollination, in some cases, reaching up to 30%, depending on the shape and type of panicles. It is an indigenous crop of Ethiopia grown in highly diverse environments of having water stress, soil fertility and temperature conditions. In Ethiopia, sorghum grows from the lowland areas which receive lower amount of rainfall and has high temperature to the highland characterized by low temperature and higher amount of rainfall (Mindaye *et al.*, 2016). Currently sorghum is produced by 6 million holders and its production is estimated to be 5.1 million metric tons from 1.9 million hectares of land giving the national average grain yield of around 2.71 tons per hectare (CSA, 2019). The livelihoods of millions of subsistence farmers depend on sorghum production because of its multiple purposes and its ability to cope up with unfavorable growing conditions, sorghum will continue to feed the world's expanding populations (Asfaw *et al*., 2012). Moreover, sorghum will be the crop of the future due to the changing global climatic trends and increase in use of marginal lands for agriculture (Paterson *et al*., 2008). Hence, variety development considered dual purpose interest both grain and biomass yield.

Exploitation of genetic variability is the most important tool in plant breeding, and this has to be inferred by phenotypic expression. Developments of early maturing and drought tolerance varieties containing high yielder and large biomass trait are the major strategies in the Fadis Agricultural Research Center (FARC) in sorghum breeding program of Oromia Agricultural Research Institute (OARI). Eastern part of Ethiopia particularly, East Hararghe have high potential of sorghum in which the crop is the stable food for the farmers of the area. However, farmers are producing the long maturing local sorghum variety which is highly susceptible to drought and Striga weeds. Lack of improved varieties that are high yielding and resistance/tolerant to drought with wide adaptability is among the major factor contributing to low production and productivity of the crop in the area. Hence, it is essential to evaluate and release early maturing sorghum genotypes that are stable, high yielding and adaptable for East Hararghe lowland, mid altitude and similar agro ecologies of the area.

Varietal Origin/Pedigree and Evaluation

'Erer (2005MI5081)' early maturing variety developed and released by Oromia Agricultural Research institute, Fadis Agricultural Research Center for East Hararghe lowland, mid-altitude and similar Agro ecologies. Originally it was obtained from Melkasa Agricultural Research Center (MARC) of sorghum research program and evaluated through screening. A total of five genotypes were evaluated for yield and early maturing against one standard check 'Dakaba' for three consecutive years (2016/17-2019/20) across two locations of Babile and Fadis districts. Two promising genotypes '2005MI5081' and 'IESV92168-DL' and two standard checks were planted on 10x10 m^2 at six locations for variety verification trial in 2020 for evaluation. Finally 'Erer' approved as superior sorghum variety for East Hararghe lowland, mid altitude and similar agro ecologies in 2021.

Agronomic and Morphological Characteristics of Erer

Varietal Origin/Pedigree and Evaluation

Erer sorghum variety has white creamy seed color, 180 cm to 200 cm plant height, and early maturing (135-141 days). Erer sorghum variety had sweet juice stack and stay green and had 30 gm of 1000 seed weight (Table 1).

Yield Performance: *Erer (#2005MI5081)* showed superior yielding ability, producing a mean grain yield of 49 - 51 Qt ha-1 at research field and 34 –40 Qt ha-1 on farmers' field (Table 1). The grain yield of the new variety exceeded that of the standard check Dekeba about 18. 75%.

Adaptation and Agronomic recommendation

Erer is early maturing sorghum variety released for East Hararghe low lands, Eastern Ethiopia. It is well adapted in similar agro ecologies with altitude of 1300 -1700 m.a.s.l with annual rainfall 400 – 700 mm. Recommended fertilizer rate for Erer sorghum variety is 100 kg ha^{-1} NPS which is applied at planting and 100 kg ha^{-1} UREA which is applied 35-40 days after planting and the spacing between rows and plants is 75 and 15-20 cm respectively.

Table 1: Agronomic and Morphological Characteristics for newly released Sorghum variety

Variety Name	Erer (#2005MI5081)
Agronomic and Morphological Characteristics	
Adaptation areas:	Fadis, Babile and others similar agro-ecologies
Altitude (m.a.s.l)	<1700 m
Rain fall (mm)	400 mm-700 mm
Seed rate (kgha^{-1})	8-10 kg ha^{-1}
Planting date:	Early June to Mid June
Spacing(cm)	15-20 between plant & 75 between rows
Fertilizer rate(kg/ha)	
NPS:	100
Urea	100
Days to flowering	84
Days to maturity	141
Plant height (cm)	180-200
Panicle appearance	Semi-compact and erect
1000 seed weight(g)	30
Seed color	White (creamy white)
Yields (Qt/ha)	
Research field	49-51
Farmers' field	34-40
Year of release	2021
Breeder/maintainer	FARC/IQQO

Conclusions and Recommendations

Chemeda and Gemedi sorghum varieties were released for western Oromia (Bako, Gute and Biloboshe) areas and similar agro-ecologies based on their higher grain yield, ideal grain color particularly Chemeda (creamy), well preferred to make Injera. *'Erer'* sorghum variety was released for Eastern Oromia particularly, for East Hararghe (Babile and Fadis districts) and similar agro-ecologies based on earliness in maturity, high biomass (large stalk), stay green and high grain yield. Therefore, '*Erer'* sorghum variety could be cultivated sustainably and profitably by smallholder farmers and investors in East Hararghe and similar agro ecologies in the country.

Acknowledgement

The authors want to acknowledge Inistituutii Qorannoo Qonna Oromiyaa (IQQO) for funding the research budget and all staffs of cereal research team of Fadis Agricultural Research center is also acknowledged for field management and data collection.

Reference

Paterson AH, Bowers JE, Bruggmann R, Dubchak I, Grimwood J, et al. (2009) The Sorghum bicolor genome and the diversification of grasses. Nature 457: 551.

Mindaye TT, Mace ES, Godwin ID, Jordan DR (2016) Heterosis in locally adapted sorghum genotypes and potential of hybrids for increased productivity in contrasting environments in Ethiopia. The Crop Journal 4: 479-489.

CSA (Central Statistical Agency of the Federal Democratic Republic of Ethiopia), 2019. Agricultural Sample Survey, 2018/19. Report on Area and production of major crops (Private Peasant Holdings, meher season). Statistical Bulletin 278. Vol. I, Addis Ababa, Ethiopia

Adugna Asfaw, 2007. The role of introduced sorghum and millets in Ethiopian agriculture. J. SAT Agric. Res., 3(1).

Participatory Varietal Selection of Sorghum (Sorghum bicolor L. Meonch) Varieties for mid-land areas of East Hararghe, Ethiopia

Zeleke Legesse*, Jifara Gudeta, Fikadu Tadesse, Biranu Diribsa and Alemayehu Biri

Oromia Agricultural Research Institute, Fadis Agricultural research center, P.O Box 904, Harar, Ethiopia.

Corresponding author: zalelegesse12@gmail.com

Abstract

Participatory varietal selection (PVS) has shown success in identifying more number of preferred varieties by the farmers in shorter time and it was done on sorghum in Eastern part of Ethiopia in Harari region. The objectives of the study were to evaluate and select the performance of improved sorghum varieties in terms of agronomic, yield and yield parameters and farmers criteria. Eleven (11) Sorghum varieties including one local check were evaluated in RCBD with three replications at Meta and Kurfa Chale districts of East Hararghe in 2018, 2019 and 2020 main cropping season. Among ten and one local varieties farmers were put their rank the first five improved varieties as compared to their local varieties depending on their preference and selection criteria like; earliness in maturity, bird damage, plant biomass, grain color and size, disease tolerance, head size and expected to give yield. Accordingly, farmers preferred sorghum varieties Adele, Dibaba, Gemedi, Chiro, Dano and local check respectively. Data were collected on Days to flowering, Days to maturity, Plant height, grain yield and disease score. The result of combined analyses revealed significance difference in all traits evaluated among the varieties evaluated. Accordingly, Adele (42.74 Qt ha^{-1}) gave the highest yield followed by Dibaba (40.45 Qt ha^{-1}), Gemedi (40.09 Qt ha^{-1}), Dano (35.62 Qt ha^{-1}) whereas the lowest yield was recorded from Muyra-2 (30.36 Qt ha^{-1}), Jiru(31.55 Qt ha^{-1}) respectively. The results also revealed that farmers' preferences in most cases coincide with the researchers' selection. Based on the result of analysed data and the farmers' preference, the first three sorghum varieties namely; Adele, Dibaba and Gemedi were recommended for the farmers of the study area and similar agro-ecologies of East Hararghe mid altitude and similar agro-ecologies. Therefore, the selected varieties would be multiplied and distributed to the farmers in order to improve adoption and varietal diversity.

Keywords: Sorghum. Selection criteria, varieties, farmers'

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth important cereal crop in the world and the third major cereal crop next to tef and maize in area cultivated and in total production in Ethiopia

(CSA, 2016). It provides food, fodder and alcoholic beverages in the country. The main use of sorghum in Ethiopia is for making Injera (leavened bread) and accounts for an average of 10% daily caloric intake in Ethiopia (Rashid, 2010). The livelihoods of millions of subsistence farmers depend on sorghum production because of its multiple purposes and its ability to cope up with unfavorable growing conditions, sorghum will continue to feed the world's expanding populations (Asfaw *et al*., 2012). Moreover, sorghum will be the crop of the future due to the changing global climatic trends and increase in use of marginal lands for agriculture (Paterson *et al*., 2008). In Eastern part of Ethiopia, including East Hararghe, out of the total grain cropped area of 253,816.82 ha, cereals accounted for about 84% (214,061.59 ha) of which sorghum accounted for the lion's share of about 56% (119,262.36 ha) of the totally annually cropped land in 2014/15 cropping season (CSA, 2015). Over the years, a number of late, medium and early-maturing sorghum varieties have been evaluated and released by federal and regional research centers for different agro-ecologies of the country. However, those varieties are not being adopted by the farmers in a satisfactory rate, probably due to poor farmers' participation during selection process (on-station), inadequate knowledge of the farmers about the varieties lack of improved variety (ies) that adapt the specific environments and inadequate supply of seed of the varieties to satisfy farmers' needs.

Although, there are many newly varieties released for potential sorghum areas from different research centers, farmers in Harari region are still producing local sorghum and were not aware of the available sorghum varieties released for their agro-ecologies. This is mainly because of the following limitations; poor participation of farmers' in varietal selection process, inadequate research interventions, lack of improved varieties that give reasonable yield under farmers' cultural management, in adequate improved seed supply system and poor research-extension-farmer linkage. Participatory Variety Selection (PVS) can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow late maturing varieties which are susceptible to drought, disease and pest (Witcombe *et al.,* 1996). Moreover, participatory research increases the job efficiency of the scientists (Bellon, 2002) and farmers' knowledge that enables to be retained effectively from year to year (Grisley & Shamambo, 1993). Research costs can be reduced and adoption rates increased if farmers are allowed to participate in variety testing and selection (Joshi *et al.,* 1995). No trial has been conducted with high-land sorghum in East Hararghe that has been growing sorghum using their own landraces. Therefore, the objectives of this study were to evaluate and select best performing mid-land sorghum variety/ies and to identify farmers' preferences and selection criteria to the study sites of East Hararghe highlands with the participation of farmers.

Material and Method

Treatments and Experimental material

The experiment was conducted on two locations of Kurfa chele and Meta districts of Oromia region on FTC and farmers' field for three consecutive years during 2018, 2019/20 and 2020/21 main cropping seasons. A total of eleven (11), ten (10) recently released and previously untested sorghum varieties and one local check had been evaluated in the study areas. The materials used for the experiment were; Adele, Jiru, Dibaba, Gemedi, Chemeda, Dano, Lalo, Muyra-1, Muyra-2 and Chiro with one local check.

A field experiment had been laid out in Randomized Complete Block Design (RCBD) with three replications and with the spacing of 1 m and 0.5 m between blocks and plots respectively and plot size of in 3.75 m x 5 m had been used. During planting, the seeds were manually drilled into five meters long and six row plot spaced 0.75 m apart at seed rate of 10 kg ha^{-1}. At approximately 21 days after planting, the seedlings were thinned to 0.20- 0.25 m distance between plants giving a total population of 66666 plants ha^{-1}. Nitrogen and phosphorus fertilizers were applied in the form of UREA and NPS at the recommended rate of 100 kg ha^{-1} each. NPS was applied at sowing time and Urea was top dressed before heading when the crop was reach at knee height. All other agronomic management was applied as recommended for the sorghum production.

Data Collection: Data were collected on plant and plot high basis for different agronomic traits. Plant height (cm) and panicle length were recorded from plant basis whereas; days to 50% flowering, days to physiological maturity and grain yield (kg ha^{-1}) were collected from plot basis.

Farmers' Participatory Varietal Selection (PVS): Participatory varietal selections were conducted using participatory tools (direct matrix ranking). Farmers' selection was done based primarily on their sorghum growing experience, gender ratio and willingness to participate in the research. A total of 22 farmers of both sexes (male=17, female=5) participated in the study. Farmers had been evaluated the varieties on physiological maturity and harvest stage with their own criteria. Farmers' feedback had been collected at these stages to select the best performing varieties. Farmer's criteria for evaluation had been recorded and scores were given on a scale from 1(very good) to 5 (very poor) for the criteria. From the total of eleven sorghum varieties, farmers were selected the first five sorghum varieties depending on their willingness and gave the rank to these varieties. A direct matrix table was prepared for the evaluated genotypes listed in the row and traits preferred by farmers listed in the column. Scores were given to each variety based on the selection criteria (1 = very good, 2 = good, 3 = average, 4 = poor and 5 = very poor). During direct matrix ranking, farmers have given rating of importance (a relative weight) of a selection criterion ranked from 1 to 3 (1= very important, 2= important and 3= less important) and rating of performance of a variety for each trait of interest (selection criteria) was given based on their level of importance on the basis of common agreement of evaluators. The score of each variety was multiplied by the relative weight of a given character to get the final result and then added to the results of other characters to determine the total score of a given variety. Scoring and ranking were done on consensus and differences were resolved by discussion as indicated by de Boef and Thijssen [6].

Statistical Data Analysis: The data collected from the experiment had been subjected to statistical analysis using GENSTAT 15th edition software. Mean separation was carried out using Duncan's Multiple Range Test (DMRT) at 0.05 probability level.

Results and discussion

Performance Evaluation of Mid-land Sorghum Varieties

Analysis of variance (ANOVA) revealed that significance defenses (P< 0.05) were observed among the sorghum varieties evaluated. Significance differences were recorded on the traits (days to 50% flowering, days to physiological maturity, Plant height and grain yield) (Table1).

The analysis of variance (ANOVA) revealed that there was significant difference among sorghum varieties for yield (Table 2). The grain yield ranged from 2986 kg /ha to 4274 kg /ha and grand mean of 3733 kg/ha. The highest yield (4274 kg/ha) was recorded from Variety Adele followed by the varieties Gemedi (4109 kg/ha), and Dibaba (4045 kg/ ha) which was no significance difference from the highest yielded variety, while the lowest yield (2986 kg/ha) was obtained from Chiro which was statistically not significant from local check (3533 kg/ha). The variation in grain yield of the tested varieties showed the difference in adaptability of these varieties to the agro-ecology of the study area. The highly performed varieties revealed that the most adaptability to this environment.

Table 1: Mean squares from analysis of variance (ANOVA) of measured phenological and agronomic traits in 2018 and 2019/20 main cropping season at the study area

Source of Variation	Df	DF (days)	DM (days)	PH-cm	Gyld-Qt-ha
Replication	2	65.92	53.379	576.7	4.08
Treatment	10	440.07***	282.633***	4678.5***	83.63**
Error	42	20.64	8.379	704.6	24.47
Mean		142.62	206.17	255.3	25.9
CV (%)		3.2	1.4	10.4	19.1

Highly, * very highly significant at 1% probability level, where, df= degree of freedom, DF= days to 50% flowering, DM= days to physiological maturity, PH= plant height, Gyld- Qt-ha-= grain yield (Qt/ha)

Table 2: Combined Mean values of DF, DM, PH and Grain yield of sorghum tested during 2018-2020/21 main cropping season at East Hararghe and Harari region

Varieties	DF	DM	PH (cm)	GYLD (kg/ha)
Adele	140.4 ab	205.7 b	226.8 de	4274 a
Chemeda	155.2 d	215 cd	246.8 cd	3474 cd
Chiro	138.8 a	207 b	217.9 e	2986 d
Dano	155.3 d	215.7 d	278.3 ab	3562 cd
Dibaba	136.1 a	203 a	214.9 e	4045 abc
Gemedi	153.8 d	218.7 e	225.9 de	4109 ab
Jiru	144.6 bc	205 ab	246.4 cd	3155 d
Lalo	154.6 d	218.3 e	301.5 a	3594 bcd
Local check	148 c	212.7 c	254.7 c	3533 cd
Muyra 1	147.2 c	207 b	269 bc	3203 d
Muyra 2	147.9 c	206.7 b	252.9 c	3036 d
Mean	147.44	210.42	248.60	3733.70
LSD (5%)	8.20	4.34	40.31	1196.74
CV %	3.40	1.30	9.90	19.70

Means in the same column followed by the same letters are not significantly different at 5% level of significance according to DMRT; DF= days to 50% flowering, DM= days to physiological maturity, PH= plant height, Gyld-Qt-ha-1= grain yield (Qt/ha)

Analysis of variance revealed very highly significant difference ($p<0.001$) among varieties for plant height (Table 2). The plant height ranged between 214.9 cm to 301.5 cm. The highest height was given by variety Laaloo while the lowest was by variety Dibaba. As the data indicated; Laaloo, and Danno were taller standing with mean values of; 301.5 cm and 278.3 cm respectively, while Dibaba, Chiro, Adelle and Gemedi were shorter standing; 214.9 cm, 217.9 cm, 226.8 cm and 225.9 cm respectively. Even though, plant height has no direct relation with grain yield, the tallest plant is important for its highest biomass which is desirable for different purposes. Dibaba was the earliest maturing of all the varieties tested with 203 days, whereas Lalo and Gemedi with 218.3 and 218.7 days were the longest maturing varieties respectively.

Table 3: Direct matrix ranking evaluation of sorghum varieties by of group of farmers'

Variety	Criteria Earliness	Panicle weight	Seed size and color	Disease tolerance	Bird damage	Biomass yield	Grain Yield	Total score	Average score	Rank
Adele	1	1	1	1	1	2	1	8	1.14	1
Chiro	3	3	4	3	2	3	3	21	3	4
Dano	4	3	3	3	2	3	3	21	3	5
Dibaba	1	1	2	1	2	1	1	9	1.3	2
Gemedi	3	3	3	2	2	3	2	18	2.6	3
Local check	5	4	4	5	3	3	5	29	4.14	6

In this participatory varietal selection, farmers were selected the first five (5) sorghum varieties depending on their own selection criteria's. Farmers were gave relative weight to the selection criteria the set. Accordingly, the set grain yield and disease tolerance (very important), bird damage (important and) grain color and size and plant biomass (less important). Based on mean overall score the most preferred varieties were Adele and Gemedi (Table 3). Variety Adele ranked first because of higher productivity, bird damage and plant biomass whereas Dibaba and Gemedi ranked second and third respectively for their better in grain yield, bird damage, grain color and size.

Conclusion and Recommendation

Participatory varietal selection was done in the study were tested at district not only because farmers' cultivars were old, but also none of these evaluated varieties was previously grown by farmers except the local check. The key criteria used by farmers to evaluate and select the preferred varieties were grain yield, disease tolerance, grain size and color, plant biomass and bird damage. Farmers used different parameters and methods to evaluate the tested mid-land sorghum varieties. For fast adoption and dissemination the new variety/ies considering the preferences of farmers and consumers are necessary, otherwise it is less likely to be widely adopted or accepted by the farming community. In this study farmers 'and breeders evaluation and selection were confirmed that Adele, Dibaba and Gemedi, were found good for yield potential and other agronomic traits among the eleven tested varieties based on both farmer's and researchers evaluation. According to the analysis of result and farmers' selection variety Adele, Dibaba and Gemedi, were best performing with grain yield and yield components and were selected for the study area.

References

CSA (Central Statistics Agency), 2013. Agricultural Sample Survey 2012/2013 (2005 E.C.).Volume I. Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Statistical Bulletin 532, Addis Ababa, Ethiopia.

Rashid, S., 2010. Staple Food Prices in Ethiopia. Prepared for the COMESA policy seminaron "Variation in staple food prices: Causes, consequence and policy options, Maputo, Mozambique, 25-26 January 2010 under the African Agricultural Marketing Project (AAMP).

Alemayehu Biri, Kibret Ketema, Meles Furgasa, Lelisa Ofgaha, Abdulahi Umer, 2016. A participatory agricultural production systems analysis of AGP-II districts: the case of dire Dawa administrative council and Harari region, eastern Ethiopia, implications for research and development. AGP- II report.

Adugna Asfaw, 2007. The role of introduced sorghum and millets in Ethiopian agriculture. J. SAT Agric. Res., 3(1).

Bellon, M.R., 2002. Analysis of the Demand for Crop Characteristics by Wealth and Gender: A Case Study from Oaxaca, Mexico. In: Quantitative Analysis of Data from Participatory Methods in Plant Breeding, Bellon, M.R. and J. Reeves, (Eds.). CIMMYT, Mexico, DF., pp: 65-80.

Adaptation Trial of Drought Tolerant Hybrid Maize (*Zea mays*) Varieties in Moisture Deficit Areas of East Hararghe, Ethiopia

Zeleke Legesse*, Jifara Gudeta, Fikadu Tadesse, Biranu Diribsa and Alemayehu Biri
Oromia Agricultural Research Institute, Fadis Agricultural research center, P.O.B 904, Harar.
Corresponding author Email: zalelegesse12@gmail.com

Abstract

Maize is one of a major crop in Ethiopia in production, consumption and income generation for both resource constrained men and women. The experiment was conducted moisture deficit areas of East Hararghe namely Fadis and Erer in 2019/20 and 2020/21 cropping seasons. The study was done with the objectives of to evaluate the performance of hybrid maize varieties for their adaptability, stability, high yielder and to recommend variety/ies for the study areas and similar agro-ecologies. The experiment was conducted with randomly complete block design with four replications. The analysis of variance revealed the significance variation of hybrid maize varieties for the traits evaluated. The variety Damote (182.9 cm) had the tallest in plant height which is not significant different from varieties, MH-140 and MH-138 with a mean values of 172.1, 169.8 cm respectively. MH-140 variety had the highest grain yield (72.78 Qtha-1), while Melkasa-4 had the lowest grain yield (32.45 Qtha-1). Thus, it can be concluded that hybrid maize varieties MH-140 and MH-138 resulted in best results in terms of yield and yielding component across the study areas. Therefore, for sustainable maize production in the study area these varieties had been recommended and need to be demonstrated with available local varieties to users along with their improved production packages.

Key words: Grain yield, Hybrid maize, Variety evaluation

Introduction

Maize (*Zea mays* L) is one of the most important cereals broadly adapted worldwide (Christian et al., 2012). It is a major food crop and source of animal feed in Africa, Americas and Asia (Bergvinson, 2000). Maize is largely produced in Western, Central, Southern and Eastern parts of Ethiopia. It is the third most important cereal after wheat and rice globally and the most widely distributed (Siwale *et al.,* 2009). Maize is one of the most important crops grown in Ethiopia (Mosisa *et al.,* 2007). It ranks second after tef in area coverage 18.60% (2,367,797.39 ha) and first in total production 30.08% (94,927,708.34 quintals) (CSA, 2019). In Ethiopia, it is grown in the lowlands, the mid-altitudes and the highland regions and most important field crop in terms of area coverage, production and utilization for food and feed purposes. In Ethiopia maize is produced for food, especially, in major maize producing regions mainly for low-income groups, it is also used as staple food. Maize is consumed as "Injera," Porridge, Bread and "Nefro." It is also consumed roasted or boiled as vegetables at green stage. In addition to the above, it is used to prepare "Tella" and "Arekie." The leaf and stalk are used for animal feed and dried stalk & cob are used for fuel. It is also used as industrial raw material for oil & glucose production (MARD, 2014).

Maize is currently grown across thirteen agro-ecological zones, which together cover about 90 percent of the country. The small-scale farmers that comprise some 80 percent of Ethiopia's population are both the primary producers and consumers of maize in Ethiopia. Maize production of Ethiopia increased from 2.34 million tones in 1998 to 9.5 million tonnes in 2019 growing at an average annual rate of 30.08%. Despite the large area under maize, the national average yield of maize is about 3.992 t/ha which is far below the world's average yield of about 5.21 t/ha (CSA, 2019). The low productivity of maize is attributed to many factors like frequent occurrence of quality of seed varieties, drought, declining of soil fertility, poor agronomic practice, limited use of input, insufficient technology generation, lack of credit facilities, poor seed quality, disease, Insect, pests and weeds particularly, Striga. Although the production of maize was there, it is still relatively concentrated in the areas of some highlands of Oromia regions of Ethiopia. Some improved hybrid maize varieties has been released by the different regional and federal research centers in the nation but farmers are still stress on few local maize varieties. Therefore, the objective of this study was to study the adaptability and performance of the hybrid maize varieties for the moisture stress condition of the study areas.

Materials and Methods

The experiment was conducted at Fadis on-station (Boko) and Erer farmers field in 2019 and 2020/21 cropping seasons. The Fadis research station have an altitude of 1700 m.a.s.l and temperature range of 25-30oC. Three recently released lowland hybrid maize varieties (MH-140, MH-138 and Damote) including two standard check varieties (Melkasa-2 and Melkasa-4) were used and planted at Fadis research station and Qilee on-farm. Randomized Complete Block Design (RCBD) with four replications was applied during the experimentation. A plot size of 4 m x 3 m with plant spacing of 75cm and 25 cm between row and plant respectively was used. The distance between plots and replications were 0.5 m and 1 m apart respectively. Two seeds per hill were sown, which were thinned to one plant per hill after three weeks with the rate of 25 kg ha^{-1}. Fertilizer in the form of UREA and NPS was applied at the rate of 100 and 100 kg ha^{-1}, respectively. NPS was used all once during planting while UREA was applied at knee height (during 8-10 leaf). All other important agronomic practices and management was applied equally to all the entries at their proper time as required.

Data Collection and Analysis

The important data collected from plant and plot base were days to anthesis, days to silking, days to physiological maturity, plant height, grain yield and hundred seed weight. The recorded data were subjected to statistical analysis of variance (ANOVA) using Genstat 18th edition. Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 5% level of probability.

Results and Discussion

The analysis of variance (ANOVA) showed significant differences among the genotypes ($P \leq 0.05$) for all the traits measured. However, mean squares for replication were not significant for all the traits measured (Table 1). Analyses of variance (ANOVA) revealed that very highly significant difference ($P<0.001$) on days to 50% anthesis, days to 50% silking and days to physiological maturity (Table 1) and also showed highly significant ($P<0.001$) on number of cobs per plant, plant height, grain yield and hundred seed weight whereas significant variation (P<0.05) on cob length (Table 2).

Table 1: Analysis of variance for growth and Phenological traits of hybrid maize tested Fadis and Erer in 2019/20 and 2020/21

Source of Variation	Replication (3/)	Variety (4)	Error (32)	Mean	CV%	LSD (P<0.05)
DTT	20.95	154.642***	6.504	77.85	2.8	2.086
DTS	44.4	84.7***	219.6	93.3	2.6	12.14
DTM	47.6	93.86***	13.68	12.14	15.9	3.03

*-Significant at 5%, ***- Significant at 1%.; DTT= Days to 50 % Tasseling; DTS= Days to 50% silking; DTM= Days to physiological maturity

Table 2: Mean square of yield and yield related traits for the hybrid maize varieties evaluated during 2019/20 and 2020/21 main cropping season

S.V	Replication (3)	Variety (4)	Error (32)	Mean	CV (%)	LSD (5%)
CL (cm)	0.558	3.579*	1.775	18.01	7.4	1.357
CPP	0.09089	0.46856***	0.06851	1.7	15.6	0.27
PH (cm)	347.5	4026***	271.6	162.6	10.1	13.5
Gyld (Kg ha^{-1})	3637693	27459865***	1651301	5581.8	24.4	1052.71
HSW (g)	2.6	58.667***	1.017	33	3.1	6.151

*-Significant at 5%, ***- Significant at 1%.; CL= Cob length; CPP= Cob per plant; PH = plant height, Gyld= grain yield (Kg ha^{-1}); HSW = Hundred seed weight.

Mean performance of growth and phenological parameters of maize varieties

Days to tasseling, silking and Maturity are one of the variety selection criteria, in particular in areas where droughts are the major problems. The analyses of variance for the phenological data were presented in Table 3. The analysis stated highly significant differences (P≤ 0.001) for days to 50% tasseling, days to 50% silking, days to physiological maturity (P< 0.001). The overall average days to 50% tasselng was 77.86 days with a range of 73.33 days for the standard check (Melkasa-4) to 83.08 days for the variety Damote and days to 50% silking ranged from 90.08 days (Melkasa-4) to 97.33 days (Damote) with the mean values of 93.33 days (Table 3). The earliest variety in days to physiological maturity was recorded from standard check Melkasa-4 (134.3 days) followed by Melkasa-2 (136.9 days) and MH138 (138.2 days) in which no significance difference was observed whereas the latest days to physiological maturity was recorded by variety Damote followed by MH-140 with the mean values of 141.7 days and 139.8 days respectively. The varieties have different genetic background, which might be the reason for the variation in tasseling, silking and maturity duration among the tested varieties. These results are in line with the findings of Hassan (2005) and Ayelene (2011).

Table 3: Mean values of growth and phonological parameters of hybrid maize varieties tested at Qilee on farm and Fadis research station in 2019/20 and 2020/21 cropping season

Variety	DTT	DTS	DTM
Damote	83.08d	97.33c	141.7d
Melkasa-2	76.08b	92.25b	136.9b
Melkasa-4	73.33a	90.08a	134.3a
MH-138	78.58c	92.92b	138.2bc
MH-140	78.17c	93.92b	139.8cd
Mean	77.85	93.3	138.2
CV (%)	2.8	2.6	2.1
LSD (P< 0.05)	2.343	2.016	2.416

DTT= Days to 50% Tasseling, DTS= Days to 50% Silking, DTM= Days to physiological maturity. Means with the same letter within the same column are not significantly different.

Mean performance of Yield and Yield related parameters of hybrid maize varieties

The overall mean plant height (PH) recorded was 162.6 cm. Greater variation in plant height ranging from 151.4 to 182.9 cm was observed (Table 4). The maximum height was measured in variety Damote which was the tallest (182.9 cm) among the five maize varieties and produced more than 31.5 cm long and remained significantly taller than all the hybrid maize varieties tested. The tallest in plant height was recorded by variety Damote with height of 182.9 cm followed by MH-138 and MH-140 with a mean height of 172.1 cm and 169.8 cm respectively. The standard checks; Melkasa-2 and Melkasa-4 varieties had recorded the lowest mean plant height 151.4 cm and 136.9 cm, respectively (Table 4). The mean grain yield value of the tested maize varieties ranged from 3245 $Kgha^{-1}$ to 7278 $Kgha^{-1}$. The highest grain yield was obtained from hybrid maize varieties MH-140 with a value of 7278 $Kgha^{-1}$. In addition, two hybrid maize varieties (MH138 and Damote) gave high yields (Table 2). However, the lowest grain yield was obtained from OPV maize varieties (standard checks) Melkasa-2 and Melkasa-4 with a mean values of 5125 gha^{-1} and 3245 $Kgha^{-1}$, respectively.

Table 4: Mean values of yield and yield related parameters of hybrid maize varieties tested at Qilee on farm and Fadis research station in 2019/20 and 2020/21 cropping season

Variety	CL-cm	CPP	PH-cm	Gyld-kg ha^{-1}	HSW-g
Damote	18.29 ab	1.515 bc	182.9a	6086b	36.75ab
Melkasa-2	17.59 b	1.75 ab	151.4b	5125b	33ab
Melkasa-4	18.05 ab	1.354 c	136.9c	3245c	33ab
MH-138	17.2 b	1.844 a	172.1a	6174ab	30.75b
MH-140	18.95 b	1.942 a	169.8a	7278a	38a
Mean	18.01	1.7	162.6	5581.8	34.3
CV (%)	7.4	15.6	10	24.4	11.6
LSD (P< 0.05)	1.357	0.27	13.4	1119.55	6.151

CL=Cob length, CPP= Cob per plant, PH = plant height, Gyld = grain yield, HSW = Hundred seed weight. Means with the same letter within the same column are not significantly different.

Conclusion and Recommendation

Using improved varieties of hybrid maize could make an important contribution to increase agricultural production and productivity in areas like eastern Hararghe where there is low practice of using improved technologies such as improved crop varieties. According to the results of analysis of variance, all of the agronomic traits evaluated were revealed significant statistical variation. Hybrid maize variety MH-140 and MH-138 gave the highest grain yield of all the test varieties respectively, while standard checks Melkasa-4 and Melkasa-2 varieties showed the smallest grain yield respectively. Thus, it can be concluded that hybrid maize varieties MH-140 and MH-138 resulted in best results in terms of yield and yielding component across the study area. Therefore, for sustainable maize production in the study area these varieties had been recommended and need to be demonstrated to users along with their improved production packages.

References

Bellon, M.R., 2002. Analysis of the Demand for Crop Characteristics by Wealth and Gender: A Case Study from Oaxaca, Mexico. In: Quantitative Analysis of Data from Participatory Methods in Plant Breeding, Bellon, M.R. and J. Reeves, (Eds.). CIMMYT, Mexico, DF., pp: 65-80.

Bergvinson D J. 2000. Storage Pest Resistance in Maize. Maize Research Highlights. 1999-2000.

CSA (Central Statistical Agency of the Federal Democratic Republic of Ethiopia), 2006. Agricultural Sample Survey, 2006. Report on Area and production of major crops (Private Peasant Holdings, meher season). Statistical Bulletin 278. Vol. I, Addis Ababa, Ethiopia

CSA (Central Statistical Agency of the Federal Democratic Republic of Ethiopia), 2006. Agricultural Sample Survey, 2015. Report on Area and production of major crops (Private Peasant Holdings, meher season). Statistical Bulletin 278. Vol. I, Addis Ababa, Ethiopia

CSA (Central Statistical Agency of the Federal Democratic Republic of Ethiopia), 2006. Agricultural Sample Survey, 2019. Report on Area and production of major crops (Private Peasant Holdings, meher season). Statistical Bulletin 278. Vol. I, Addis Ababa, Ethiopia

Dagne W, Habtamu Z, Demissew A, Temam H, Harjit S. The combining ability of maize inbred lines for grain yield and reaction to Gray leaf spot disease. East Afr J Sci, 2008, 2: 135-145.

Mosisa W, Wonde A, Berhanu T, Legesse W, Alpha D, Tumassi A (2007). Performance of CIMMTY maize germplasm under low nitrogen soil conditions in the mid altitude sub humid agro ecology of Ethiopia. Afr. J. Sci. Conf. Proc. 18:15-18.

Rao, N.H., J.C. Katyal and M.N. Reddy, 2004. Embedding the sustainability perspective into agricultural research: Implications for research management. Outlook Agric., 33: 167-176.

Effect of Intercropping Soybean (*Glycine max* L.) with Sorghum [*Sorghum bicolor* (L.) Moench] at Fadis East Hararghe, Oromia

*Habte Berhanu,Fikadu Tadesse Motuma Dalasa
Fedis Agricultural Research Center P.O.Box:904
Oromia Agricultural Research Institute P.O. Box 81265, Addis Ababa/Finfinne, Ethiopia

Abstract

Field experiments were conducted at Fedis and Erer during 2018 and 2019 to identify the effect of intercropping sorghum with soybean for grain yield. Seed yield of the sole crops of sorghum and soybean were higher than the individual components in the intercrops. Yields of component crops in the intercrop varied significantly with different varieties. The sorghum/soybean (Teshale/Awasa-95) intercrops which had LER (Land Equivalent Ratio) 1.72 were more productive than Sorghum/soybean (Dhaqaba/Awasa-95) intercrop with maximum LER of 1.14. Maximum grain yield and LER greater than one were obtained from intercropping of sorghum (Teshale) with soybean (Awasa-95) indicating that intercropping has advantage as compared sole cropping. Therefore, intercropping of sorghum with soybean is compatible, advisable and more advantageous to increase production as compared to their sole cropping in the same conditions.

Introduction

Crop intensification is one of the strategies to increase productivity per unit area of land (Wondimu *et al*. 2016). Due to decreasing land units and decline in soil fertility integrating soybean in to the Sorghum production system is a viable option for increasing productivity and as well protein source. Sorghum [*Sorghum bicolor* (L.) Moench] was domesticated in Ethiopia about 5000 years ago. It is staple food and feed of eastern parties of the country particularly east Hararghe having 72.9%. Reports of persistence of high rate of acute malnutrition in certain specific areas of East Hararghe. Report of Carine Magen, 2014 stated that although people had access to staple food groups the dietary diversity and therefore dietary quality was low. Furthermore, very low consumption of valuable protein sources (animal proteins such as meats, eggs, dairy products) implied low nutritional value of the diet. Even though a high proportion of households had access to staple food, their knowledge on diversification of food remains limited. Hence, the essential nutritional value needed for each individual was not reached and poor nutritional status was expected to be found in households. A general assumption in intercropping cereals with legume crops is that the legume, when associated with the specific Rhizobium, may have most of its N need supplied through fixation of atmospheric N, leaving the soil available N for the companion cereal(Saberi AR,2018). There is evidence that leguminous plants can benefit the intercrop cereals in the same season through N excretion and nodule decomposition. Intercropping soybean (*Glycine max* L.) with sorghum (*Sorghum bicolor* L.) is common in the semiarid tropics (Ghosh *et al*., 2006). Sorghum and soybean are being intercropped in the tropics so that crops more effectively ((Wahua T. and Miller A., 1978) for utilize water, weed control, and soil fertility is improved. In view of the current situation of food security, particularly in developing countries, land availability for agricultural activities, fresh water resources, biotic and abiotic stresses, and low economic activity in agricultural sector are factors a that decrease in crop productivity. Intercropping is affected by factors include rootstock or variety, manure lack, stage of plant growth and irrigation management (Saberi AR, 2018). Intercropping is a common practice for Hararghe because of shortage of land, resource, and risk management due to erratic rain fall. Sorghum with common bean, sorghum with groundnut and maize with common bean is the common practice that farmers used in general.Even though intercropping is common practice for east Hararghe farmers; soybean is the new crop for farmers and intercropping sorghum with soybean is also new practice. Therefore the experiment was done to familiarize the technology and identify the compatibility of the commodity.

Materials and Methods

Description of the study Area

The field experiment was conducted in midland and lowland areas of East Hararghe zone, Fadis and Babile district. Fadis district is found at about 24 km far to the East of Harar, the capital city of the East Hararhge Zone. The maximum and minimum annual temperature is 28.23^{o}c and 10.2^{o}C, respectively. The altitude of the study area is about 1702 m. a. s. l; the specific soil type of the site is *Alfisols* types of soil and sandy clay loam in texture with the pH value ranging from 8.1 to 8.6. The soil physical properties characterized as sandy clay with Clay (48%) Silt (29%) and Sand (23%) and the soil chemical property include, total Nitrogen (0.167%); Organic Carbon (1.268%) and available Phosphorus (2.61 ppm) (FARC, 2013). The experimental area receives a mean rainfall of about 749.9 mm The rainfall has a bimodal distribution pattern with heavy rains from April to June and long and erratic rains from August to October.

Experimental materials

The improved sorghum varieties known as Teshale, and Dhaqaba were used as a test crop. From Soybean commodity two varieties (Awasa95 and Awasa04) were used.

Treatments and experimental design

Soybean was intercropped with sorghum in 1:1 ratio. Single row of sorghum and single row of Soybean in sequence (1S:1S): Teshale*Awasa95, Teshale*Awasa04, Dahaqaba*Awasa95, Dhaqaba*Awasa04, Teshale Sole, Dhaqaba Sole, Awasa95 Sole, and Awasa04 Sole.

Data Collection

Sorghum, and Soybean yield was collected. For both commodities yield and yield related traits were collected. For Sorghum (panicle length, panicle diameter, plant height, days to flowering and days to maturity) were collected. Similarly, for Soybean (Pod/plant, seed/pod, primary branches/plant and plant height).

Data Analysis

The analysis of variance (ANOVA) was carried out using statistical packages and procedures out lined by Gomez K. and Gomez A., 1984. Appropriate to Randomized Complete Block Deign using SAS Computer Software Version 9.0. Mean separations was carried out using least significant difference (LSD) at 5% probability level.

Results and discussion

Combined mean of analysis of variance revealed that significant variation was found among the intercropping combination for yield, and yield related components for each crop commodity. For sorghum yield, Panicle length, panicle diameter, and plant height show significant variation. Similarly, for Soybean significant variation was recorded for yield, number of pods per plant, number of primary branches per plant and plant height.

Table 1. Effect of Sorghum and Soybean intercropping on yield and yield components of Sorghum

Treatments	PL	PH	PD	GY(qt/h)
Teshale sole	29a	184.3a	10.444a	37.67a
Teshale x Awasa95	28.78a	164.8b	10.667a	27.70ab
Teshale x Awasa04	27.33ab	171.8ab	9.444ab	24.20b
Dhaqaba sole	25.22ab	123c	9.333ab	32.96ab
Dhaqaba x Awasa95	23.67bc	117c	8.667ab	23.00b
Dhaqaba x Awasa04	22.78c	117.7c	8b	22.30b
Lsd	3.57	16.44	2.12	10.35
Cv	7.5	3.3	12.4	20.3

NB: PL=panicle length, PH=plant height, PD=panicle diameter, GY=Grain yield

Analysis of variance showed that significant variation was observed due to intercropping among the treatments. Accordingly, for panicle length the longest panicle was measured from intercropping of Teshale with Awasa95 Followed by Teshale with Awasa04; while the shortest panicle was measured from intercropping of Dhaqaba with Awasa04.the wider the diameter was measured from intercropping of Teshale with Awasa95 followed by Teshale sole and Teshale with Awasa04. Significant variation was measured for grain yield because of intercropping. Accordingly, the maximum grain yield was harvested from Teshale sole, and Dhaqaba sole followed by intercropping of Teshale with Awasa95.

Table 2. Effect of Sorghum and Soybean intercropping on Yield and yield components of Soybean

Treatments	SPP	PPP	PH	NBPP	GY(qt/h)
Awasa04 sole	2.67	24.89bc	65.00a	5.11ab	19.6a
Dhaqaba x Awasa95	2.67	30.22abc	55.22bc	6.00ab	6.2b
Awasa95 sole	2.44	38.33a	60.67ab	6.778a	14.0a
Dhaqaba x Awasa04	2.44	18.89c	49.89c	4.00b	5.6b
Teshale x Awasa04	2.44	24.00bc	50.67c	6.00ab	9.0b
Teshale x Awasa95	2.33	36.67ab	57.56abc	5.56ab	13.8ab
Lsd	NS	11.97	8.68	2.39	5.89
Cv	10.19	5.37	3.89	11.07	12.64

NB: spp=seed/pod, ppp=pod/plant, PH=plant height, NBPP=Number of branches/plant and GY=Grain yield

Intercropping of Sorghum and soybean shows significant variation for number of pods per plant, plant height, number of primary branches per plant and seed yield. Maximum number of pod per plant was counted from Awasa95 sole followed by intercropping of Teshale with Awasa95, Dhaqaba with Awasa95. While, minimum number of pod per plant was counted from intercropping of Dhaqaba with Awasa04. Both sole Awasa95 and Awasa04 have the longest plant height compared to the intercropping. Intercropping has significant effect on number of primary branches per plant. Accordingly, maximum number of primary branches per plant was counted from sole cropping of Awasa95 followed by Dhaqaba with Awasa95, Teshale with Awasa04 and Teshale with Awasa95. And the minimum number of primary branches per plant was counted from intercropping Dhaqaba with Awasa04. Seed yield show significant variation due to intercropping. The highest seed yield was measured from sole Awasa04 followed by sole Awasa95 and intercropping of Teshale with Awasa95.

Table 3. Interaction Effects of Sorghum and Soybean intercropping on yield of Sorghum and Soybean

Treatments	Yield of Soybean(qt/h)	Yield of Sorghum (qt/h)
Awasa04 X Dhaqaba	5.6b	22.3b
Awasa95 X Dhaqaba	6.2b	23.0b
Awasa04 X Teshale	6.0b	24.2b
Awasa95 X Teshale	13.8a	27.7ab
Awasa04 sole	19.6a	-
Awasa95 sole	14.0a	-
Dhaqaba sole	-	32.9ab
Teshale sole	-	37.6a
Lsd	5.89	10.35
Cv	2.64	20.3

The interaction effect of intercropping Soybean with Sorghum shows significant variation among the treatments. Maximum seed yield was harvested from the sole cropping in both crops and followed by intercropping of Teshale (Sorghum) with Awasa95 (Soybean). This indicates that intercropping has yield advantages as compare to sole cropping. Similarly, Saberi AR, (2018) reported Sorghum intercropping with soybean treatment 60% was better than pure cultivate and if each crop alone was sown for getting this yield the area needed was equal to 1.6. Mortatha Ogee *et al*., 2019 added these results indicate that soybean mixed with sorghum had a better soil environment than that in the sole soybean treatment.

Land Equivalent Ratio (LER): Land equivalent ratio (LER) was calculated which verifies the effectiveness of intercropping for using the resources of the environment compared to sole cropping (Dhima K, *et al*., 2007). When LER is greater than 1, the intercropping favors the growth and yield of the species. In contrast, when LER is lower than one, the intercropping negatively affects the growth and yield of plants grown in mixtures (Caballero R, 1995). The LER values were calculated as: LER = (LER Sorghum + LER Soybean), where LER Sorghum = (YSorSoy / YS), and LER Soybean = YSoySorg / YSoy, where YSor and YSoy are the yields of Sorghum and Soybean as sole crops, respectively, and YSoySorg and YSorSoy are the yields of Soybean and Sorghum as intercrops, respectively.

Table 4. Land equivalent ratio of sorghum and soybean intercropping

		Teshale	Teshale	Dhaqaba	Dhaqaba
Sorghum	Sole	37.67	37.67	32.96	32.96
	Intercropping	24.2	27.7	22.3	23
	Partial LER	0.64	0.74	0.68	0.7
		awasa04	awasa95	awasa04	awasa95
Soybean	Sole	19.6	14.0	19.6	14
	Intercropping	6.0	13.8	5.6	6.2
	Partial LER	0.31	0.98	0.29	0.44
	LER	0.95	1.72	0.97	1.14

LER=land equivalent ratio

The total land equivalent ratios (LER) were obtained by summing up of the partial land equivalent ration of sorghum and Soybean crops. The mean values of sorghum partial land equivalent ration were not significantly (P>0.05) influenced due to the main effect of sorghum intercropping with Soybean. Even if the analysis of variance did not show variation, the higher total LER (1.72) was obtained from sorghum (Teshale) and Soybean(Awasa95) followed by LER 1.14 Sorghum (Dhaqaba) intercropping with Soybean (Awasa 95), indicating that 72% and 14% yield advantage respectively over sole crops. Mean square reveals that intercropping of Sorghum with Soybean shows significant variation among the varieties. Maximum grain yield was obtained from intercropping of Sorghum (Teshale) with Soybean (Awasa95). LER 1.72 indicating about 72% of land is needed to compensate the yield obtained by intercropping of Sorghum by Soybean. Similarly Layek J. *et al*., (2014) Land equivalent ratio, indicating soybean with Maize intercropping has greatest advantages proving maximum yield advantages. Land equivalent coefficient (LEC) 1.27 which is greater than 0.25 was obtained when Sorghum (Dhaqaba) and Soybean (Awasa-95).

Conclusion and Recommendation

Analysis of variance states that intercropping of Sorghum with Soybean shows significant variation among the varieties. Maximum grain yield was obtained from intercropping of Sorghum (Teshale) with Soybean (Awasa95). LER 1.72 indicating about 72% of land is need to comp onset the yield obtained by sole cropping of Sorghum and soybean alone. Therefore sorghum intercropping with soybean is compatible and maximum grain yield was obtained by intercropping of sorghum (Teshale) with Soybean (Awasa95). Generally intercropping of Sorghum with Soybean is compatible and advisable.

References

Caballero R, Goicoechea E and Hernaiz P. "Forage yields and quality of common vetch and oat sown at varying seeding ratios and seeding rates of common vetch". Field Crops Res 41(1995): 135-140.

Dhima K, A Lithourgidis, Vasilakoglou I and Dordas C. "Competition indices of common vetch and cereal intercrops in two seeding ratio". Field Crop Res 100(2007): 249-256

Gomez K and Gomez A."Statistical Procedures for Agricultural Research". 2nd Edition. John Wiley and Sons Inc. Inter-Science Publications . New York (1984) 180-225

Isaiah Nyagumbo, Munyaradzi Mutenje, Sita R. Ghimire, and Esther Bloem 2020. Cereal-Legume Intercropping and Rotations in Eastern and Southern Africa.

Magen, C. (2014). Health Anthropologist, and ACF team. *East Hararghe Zone*, Nutrition Causal Analysis Report *of Fedis and Kersa Woredas, Ethiopia*.

Mortatha Ogee, Chris Guppy, Richard Flavel, Graeme Blair 2019. Impact of intercropping soybean and sorghum on shoot production and phosphorus use efficiency in a Vertosol soil. *Agronomy and Soil Science*, University of New England, Armidale NSW, Australia

Pal and Dr. T. O. Oseni, Abubakar Tafaw, 1993. Effect of Component Densities on the Productivity of Soybean/Maize and Soybean/Sorghum Intercrop journal of agronomy and crop science

Saberi AR. Comparison of Intercropped Sorghum- Soybean Compared to its Sole Cropping. Biomed J Science and Technology Research 2(1)- 2018. BJSTR.MS.ID.000701. DOI: 10.26717/BJSTR.2018.02.000701

Wondimu Bekele, Ketema Belete, Tamado Tana 2016. Effect of Soybean Varieties and Nitrogen Fertilizer Rates on Yield, Yield Components and Productivity of Associated Crops under Maize/Soybean Intercropping at Mechara, Eastern Ethiopia. *Agriculture, Forestry and Fisheries*. Vol. 5, No. 1, 2016, pp. 1-7. doi: 10.11648/j.aff.20160501.11

Genotype by Environment additive main effects and multiplicative interaction (AMMI) analysis of small seed Common bean (*Phaseolus vulagris* L.) at Fadis east Hararghe, Oromia

*Habte Berhanu, Fikadu Tadesse and Motuma Dalasa
Fedis Agricultural Research Center P.O.Box:904
Oromia Agricultural Research Institute P.O. Box 81265, Addis Ababa/Finfinne, Ethiopia

Abstract

The objective of this study was to assess genotype by environment interaction for Seed yield in Common bean genotypes grown in East Hararhge by the AMMI (additive main effects and multiplicative interaction) model. The study comprised 12 Common bean genotypes, analyzed in 3 years at two locations through field trials. In the variance analysis, the model revealed that differences between the environments accounted for about 68.12% of the treatment sum of squares while the genotypes and the GxE interaction also accounted significantly for 38.22% and 72.29% respectively of the treatment sum square. The mean squares for the PCA 1 and PCA 2 were significant at P = 0.01 and cumulatively contributed to 26.63% and 43.95 respectively. The AMMI and AMMI stability value (ASV) identified G4 and G5 as the most stable genotypes and also identified Erer (E1) was identified as conducive environment as its IPCA2 score and vector was near to the source (zero). Genotypes with obtuse angles with test environments had below average yields at those particular sites.

Key words: AMMI, Genotype and stability

Introduction

Climate changes may result in strong impacts on agriculture, especially on crop growth and yield. Crops are largely determined by climate conditions during growing season; thus, even minor deviations from optimal conditions can seriously threaten yield (Odewale J. O., 2013). Common bean is the most economically important warm season pulse crop grown in Ethiopia. Currently, commercial farming of Common bean is growing though it is usually grown by subsistence farmers as a sole crop or intercropped with other crops (Nigussie Kefelegn, *et al*., 2020). The breeding program gives additional attention to market class or seed color and seed size. In the Ethiopian bean breeding program, about 57 common bean varieties were registered since 1973 (MoA, 2016).

The improvement of a crop is largely dependent on the nature and magnitude of available genetic variability, heritability, and the transfer of desired characters into new Varieties.

Plant breeders constantly encounter genotype x environment interactions (GEIs) when testing varieties across a number of environments. Depending upon the magnitude of the interactions or the differential genotypic responses to environments, the varietal rankings can differ greatly across environments. The AMMI model is a hybrid analysis that incorporates both the additive and multiplicative components of the two-way data structure. There for the present investigation was carried out to quantify the Genotype by environment interaction effect on yield and to determine the stable genotypes among the tested entities. The AMMI (Additive Main and Multiplicative Interaction) model suggested by Zobel *et al*. 1988 is considered to be a better model for analysis of G×E interaction in yield data of multi-location varietal trials. It not only gives estimate of total G×E interaction effect of each genotype but further partitions it into interaction effects due to individual environments. The present study in finger millet was undertaken to analyze G×E interaction using AMMI model and to evaluate stability and adaptability genotypes in different environments.

Materials and methods

In order to determine stable Common bean genotypes field experiments were conducted for three consecutive years (2018, 2019 and 2020) at two locations (Fadis and Babile). Therefore six environments were created. The experimental layout at each environment was RCBD with three replications.

Data analysis:

Additive means effect and multiplicative interaction model:

The AMMI model: Yger =μ+ αg + βe + ∑nλnγgnδen + εger +ρge;

where Yger was the observed yield of genotype (g) in environment (e) for replication (r); μ was the grand mean; αg is the deviation of genotype g from the grand mean, βe is the deviation of the environment e; λn was the singular value for interaction principal component axis (IPCA) n, γgn was the genotype eigenvector for axis n, and δen is the environment eigenvector; εger is the error term and ρge are PCA residuals

AMMI Stability Value (ASV): According to Purchase, (1997) ASV is the distance from the coordinate point to the origin in a twodimensional plot of IPCA1 scores against IPCA2 scores in the AMMI model. Because the IPCA1 score contributes more to the G x E interaction sum of squares, a weighted value is needed. This was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 as follows:

$$ASV = \sqrt{\left[\left(\frac{SSIPCA1}{SSIPCA2}\right)(IPCA1score)2\right] + (IPCA2score)2}$$

Where, SS_{IPCA1}/SS_{IPCA2} was the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype was to certain environments.

Genotype selection index

Based on the rank of mean grain yield of genotypes (RY) across environments and rank of AMMI stability value (RASV) a selection index called GSI was calculated for each genotype which incorporate both mean grain yield and stability index in a single criteria (GSI) as follow:

GSI=RASV+RY

Results and Discussion

Analysis of variance states that significant variation was there among the genotypes for seed yield. Genotypes and interaction show highly significant variation (at 0.01), while the environment shows significant variation (at 0.05).

Table 1 Estimate of analysis of variance for seed yield of Common bean genotypes

Source of variation	d.f.	Sum square	Mean square
Replication	2	0.26	0.13
Genotypes	7	561.1	80.157**
Environment	5	75.292	15.058*
Interaction	35	831.834	23.767**
Residual	94	686.844	7.307
Total	143	2155.331	

Mean seed yield of Common bean Genotypes

Significant variation was found among the genotypes for seed yield (Table2). Accordingly, maximum seed yield was harvested from G4 (241758) 18.45qt/ha followed by G5 (16378) 17.36qt/ha. Significant variation was found for number of pods/plant, number of seeds/pod and plant height. Maximum numbers of pods 14.54 and 13.96 were harvested from G5 (16378) followed by G4 (241758) respectively.

Table.2. Combined Mean of yield and other parameters of Common bean over year and location

Genotypes Name	Plant height	Pod/Plant	Seed/pod	Grain Yield(qt/ha)	Yield adva. st.check
G1(207942)	33.35b	15.2a	5.417ab	16.68ab	5.76
G2(241134)	39.33a	12.54ab	4.204b	13.94cd	-
G3(230778)	27.02c	7.7c	4.667ab	12.88d	-
G4(241758)	34.54ab	13.96a	5.463ab	18.45a	12.52
G5(16378)	32.61bc	14.54a	5.33ab	17.36ab	9.56
G6(16384)	35.8ab	15.3a	6.093a	17.09ab	8.05
G7(16392)	30.43bc	9.02bc	4.648ab	13.06d	-
G8(Awash-2)	30.93bc	16.54a	5.481ab	15.65bc	-
Lsd	5.68	4.56	1.71	2.38	
Cv	19.6	19.7	17.8	17.3	

Combined analysis of variance revealed highly significant ($P \leq 0.01$) variations among Genotypes, genotype x environment interaction and IPCA1 (Table 3). This result indicated that there was a differential yield performance among the Common bean genotypes across testing environments and the presence of strong genotype by environment (G X E) interaction. As G x E interaction was significant, further calculation of genotype stability is possible.

Table 3. Additive main effects and multiplicative interactions analysis of variance for grain yield (kg ha-1) of the genotypes across environments

Source of variation	d.f.	sum square	mean square	Explained (%)
Total	143	21553309	150722	
Environments	5	14682267	312389**	68.12
Genotypes	7	5611002	801572**	38.22
Block	12	1219946	101662	14.66
Interactions	35	8318341	237667**	72.29
IPCA 1	11	6012913	546628**	26.63
IPCA 2	9	1601485	177943*	43.95
Residuals	15	703943	46930	
Error	84	5651096	67275	

NB: **=highly significant, *=significant, d.f=degree of freedom, s.s.=sum square, m.s.=mean square

The AMMI analysis of variance of grain yield (kg ha-1) of the 8 genotypes tested in six Genotypes showed that 68.12% of the total sum of squares was attributable to environmental effects, and genotypic effects, contributes 38.22% while the interaction attributes 72.29% (Table 3). A large sum of squares for environments indicated that the environments were diverse, with large differences among environmental means causing most of the variation in grain yield. The magnitude of the interaction sum of squares was two times larger than that for genotypes, indicating that there were substantial differences in genotypic response across environments.

According to the suggestion of Purchase, (1997) smaller ASV value indicated a more stable genotype across environments. From the AMMI stability values genotype G4 score smaller ASV (0.856737) indicating that the genotype is more stable than the tested genotypes. Genotype G4 is high yielding and more stable. G5 is the second ranking in terms of yield, but it is not stable genotype.

Table. 4 Estimate of AMMI Stability Value

Genotype	Mean	IPCAg1	IPCAg2	ASV
G1	16.68	1.13827	-1.07576	2.454275
G2	13.94	2.53022	-0.37279	4.917673
G3	12.88	-0.18686	1.86686	1.901659
G4	18.45	-0.4419	0.02421	0.856737
G5	17.36	-1.55817	-0.3976	3.04577
G6	17.09	-1.67485	-1.24671	3.477025
G7	13.06	-0.60257	0.81289	1.422841
G8	15.65	0.79586	0.3889	1.590637

Conclusion and Recommendation

ANOVA stated that significant variation was observed among the genotypes for yield and yield related components. AMMI stability model revealed significant variation was estimated for Genotypes, interaction and IPCA1. G4 (241758) and G5 (16378) were the high yielding, stable and tolerant to diseases (stem maggot) having 13% and 10% yield advantages respectively. Therefore, G4 (241758) and G5 (16378) are selected for Variety verification trial.

Reference

Gauch, H.G., 1992. Statistical analysis of regional yield data: AMMI analysis of factorial designs. Amsterdam, Elsevier.

Ministry of Agriculture and Natural Resource, Plant Variety Release Protection and Seed Quality Control Directorate, Crop Variety Registration, Ministry of Agriculture and Natural Resource, Addis ababa, Ethiopia, 2016

Nigussie Kefelegn Frew Mekibib, and Yigzaw Dessalegn, 2020. Genetic Advancement and Variability of Released Common Bean (Phaseolus vulgaris L.) Varieties from 1974–2009 GC in Ethiopia. *Advances in Agriculture*

Odewale J. O., Ataga C. D., Agho C., Odiowaya G., Okoye M. N. and Okolo E. C., 2013. Genotype evaluation of coconut (Cocos nucifera L.) and mega environment investigation based on additive main effects and multiplicative interaction (AMMI) analysis. *Research Journal of Agricultural and Environmental Management* Vol. 2(1), pp. 001-010

Zobel, R.W., J.W. Madison and H.G. Gauch, 1988. Statistical analysis of a yield trial. Agron. J., 80: 388-393.

Participatory Variety Selection of Improved Irish Potato (*Solanium tuberosum* L) Varieties at North Shewa, Oromia, Ethiopia

Zewdu Tegenu, Geleta Negash and Gashaw Sefara
Oromia Agricultural Research Institute (IQQO), Fitche Agricultural Research Centre, Fitche, Oromia, Ethiopia
Corresponding author: zedtegenu@gmail.com

Abstract

Participatory varietal selection involves both scientific measurements and farmers' evaluations; hence it has emerged as the best method to identify farmers' preferred crop varieties and their popularization. The experiment was conducted during the 2020 cropping season at two kebele Degam districts of North Shewa, *Zone of Oromia Region. The objective of the study was to identify adaptable, high-yielding, and diseases and pest tolerant potato varieties based on farmer`s performance and to evaluate and select potato varieties based on farmer's preference. The treatments were arranged in a randomized completed block design (RCBD) with three replications for the mother trial and farmers were used as replication for baby trials. Treatments have consisted of five potato varieties including standard check. Both agronomic data and farmers' preferences toward the varieties were collected and analyzed using* Statistical Analysis System (SAS) version 9.2 Software *and matrix ranking respectively. The analysis result showed that there were significant (p<0.05) differences among the varieties in all agronomic parameters except a number of Unmarketable yield and number of tubers per hill. Variety Gudane gave the highest yield (42.98*tons/ha*) followed by Belete (36.76*tons/ha*) and Moti (30.93*tons/ha*). Matrix ranking of farmers' preference also showed that Gudane, Belete, and Moti varieties ranked first and second in both kebele. Ararsa and Hunde were not only the low-yielding variety but also the least preferred varieties by farmers in the study kebele. Farmers also Selected Gudane for earliness higher marketable yield and vegetative performance. Therefore based on the findings, Gudane and Belete varieties could be recommended to potato growers in the study area and similar agroecology for further promotion and the two varieties (Moti and Hunde) could be used by potato breeders in their breeding program to exploit their merits*

Keywords: *Farmers' Preferences, Irish potato improved variety, Participatory Variety Selection*

Introduction

The Irish potato (Solanum tuberosum L.) is one of the most widely grown tuber crops in the world and contributes immensely to human nutrition and food security (Karim *et al*., 2010). It is popularly known as 'The king of vegetables', the fourth most important food crop in the world after rice, wheat, and maize in terms of human consumption (Kandil *et al*., 2011). In Ethiopia, the potato has promising prospecting of improving the quality of the basic diet in both rural and urban areas (Abebe *et al*., 2017). Potato is an important crop for smallholder farmers in Ethiopia, serving both as a cash crop and food security crop. It is a short-duration crop that can mature within a short period. It contains practically all essential dietary constituents like carbohydrates, essential nutrients, protein, vitamins, and minerals (Sriom *et al*., 2017). Potato production has been considered as the priority compared to other food crops because of its contribution to food security, income generation and double cropping and its utilization in different forms (Lung'aho *et al*., 2007 and Muthoni J and Nyamongo,2009). In Ethiopia, the variety development study began in 1975 to develop varieties that are high yielder, widely adaptable, and resistant to late blight, which is the most devastating disease (Gebremedhin *et al*., 2008), and about 31 varieties were formally released for production for wider adaptation (MOA, 2013). Wider adaptation and researchers' criteria may not fit all agro-ecologies and fulfill farmers' preferences. Agro-ecologies varied concerning soil type, moisture and temperature regimes, fertility condition and the onset, intensity, and duration of rain as well as irrigation facilities, where farmers thrive to grow potato (Gebremedhin *et al*., 2008). Many varieties are officially released, but few are adopted by farmers. In contrast, farmers often grow varieties that have not been officially released, a phenomenon known to be associated not only with an inefficient and biased testing system before variety release, but also with breeders using different selection criteria from the farmers and particularly G×E interactions in the case of farmers in marginal environments (Ceccarelli, 2012). That is why in many parts of Ethiopia farmers grow their local varieties (Gebremedhin *et al*., 2001). Many potato varieties were released at national and regional but all released potato varieties were not tested until today in the north shewa zone of the Oromia region. In the study area that root and tuber crops especially potatoes took great account in their production and food system but still, many farmers use local varieties. Participatory Variety Selection (PVS) can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old or obsolete varieties (Witcombe *et al*., 1996). Therefore; the current study aimed to test the adaptability of different improved potato varieties through a participatory variety selection approach and recommend the best performing variety to farmers to increase production and productivity.

Materials and Methods

Description of the Experimental Site

The experiment was conducted at one location (Degam farmers' training centers (FTC) for mother trials and on seven farmers' fields for baby trials) during the 2020/21 main cropping season. The district is located 124 km North-West of Addis Ababa, and 12 km from Fitche, the capital city of North Shewa Zone, and Oromia Regional State. Geographically, the district is situated at the latitudes of 9°34′ to 10°03′N and longitudes of 38°29′ to 38°44′E. The site is located at 9°49′48.2″ North latitude and 38°33′43.8″ East longitude with an elevation of 2897 m above sea level. The temperature varied between 5.6°C to 23°C. The annual rainfall ranges from 800 mm to 1300 mm and the rainfall pattern is bi-modal; a short rainy season (Belg) from February to March, and a main rainy season (Kiremt) that extends from June to September. The study area is characterized by *Nitosol* which is locally known as '*Biye Dima*. Barley is the major crop produced in the area (Anonymous, 2017).

Breeding materials and experimental design

Five (5) improved Irish potato varieties (Gudane, Belete, Moti, Ararsa, and Hunde) were used as a testing crop. The varieties were brought from Sinana Agricultural Research Center. The treatments were arranged in randomized completed block design with three replications for the mother trial (Degam subsite) and seven farmers' fields were used as replication for baby trials. At mother trial and baby trials sites, the materials were planted on a plot size of, 3 m length and 3.75 m width =11.25 m^2 having 5 rows with 75 and 30 cm between rows and plants respectively. Inputs (tubers, fertilizers) and management practices were applied as recommended for Irish potato production. Data were collected in two ways: agronomic data and farmer's data. For agronomic data phenological, growth, yield, and yield components were collected following their principles. At the vegetative and harvest stage of potatoes, the training was arranged.

Field Management

The experimental field was prepared following the conventional tillage practice using an oxen plow. The medium-sized potato tubers (35-45) mm in diameter and well-sprouted tubers were planted at the spacing of 75 cm between ridges and 30cm between tubers. Urea fertilizer was applied in the split that is 50% during the time of planting and the rest 50% urea was applied near to tie of flowering while all the NPS at time of planting. On the other hand, weed control was done timely by hoeing. The first, second, and third earthling-up were done 15, 30, and 45 days after planting to prevent exposure of the tubers to direct sunlight, promote tuber bulking, and ease of harvesting. Haulms were mowed two weeks before harvesting at physiological maturity for reducing skinning and bruising during harvesting and post-harvest handling.

Agronomic Data Collection

Data collected were days to 50% flowering, days to maturity, plant height(cm), stand counts, tuber sizes(cm), tuber number per hill, number of marketable, unmarketable yield the weight of marketable yield(g), total tuber yield (t/ha), and diseases. All data were based on the recommended recording stage and methods.

Farmers Data Collection

Potato varieties were evaluated before harvest and at harvest by 14 farmers (12 males and 2 females) at each site. Before the evaluation of varieties was carried out, selected farmers at different sites were familiarized with the selection procedure and criteria. Farmers' evaluation and selection criteria data were collected on a plot basis from the two baby trials i.e., farmers were grouped around each host farmer of the trials. Farmer's evaluation criteria were tuber number per hill, tolerance to disease, days to maturity, tuber size, palatability, marketability, and high yielder. The ranking procedure was explained for farmer participants and then each selection criterion was ranked from 1 to 5 (5=very good, 4=good, 3=average, 2=poor, and 1=very poor) for each variety.

Data Analysis

Farmers' selection data were analyzed using the simple ranking method with a given value. Agronomic data were subjected to ANOVA by using Statistical Analysis System (SAS) version 9.2 Software (SAS, 2008). Means that differed significantly were separated using the LSD (Least Significant Difference) test at 5% level of significance.

Results and Discussion

Phenology and Growth

The mean values for the five (5) varieties are shown (Table 1). The variation for days to flowering and maturity was ranged from 74.33 to 87 and 128 to 136 days respectively. Based on the study result, the longest days to 50% flowering was revealed by Belete and Ararsa (87 and 85 days) followed by Hunde (82.67 days) respectively. However, early flowering was recorded for varieties Gudane(74.33 days) followed by Moti (79.67 days). In other cases, variety Gudane was an early maturing variety (124 days) followed by Belete (128 days). Among the tested varieties, Ararsa was late maturing with 136 days followed by Hunde, and Moti (134 and 130 days) respectively. The mean values revealed that the highest stand count was recorded by Gudane variety (28.67) followed by variety Belete (26) respectively. However, the lowest stand count was Ararsa variety (20) followed Hunde variety (22.33) respectively. Stem density, which is influenced by genetic makeup, increases tuber yield as stem density increases numbers of tubers, or size of tubers, or both (Zelalem. *et al., 2009*). The longest plant height was exhibited by Gudane variety (61.89cm) followed by Moti variety (60 cm). However, the shortest plant height was recorded by Ararsa variety (31.77cm) followed by Hunde variety (37.89cm) respectively (Table 1). These differences in plant height among the varieties may be caused by plant genetics and the quality of the plant material (Eaton *et al*., 2017).

Yield and Yield Components

Based on agronomic data results showed that the highest tuber number per hill was recorded from moti variety (10.80) followed Gudane, and Belete variety (10.73 and 8.40) respectively. Whereas the lowest tuber number per hill from Ararsa variety (8.40). The highest weight of marketable yield was recorded from Belete variety (4056.7g) followed Gudane variety (3873g) whereas the lowest weight of marketable yield was from Ararsa variety (1079.9g) and followed Hunde varieties (1896.2g). Variation among different varieties in the number of tuber marketable yield may be due to the genetics, management practices, the seed quality, or the agro-ecological conditions of the experimental sites (Eaton *et al*., 2017, Amdie *et al.* 2017). Significant variations were revealed among potato varieties number tuber marketable yield and weight of tubers marketable yield (Addis *et al*.,2017)The highest number of unmarketable yields were obtained from Ararsa variety (3.73) followed by Moti variety (3) respectively whereas the lowest number of unmarketable yield Gudane variety (1.73) followed by Belete variety (1.87) was recorded respectively. In other cases, the highest total tuber yield was obtained from Gudane variety (42.98tha-1) followed by Belete variety (36.76tha-1) respectively whereas the lowest total tuber yield Ararsa variety (16.99tha-1) followed by Hunde variety (21.64tha-1) was recorded respectively (Table 1). Thus, the yield differences between these varieties may be related to their genetic makeup in the efficient utilization of inputs like nutrients as reported by (Tisdale *et al*., 1995) Significant variations were revealed among potato varieties for no number of tuber per hill and number of unmarketable tuber yields (Tapiwa *et al*., 2016) Reported a significant difference in the yields due to genetic makeup of potato varieties

Farmer’s Variety Selection Criteria's

Farmers’ perceptions on the performance of potato varieties were tested in the study area and analyzed using matrix ranking. Farmers were informed to set criteria for selecting the best Irish potato variety according to their area before undertaking varietal selection. This was done by making group discussion among the farmers which comprises elders, women, and men. After setting the criteria they were informed to prioritize the criteria according to their interest. By doing this, farmers were allowed to select varieties by giving their value. Accordingly, tolerance to disease, Palatability, maturity, tuber number per hill, tuber size, marketability, and high yielder. Based on set criteria, the evaluated varieties were revealed various values by the evaluators (farmers). With this regard, farmers selected/ranked the varieties Gudane (1st), Belete (2nd) and Moti (3rd) were showed better performance tolerance to disease, highest tuber number per hill, tuber size, Palatability, maturity, good for marketability, and highest yielder. However, farmers ranked least Ararsa (5th) and Hunde (4th) potato varieties respectively (Table 2). This suggestion is in agreement with that of (Witcombe *et al*., 1996) who report participatory variety selection can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old or obsolete varieties. This suggestion is consistent also with that of(Chambers *et al*.,1989) who reported that identification of suitable improved, released cultivars to provide a large ‘basket of choices’ to farmers. On the other hand, (Witcombe *et al*., 2008) reported that PVS is a more rapid and cost-effective way of identifying farmer-preferred cultivars if a suitable choice of cultivars exists. Hence, Research costs can be reduced and adoption rates increased since farmers participate in variety testing and selection. Moreover, (Graham *et al*., 2001) reported that farmers were actively involved in plant breeding at various levels of the breeding process; the new varieties were successfully adopted. Furthermore, (Ortiz *et al.*,2008) reported that participatory methods consider the value of farmers' knowledge, their preferences, ability and innovation, and their active exchange of information and technologies as it was demonstrated during the farmer field school approach.

Table 1: Mean values of yield and yield components of potato varieties from mother trial at Degam districts in 2020/21 main cropping season

Variety	DF	DM	PH(cm)	SC	TS(cm)	NTH	NMY	WMY(g)	NUMY	TtYtH
Moti	79.67^{c}	110.00^{c}	60.00^{ab}	25.67^{b}	19.87^{b}	10.80	8.07^{ab}	3611.9^{a}	3.00	30.93^{c}
Belete	87.00^{a}	108.00^{d}	53.55^{b}	26.00^{b}	21.33^{a}	8.40	6.67^{b}	4056.70^{a}	1.87	36.76^{b}
Gudane	74.33^{d}	104.00^{e}	61.89^{a}	28.67^{a}	17.73^{c}	10.73	9.00^{a}	3873.0^{a}	1.73	42.98^{a}
Hunde	82.67^{b}	114.00^{b}	37.89^{c}	22.33^{c}	17.80^{c}	9.07	6.53^{b}	1896.20^{b}	2.60	21.64^{d}
Ararsa	85.00^{a}	116.00^{a}	31.77c	20.00^{c}	17.47^{c}	8.40	3.87^{c}	1079.90^{c}	3.73	16.99^{d}
Mean	81.73	110.40	49.02	24.53	18.84	9.48	6.83	2903.55	2.59	29.66
Lsd(5%)	8.00	12	8.27	2.49	1.38	3.35	1.92	793.75	2.01	2.94
Cv(%)	1.30	8.66	8.97	5.37	3.87	18.77	14.96	14.52	41.23	15

Keys: DF =Days to flowering date, DM= Days to maturity, PH=plant height (cm), SC=Stand count, TS(CM)=Tuber Size NTH= Number tubers per hill, NMY =Number of Marketable yield, WMY (g)= weight of Marketable yield, NUMY = Number Unmarketable yield, TtYtH= and Total tuber yield tons per hectare Means followed by different letters within columns are significantly different by Duncan’s new multiple range test (P = 0.05).

Disease Reaction Score

From this graph, the varieties Ararsa, Hunde, and Moti were highly susceptible to late blight disease whereas Belete, and Gudane varieties have tolerance reactions against the disease (Figure1)

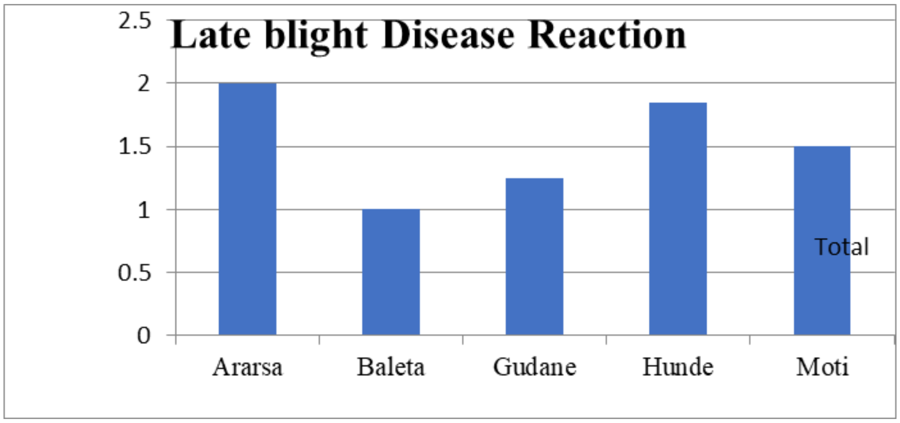


Figure 1. Mean of disease score per varieties.

Scores: 0=highly disease resistant, 1=disease resistant, 2=moderate disease resistant, 3=susceptible, 4=highly susceptible, 5=Very susceptible

Table 2: Farmers' preference scores and ranking for baby trials at Degam of north shewa zone, during 2020/21 cropping season

		Farmers selection criteria.									
Variety	Location	dise	Pality	Mrity	No trs	Tr size	Mblty	yielder	Total	Average	Rank
	A/Doro	20	30	30	20	40	35	49			
Gudane	G/Shano	25	35	35	35	50	55	56	515	36.79	1
	A/Doro	16	14	24	30	35	55	40			
Belete	G/Shano	25	28	25	40	50	52	50	484	34.57	2
	A/Doro	30	22	22	16	30	35	40			
Moti	G/Shano	20	25	24	35	42	24	16	381	27.21	3
	A/Doro	36	18	8	30	35	16	20			
Hunde	G/Shano	35	20	18	20	25	23	30	334	23.86	4
	A/Doro	36	11	9	40	39	30	12			
Ararsa	G/Shano	34	7	6	30	25	20	13	312	22.29	5

Rank: Degree of satisfaction 5=very good, 4=good, 3=average, 2=poor and 1=very poor

Table 2: Farmers' preference scores and ranking for baby trials at Degam of north shewa zone, during 2020/21 cropping season

Variety	Location	Farmers selection criteria.							Total	Average	Rank
		dise	Pality	Mrity	No of trs	Tr size	Mblty	yielder			
Gudane	A/Doro	20	30	30	20	40	35	49	224	32.00	1
Belete	A/Doro	16	14	24	30	35	55	40	214	30.57	2
Moti	A/Doro	30	22	22	16	30	35	40	195	27.86	3
Hunde	A/Doro	36	18	8	30	35	16	20	163	23.29	4
Ararsa	A/Doro	36	11	9	40	39	30	12	177	25.29	5

Conclusions and Recommendations

In varieties selections, different criteria were considered by farmers which mostly matched researchers' selection criteria. The result of this study indicated that Gudane and Belete were higher-yielding and the most preferred potato varieties by farmers in the study area. Therefore, based on these findings, Gudane and Belete could be recommended to potato growers in Degam Districts for further promotion. However, the experiment was done for one year and in one location, so it needs further study under different agro-ecologies and additional years to determine the best-high yielder and to increase the production and productivity of Potato varieties in the study area.

Acknowledgments

The authors were greatly indebted to acknowledge Oromia Agricultural Research Institute and Fitche Agricultural Research Centre (FiARC) to facilities and operate the research. Sinana Agricultural Research Center for providing us planting materials of Irish potato for conducting the research. Lastly, the authors acknowledge participated farmers in the evaluation and for their indigenous technical support, land, and labor.

References

Abebe Chindi, Egata Shunka, Atsede Solomon, Gebremedhin W/Giorgis, EbrahimSeid, *et al.* (2017) Participatory potato seed production: a breakthrough for food security and income generation in the central highlands of Ethiopia. Open Agriculture 2(1): 205-212.2.

Addis S, Dessalegn R, Wakene T. Irish Potato (Solanum tuberosum L.) variety evaluation atBule Hora District of Borena Zone. Global Journal of Science Frontier Research: D Agriculture and Veterinary. 2017;17(2).

Amdie A, Afeta T, Bobo T (2017). Adaptability study of improved Potato (Solanumtuberosum L.) varieties in highland of Guji zone, Southern Oromia. Acad. Res. J. Agri. Sci. Res. 5(3): 186-191

Anonymous, 2017.Degam Woreda profile North Shewa Zone,Oromia Regional State Unpublished.

Ceccarelli S, Grando S, Booth RH.1996. International breeding programmes and resourcepoor farmers: crop improvement in difficult environments. In: Eyzaguirre P, Iwanaga M (eds.).

Participatory plant breeding. Proceeding of a workshop on participatory plant breeding, 26-29 July 1995, Wageningen, The Netherlands. IPGRI, Italy, pp 99-116.

Ceccarelli, S. 2012. Plant breeding with farmers a technical manual. ICARDA, PO Box 5466, Aleppo, Syria.

Chambers R. Institutions and practical change: Reversals, institutions and change. In, R. Chambers, A. Pacey LA. Thrupp, eds. Farmer first. London: Intermediate Technology Publications. 1989;181-195.

Eaton TE, Azad AK, Kabir H, Siddiq AB. Evaluation of Six Modern Varieties of Potatoes for Yield, Plant Growth Parameters and Resistance to Insects and Diseases. Agricultural Science 2017;8(11):1315–26.

Gebremedhin, G.; W. Giorgis; EndaleGebre; Kiflu Bedane; Bekele Kassa. 2001. Country Profile on Potato Production and Utilization: Ethiopia. Ethiopian Agricultural Research Organization (EARO), Holetta Agricultural Research Centre, National Potato Research Program.

Graham T, Van de Fliert E, Campilan D. What happened to participatory research at the International Potato Center? Agriculture and Human Values. 2001;18:429-446.

Kandil, A.A., Attia, A.N., Badawi, M.A., Sharief, A.E. and Abido, W.A.H (2011). Effect of Water Stress and Fertilization with Inorganic Nitrogen and Organic Chicken Manure on Yield and Yield Components of Potato. Australian Journal of Basic and Applied Sciences, 5(9):9971005

Karim, M.R., M.M. Hanif, S.M. Shahidullah, A.H.M.A. Rahman, A.M. Akanda and A. Khair, 2010. Virus free seed potato production through sprout cutting technique under net-house. African J. Biotech., 9: 5852–5858

Lung'aho C, B Lemaga, M Nyongesa, P Gildermacher, P Kinyale, *et al*. (2007) Commercial seed potato production in eastern and central Africa. Kenya Agricultural Institute, Pp. 140.4.

MOA (Ministry of Agriculture), 2013. Animal and plant healath regulatory Directorate, Crop Variety Registration ,No. 13, Addis Abeba Ethiopia.

Muthoni J, Nyamongo DO (2009) A review of constraints to ware Irish potatoes production in Kenya. Journal of horticulture and forestry 1(7).5. Gildemacher PR, Demo P, Barker I, Kaguongo W, Woldegiorgis

Ortiz O, Frias G, Ho R, Cisneros H, Nelson R, Castillo R, et al. Organizational learning through participatory research: CIP and Care in Peru. Agriculture and Human Values. 2008;25: 419-431.

SAS Institute Inc. (2008). Statistical analysis Software version 9.2, Cary, NC: SAS Institute Inc. USA

Sriom DPM, Priyanka R, Devraj S, Rajat KS, Sudhir KM (2017) Effect of Different Levels of Nitrogen on Growth and Yield in Potato (Solanumtuberosum L.) CV. KufriKhyatiInt J CurrMicrobiol App Sci 6(6): 14561460.3.

Tapiwa R Mpemba. Evaluation of new Irish Potato (Solanum tuberosum L.) varieties for yield potential in Zimbabwe. BSc thesis, Midlands State University, Faculty of Natural Resources Management and Agriculture; 2016.

Tisdale SL, Nelson W, Beaton JD, Havlin JL. Soil fertility and fertilizers. 5th edition. Macmillan, USA; 1995.

Witcombe JR, Joshi A, Joshi KD, Sthapit BR. Farmer participatory crop improvement. I. Varietal selection and breeding methods and their impact on biodiversity. Experimental Agriculture. 2008;32(04):445.

Witcombe JR, Joshi A, Joshi KD, Sthapit BR. Farmers participatory crop improvement. I. Varietal selection and breeding methods and their impacts on biodiversity. Expl Agric. 1996;32:445-460.

Zelalem A, Tekalign T, Nigussie D. Response of potato (Solanum tuberosum L.) to different rates of nitrogen and phosphorus fertilization on vertisols at DebreBerhan, in the central highlands of Ethiopia. African Journal of Plant Science. 2009;3(2):16-24.

Evaluation of Improved Tef (Eragrostis tef) varieties at North Shewa, Oromia, Ethiopia

Geleta Negash[1,*], Zewdu Tegenu[2], Gashaw Safara[2]

[1*2] Oromia Agricultural Research Institute (IQQO), Fitche Agricultural Research Centre, Fitche, Oromia, Ethiopia

Abstract

Tef is endemic to Ethiopia and its major diversity is found only in that country as with several other crops. The exact date and location for the domestication of tef is unknown. The information of the interface between varieties and environment with yield and yield components is important aspect of effective selection in crop improvement. Therefore, the objective of this study was: to evaluate and identify tef varieties with high grain yield and yield stability with good agronomic performance across locations. The study was conducted on fifteen enhanced tef varieties, against local check at Fitche Agricultural Research Center in 2020/21cropping season. Analysis of variance detected significant difference, among varieties in separated and combined analysis of variance. The combined ANOVA and AMMI analysis for grain yield across environments indicated significantly affected by environments, explained 81.23% of the total variation. Varieties and variety x environmental interation were significant and accounted for 6.73% and 7.58 %, respectively.PCA1 and PCA2 accounted for 3.59 % and 2.71 % of the GEI, respectively, with a total of 6.3 % variation. Generally, Dagim and Nigus were identified as better varieties for yielding ability and stability across environments and will be demonstrated and widely disseminated for end user.

Keywords*: AMMI, GGEI, Performance, Stability, Eragrostis tef*

Introduction

Tef (Eragrostis tef) is belongs to the family Poaceae. It is self-pollinated, chasmogamous annual cereal crop. It is an allotetraploid plant with a chromosome number of 2n =40 and the basic chromosome number of the genus Eragrostis is x =10 (Tavassoli, 1986). Tef is endemic to Ethiopia and its major diversity is found only in that country as with several other crops. The exact date and location for the domestication of tef is unknown. However, there is no hesitation that it is a very ancient crop in Ethiopia. According to Ponti (1978), tef was introduced to Ethiopia well before the Semitic invasion of 1000 to 4000 BC. In Ethiopia, tef is traditionally grown as a cereal crop. The grain is ground to flour which is mainly used for making popular pancake-like local bread called enjera and sometimes for making porridge. The grain is also used to make local alcoholic drinks, called tela and katikala. Tef straw, in addition being the most appreciated feed for cattle. Is also used to reinforce mud and plaster the walls of tukuls and local grain storage facilities called gotera. Tef is adapted to a wide range of environments and is currently cultivated under diverse agro climatic conditions from sea level up to 2800masl, under various rainfall, temperature and soil regimes. However, according to experiences from different locations across the country, tef performs excellently at an altitude of 1800-2100masl, annual rainfall of 750-850 mm, growing season rainfall of 450-550 mm and a temperature range of 10°C-27°C.

In Ethiopia, tef cultivation is the same way as wheat and barley. Under current farmers' practices, tef field is ploughed two to five times depending on the soil type, weed conditions and water logging. Seed bed packing is done before sowing of tef to make the seed bed firm, prevent the soil surface from drying quickly, assist germination of seeds and minimize the damaging effect of high moisture during late onset of rain. Packing of the seed bed is also practiced to free the seed bed from weeds by turning them tinder. Overcoming low grain yield, and production constraints such as lodging, drought, water logging, heat and frost is overcoming production constraints and improving productivity of the crop.

Introduction for sustainable and stable food production and sustain food security, maintaining genetic diversity within and between crop types is increasingly being realized as the most appropriate and indispensable action. This is further emphasized by unpredictable human food needs, changes in taste, technological demand and the biotic and a biotic production constraint that change with the environments. Identifying, maintaining and using crop types that can grow under various stress and limiting conditions with capable of environmental fluctuations is the most indispensable. Environmental instabilities and interaction with crop plant are the major constraint of cereal crops including tef production and productivity. Genotype/variety x environment (GE) interaction reduces genetic progress in plant breeding programmes through minimising the association between phenotypic and genotypic values (Comstock and Moll, 1963). Consequently,multi-environment yield trials are significant in assessment of genotype by environment interactionn (GEI),identification of superior and stable genotypes in the final selection cycles (Kaya et al., 2006; Mitrovic et al., 2012). Phenotypes are a mixture of genotype (G) and environment (E) components and their interactions (G x E).Genotype by environment interactionn (GEI) is a complicate process of selecting genotypes with superior performance. Terefore, multi-environment trails (METs) are commonly used by plant breeders to assess the relative performance of genotypes for target environments (Delacy et al., 1996). The additive main effects and multiplicative interaction (AMMI) model have directed to more understanding of the complicated forms of genotypic responses to the environment (Gauch, 2006).These patterns have been successfully related to biotic and abiotic factors. Yan et al. (2000), proposed another methodology known as GGE-biplot for graphical exhibit of GE interaction pattern of MET data with many advantages. GGE biplot is an effective method based on principal component analysis (PCA) which fully explores MET data. It allows visual inspection of the associations among the test environments, genotypes and the GE interactions. The first two principle components (PC1 and PC2) are used to produce a two dimensional graphical display of genotype by environment interaction (GGE-biplot). If a large portion of the variation is explained by these components, a rank-two matrix, represented by a GGE- biplot, is appropriate (Yan and Kang, 2003). Using a mixed model analysis may present superior results when the regression of genotype by environment interaction on environment effect does not explain all the interaction (Yan and Rajcan, 2002).Therefore, the objective of this study was: to identify tef varieties with high level of grain yield and yield stability across locations.

Materials and Methods

Study Area

The multi-location yield evaluation (MLYT) was conducted on six locations at Fitche Agricultural Research Center sub sites (H.Abote, Kuyu, W.Jarso, Wachale,Y.Gulale and G. Jarso) in North shewa, Oromia, Ethiopia, during the 2020/21 main cropping season.

Breeding materials and experimental design

Totally, fifteen released tef varieties (Table1) including local check were evaluated using randomised completed block design (RCBD) with three replications. Six rows per plot of 0.2 m spacing between rows and 3m row length and harvestable plot size was 2.4 m^2 (four harvestable rows per plot) . A seed rate of 20kgha^{-1} and fertiliser rate of 100kgha^{-1} NPS and 100kgha^{-1} UREA were used.

Statistical analysis

Analysis of variance was calculated using the model:Yij = μ + Gi + Ej + GEij, Where: Yij is the corresponding variable of the i^{-th} genotype in j^{-th} environment, μ is the total mean, Gi is the main effect of i^{-th} genotype, Ej is the main effect of j^{-th} environment, GEij is the effect of genotype x environment interaction.

The AMMI model used was: $Y_{ij} = \mu + g_i + e_j + \sum_1^N \lambda k\ Yik\ \delta jk + \varepsilon ij$

Where: Yij is the grain yield of the i^{-th} genotype in the j^{-th}environment, μ is the grand mean, gi and ej are the genotype and environment deviation from the grand mean, respectively, ʎk is the eigenvalue of the principal component analysis (PCA) axis k, Yik and δjk are the genotype and environment principal componentscores for axis k, N is the number of principal components retained in the model, and Ɛij is the residual term.

Table1. List of evaluated released tef varieties

No	Variety	No	Variety	No	Variety
1	Abay	6	Flagot	11	Kuncho
2	Boset	7	Guduru	12	Local
3	Dagim	8	Hiber1	13	Nigus
4	Dursi	9	Kena	14	Tesfa
5	Estub	10	Kora	15	Warekiyu

GGE-biplot methodology, which is composed of two concepts, the biplot concept (Gabriel, 1971) and the GGE concept (Yan et al., 2000) was used to visually analyse the METs data. This methodology uses a biplot to show the factors (G and GE) that are important in genotype /varieties evaluation and that are also the sources of variation in GEI analysis of METs data (Yan, 2001).The GGE-biplot shows the first two principal components derived from subjecting environment centered yield data (yield variation due to GGE) to singular value decomposition (Yan et al., 2000)

AMMI Stability Value (ASV)

ASV is the distance from the coordinate point to the origin in a two-dimensional plot of IPCA1 scores against IPCA2 scores in the AMMI model (Purchase, 1997). Because the IPCA1 score contributes more to the GxE interaction sum of squares, a weighted value is needed. This weighted value was calculated for each genotype and each environment according to the relative contribution of IPCA1 and IPCA2 to the interaction sum of squares as follows:

$$ASV=\sqrt{[(SSIPCA1 + SSIPCA2)(IPCA1score)]2 + (IPCA2score)2}$$

Where: SS_{IPCA1}/SS_{IPCA2} is the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype is to certain environments. A smaller ASV values indicate more stable genotypes across environments (Purchase, 1997).

Genotype Selection Index (GSI): stability is not the only parameter for selection as most stable genotypes would not necessarily give the best yield performance.

Therefore, based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value (RASVi), genotype selection index (GSI) was calculated for each genotype/varieties as:

GSIi = RASVi + RYi

A genotype with the least GSI is considered as the most stable (Farshadfar, 2008). Analysis of variance was carried out using Statistical Analysis System (SAS) version 9.2 Software (SAS, 2008). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 15th edition statistical package (VSN, 2012).

Data collection method

Sample were selected randomly before heading from each row (four harvestable rows) and tagged with thread and plant-based data were collected from the sampled plants.

Plant-based

Plant height, Spike length and productive tillers, Plant height (cm); was measured and recorded when it reached at 95% physiological maturity from the ground level to the base of the spike of plant. Spike length (cm); was measured from the base of the spike to the tip of the highest spikelet.

Plot based

Days to heading, days to maturity, grain filling period, biomass, grain yield and harvesting index. Days to heading; was recorded by counting the number of days from sowing to the time when at least 50% of the heads of the plot fully exerted from the boom or flowered. Days to maturity; was recorded by counting the number of days from sowing to the days when 95% of the heads of the plot were physiologically matured; yield per plot was taken and moisture was adjusted to the standard moisture content of 12% moisture basis after threshing the crop using moisture tester by the following formula.

It was calculated as: Adjusted yield per plot = Actual yield per plot (100-Y/100-X), Where =Actual yield is yield per a given area in a unit at threshing, Y = is moisture in % age at threshing,X= is standard moisture in % age.

Results and discussions

Combined analysis of variance (ANOVA)

The mean square of analysis of variance for all varieties at different environmental conditions, for grain yield and yield related traits, are presented (Table 2). Highly significant differences were noticed among treatments ($P \leq 0.01$) for all parameters. The combined analysis of variance showed that location by treatment effects was significant for all parameters. Treatment by environment interaction mean square was highly significant ($P \le 0.01$) for all parameters.

Table: 2 combined analysis of variance (ANOVA) for grain yield and yield related traits

S. V	DF	DH	DM	GFP	PTL	SL	PH	BM kgha-1	YLD kgha-1	HI
loc	5	7984.9**	11420.3**	3399.7**	72.3**	1205.0**	7996.8**	289548369**	22947243.3**	737.9**
rep	2	20.3*	72.6**	20.6 ns	24.2**	79.9**	124.0*	731835 ns	107178 ns	3.4ns
trt	14	85.9**	485.1**	329.3**	8.9**	180.4**	179.4**	2617662**	742875.9**	169.1**
loc*trt	70	33.1**	126.1**	147.4**	3.5**	29.6**	44.8**	2752225**	187871.4**	90.6**
rep*trt	28	4.7 ns	5.9 ns	8.8 ns	1.2 ns	9.9 ns	21.14	148473	23495.5 ns	24.2 ns

ns * ** non –significant, significant at 5% and 1% respectively, Loc *trt = location by treatment, Loc= location, trt = treatment, rep = replication, rep*trt = replication by treatment, DF = degree of freedom, DH = Days to Heading, DM = Days to Maturity, PH = Plant Height, GFP= grain filling period, PTL= productive tillers, SL= spike length, BMkgha = biomass kilogram per hectare, YLD kgha^{-1} = Yield in kilogram per hectare and HI% = harvest index in percent

Agronomic performance

Combined mean grain yield and other agronomic traits are presented in Table 3. Medium days to heading, days to maturity, grain filling period, productive tillers, spike length, plant height and biomass were recorded by Dagim, Nigus and Kuncho varieties (Table3). These bargain great flexibility for recommended improved varieties suitable for various agro-ecologies with variable length of growing period and high in grain yield status. In contrary, Tesfa variety was with short plant height, indicating that, the variety might be resistant against lodging problems. Furthermore, Dagim, Nigus and Kuncho varieties were recorded the highest grain yield and had 1511.7kgha^{-1}, 1379.3kgha^{-1} and 1379.3kgha^{-1} respectively and they recorded 28.11%, 15.25% and 15.26% of yield advantages over the local check, respectively (Table 3).

Table 3: Combined mean for grain yield and yield related traits

variety	DH	DM	GFP	PTL	SL	PH	BM kgha^{-1}	YLD kgha^{-1}	HI%	YLA%
Abay	80.3^{bc}	144.6^{de}	64.3^{de}	3.9^{d-g}	32.6^{ab}	42.6^{abc}	4643.9^{abc}	1219.4^{cde}	25.2^{efg}	2.9
Boset	77.6^{fg}	140.9^{gh}	63.3^{def}	4.4^{bcd}	25.3^{fg}	37.46^{bcd}	3804.1^{efg}	1104.5^{efg}	29.7^{bc}	-7.2
Dagim	78.2^{def}	138.9^{h}	60.7^{fg}	3.9^{d-g}	27.6^{def}	35.4^{cde}	4682.2^{ab}	1511.7^{a}	33.6^{a}	21.7
Dursi	82.3^{a}	151.4^{b}	69.1^{b}	3.4^{fgh}	33.6^{a}	34.8^{cde}	3656^{g}	771.9^{h}	27.8^{b-f}	-53.4
Estub	77.5^{fg}	151.2^{b}	73.7^{a}	4.1^{def}	31.6^{ab}	32.6^{de}	4659.9^{abc}	1305.1^{bc}	28.4^{b-e}	9.3
Flagot	76.9^{fg}	135.5^{i}	58.6^{g}	5.3^{a}	25.3^{fg}	34.3^{cde}	4352.9^{bcd}	1241.1^{cd}	26.9^{c-g}	4.6
Guduru	81.7^{ab}	153.5^{a}	71.8^{a}	2.9^{h}	32.6^{ab}	38.2^{bcd}	4175.6^{de}	816.5^{h}	21.4^{h}	-45.0
Hiber1	79.3^{cde}	148.3^{c}	69^{b}	3.5^{fgh}	31.4^{ab}	46.1^{ab}	4292.3^{cd}	987.2^{g}	23.8^{gh}	-19.9
Kena	80.9^{abc}	144.8^{de}	63.9^{de}	3.6^{efg}	26.0^{ef}	34.5^{cde}	4170.3^{de}	1121.3^{def}	29.5^{bcd}	-5.6
Kora	80.9^{abc}	143.1^{ef}	62.1^{ef}	3.4^{fgh}	31.1^{b}	32.7^{de}	4082.7^{def}	1123.9^{def}	27.7^{b-f}	-5.3
Kuncho	79.8^{cd}	140.4^{gh}	60.7^{fg}	3.3^{gh}	30.3^{bc}	48.1^{a}	4644.4^{abc}	1379.3^{b}	29.8^{bc}	14.2
Local	74.3^{h}	138.9^{h}	64.6^{de}	5.1^{ab}	23.2^{g}	31.9^{de}	3977.9^{d-f}	1183^{cde}	26.1^{d-g}	0.0
Nigus	76.5^{g}	141.6^{fg}	65.1^{cd}	4.9^{abc}	28.4^{cde}	37.5^{bcd}	4746.5^{a}	1379.3^{b}	29.2^{bcd}	14.2
Tesfa	78.6^{def}	141.6^{fg}	63^{def}	4.3^{cde}	27.5^{def}	26.6^{e}	3746.4^{fg}	1135.3^{def}	30.9^{ab}	-4.3
Warekiyu	77.7^{efg}	145.2^{d}	67.5^{bc}	3.8^{d-g}	28.6^{cd}	35.3^{cde}	4715.1^{ab}	1127.9^{def}	24.8^{fgh}	-5.0
LSD	1.71	1.97	2.7	0.7	2.4	9.3	382.9	128.9	3.5	
CV%	3.3	2.1	6.3	27.9	12.9	10.0	13.6	17.0	19.2	
Mean	78.8	144	65.2	4	29	48.8	4290.0	1148.9	27.7	

LSD (5%) = least significant difference, R^2 = R square, CV= coefficient of variation, DF = degree of freedom, DH = Days to Heading, DM = Days to Maturity, PH = Plant Height, GFP= grain filling period, PTL= productive tillers, SL= spike length, BMkgha= biomass kilogram per hectare, YLD $kgha^{-1}$ = Yield in kilogram per hectare and HI% = harvest index in percent, YLA= yield advantage

Yield performance across environments

The performance of tef varieties for grain yield across locations are presented in Table 4. Some varieties such as Dagim, Nigus and Kuncho are constantly performed best in a group of environments, while other varieties (for instances, Dursi, Guduru and Hiber1) are varying across locations. The average grain yield ranged from the lowest (422.3$kgha^{-1}$) at Kuyu sub site to the highest (2072.9$kgha^{-1}$) at Abote sub site. The grain yield across environments ranged from the lowest of 771.9$kgha^{-1}$ for Dursi variety to the highest of 1516.4$kgha^{-1}$ for Dagim variety .This wide variation might be due to their genetic potential of the varieties. Dagim variety was the top ranking variety in all environments, except at Kuyu sub site. Similarly, Nigus and Koncho varieties were well performed across location except at Kuyu sub site. Conversely, Dursi variety ranked the least in all environmental sites throughout cropping season. The difference in yield rank of varieties across the environments exhibited the high crossover type of varieties x environmental interaction (Yan and Hunt, 2001).

Table 4: Across Locations mean performance of grain yield (kg/ha)

variety	Locations						
	Kuyu	Warajarso	HAbote	Girarjarso	YayaGulale	Wachale	com.mean
Abay	396.7^{cde}	1305.4^{ab}	2202.4^{b-e}	2278.6^{ab}	493.3^{e-h}	640.1^{c}	1219.4
Boset	412.1^{cd}	880.6^{cd}	2286.1^{bcd}	1859.5^{cd}	550^{d-h}	638.6^{c}	1104.4
Dagim	468.8^{c}	1186^{ab}	3112.7^{a}	2472.9^{a}	959.9^{a}	898.1^{a}	1516.4
Dursi	349.4^{efg}	724.9^{d}	1442^{gh}	1375.3^{ef}	406.4^{gh}	333.3^{d}	771.9
Estub	297.4^{g}	1349.3^{ab}	2009.6^{c-f}	2540^{a}	866.1^{ab}	768.3^{abc}	1305.1
Flagot	364.7^{def}	1076.7^{bc}	1946.8^{def}	2681.2^{a}	621.8^{c-f}	755.3^{abc}	1241.1
Guduru	349.1^{efg}	1222.6^{ab}	1501^{gh}	1108.5^{f}	336.2^{h}	381.7^{d}	816.5
Hiber1	575^{b}	716.7^{d}	1294^{h}	1927.6^{bcd}	570.6^{c-g}	839^{ab}	987.2
Kena	332.1^{fg}	1220.4^{ab}	1823.9^{efg}	1958.3^{bcd}	659.6^{b-e}	733.1^{abc}	1121.2
Kora	298.1^{g}	1207.4^{ab}	2410.6^{bc}	1757.7^{cde}	431.2^{fgh}	638.3^{c}	1123.9
Kuncho	609.3^{a}	1444.1^{a}	2557.2^{b}	1901.4^{bcd}	873.3^{ab}	800.4^{abc}	1364.3
Local	570.9^{b}	868.3^{cd}	2701.4^{fgh}	1546.5^{de}	719.5^{bcd}	695.8^{bc}	1183.7
Nigus	509.7^{b}	1453.4^{a}	2582.5^{b}	2327.4^{ab}	603.3^{c-g}	709.3^{abc}	1364.3
Tesfa	385.1^{def}	1177.4^{ab}	2113.1^{c-f}	1997.6^{bc}	682.3^{b-e}	456.4^{d}	1135.3
Warekiyu	370.8^{def}	856^{cd}	2110.7^{c-f}	1827.8^{cd}	777.8^{abc}	824.1^{ab}	1127.9
LSD	62.5	276.9	425.5	417.7	213.9	172.4	
CV%	8.8	14.9	12.3	12.7	20.1	15.2	
Mean	422.3	1109.9	2072.9	1974.0	636.3	677.6	

LSD = least significant difference, R^2 = R square, CV= coefficient of variation, kg/ha = kilogram per hectare

Additive main effects and multiplicative interaction (AMMI) model

The combined ANOVA and AMMI analysis of grain yield at six locations are presented in Table 5.The result indicated, tef grain yield was extensively exaggerated by environments. This was explained 81.23% of the total treatment variation, while the G and GEI were significant and accounted for 6.73% and 7.58%, respectively .Similar findings have been reported in previous studies (Kaya et al., 2006; Farshadfar et al., 2012). A study conducted by Gauch and Zobel (1997) reported in standard multi-environment trials (METs), environment effect contributes 80% of the total sum of treatments and 10% effect of genotypes/varieties and interaction.In additive variance, the portioning of GEss data matrix using AMMI analysis, indicated the first PCAs were significant ($P < 0.01$). PCA1 and 2 accounted for 3.59 % and 2.71% of the GE interaction,respectively; representing a total of 6.3% of the interaction variation .A comparable results have been reported in earlier studies (Mohammadi and Amri, 2009). Large yield variation explained by environments indicated that environments were diverse,with large differences between environmental means contributing maximum of the variation in grain yield (Table 6).Grain yield of environments ranged from 297.4kgha^{-1} in E1 to 3112.7 kgha^{-1} in E3, Varieties mean grain yield varied from 771.9kgha^{-1} (Dursi) to 1516.4kgha^{-1} (Dagim) with (Table 6).

Table 5. AMMI for grain yield of 15 tef varieties evaluated on six locations

Source variation	DF	SS	SS%	MS
Total	269	8260108	100.00	30707
Treatments	89	7891891	95.54	88673**
Varieties	14	555977	6.73	39713**
Environments	5	6709968	81.23	1341994**
Block	12	108674	1.32	9056**
Interactions (G x E)	70	625946	7.58	8942**
IPCA 1	18	296241	3.59	16458**
IPCA 2	16	224239	2.71	14015**
Residuals	36	105465	1.28	2930*
Error	168	259543		1545

DF = degree of freedom, SS = sum of squares, MS = mean squares, IPCA = Interaction Principal Component Axis, EX. SS% = Explained Sum of square ns * ,** non-Significant,Significant at the 0.5% and 0.1% level of probability, respectively

Table 6. Average grain yield (kgha^{-1}) of 15 tef varieties tested across six locations in 2020/21 main cropping season

Varieties	E1	E2	E3	E4	E5	E6	Mean
Abay	396.7	1305.4	2202.4	2278.6	493.3	640.1	1219.4
Boset	412.1	880.6	2286.1	1859.5	550	638.6	1104.5
Dagim	468.8	1186	3112.7	2472.9	959.9	898.1	1516.4
Dursi	349.4	724.9	1442	1375.3	406.4	333.3	771.9
Estub	297.4	1349.3	2009.6	2540	866.1	768.3	1305.1
Flagot	364.7	1076.7	1946.8	2681.2	621.8	755.3	1241.1
Guduru	349.1	1222.6	1501	1108.5	336.2	381.7	816.5
Hiber1	575	716.7	1294	1927.6	570.6	839	987.2
Kena	332.1	1220.4	1823.9	1958.3	659.6	733.1	1121.2
Kora	298.1	1207.4	2410.6	1757.7	431.2	638.3	1123.9
Kuncho	609.3	1444.1	2557.2	1901.4	873.3	800.4	1364.3
Local	570.9	868.3	2701.4	1546.5	719.5	695.8	1183.7
Nigus	509.7	1453.4	2582.5	2327.4	603.3	709.3	1364.3
Tesfa	385.1	1177.4	2113.1	1997.6	682.3	456.4	1135.3
Warekiyu	370.8	856	2110.7	1827.8	777.8	824.1	1127.9
Mean	419.3	1112.6	2139.6	1970.7	636.8	674.1	1158.8

E1 = Kuyu, E2=Warajarso,E3=HAbote ,E4= Girarjarso, E5= YayaGulale,E6=Wachale, E= environment

The average environment is defined by the average values of PC1 and PC2 for the all environments and it is presented with a circle (Purchase, 1997). The average ordinate environment (AOE) is defined by the line which is perpendicular to the AEA (average environment axis) line and pass through the origin. This line divides the varieties in to those with higher yield than average and in to those lower yield than average. By projecting the varieties on AEA axis, the varieties are ranked by yield;where the yield increases in the direction of arrow. In this case, the highest yield varieties are Dagim , Nigus and Kuncho. In contrary, Dursi and Guduru varieties recorded the lowest grain yield (Fig1).Stability of the varieties depends on their distance from the AE abscissa. Those varieties closer to or around the center of concentric circle indicated these varieties are more stable than others. Therfore, the greatest stability in the high yielding group had varieties Dagim, Nigus and Kuncho, whereas the most stable and yielder of all was Dagim variety (Fig.1)

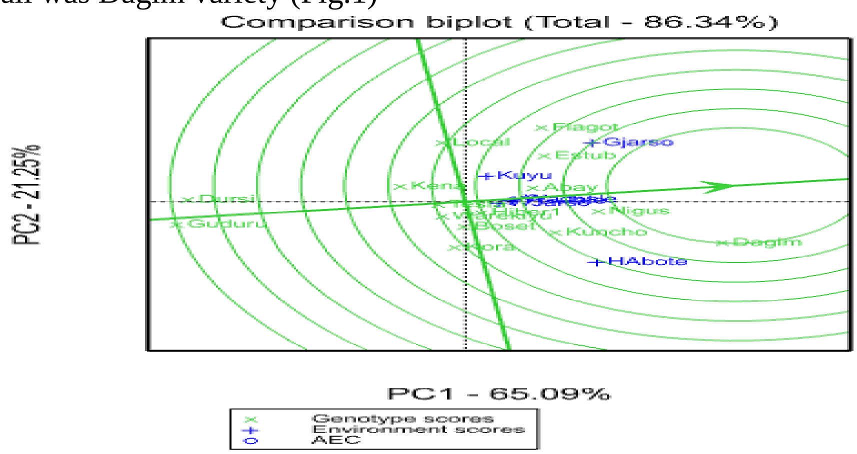


Fig 1 GGE bi-plot comparison of varieties for their yield potential and stability

The variety ranking is shown on the graph of variety so-called “ideal” variety (Fig. 1). An ideal variety is defined as one that is the highest yielding across test environments and it is completely stable in performance that ranks the highest in all test environments; such as Dagim , Nigus and Kuncho (Farshadfar et al., 2012; Yan and Kang, 2003). Even though such an “ideal” variety may not exist in reality, it could be used as a reference for variety evaluation (Mitrovic et al., 2012)

A variety is more appropriate if it is located closer to “ideal” variety (Kaya et al., 2006; Farshadfar et al., 2012). So, the closer to the “ideal” variety in this study was Dagim (Fig. 1). The ideal test environment should have large PC1 scores (more power to discriminate variety in terms of the genotypic main effect) and small (absolute) PC2 scores (more representative of the overall environments). Such an ideal environment was represented by an arrow pointing to it (Fig. 2). Actually, such an ideal environment may not exist, but it can be used as an indication for variety selection in the METs. An environment is more desirable if it is located closer to the ideal environment. Therefore, using the ideal environment as the centre, concentric circles were drawn to help ideal test environment in terms of being the most representative of the overall environments and the most powerful to discriminate varieties (Fig.2).

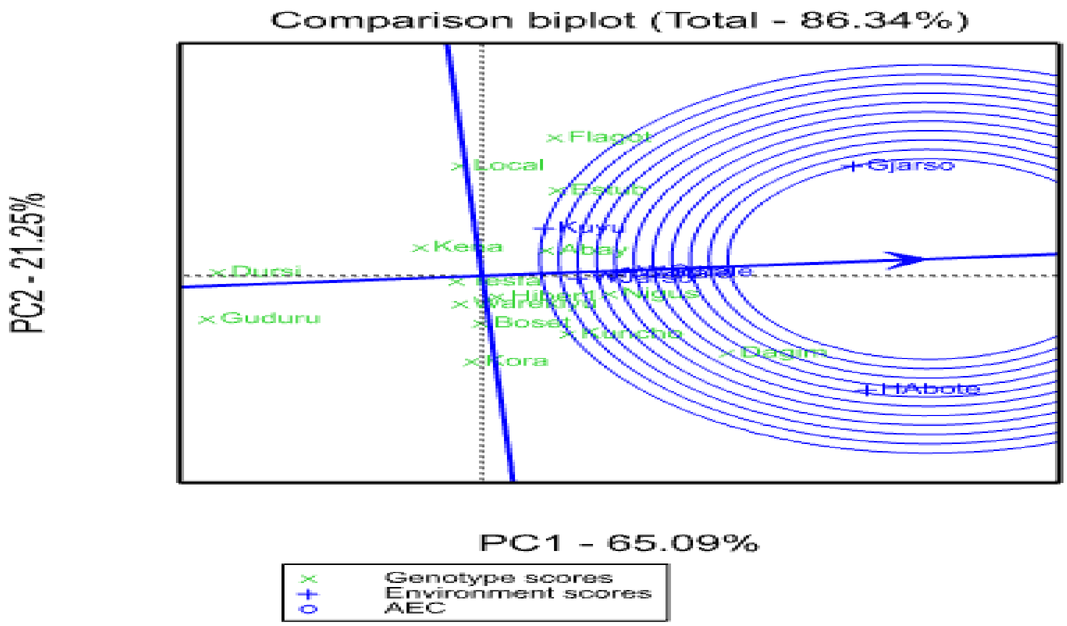


Fig 2 GGE bi-plot based on tested environments-focused comparison for their relationships
Additive main effects and multiple interactions (AMMI)

AMMI stability value (ASV).

Varieties exhibited significant varieties by environment interaction effects and the additive and multiplicative interaction effect stability analysis (ASV) implied splitting the interaction effect. In view of the mean grain yield as a first criterion for evaluating, Dagim variety was the highest mean grain yield (1516.4$kgha^{-1}$), followed by the variety Nigus and Kuncho with the mean grain yield of (1364.3$kgha^{-1}$ and 1364.3$kgha^{-1}$, respectively). Whereas, variety Dursi and Guduru were with low mean grain yields across the testing locations (Table 7). The IPCA1 and IPCA2 scores in the AMMI model are indicators of stability (Purchase, 1997). Considering IPCA1, Dagim variety was the most stable variety with IPCA1 value (-11.19), followed by Kuncho and Nigus with IPCA1 value of -2.59 and -4.38 respectively. Likewise, in IPCA2, Flagot variety was the most stable with interaction principal component value (-9.74) but recorded low grain yield. The two principal components have their own extremes; however, calculating the AMMI stability value (ASV) is a balanced measure of stability (Purchase, 1997).Varieties with lower ASV values are considered more stable and varieties with higher ASV are unstable. According to the ASV ranking in the (Table7), a Dagim variety was the most stable with an ASV value of 15 followed by Kuncho and Nigus with ASV value of 7 and 11 respectively. The stable variety was followed with mean grain yield above the grand mean and this result was in agreement with Hintsa and Abay (2013), who has used ASV as one method of evaluating grain yield stability of bread wheat varieties in Tigray and similar reports been made by Abay and Bjørnstad (2009); Sivapalan et al. (2000) in barley in Tigray and bread wheat using AMMI stability value. A variety with the least of genotype/variety selection index (GSI) is considered as the most stable genotype (Farshadfar, 2008). Accordingly, Dagim variety was the most stable variety since with the low of genotype/variety selection index (GSI) and the highest mean grain yield of all

(Table 7).

Table7. AMMI stability value, AMMI rank, yield, yield rank and genotype/variety selection index and principal component axis

Variety	ASV	ASV rank	YLD	YLD rank	GSI	IPCAg1	IPCAg2
Dagim	142.77	15	1516.4	1	16	-11.19	-1.58
Kuncho	5.32	7	1364.3	2	9	-2.59	3.96
Nigus	25.10	11	1364.3	3	14	-4.38	-1.35
Estub	8.51	9	1305.1	4	13	1.10	-6.30
Flagot	21.56	10	1241.1	5	15	2.75	-9.74
Abay	2.37	3	1219.4	6	9	-0.40	-2.14
Local	32.45	12	1183.7	7	19	7.42	-3.07
Tesfa	1.39	1	1135.3	8	9	-0.86	-0.61
Warekiyu	3.07	4	1127.9	9	13	0.33	2.87
Kora	4.19	6	1123.9	10	16	-4.23	3.83
Kena	5.77	8	1121.2	11	19	2.69	-0.56
Boset	3.34	5	1104.4	12	17	-1.76	2.80
Hiber1	1.65	2	987.2	13	15	-0.64	1.54
Guduru	95.90	14	816.5	14	28	6.52	8.13
Dursi	38.74	13	771.9	15	28	5.22	2.20

Conclusions and Recommendation

In general, based on the two analyses of AMMI and GGE-bi-plot models, Dagim and Nigus varieties were high yielder, stable and adaptable. Therefore, demonstration and popularization of Dagim and Nigus are important to improve tef productivity in the study areas and other similar agro-ecology until other option will be obtained

Acknowledgement

The authors greatly acknowledged Oromia Agricultural Research Institute (IQQO) for financial support and greatly acknowledged those centers that provided the test materials. And from all Fitche agricultural research center staff members and specifically cereal research case team members are greatly acknowledged for their technical and moral support.

References

Abay, F. andBjørnstad A (2009).Specific adaptation of barley varieties in different locations in Ethiopia.*Euphotic* 167: 181-195.

Comstock, R.E. and Moll, R.H (1963). Genotype x Environment Interactions: Symposium on Statistical Genetics and Plant Breeding. National Academy Science National Research Council, Washington, D.C. pp. 164-196

Delacy, I.H., Basford, K.E., Cooper, M. and Bull, J.K. (1996). Analysis of multi- environment trials- an historical perspective. Plant Adaptation and Crop Improvement. Cooper, M. and Hammer, G.L. (Eds.). CAB International. pp. 39-124.

Farshadfar, E. (2008). Incorporation of AMMI stability value and grain yield in a single non-parametric index (Genotype Selection Index) in bread wheat. Pakistan Journal of Biological Sciences11: 1791-1796.

Farshadfar, E., Mohammadi, R., Aghaee, M. andVaisi, Z.(2012).GGE biplot analysis of genotype × environment interaction in wheat-barley disomic addition lines. Australia Journal of Crop Sciences 6:1074-1079.

Gabriel, K.R.(1971).The biplot graphic of matrices with application to principal component analysis Biometrics 58:453-467.

Gauch, H.G.(2006).Statistical analysis of yield trials by AMMI and GGE Crop Sciences 46:1488-1500.

Gauch,H.G.and Zobel, R.W.(1997). Interpreting mega-environments and targeting genotypes. Crop Sciences 37:311-326

Hintsa, G. and Abay, F. (2013).Evaluation of bread wheat genotypes for their adaptability in wheat growing areas of Tigray Region, northern Ethiopia. Journal of Biodiversity and Endangered Species

Kaya, Y., Akcura, M. andTaner, S. (2006).GGE-bi-plot analysis of multi- environment yield trials in bread wheat.*Turkish Journal of Agriculture* 30:325- 337

Mitrovic, B., Stanisavljevi, D., Treski, S., Stojakovic, M., Ivanovic, M., Bekavac, G. and Rajkovic, M. (2012). Evaluation of experimental Maize hybrids tested in Multi-location trials using AMMI and GGE bi-plot analysis. *Turkish Journal of Field Crops* 17:35-40.

Mohammadi, R. andAmri, A. (2009). Analysis of genotype × environment interactions for grain yield in durum wheat. Crop Sciences 49:1177-1186.

Ponti, J.A. (1978). The systematics of Eragrostis tef (Graminae) and related species. PhD Thesis, University of London, London, UK

Purchase, J.L.(1997).Parametric analysis to describe genotype x environment interaction and yield stability in winter wheat Ph.D. Thesis, Department of Agronomy, Faculty of Agriculture of the University of the Free State, Bloemfontein, South Africa

SAS Institute Inc. (2008). Statistical analysis Software version 9.2, Cary, NC: SAS Institute Inc. USA

Sivapalan, S., Obrien, L., Ortiz-Ferrara, G., Hollamby, GJ., Barclay, I. and Martin, PJ. (2000). An adaptation analysis of Australian and CIMMYT/ICARDA wheat germplasm in Australian production environments. Crop Science Pastures 51: 903-915.

Tavassoli, A.(1986). The cytology of Eragrostis tef with special reference to E. tef and its relatives. PhD Thesis, University of London, London, UK

VSN International, (2012). "Gen Stat for Windows 15th Edition. VSN International, Hemel Hempstead, UK. Available: www.genStat.co.uk

Yan, W. and Hunt, L.A., Sheng, Q. andSzlavnics, Z. (2000).Cultivar evaluation and mega environment investigation based on the GGE bi-plot. Crop Science40:597-605.

Yan, W. and Hunt, LA.(2001). Genetic and environmental causes of genotype by environment interaction for winter wheat yield in Ontario. Crop Science 41:19-25.

Yan, W. and Kang, MS. (2003). GGE bi-plot analysis: a graphical tool for breeders, In: Kang MS. (Ed). Geneticists, and Agronomist. CRC Press, Boca Raton, FL. pp. 63-88.

Yan, W. and Rajcan, I. (2002).Bi-plot analysis of test sites and trait relations of soybeanin Ontario. Crop Science 42:11-20.

Yan, W.(2001). GGE bi-plot- a windows application for graphical analysis of multi-environment trial data and other types of two-way data *Journal of Agronomy* 93:1111-1118.

Effect of NPS and Nitrogen Fertilizer Rate on Yield and Yield Related Components of Maize (Zea Mays L.) at Western Oromia, Ethiopia

Wakgari Raga[1] Abdi Asfaw[2]

Oromia Agricultural Research Institute (IQQO), HaroSabu Agricultural Research Center, P.0.Box 10, Kellem Wollega, Dembi Dollo

*Corresponding author: E-mail: wak.raga@gmail.com

Abstract

The fertilizer trial was conducted on maize variety BH-661 at Haro Sabu, Sadi Chanka and Bellam for the last two consecutive years (2019-2020 to evaluate the effect of different rate of blended NPS and Nitrogen fertilizer on yield and yield components of maize and to provide economically acceptable fertilizer rate recommendations. The factorial combination of four rates of NPS (0, 50, 100 and 150 kg ha-^{1}) and five rates of N fertilizer (0, 46, 69, 92 and 115 kg ha-^{1}) were arranged in Randomized in Complete Block Design (RCBD) to constitute thirteen treatments with three replications on a plot size of 3m x 3.75m. There were 0.3m, 0.75m,1m and 1.5m spacing/ paths between plants, rows, plots and blocks respectively. Urea was used as a source of Nitrogen. Nitrogen fertilizer was applied by equal doses at planting and knee height stage in split while all NPS was applied at planting. The required data were collected and analysis was computed using SAS statistical package (SAS, 2003) version 9.1.3. Combined analysis of variance revealed highly significant ($P \leq 0.05$) differences among the treatments for parameters like days to maturity, grain yield and harvest index while significant differences were detected ($P \leq 0.05$) for days to silking, plant height, ear height, kernels per row, kernels per cob, thousand kernel weight and biomass yield . The combined analysis of variance showed location effects for the treatments were significant for all parameters except lodging, rows per cob and kernels per cob. Economic analysis was computed to give general recommendation. Accordingly, the combined application of 100kg/ha NPS X 69kg N /ha fertilizer rate is economically acceptable for the study areas. At this level of fertilizer, mean grain yield of maize obtained was 8337.8kg/ha with marginal rate of return 1414.71%. Also yield advantage gained over control treatment due to application of 100kg/ha NPS X 69kg N /ha fertilizer to maize was 19.03%. Therefore, combined application of 100kg/ha NPS X 69kg/ha N fertilizer to maize is recommended for the areas.

***Keywords**: NPS, Sayo, Lalo Kile, Thousand Kernel Weight, Harvest Index, Marginal Rate of Return.*

Introduction

Agriculture is the basis of the Ethiopian economy and the main source of livelihood of the population. The potential for developing agricultural production is high but despite this, Ethiopia is currently unable to produce enough food to meet the demands of its ever increasing population. According to the International Food Policy Research Institute (IFPRI, 2010), 5-7 million people in Ethiopia are chronically food insecure. The reasons for this are diverse and complex but declining soil fertility and soil degradation is a primary factor.

Maize (*Zea mays L*.) is an important cereal crop which ranks the third after wheat and rice in the world (David and Adams, 1985). It is the major crops, ranked second to tef [Eragrostistef (Zucc.)] and first in production (Mosisa et al., 2002, 2012) in Ethiopia. In Ethiopia, maize grows from moisture stress areas to high rainfall areas and from lowlands to the highlands (Kebede *et al*., 1993). It is one of the important cereal crops grown in the country. The total annual production and productivity exceed all other cereal crops, though it is surpassed by tef in area coverage (Benti *et al*., 1997). Therefore, considering its importance in terms of wide adaptation, total production and productivity, maize is one of the high priority crops to feed the increasing population of the country (Mosisa Worku et al., 2001). Normal maize grain has greater nutritional value as it contains 72% carbohydrate, 8.8% protein, 2.15% fiber and 2.33% ash (Shah et al., 2015). It is a good source of carbohydrates, fat, protein and some important vitamins (B6, A and E) and minerals (magnesium, potassium and phosphorus).The per capita consumption of maize is 60 kg year^{-1} per annum in Ethiopia (Mosisa et al., 2012). Maize is therefore a crucial for Ethiopia in the short and medium term, and the GTP proposes a maize doubling of production by 2015 (FDRE, 2011). However, yield has not increased significantly and per capita food production has declined since the 1980s (Greenland et al., 1994; Sanchez et al., 1996; Muchena et al., 2005). The main contributing factors are poor soil fertility, particularly N, P and other nutrient deficiencies (Bekunda et al., 1997), aggravated by soil fertility depletion (Vlek, 1993; Sanchez et al., 1996; Lynam et al., 1998) and other biophysical factors. Declining soil fertility and aggravated land degradation have particularly replaced the land on which the poor depend and exposed to food insecurity for the smallholder farmers (Sanchez, 2002). In Ethiopia research results in high potential maize growing areas are in average 7000-8000 kg ha-1. However, yield levels obtained by small scale farmers remained stagnant despite the availability of improved varieties [Benti Tolessa, 1993]. One of the main causes for this discrepancy is the low use of external inputs, leading to negative balances for N, P and K(Rhodes et.al,1996). Similar trends observed in Western Oromia especially in West and Kellem Wollega zones in maize production even though maize is the dominant and potential crop in the zones. Therefore, it is mandatory to treat the soil with fertilizer thereby determining the rate and providing the recommendations for farmer is obligatory. So, the present study focuses on determining the rate of NPS and Nitrogen fertilizer to forward best recommendation for the farmers of the area.

.**Objective**: To evaluate the response of maize to the newly introduced blended NPS and Nitrogen fertilizer and to recommend economically acceptable fertilizer rate.

Materials and Methods

Description of the Study Area

The experiment was conducted Haro Sabu, Sadi Chanka and Bellam for the last two consecutive years (2019-2020). The locations were situated at Kellem Wollega Zone of Western Oromia, Western Ethiopia. The locations have different agro-climatic conditions. According to the 2016/7 season weather data collected at study sites, the Haro Sabu and Sadi Chanka had an average of 1100 mm annual rainfall and temperature was 30°C, while Bellam received an average of 1600 mm and temperature of 22°C. The sites also characterized by different soil types, which range from the Brown sandy-loam soils at Bellam and black clay loam at Sadi Chanka and light red sandy at Haro Sabu. Haro Sabu is found on altitude of 1450 masl while Sadi Chenka and Bellam found on 1449 masl and 1731 masl respectively.

Treatments and Experimental Design

The factorial combination of four rates of NPS (0, 50, 100 and 150 kg ha-^{1}) and five rates of N fertilizer (0, 46, 69, 92 and 115 kg ha-^{1}$_{)}$ were arranged in Randomized in Complete Block Design (RCBD) to constitute thirteen treatments with three replications on a plot size of 3m x 3.75m. The experimental plots were plowed three times. There were 0.3m, 0.75m,1m and 1.5m spacing/ paths between plants, rows, plots and blocks respectively. Urea was used as a source of N. Nitrogen fertilizer was applied by equal doses at planting and knee height stage in split while all NPS was applied at planting. Maize variety, BH-661 was used as planting material by the population of 44,444 plants/stands per hectare. Management of non-treatment routines were similar for all experimental units including the control. Plant height, Ear height, leaf length & diameter and cob length were measured by randomly selecting 10 plants per plot. Above ground biomass, ear weight and 1000 grain weight were measured during harvesting. Grain yield and 1000 grain weight data was adjusted to 12.5% moisture content before analysis.

Data collection: Five plants were selected randomly before heading from each rows (three harvestable rows) and tagged with thread and all the necessary plant based data were collected from the sampled plants.

Plant-based data : Plant height, leaf area, rows per cob, cob length and kernels per cob

Plot-based data: Days to tasseling, days to physiological maturity, lodging percentage, thousand kernel weight, grain yield, biological yield and harvest index

Statistical Analysis: The collected data on various parameters of the crop under study were statistically analyzed using SAS statistical package (SAS, 2003) version 9.1.3. The Least Significant Difference (LSD) test at 5% level of significance was used to separate the means when the ANOVA showed the presence of significant difference.

Partial Budget Analysis: To identify the economic optimum rate of applied fertilizer, economic analysis was done using the CIMMYT partial budget analysis methodology (CIMMYT, 1988). Following the CIMMYT partial budget analysis methodology, total variable costs (TVC), gross benefits (GB) and net benefits (NB) were calculated. Then treatments were arranged in an increasing TVC order and dominance analysis was performed to exclude dominated treatments from the marginal rate of return (MRR) analysis. A treatment is said to be dominated if it has a higher TVC than the treatment which has lower TVC next to it but having a lower net benefit. A treatment which is non-dominated and having a MRR of greater or equal to 50% and the highest net benefit is said to be economically profitable.

Marginal rate of return was computed by the formula;

$$\text{MRR (\%)} = \frac{\text{Marginal benefit}}{\text{Marginal Cost}} \times 100$$

Results and discussion

Combined Analysis of Variance

Mean square of analysis of variance of all treatments for grain yield and yield related parameters were presented in Table 1. Highly significant differences were observed among the treatments ($P \leq 0.05$) for parameters like days to maturity, grain yield and harvest index while significant differences were detected ($P \leq 0.05$) for days to silking, plant height, ear height, kernels per row, kernels per cob, thousand kernel weight and biomass yield . The combined analysis of variance showed location effects for the treatments were significant for all parameters except lodging, rows per cob and kernels per cob.

Table 1. Analysis of variance of major agronomic and yield components o f maize against different level of NPS and N fertilizer at Western Oromia

SV	DF	Mean squares											
		DT	DS	DM	PH	LD	LA	RPC	KPC	TKW	GY(Kg/ha)	^{BY}(ton/ha)	Hi(%)
Trt	12	6.15	4.87*	74.4**	503.6*	0.06ns	3422.239ns	298.9ns	595690.85*	2682.14*	3704974.27**	5810286.8*	78.9**
Rep	2	20.5*	27.17**	9.43*	2488.5**	0.03ns	22312.14*	331.8ns	612610.6	1949.	1059351.7	23510657.6*	42.2
Loc	4	1304.3**	1131..0**	3321.4**	8515.7**	0.73*	237726.4**	57.502	116077.1	40918.042**	9419811.27**	34522614.4**	117.283**
Trt*Loc	48	5.1*	2.4	0.0	217.5	0.2	3518.7	111.5	215954.4	1269.3	1625351.1*	1647881	35.222*

Key: ns- non-significant; * - significant; **- highly significant at 5% probability level; Loc- location; Trt - treatment; DF -degree of freedom; DT- Days to 50% tasseling; DM- Days to 50% Maturity; PH- Plant Height; LD- Lodging percentage; LA-leaf area; RPC-rows per cob; KPC-kernels per cob; TKW-Thousand kernel Weight, GY(Kg/ha)- grain yield in Kilogram per Hectare; ^{BY}(ton/ha)- Biological yield in ton per Hectare; Hi(%)-harvest index in percentage

Yield Performance of maize against different rate of NPS and N across locations

The results read from Anova indicates that there is highly significant ($P<0.05$) difference in grain yield across locations. The highest mean grain yield of maize 8504. 37 kg/ha was recorded at Haro Sabu followed by 8250.67kg/ha at Bellam and the lowest mean grain yield 7725.82kg/ha was obtained at Sadi Chanka. Analysis of combined mean (Table 3.) shows highest mean grain yield 9005.2kg/ha was achieved at the combination of application of 100kg/ha NPSX115kg/ha fertilizer rate while the lowest grain yield (7004.3kg/ha) was achieved by control treatment (zero fertilizer application).

Table 3.Over location mean grain yield of maize against different level of NPS and N fertilizer at Western Oromia

	Grain Yield in Kg/ha					
	2019 G.C		2020 G.C			
NPS XN Level(Kg/ha)	Haro Sabu	Sadi Chanka	Haro Sabu	Sadi Chanka	Bellam	Combined Mean
50 X 92	8975.3ab	6879.9eg	8624ab	8219.9ab	8071.7ab	8124.5b-d
100 X 69	8260.3bc	9327.4ab	8653ab	7585.3a-c	8224.3ab	8537.8a-d
100 X 46	8862.4ab	8421.5b-d	6797b	7756.6a-c	8471.4ab	8204.8b-d
100 X 115	8521.4a-c	9862.3a	8072ab	8826.1a	9285a	9005.2a
150 X 69	9240a	8204.4cd	8453ab	7391.3a-c	8163.9ab	8445.1a-d
150 X 115	8493.2a-c	6819e-g	8349ab	7748.4a-c	7947.2b	7911.2d
0 X 0	7017.5d	5442.6h	7382b	6167.8c	7589.5b	7004.3e
50 X 115	8876.9ab	8981a-c	8486ab	7081.4bc	8152.6ab	8529.9a-d
50 X 46	8535.8a-c	6717.1fg	8283ab	7491.3a-c	8269.2ab	8014.9cd
100 X 69	8668.3ab	7874.2de	10031a	7613.2a-c	8321.6ab	8643.3a-c
150 X 46	7779.5cd	7799.9d-f	9165ab	7462.6a-c	7675.9b	8019.2cd
50 X 69	8614.3a-c	6679.6g	8291ab	8244.7ab	8412.7ab	8082b-d
150 X 92	8780.9ab	7558.5d-g	9901a	8715.3ab	8673.7ab	8717.5ab
Mean	8509.676	7735.945	8499.087	7715.695	8250.676	8249.212
CV	6.192852	8.47	17.29	13.35	13.01	11.48
LSD	888.07	1104.3	2489.1	1737	1238.9	684.90
Ftest	*	**	ns	ns	ns	**

Agronomic performance

Days to maturity: Anova indicates that there is highly significant ($P<0.05$) difference in days to 50 % maturity. Highest mean of days to maturity (160 days) was recorded by the application of 150kg/ha NPS X 69kg N /ha while the lowest days to maturity (152.73 days) were recorded by the application of 50kgNPS/ha X69kgN rate per hectare .

Days to Silking: Variation occurred in days to silking due to application of different NPS and N rate for maize is significant ($P<0.05$). The highest figure (89 days) was recorded at control treatment (zero application) where as the lowest figure (87 days) was registered at 150kg/ha NPS X 69kg N /ha fertilizer application rate.

Plant height: Different application rate of NPS and N fertilizer to maize affect plant height significantly ($P<0.05$). The maximum plant height (283.79cm) was recorded at the application of 50kg/ha NPS X 69kg N /ha while the minimum plant height (264.28cm) was recorded at control treatment (zero fertilizer application) rate.

Kernels per cob: Significant difference ($P<0.05$) was obtained for number of kernels per cob due to application of different rate of NPS and N fertilizer for maize. Highest figure (608.21) number of kernels per was observed at the application of 50kg/ha NPS X 92kg N /ha while the lowest figure (526.1) number of kernels per cob was observed at control treatment (zero application) fertilizer rate.

Thousand kernel weight: Thousand kernel weight is also affected significantly (P<0.05) against different rate of NPS and N in maize production. The maximum number of thousand kernel weight (395.53gm) was scored at the application of 150kg/ha NPS X 92kg N /ha while the minimum thousand kernel weight (348.51gm) was recorded at the treatment 150kg/ha NPS X 92kg N /ha fertilizer rate.

Biological yield (ton/h): Maize biological yield respond significantly (P<0.05) to the application different rate of NPS and N. The combination application of 150kg/ha NPS X 92kg N /ha has resulted highest biological yield (20.2 ton/ha) while the lowest biological yield (18.42 ton/ha) was resulted at control treatment (zero application) fertilizer rate.

Harvest index: As it is possible to observe from Anova, there is highly significant (P<0.05) difference in harvest index. Highest mean of harvest index (46.45%) was recorded by the application rate of 100kg/ha NPS X 115kg/ha N /ha while the lowest harvest index (38.05%) were recorded by control treatment (Zero application) of fertilizer per hectare.

Table 1. Combined Mean effect of NPS and N rate on yield and yield components of Maize at Haro Sabu and Sedi Chenka and Bellam during 2019-2020

NPSXN level (kg/ha)	DT	DS	DM	PH	LD	LA	KPC	TKW	GY (Kg/ha)	BY (ton/ha)	Hi(%)
50 X 92	83b-d	87.5b-d	152.73e	274.43a-c	1.27a	752.74ab	608.21a	367.33cd	8124.5b-d	18.75bc	43.31b-d
100 X 69	83.87ab	88.27a-c	157.67b	281.38ab	1.27a	710.87b	587.98ab	382.53a-c	8537.8a-d	18.568c	46.1ab
100 X 46	83.4bc	87.4cd	154.33d	279.61a-c	1.07a	768.04a	561.26bc	348.51d	8204.8b-d	18.54c	44.3a-c
100 X 115	83.53bc	87.67b-d	155d	270.66cd	1.27a	749.23ab	587.11ab	367.15cd	9005.2a	19.42a-c	46.45a
150 X 69	82.2d	87d	160a	282.47ab	1.2a	764.2a	579.82ab	376.34a-c	8445.1a-d	19.94a	42.39c-e
150 X 115	83.6ab	88.33a-c	153e	282.27ab	1.27a	749.18ab	594.78ab	375.67a-c	7911.2d	19.73ab	40.12ef
0 X 0	83.47bc	89a	153.33e	264.28d	1.2a	726.11ab	526.1c	374.15a-c	7004.3e	18.42c	38.05f
50 X 115	83.47bc	88.47a-c	157.67b	276.93a-c	1.2a	739.45ab	578.02ab	374.14a-c	8529.9a-d	19.56a-c	43.51bc
50 X 46	83.3b-d	88.6ab	155d	273.38b-d	1.27a	743.38ab	574.66ab	392.11ab	8014.9cd	19.08a-c	42.03c-e
100 X 92	83.87ab	88.33a-c	156c	281.75ab	1.2a	756ab	592.82ab	394.08a	8643.3a-c	20.14a	42.88c-e
150 X 46	82.4cd	87.6b-d	153.4e	273.62b-d	1.13a	744.89ab	600.22ab	368.23b-d	8019.2cd	19.76ab	40.57d-f
50 X 69	84.73a	88.33a-c	156c	283.79a	1.13a	742.2ab	584.9ab	363.14cd	8082b-d	19.35a-c	42.07c-e
150 X 92	83.6ab	87.73b-d	153.07e	272.7b-d	1.27a	753.72ab	570.81ab	395.53a	8717.5ab	20.221a	43.12cd
Mean	83.42051	88.02	155.16	276.71	1.26	746.15	580.51	375.3	8249.21	19.34	42.68
CV	1.97	1.79	0.64	4.99	34.46	8.59	9.73	9.12	11.48	8.31	9.29
LSD	1.19	1.13	0.71	9.98	0.30	46.35	40.856	24.74	684.90	11.6	2.87
Ftest	*	*	**	*	ns	ns	ns	*	**	*	**

***Means with the same letter are not significantly different.*

Economic Analysis

Table 4. Partial Budget analysis of NPS and N fertilizer rate on Maize at Haro Sabu and Sadi Chenka and Bellam during 2019-2020

NPSXN level (kg/ha)	Average GY(kg/ha)	TVC	Gross benefit	Net benefit (ETB)	Marginal increase in net benefit	Margin increase in total variable cost	Dominance Analysis	MRR (%)
0X0	7004.3	0	49030.1	49030.1				
50 X 46	8014.9	2880.5	56104.3	53223.8	4193.7	2880.5		145.59
50 X 69	8082	3777	56574	52797			D	
100 X 46	8204.8	3968	57433.6	53465.6	668.6	191		350.05
50 X 92	8124.5	4673.5	56871.5	52198			D	
100 X 69	8537.8	4864.5	59764.6	54900.1	2702.1	191		1414.71
150 X 46	8019.2	5055.5	56134.4	51078.9			D	
50 X 115	8529.9	5570	59709.3	54139.3	3060.4	514.5		594.83
100 X 92	8643.3	5761	60503.1	54742.1	602.8	191		315.60
150 X 69	8445.1	5952	59115.7	53163.7		191	D	
100 X 115	9005.2	6657.5	63036.4	56378.9	3215.2	705.5		455.73
150 X 92	8717.5	6848.5	61022.5	54174		191	D	
150 X 115	7911.2	7745	55378.4	47633.4		896.5	D	

Conclusions and Recommendations

Economic analysis was computed to give general recommendation and it was shown in table 4.
Partial budget analysis for the experiment revealed that the combined application of 100kg/ha NPS X 69kg N /ha fertilizer rate is economically acceptable for the study areas. At this level of fertilizer, mean grain yield of maize obtained was 8337.8kg/ha with marginal rate of return 1414.71%. Also yield advantage gained over control treatment due to application of 100kg/ha NPS X 69kg N /ha fertilizer to maize was 19.03%.

Therefore, combined application of 100kg/ha NPS X 69kg/ha N fertilizer to maize is recommended for the areas.

Acknowledgement

The authors warmly acknowledge Oromia Agricultural Research Institute (IQQO) for financial support and guidance. The contribution of Haro Sabu Agricultural Research Center staff members are also unforgettable for technical and administrative support

References

Benti Tolessa, 1993. The need and objective of the 1st National Maize Workshop. *In: Proceedings of the 1st National Maize Workshop of Ethiopia*. 5-7 May, 1992, IAR and IMWIC, Addis Ababa, Ethiopia.

Federal Democratic Republic of Ethiopia, 2011

IFPRI, 2010. Fertilizers and Soil Fertility Potential in Ethiopia: Constraint and Opportunities for Enhancing the System. IFPRI, Washington.

Rhodes, E., A. Bationoa, E A. Smaling and A. Viskerc, 1996. Nutrient stocks and flows in West African soils. Pp: 22-32. In: AUMok Wuange, A. deJager and E. M. A. Smaling (eds). *Key to sustainable development*.

Sanchez, A. P. and R. B. Leakey, 1997. Land use transformation in Africa: three determinants for balancing food security with natural resource utilization. *Agron J.* 7: 15-23.

Vlek, P. L., 1990. The role of fertilizers in sustaining agriculture in sub-Saharan Africa. *Fert. Res. J.* 26:327-339.

Effect Of NPS and Nitrogen Fertilizer Rate on Yield And Yield Related Components of Sorghum *(Sorghum Bicolor L.)* at Western Oromia, Ethiopia

Wakgari Raga[1] and Abdi Asfaw[2]

Oromia Agricultural Research Institute (IQQO), HaroSabu Agricultural Research Center (HSARC), P.0.Box 10, Kellem Wollega, Dembi Dollo

*Corresponding author: E-mail: wak.raga@gmail.com

Abstract

The fertilizer trial was conducted on sorghum variety Gemedi at Haro Sabu, Sadi Chanka and Bellam for the last two consecutive years (2019-2020 to evaluate the effect of different rate of blended NPS and Nitrogen fertilizer on yield and yield components of maize and to provide economically acceptable fertilizer rate recommendations. The factorial combination of five rates of NPS (0, 50, 100, 125 and 150 kg ha-^{1}) and four rates of N fertilizer (0, 23,46 and 69 kg ha-^{1}$_{)}$ were arranged in Randomized in Complete Block Design (RCBD) to constitute thirteen treatments with three replications on a plot size of 3m x 3.75m. There were 0.15m, 0.75m,1m and 1.5m spacing/ paths between plants, rows, plots and blocks respectively. Urea was used as a source of Nitrogen. Nitrogen fertilizer was applied by equal doses at planting and knee height stage in split while all NPS was applied at planting. The required data were collected and analysis was computed using SAS statistical package (SAS, 2003) version 9.1.3. Combined analysis of variance revealed highly significant ($P \leq 0.05$) differences among the treatments for parameters like days to heading, days to maturity, grain yield and harvest index while significant differences were detected ($P \leq 0.05$) for leaf area, lodging percentage, panicle weight and thousand seed weight. The combined analysis of variance showed location effects for the treatments were significant for all parameters evaluated. Economic analysis was computed to give general recommendation. Accordingly, the combined application of 150kg/ha NPS X 69kg N /ha fertilizer rate is economically acceptable for the study areas. At this level of fertilizer, mean grain yield of sorghum obtained was 4007.4kg/ha with marginal rate of return 1354.49%. Also yield advantage gained over control treatment due to application of 150kg/ha NPS X 69kg N /ha fertilizer to sorghum was 54.4%.Therefore, combined application of 150kg/ha NPS X 69kg/ha N fertilizer to sorghum is recommended for the areas.

Keywords*: NPS, Sayo, Lalo Kile, Panicle height, Leaf area, Biological yield, Marginal Rate of Return.*

Introduction

Sorghum (Sorghum bicolor (L.) Moench) belongs to the family Poaceae and it is the fifth most important world cereal, following wheat, maize, rice and barley in terms of tonnage (FAO, 2012).. It is one of the most important cereal crops grown in arid and semi-arid parts of the world, evolved in semi-arid tropical Africa, India and China where it is still used as a major food grain (Taye, 2013. Nowadays, sorghum is attracting industries beyond animal feed elsewhere and human consumption in Africa. It is gaining commercial value in malting and brewing industries. Grain sorghum is a major cereal crop with multi-purposes in lower and mid altitude regions of Ethiopia. It is a staple food crop in the rural areas where it grows. Grain sorghum in Ethiopia is used primarily to prepare local foods such as 'injera', bread, thick porridge, soup, boiled grains and pop, medicinal values for some landraces is also common (Rooney and Murty, 1982). Sorghum, because of its drought resistance, is the crop of choice for dry regions and areas with unreliable rainfall (Taye, 2013). It is adapted to wide range of ecological conditions and can be grown under conditions which are unfavorable for most of the cereals (Onyango et al., 1998). In Eastern Africa, more than 70% of sorghum is cultivated in the dry and hot lowlands where serious water deficit is the major production constraint. Most East African sorghum is grown between the altitude of 900 and 1,500 m (Taye, 2013). In Ethiopia, it is grown all over the country across various agro ecologies (12 of the 18); from high altitude with sufficient amount of rainfall to low lands receiving low rainfall. It is grown as one of the major food cereals in Ethiopia annually 1.8 million ha of land is allotted for sorghum production and 4.3 million ton of grain is produced in the country (CSA 2015). Even though it can grow in different agro-ecological zones, it predominantly cultivated in dry areas that cover nearly 66% of the total area of Ethiopia (Geremew et al. 2004). Nevertheless, crop productivity is estimated at 2300 Kgha-1 (CSA 2015), which is considerably lower than experimental yield that reaches up to 3500 Kgha-1 on farmers' fields in major sorghum growing regions of the country. This still is very low when compared with the yield of 7000Kg to 9000Kgha-1 obtained under intensive management (Geremew et al. 2004). Low soil fertility and shortage of moisture is the major constraints in the reduction of growth and productivity of sorghum (Gebreyesus, 2012). Low soil fertility, particularly N and P deficiencies are among the major biophysical constraints affecting agriculture in SubSaharan Africa. According to Sanchez et al. (1997), soil fertility depletion in smallholder farmers' holdings is the basic root cause for declining per capita food production in the region.

To increase production of cereal crops, increasing appropriate use of all essential nutrients is an option. Fertilizers are efficient exogenous sources of plant nutrients (Akram et al., 2007).

Traditionally, sorghum has been known for being nutrient-use efficient and managed with low fertilizer rates, but yields can be increased with higher fertilizer application rates (Maranville, Clark, & Ross 1980). Many studies have been published on N, P, or K fertilizer response in sorghum (Elkased&Nnadi 1982; Ogunlela& Yusuf 1988; Buah et al. 1998; Varvel &Wilhelm 2003; Kayuki et al. 2007; Wortmann, Mamo, & Dobermann 2007). The major problem for low productivity of sorghum is a decline in the soil fertility due to high soil erosion, blanket application fertilizer and lack of blended fertilizer in Western Oromia. It very is important to know the appropriate fertilizer rate that can improve sorghum production and productivity. Therefore the activity was initiated to determine the rate of NPS and Nitrogen fertilizer that enable the crop to provide high yield under the case of West and Kellem Wollega Zones.

Objective: to evaluate the response of sorghum to the newly introduced blended NPS and Nitrogen fertilizer and to recommend the right level/rate for the area

Materials and Methods

Description of the Study Area

The experiment was conducted Haro Sabu, Sadi Chanka and Bellam for the last two consecutive years (2019-2020). The locations were situated at Kellem Wollega Zone of Western Oromia, Western Ethiopia. The locations have different agro-climatic conditions. According to the 2016/7 season weather data collected at study sites, the Haro Sabu and Sadi Chanka had an average of 1100 mm annual rainfall and temperature was 30°C, while Bellam received an average of 1600 mm and temperature of 22°C. The sites also characterized by different soil types, which range from the Brown sandy-loam soils at Bellam and black clay loam at Sadi Chanka and light red sandy at Haro Sabu. Haro Sabu is found on altitude of 1450 masl while Sadi Chenka and Bellam found on 1449 masl and 1731 masl respectively.

Treatments and Experimental Design

The factorial combination of five rates of NPS (0, 50, 100, 125 and 150 kg ha^{-1}) and four rates of N fertilizer (0, 23,46 and 69 kg ha^{-1}) were arranged in Randomized in Complete Block Design (RCBD) to constitute thirteen treatments with three replications on a plot size of 3m x 3.75m. The experimental plots were plowed three times. There were 0.15m, 0.75m,1m and 1.5m spacing/ paths between plants, rows, plots and blocks respectively. Urea was used as a source of N. Nitrogen fertilizer was applied by equal doses at planting and knee height stage in split. Sorghum variety, Gemedi was used as planting material. Management of non-treatment routines were similar for all experimental units including the control. Plant height, Panicle height, leaf length & diameter were measured by randomly selecting 5 plants per plot. Above ground biomass, panicle weight and 1000 grain weight were measured during harvesting. Grain yield and 1000 grain weight data was adjusted to 12.5% moisture content before analysis.

Data collection

Five plants were selected randomly before heading from each rows (three harvestable rows) and tagged with thread and all the necessary plant based data were collected from these sampled plants.

Plant-based data : Plant height, Panicle height, leaf length & diameter were collected

Plot- based data: Days to tasseling, days to physiological maturity, lodging percentage, thousand seed weight, grain yield, biological yield and harvest index were collected

Statistical Analysis

The collected data on various parameters of the crop under study were statistically analyzed using SAS statistical package (SAS, 2003) version 9.1.3 using Fishers' LSD. The Least Significant Difference (LSD) test at 5% level of significance was used to separate the means when the ANOVA showed the presence of significant difference.

Partial Budget Analysis

To identify the economic optimum rate of applied fertilizer, economic analysis was done using the CIMMYT partial budget analysis methodology (CIMMYT, 1988). Following the CIMMYT partial budget analysis methodology, total variable costs (TVC), gross benefits (GB) and net benefits (NB) were calculated. Then treatments were arranged in an increasing TVC order and dominance analysis was performed to exclude dominated treatments from the marginal rate of return (MRR) analysis. A treatment is said to be dominated if it has a higher TVC than the treatment which has lower TVC next to it but having a lower net benefit. A treatment which is non-dominated and having a MRR of greater or equal to 50% and the highest net benefit is said to be economically profitable.

Marginal rate of return was computed by the formula;

$$MRR\ (\%) = \frac{\text{Marginal benefit}}{\text{Marginal Cost}} \times 100$$

Results and Discussion

Combined Analysis of Variance

Mean square of analysis of variance of all treatments for grain yield and yield related parameters were presented in Table 1. Highly significant differences were observed among the treatments ($P \leq 0.05$) for parameters like days to heading, days to maturity, grain yield and harvest index while significant differences were detected ($P \leq 0.05$) for leaf area, lodging percentage, panicle weight and thousand seed weight. Non-significant difference was detected for parameters like plant height, panicle height and biological yield . The combined analysis of variance showed location effects for the treatments were significant for all parameters.

Table 1. Analysis of variance of major agronomic and yield components o f Sorghum against different level of NPS and N fertilizer at Western Oromia

SV	DF	Mean Squares										
		DH	DM	PH	PNH	LD	LA	PNW	TSW	GY	BY(ton/ha)	Hi (%)
Trt	12	106**	151.4**	667.5	20.6	0.4*	5681.13*	1865.9*	33.1*	1882901.5**	4810.3*	78.9**
Rep	2	25.7**	23.4**	539.3	13	0.6**	7616.8	4101.2*	1.62	1126792.6*	13510.7*	42.3
Loc	4	955.5**	419.5**	153427.6**	135.3**	11.81**	1363835.8**	92385.8**	745.1**	2348939.1**	24522.6**	117.3**
Trt*Loc	48	0	2.7**	269.3	5.5	0.3**	2511.8	613.3	15.9	500055.2*	1147.8	35.2*

Key: ns= non significant, * = significant,* *= highly significant, DH=Days to heading, DM= Days to maturity, PH= Plant height ,PNH=Panicle height, LD= Lodging, HW= Head weight, TSW= Thousand seed weight, GY= Grain weight in Kilogram per hectare, BY(ton/ha)- Biological yield in ton per Hectare; Hi(%)-harvest index in percentage.

Yield Performance of Sorghum against different rate of NPS and N across locations

The results read from Anova indicates that there is highly significant (P<0.05) difference in grain yield across locations. The highest mean grain yield of Sorghum (3033.38 kg/ha) was recorded at Sadi Chanka followed by Haro Sabu (2986.9kg/ha) and the lowest mean grain yield(2919.64kg/ha) was obtained at Bellam. Analysis of combined mean (Table 3.) shows highest mean grain yield (4007.4kg/ha) was achieved at the combined application of 150kg/ha NPSX69 kg/ha N fertilizer rate while the lowest grain yield (2595.3kg/ha) was achieved at control treatment (zero application).

Table 2.Over location mean grain yield of Sorghum against different level of NPS and N fertilizer at Western Oromia

	Grain Yield in Kg/ha					
		2019				
			2020			
NPS XN Level(Kg/ha)	Haro Sabu	Sadi Chanka	Haro Sabu	Sadi Chanka	Bellam	Comb. Mean
50X69	3610.8a-c	4036.9ab	2652.3e-g	2389.7d	2642.3e-g	3066.4b
100X69	2726.8cd	2834.4b	3569.6ab	2569.5cd	3559.6ab	3052b
100X46	2622.1cd	3360.7ab	3217.5b-d	3146.5b	3207.5b-d	3110.9b
125X46	2806cd	3334.9ab	2499.5fg	2926.9bc	2489.5fg	2811.4b-d
150X23	2566.4cd	2679.8ab	3061.9c-e	2492.3cd	3051.9c-e	2770.5b-d
150X69	4373.8a	4418.1a	3780.1a	3695a	3770.1a	4007.4a
0X0	3252.3a-c	2858.8b	2291g	2293.5d	2281g	2595.3d
100X23	4025.9ab	3271ab	2910.3d-f	2622.5cd	2900.3d-f	3146b
50X23	2603cd	2996.9b	2484fg	2644b-d	2474fg	2640.4cd
125X23	2929.7b-d	3982.5ab	2721.7d-g	2560.5cd	2711.7d-g	2981.2b-d
125X69	2839.6cd	2635.3b	3533.1a-c	2563.1cd	3523.1a-c	3018.8bc
50X46	2113d	3639.7ab	2691.4e-g	2576.1cd	2681.4e-g	2740.3b-d
150X46	3104.4b-d	3749.6ab	2672.9e-g	2585.1cd	2662.9e-g	2955b-d
Mean	3044.12	3369.119	2929.641	2697.285	2919.641	2991.961
CV	22.14	25	10.12	11.44	10.15	18.77
LSD	1135.6	1419.5	499.61	520.16	499.61	405.84
Ftest	*	ns	**	*	**	**

Agronomic performance

Days to heading

Anova shows that there is highly significant (P<0.05) difference in days to 50 % heading among the treatments. Highest mean of days to heading (140.67 days) was recorded by the application of 150kg/ha NPS X 46kg N /ha while the lowest days to heading (133.6 days) was recorded by the application of 125kgNPS/ha X69kgN rate per hectare .

Days to maturity: Anova indicates that there is highly significant (P<0.05) difference in days to 50 % maturity. Highest mean of days to maturity (203.13 days) was recorded by the application of 125kg/ha NPS X 69kg N /ha while the lowest days to maturity (193.4 days) was recorded by the application of 150kgNPS/ha X46kgN rate per hectare .

Leaf Area: Variation occurred in leaf area due to application of different NPS and N rate for sorghum is significant (P<0.05). The highest leaf area (752.42 $cm^{2)}$ was recorded at 150kg/ha NPS X 69kg N /ha where the lowest leaf area (685.35 cm^2) was registered at 125kg/ha NPS X 46kg N /ha fertilizer application rate.

Panicle weight: Different application rate of NPS and N to sorghum affect panicle weight significantly (P<0.05). The maximum figure (142.64 gm) was recorded at the application of 150kg/ha NPS X 69kg N /ha while the minimum figure (99.18cm) was recorded at the application of 150kg/ha NPS X 69kg N/ha fertilizer rate per hectare.

Thousand seed weight: Significant difference (P<0.05) was obtained for thousand seed weight due to application of different rate of NPS and N fertilizer for sorghum. Highest value (30.74gm) of thousand seed weight was obtained at the application of 150kg/ha NPS X 69kg N /ha while the lowest value (24.83) was obtained at the application of 50kg/ha NPS X 23kg N /ha fertilizer rate.

Biological yield: Sorghum biological yield respond significantly (P<0.05) to the application different rate of NPS and N. The combined application of 100kg/ha NPS X 69kg N /ha has resulted highest biological yield (18.8 ton/ha kg/ha) while the lowest biological yield (13.5 ton/ha) was resulted at control treatment (zero application) fertilizer rate.

Harvest index: As it is observe from Anova, there is highly significant (P<0.05) difference in harvest index. Highest mean of harvest index (31.1%) was scored by the combined application of 150kg/ha NPS X 69kg/ha N /ha fertilizer rate while the lowest harvest index (15.6%) was recorded by 150kg/ha NPS X 23kg/ha N /ha fertilizer rate .

Table 3. Combined Mean effect of NPS and N rate on yield and yield components of Sorghum at Haro Sabu and Sadi Chenka and Bellam during 2019-2020

NPSX N rate)	DH	DM	PH	PNH	LD	LA	PNW	TSW	GY(Kg/ ha)	BY(ton/ ha)	Hi (%)
50X69	138.e	197.1g	388.6b	36a-c	1.6a	711.b-d	118.b	25.1b	3066.4b	16.5ab	27.2ab
100X69	140.a	195h	406.6a	34.cd	1.5ab	697.cd	104.b	26.3b	3052b	18.8a	17.4de
100X46	134i	200.4d	387.16b	34.7b-d	1.67a	709.98b-d	116b	27.24b	3110.9b	16.2ab	19.32b-e
125X46	139.6b	197.73f	398.73ab	34.3cd	1.6a	685.35d	112.25b	26.55b	2811.4b-d	18.3ab	19.97b-e
150X23	136.7g	199.53e	398.67ab	36.86ab	1.53ab	744.62ab	116.11b	25.02b	2770.5b-d	17.5ab	15.6e
150X69	134.7h	194.73i	401.37ab	34.62b-	1.6a	752.42a	142.64a	30.74a	4007.4a	16.5ab	31.067a
0X0	138.7d	199.6e	393.36ab	33.08d	1.27c	724.17a-d	99.52b	26.2b	2595.3d	13.5b	25.42a-c
100X23	138f	202.2b	387.17b	35.1b-d	1.33bc	719.89a-d	116.3b	26.14b	3146b	15.9ab	24.565a-d
50X23	134.7h	194.73i	398.61ab	33.83cd	1.33bc	734.53a-c	99.18b	24.83b	2640.4cd	15.7ab	18.56c-e
125X	134i	201.4	391.92	35.0b	1.27c	741.65	110.3	26.6	2981.2b-	16.0ab	24.237

23		7c	ab	-d		ab	9b	3b	d		a-d
125X69	133.67j	203.13a	402.26 ab	35.5a-c	1.33 bc	734.28 a-c	113.85b	26.04b	3018.8bc	13.91b	23.96a-d
50X46	139.3 c	200.67d	388.15 b	37.03 a	1.2c	731.78 a-c	103.24b	25.77b	2740.3b-d	16.17ab	20.932 b-e
150X46	140.7 a	193.4j	402.01 ab	33.66 cd	1.27c	736.29 a-c	115.61b	26b	2955b-d	18.3ab	24.7a-d
Mean	137.15	198.47	395.74	34.92	1.4256	724.8912	112.9	26.351	2991.96	16.4	22.51
CV	0.22	0.41	6.11	9.03	24.3	7.49	25.84	14.48	18.77	18.8	32.01
LSD	0.22	0.58	17.497	2.29	0.25	39.26	21.08	2.75	405.84	3.5	8.32
Ftest	**	**	ns	ns	*	ns	ns	Ns	**	ns	*

***Means with the same letter are not significantly different.*

Economic Analysis

Economic analysis was computed to give general recommendation and it was shown in table 4.

Table 4. Partial Budget analysis of NPS and N rate on Sorghum at Haro Sabu and Sadi Chenka and Bellam during 2019-2020

NPSXN(Kg/ha)	Average GY(kg/ha)	TVC	Gross benefit	TVC	Net benefit (ETB)	Marginal increase in net benefit	Marginaincrease in total variable cost	Dominance Analysis	MRR (%)
0	2595.3	0	20762	0	20762				
50X23	2640.4	1984	21123	1984	19139				
50X46	2740.3	2880	21922	2880.5	19042				
100X23	2946	3071	23568	3071	20496	1454.6	191		761.57
125X23	2981.2	3615	23850	3615	20234			D	
50X69	3066.4	3777	24531	3777	20754	519.85	161.75		321.39
100X46	3110.9	3968	24887	3968	20919	165	191		86.39
150X23	2770.5	4159	22164	4159	18005		191	D	
125X46	2811.4	4512	22491	4512	17979		352.75	D	
100X69	3052	4864	24416	4864	19551	1572.0	352.75		445.66
150X46	2955	5055	23640	5055	18584		191	D	
125X69	3018.8	5408.	2415	5408	18742	157.65	352.75		44.69
150X69	4007.4	5952	32059	5952	26107	7365.05	543.75		1354.49

Conclusions and Recommendations

Partial budget analysis for the experiment revealed that the combined application of 150kg/ha NPS X 69kg N /ha fertilizer rate is economically acceptable for the study areas. At this level of fertilizer, mean grain yield of sorghum obtained was 4007.4 kg/ha with marginal rate of return 1354.49%. Also yield advantage gained over control treatment due to application of 150kg/ha NPS X 69kg N /ha fertilizer to maize was 54.4%.

Therefore, combined application of 150kg/ha NPS X 69kg/ha N fertilizer to sorghum is recommended for the areas.

Acknowledgement

The author warmly acknowledge Oromia Agricultural Research Institute (IQQO) for financial support and guidance. The contribution of Haro Sabu Agricultural Research Center staff members are also unforgettable for technical and administrative support.

References

Akram, A., Mussarrat, F., Safdar, A., Ghulam, J & Rehana, A. 2007. Growth, yield and nutrients uptake of sorghum in response to integrated phosphorus and potassium management: Pak. J. Bot., 39(4):1083-1087.

CSA, 2015. CSA (2015) Report on area and production of crops. Statistical Bulletin 578. Addis Ababa: Central Statistic Authority.

Food Agriculture organization of the United Nations (FAO) (1985). FAO statistical data: www.faostat.fao.org.

Geremew G, Asfaw A, Taye T, Tesfaye T, Ketema B and Hilemichael H (2004) Development of sorghum varieties and hybrids for dryland areas of Ethiopia. Uganda Journal of Agricultural Science 9:594–605

Onyango, R.M.A., Mwangi, T.K., Kiiya, W.W & Kamidi, M.K. 1998. Maintaining maize productivity by combining organic and inorganic fertilizers in small holder farms within the Kitale region. In: Maize Production Technology for the Future: Challenges and Opportunities, Proceedings of the sixth Eastern and Southern Africa Regional Maize Conference, Addis Ababa, Ethiopia, pp242-246.

Taye T (2013) Sorghum production technologies training manual Ethiopian Agricultural Research Organization (EARO), Melkassa Research Center Nazret, Ethiopia.

Rooney, L.W & Murty, D.S. 1982. Evaluation of sorghum food quality. Proceedings of the International Symposium on Sorghum, 2-7 November, 1981, International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), volume 2, Sorghum in the eighties, Patancheru, A.P., India, 783p.

Sanchez, PA, KD Shepherd, MJ Soul, FM Place, RJ Buresh and AMN Zac, 1997. Soil fertility replenishment in Africa. Replenishing soil fertility Africa, SSSA, Special Publication 51 SSSA, Madison, USA.

Field pea (*Pisum sativum* L.) Adaptability and Performance Evaluation at Kellem Wollega Zones of west Oromia, Ethiopia

Dereje Abera*, Firaol Fikadu, Lamesa Emisha, Megersa Terefa and Rata Tamiru
Haro Sabu Agricultural Research Center, P O Box 10, Haro Sabu, West Oromia, Ethiopia
*Corresponding author e-mail: dereaber@gmail.com

Abstract

The field experiment was carried out on fourteen (14) field pea varieties including one local cultivar at mid-land research sites of Haro Sabu Agricultural research center (Badeso, Mata and Nya'a) during 2018 to 2020 main cropping seasons. The main aim of the study was to evaluate, select and recommend adaptable, high yielding, disease tolerant and stable field pea variety for potential areas of West and Kellem Wollega Zones, West Oromia. The trial was conducted in Randomized Complete Block Design (RCBD) with three replications, consisting of a gross plot size of 1.2mx3m. Combined analysis of variance (ANOVA) depicted significant main effect of variety, test location, and their interaction effect on grain yield and other yield attributing agronomic traits. The main effect of variety, location (except DF), year and their interaction effect exerted significant effect ($p<0.05$ or $p< 0.01$) on all agronomic traits, indicating the variability of test variety, location and over year fluctuating weather condition. Stability of evaluated varieties and test locations were tested by GGE biplot. Significantly larger mean value of grain was recorded from Bilalo (1542.8 kg/ha), Burkitu (1394.4 kg/ha) and Adi (1318.9 kg/ha) variety. Besides, these three varieties were also identified for their grain yield stability. The grain yield advantage of 55.93 % (Bilalo), 40.92% (Burkitu) and 33.30% (Adi) were estimated over the local cultivar. Bilalo (Shiro type), Burkitu (Kiki type) and Adi (Kiki type) were high yielder, adaptable, disease tolerant and stable varieties. Therefore, these three varieties were suggested for further demonstration in potential areas of West and Kellem Wollega Zones of West Oromia and areas with similar agro-ecology.

Keywords: *Field Pea; Adaptability; Yield; Stability*

Introduction

Field pea (Pisum sativum L.) is a cool-season legume crop which is grown for different purposes in different parts of the world. The crop contains high levels of acids, lysine and tryptophan, which are relatively low in cereals. The crop consists of approximately about 21-25% protein and rich in carbohydrates (CSA, 2012). Field pea is the third legume crop in Ethiopia, headed only by faba bean and chickpea in terms of both area coverage and total national production (Gemechu *et al*., 2013). According to Haddis *et al.* (2013), there are two botanical varieties of Field pea known to be grown in Ethiopia, namely P. sativum var sativum and P. sativum var abyssinicum, while much of the production in our country is on P.sativum var sativum. The crop performs well at altitude of 1800-3000 m.a.s.l., requiring 800-1100 and 700-900 mm rain fall in highlands and mid altitude areas, respectively for optimum growth and development. So far, the national average yield of 1.2 ton/ha was reported under farmer's management (CSA, 2012). The maximum yield of 4-6 ton/ha was reported at research field through using improved production technologies including variety (Mohammed, 2016)). Field pea is one of the best components in day-to-day dish in the form of wet either in its crashed form locally called kik or in its powder form called shiro in West and Kellem Wollega, particularly. Nevertheless, the crop is grown in limited parts of mid and highlands of the area. Field pea production is constrained by low yielding potential of farmers' variety that are widely grown in the area, disease, insect pest and poor management practices (Telaye *et al.*, 1994). Thus, introduction and evaluation of improved field pea varieties is paramount important in west and Kellem Wollega Zones of West Oromia, Ethiopia. Therefore, the main aim of the study was to evaluate, select and recommend adaptable, high yielding, stable and disease tolerant field pea variety/ies for potential areas of west and kellem wollega Zones, West Oromia, Ethiopia.

Materials and Methods

Test Materials: Thirteen (13) field pea varieties introduced from Holota and Bako Agricultural research center were evaluated with local cultivar at Badeso, Mata, Belam and Nya'a, of Kellem wollega Zone, West Oromia for three consecutive cropping season (2018-2020).

Research Methodology

The field experiment was conducted in randomized complete block design (RCBD) with three replications in gross plot size of 1.2mx3m at row spacing of 20cm. Seed was manually drilled in the row and thinned at the spacing of 5cm after seedling establishment. The blended inorganic

Table 1: Combined analysis of variance (ANOVA) for grain yield and yield components

SV	DF	DF	DM	SPP	HSW	GY
Location	3	9.97	459.12**	3.33*	11.99*	3036677.05 **
Year	2.00	19.73*	907.23**	1.66*	15.43*	1474257.99*
Rep	2.00	23.01	8.61	0.11	5.40	984247.16
Variety	13.00	32.08**	54.17**	2.12**	113.44**	550954.09**
Loc*year	26	7.45	342.11*	2.34**	12.75*	23452.**
Loc *Var	39	4.99	31.56**	0.58	3.49*	376220.20**
Year*Var	26.00	5.53	37.91**	0.47	4.86*	189802.39
Loc *Year*Var	32	4.23	23.53**	0.42	3.75*	15657.12**
Error		4.90	9.72	0.48	1.84	160054.66
R-square		0.52	0.79	0.49	0.86	0.61

Key; DF=days to 50% flowering, DM=days to 90% physiological maturity, GY= seed yield of field pea, HSW= hundred seed weight, SPP=seed/pod.

fertilizer (NPS) was applied at the rate of 100kg/ha at sowing time. The remaining agronomic practices including weeding and hoeing were uniformly applied to all varieties.

Data Collection: Plot and plant based observation was commenced to achieve objective of the study following the procedures developed in field pea descriptor. With this, days to 50%

flowering, days to 50% maturity, disease reaction, seed/pod, hundred seed weight (gm) and yield (kg/ha) were collected.

Data analysis: The collected data were organized and subjected to SAS software. The mean separation was done by using least significant difference (LSD) following the methods developed by Gomez and Gomez (1984).

Results and Discussions

Combined analysis of variance (ANOVA) revealed significant ($p<0.05$ or $p\leq0.01$) main effect of test location, year and variety on days to maturity (DM), seed/pod (SPP), hundred seed weight (HSW) and grain yield (GY), indicating the variability of test locations, varieties and over year fluctuating weather conditions (Table 1). The significant and longer mean value of DM was recorded at Belam. However, Badeso, Mata and Nya'a showed significantly lower mean value of DM than Belam, ensuring the effect of test location on performance of DM. Significant and greater than grand mean value of SPP, HSW and GY was recorded at Badeso. Inversely, Mata test location poorly performed for most of agronomic traits except for hundred seed weight. The rest test locations viz. Belam and Nya'a were identified for their medium mean value of grain yield, illustrating variability of test location in terms of their potential for field pea production (Table 2).

ANOVA identified significant variability of the three cropping seasons on all agronomic traits. With this perspective, significantly longer mean value of phonological traits (DF and DM), HSW and GY was recorded during 2020 cropping season (Table 3).

Table 2: Main effect of test location on grain yield and yield components

Location	Parameters				
	DF	DM	SPP	HSW	Gy
Badeso	63.86	128.9b	5.02a	16.78ab	1325.07ab
Belam	63.33	132.84a	4.71b	16.51b	1265.64b
Nya'a	63.98	127.79bc	4.66b-d	16.62b	1170.95bc
Mata	64.38	128.29bc	4.39d	17.29a	762.74c

On the contrary, the poor mean performance of several agronomic traits including grain yield was obtained during 2019 cropping season (Table 3), indicating significant effect of fluctuating weather condition on performance of observed traits.

Table 3: Main effect of year on grain yield and yield components

Year	DF	DM	SPP	HSW	GY
2018	63.19ab	127.38b	4.46b	16.21b	1170.55b
2019	62.83b	135.4a	4.95a	15.96b	1145.24b
2020	63.98a	135.74a	4.73ab	17.37a	1481.12a

Interaction of Location by Variety

ANOVA depicted significant interaction effect of location by variety on DM, HSW and GY. Significantly higher mean value of DM was recorded from Arjo and Harana (Mata and Nya'a site), Arjo and Bilalo (Badeso site) and Lammiif (Belam). The significant and shorter mean value of DM was obtained from Tegegnech (Mata site), Burkitu (Badeso and Nya'a site), Wayitu, Urji and Harana (Bellam site) as presented in table 4 below.

Significantly higher mean value of HSW was recorded from Tegegnech (Mata and Badeso), Adi, Bilalo and Burkitu (Belam and Nya'a) as shown in table 5.

Table 4: Interaction effect of variety by location on days to maturity

Days to 90% maturity				
Variety	Mata	Badeso	Bellam	Nya'a
Adi	127.67a-c	127ab	132.44cd	128.67a-c
Arjo	131.33a	131.67a	132.33cd	130.67bc
Bariso	129a-c	129ab	133.33b-d	129.33a-c
Bilalo	130a-c	131.33a	134.33bc	128.67a-c
Burkitu	125.33a-c	124.33b	133b-d	123.67e
Bursa	129.33a-c	129.67ab	135b	127b-e
Gedo-1	124.33bc	129.33ab	134.89b	124de
Harana	131a	130ab	129.22e	131.67a
Jidha	128.67a-c	128.33ab	135.22b	127b-e
Lammiif	130.67ab	130.67ab	139.22a	126c-e
Local	130.67ab	129.67ab	131.89d	129.33a-c
Tegegnech	124c	125ab	132.89b-d	127.67a-e
Urji	127.33a-c	130ab	127.78e	128a-d
Wayitu	126.67a-c	128.67ab	128.22e	127.33b-e
Mean	128.29	128.90	132.84	127.79
CV	3.03	3.11	1.93	1.91
Lsd	6.52	6.73	2.39	4.10

Inversely, the significant and lower mean value of HSW was obtained from Wayitu and Local cultivar (Mata), Local cultivar and Bariso (Badeso), Urji and Local cultivar (Belam), Local cultivar and Jidha (Nya'a). Moreover, Local cultivar revealed significantly lower mean value of hundred seed weigh which was lower than grand mean across test locations in uniform pattern, indicating the smaller seed size of local cultivar (Table 5).

Table 5: Interaction effect of variety by location on hundred seed weight

Hundred Seed weight (gm)				
Variety	Mata	Badeso	Bellam	Nya'a
Adi	19.17cd	19bc	20.21a	20.77ab
Arjo	14.93gh	15.2de	14.8de	14.63de
Bariso	17.03ef	14.7e	14.92de	16.47c-e
Bilalo	21.27b	20.62ab	21.2a	20.47ab
Burkitu	20.5bc	19.93ab	20.34a	21.43a
Bursa	16.47f	13.47e	14.46e	16.3c-e
Gedo-1	16.03fg	15.03de	15.86cd	17.17cd
Harana	14.77gh	15.57de	14.88de	14.7de
Jidha	18.17de	16.2c-e	15.76cd	13.63e
Lammiif	18.1de	17.7b-d	16.56c	15.83c-e
Local	13.8h	13.8e	14.49e	13.7e
Tegegnech	22.8a	22.67a	18.96b	18.13bc
Urji	14.57gh	15.57de	13.98e	14.77de
Wayitu	14.42h	15.5de	14.76de	14.73de
Mean	17.29	16.78	16.51	16.62
CV	5.25	10.36	7.13	10.79
Lsd	1.52	2.92	1.10	3.01

Significantly larger mean value of GY was recorded from Urji variety (Mata), Jidha (Badeso), Bilalo, Burkitu and Adi (Belam and Nya'a). On the contrary, the significant and lower mean value of grain yield which was below grand mean was recorded from Lammiif (Mata), Local cultivar (Badeso and Belam) and Tegegnech (Nya'a). The result, most likely detected poor performance of Local cultivar and better performance of Adi, Bilalo and Burkitu for grain yield across test location relative to the remaining varieties (Table 6).

Interaction of Variety by Year

Interaction effect of variety by year imposed significant effect ($p<0.05$ or $p<0.01$) on days to maturity (DM) and hundred seed weight (HSW) as presented so far in table 1.

Table 6: Interaction effect of variety by location on grain yield

Grain Yield Kg/ha				
Variety	Mata	Badeso	Bellam	Nya'a
Adi	588d-f	1446.6a-d	1504.1a-c	1366.6a-c
Arjo	1074.9ab	795.6d	1033.4e	1086.4a-c
Bariso	659.3c-e	1562.6a-c	1190.2c-e	1289a-c
Bilalo	661.9c-e	1608.4a-c	1828.5a	1501.1ab
Burkitu	633.2c-f	1031.6cd	1674.1ab	1679a
Bursa	808.3b-e	1240.4b-d	1270.5b-e	1296.2a-c
Gedo-1	655.3c-e	1525.2a-c	1017.2e	1174a-c
Harana	940bc	752d	1061.6de	999.4bc
Jidha	499.3ef	1909.4ab	1054.5e	823.6c
Lammiif	322.1f	1267.1b-d	1371.7b-e	829bc
Local	847.8b-d	801.9d	1052.9e	1128.1a-c
Tegegnec	533.4d-f	1142.8cd	1457.7a-d	697.7c
Urji	1339.2a	1637.4a-c	1164.8c-e	1362.6a-c
Wayitu	1115.7ab	1329.9b-d	1108.5c-e	1160.7a-c
Mean	762.74	1325.07	1265.63	1170.95
CV	24.85	31.83	34.05	34.22
lsd	318.07	707.90	404.14	672.52

With this regards, significantly longer mean value of DM which was greater than grand mean was recorded from Arjo (2018), Lammiif (2019 and 2020). Inversely, Burkitu (2018), Urji and Wayitu (2019 and 2020) showed significantly earlier and lower mean value of DM which was below grand mean. The study found no variety which was significantly late or earlier across each cropping season consistently. Never the less, Adi (Kiki type), Burkitu (Kiki type) and Bilalo (Shiro type) which were relatively high yielder than the rest had medium mean value of DM across the three cropping seasons and test locations in general.

Concerning hundred seed weight; significant and larger mean value which was above grand mean was obtained from Tegegnech variety (2018), Burkitu, Bilalo and Adi (2019 and 2020), revealing the larger seed size of these varieties (Table 6).

Table 7: Interaction effect of variety by year on days to maturity and hundred seed weight

Days to Maturity				Hundred Seed weight (gm)		
Variety	2018	2019	2020	2018	2019	2020
Adi	128a-d	133.33de	131.67b	19.37c	20.67a	20.4ab
Arjo	131.11a	135.33b-d	131b	15.07ef	14.83cd	14.57gh
Bariso	129a-c	135b-e	132.67b	15.44de	13.13d	16.75de
Bilalo	130.11ab	137b-d	132.83b	21.14ab	20.27a	21.13a
Burkitu	124.56e	136.33b-d	131.17b	20.22bc	20.35a	20.93a
Bursa	128.33a-d	138.67bc	133.67ab	14.57ef	13.33d	16.28ef
Gedo-1	126.22c-e	139b	132.33b	15.26ef	15.73bc	17.15de
Harana	129.22a-c	130.67ef	131b	14.91ef	15.3cd	14.82f-h
Jidha	127.89b-d	139b	133.5ab	16.7d	13.63cd	15.77e-g
Lammiif	128.78a-c	145.67a	136.5a	16.64d	15.37cd	18cd
Local	128.78a-c	134.33c-e	132.33b	14.11f	14.73cd	13.85h
Tegegnec	125.33de	135.33b-d	132b	21.64a	17.73b	18.9bc
Urji	128.89a-c	127.33f	127.33c	14.49ef	13.93cd	14.72f-h
Wayitu	128.44a-d	128.67f	126.67c	15.07ef	14.4cd	14.66hg
Mean	128.19	135.40	131.76	16.76	15.96	16.99
CV	2.66	1.98	2.10	8.12	8.53	8.04
lsd	3.19	4.49	3.21	1.28	2.29	1.58

On the contrary, Local cultivar had significantly lower mean value of HSW across each cropping season consistently, presenting the smaller seed size of Local cultivar.

Combined Mean performance

Combined analysis of variance (ANOVA) showed significant ($p<0.05$ or $p\leq0.01$) main effect of evaluated field pea variety on grain yield and other observed agronomic traits. Significantly earlier (shorter) days to flowering (DF) was attained by Harana and Wayitu; whereas the longer (late) DF was recorded from Lammiif, Gedo-1 and Jidha. Significantly longer days to maturity (DM) was observed from Lammiif variety and followed by Bilalo (high yielded variety). Inversely, the significant and earlier days to maturity was recorded from Wayitu and Urji (low yielded variety). On the other hands, the mean value of days to maturity (DM) for Bilalo (132.17 days) was above grand mean (130.58 days), most likely exhibiting the medium maturity of these varieties. Burkitu (128.72 days) and Adi (130.11 days) below grand mean value of days to maturity as presented in table 8 below, indicating relatively earlier maturity of these varieties.

Significantly larger mean value of seed/pod (SPP) was estimated from Bilalo and followed by Bariso, Local cultivar and Lammiif. In the same way, the significant and larger mean value of hundred seed weight (HSW) was recorded from Bilalo and followed by Burkitu, Tegegnech and Adi. On the contrary, the significantly lower mean value of HSW and relatively better seed number/pod was estimated from local cultivar, showing better number of seed/pod which was inversely small in size (Table 8).

Significantly larger mean value of grain yield (GY) which was above grand mean (1159.57 kg/ha) was estimated from Bilalo (1542.8Kg/ha) and followed by Burkitu (1394.4 kg/ha) and Adi (1318.9 kg/ha). On top of this, a grain yield advantage of 55.93%, 40.92% and 33.30% was estimated from Bilalo, Burkitu and Adi variety over the local cultivar, respectively. Unlikely, significantly lower mean value of grain yield was estimated from Urji variety followed by Harana and Local cultivar (Table 8).

The result of present study identified medium maturing varieties (Bilalo) and relatively earlier maturing variety (Burkitu and Adi) for their better seed size and grain yield in general. Moreover, these varieties are used for different dish purpose. For instance, Bilalo is the shiro type where as Burkitu and Adi are the kiki type.

Table 8: Combined mean performance of seed yield and yield components of field pea

Variety	DF	DM	SPP	HSW	GY (Kg/ha)
Adi	64.67a-c	130.11c-f	4.41d	19.93b	1318.9a-c
Arjo	61.78f	131.78bc	4.7b-d	14.86ef	1009.5d
Bariso	62.94d-f	131.22b-d	5.08ab	15.49de	1180.3b-d
Bilalo	64.33b-d	132.17ab	5.21a	20.99a	1542.8a
Burkitu	63d-f	128.72e-g	3.82e	20.48ab	1394.4ab
Bursa	64.22c-e	131.83bc	4.87a-c	14.93ef	1192.8b-d
Gedo-1	65.72ab	130.39b-e	4.72b-d	15.97d	1067.7cd
Harana	62.61f	130.06c-f	4.72b-d	14.95ef	979.4d
Jidha	65.5a-c	131.61bc	4.77a-d	15.88d	1009.5d
Lammiif	65.89a	134.17a	4.93ab	16.88c	1088.9cd
Local	63.06d-f	130.89b-d	4.95ab	14.13f	989.4d
Tegegnech	62.89d-f	129.22d-g	4.44cd	20.08b	1145.5b-d
Urji	62.78ef	128.11fg	4.75b-d	14.47f	888.9e
Wayitu	62.44f	127.89g	4.46cd	14.82ef	1155.3b-d
Mean	63.7	130.58	4.7	16.7	1159.57
CV	3.48	2.39	14.78	8.13	34.02
Lsd	1.46	2.05	0.46	0.89	263.29

Variety and Variety by Environment interaction (GGE) Bi-plot analysis

Evaluated varieties and environments fell in the center of the circle are suggested to be ideal in GGE biplot (Yan, 2002). The mean value of grain yield and yield stability are equally important in GGE bi-plot as suggested by Farshadfar et al. 2011. Accordingly, Bilalo (1542 kg/ha) found to be the ideal variety and followed by Adi (1318.9 kg/ha). On the other hand; Burkitu (1394.4 kg/ha), the second high yielding variety was relatively stable after Bariso, Urji, Bursa and Gedo-1. On the contrary, Harana, Local caltivar and Jidha were unstable and low yielder varieties. So that, Bilalo, Adi and Burkitu were depicted for their stability and larger mean value of grain yield which is equally important as shown in figure 1 below.

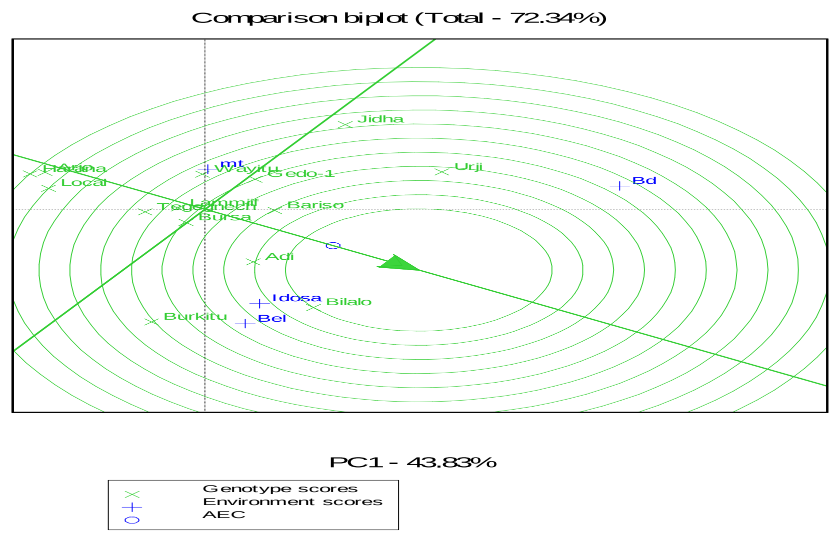


Figure 11. GGE bi-plot based on genotype focused scaling for comparison of genotype for grain yield stability

Badeso (1325.07 kg/ha) was the most ideal and followed by Nya'a (1170.96 kg/ha) and Belam (1265.83 test location. Mata (762.74 kg/ha) test environment had below grand mean value of grain yield and found to be unstable, indicating less representativeness of the environment as presented in Figure.2 below.

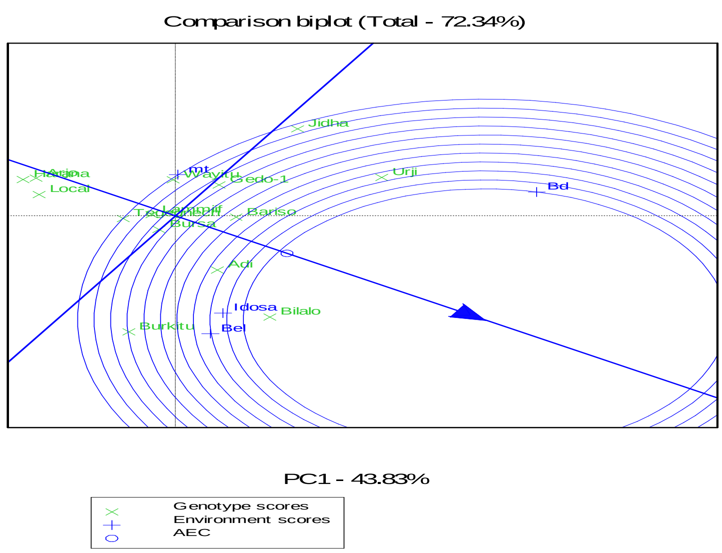


Figure 12. GGE bi-plot based on environment focused scaling for comparison of environment for grain yield stability

Conclusions and Recommendations

Combined analysis (ANOVA) of variance showed significant effect of variety, location, year and their interaction effect on grain yield and yield components. Analysis depicted no variety consistently significant for all observed parameters across each test locations and years, resulted in difficult selection of superior variety for all locations. Present study identified Bilalo, Adi and

Burkitu for their adaptability, higher mean value of grain yield, yield stability and foliar disease tolerant level. The identified varieties have a grain yield advantage of 55.93%, 40.94% and 33.30% over the local cultivar for Bilalo, Burkitu and Adi, respectively. Moreover, identified varieties are used for different dish purposes. In this view, Bilalo was found to be the best variety from the Shiro type whereas Adi and Burkitu from the kiki type. Consequently, the selected varieties were suggested for further demonstration on farmer's field with the full packages mentioned in present study thereby to contribute for food security of Kelem Wollega Zone and other similar agro-ecology.

Acknowledgements

Authors gratefully thank Oromia Agricultural Research Institute for financial grant, Bako and Holeta Agricultural Research Center for permitting access to Field Pea Varieties, Haro Sabu Agricultural Research Center for facilitation of research activity and Pulse and Oil Crop Research Case Team for trial management.

Reference

CSA (Center of Statistical Authority of Ethiopia. Agricultural Sample Survey 2012. Reports on area under cultivation, yield and production of major crops for main (Meher) season, Ethiopia; 2015.

Gemechu Keneni, Fassil Assefa, M.Imtiaz, and Endashaw Bekele. 2013. Genetic diversity for attributes of biological nitrogen fixation in Abyssinian field pea (Pisum sativum var abyssinicum) germplasm accessions. *Ethiopian Journal of applied science technology*, 4(2):1-20.

Gomez, K. A. and A. A. Gomez. 1984. Statistical Procedures for Agricultural Research. 2nd Ed., John Willey and Sons. Singapore.

Grafton, K.F., Chang, K.C., Venette, J.R., Wal, A.J. and Vander. 1993. Registration of 'Norstar' navy bean. *Crop Science* 33: 1405-1406.

Mohammed A., Asefie S., Dagnachew W., and Seyum N. 2016. Participatory evaluations of field pea (Pisum sativum L.) varieties in Wollo, Ethiopia. *Excellent World Journal of Agricultural Science*, 1(2): 1-6.

Telaye A, Getachew T and Demtsu B.1994. Genetics and Breeding of field pea. Proceedings of the 1st National cool-season Food Legumes Review conference, December 16-20, 1993, Addis Ababa, Ethiopia, 285-214.

Multi-Location Evaluation of Yield and Yield Related Trait Performance in Finger Millet (Eleusine Coracana L.) Genotypes at Western Oromia, Ethiopia

Wakgari Raga[1] Abdi Asfaw[2]
Oromia Agricultural Research Institute (IQQO), HaroSabu Agricultural Research Center (HSARC), P.0.Box 10, Kellem Wollega, Dembi Dollo
*Corresponding author: E-mail: wak.raga@gmail.com

Abstract

*The field experiment was conducted on thirteen finger millet genotypes (Regional Variety Trial) against standard checks at HaroSabu, Sadi Chanka, Sayo and Lalo Kile for the last two consecutive years (2019-2021) to evaluate high yielding, insect pest tolerant genotypes and to assess genotype by environmental interaction on grain yield and yield stability across environments. The seeds were sown in Randomized Completed Block Design (RCBD) with three replications in the net plot size of 4m^2 using four harvestable rows at the spacing of 0.4m. Different agronomic traits and economically important disease reaction were evaluated. Analysis of variance detected significant difference among genotypes for most of traits. Highly significant difference was recorded for finger millet traits like days to heading, plant height, Finger weight and lodging whereas significant difference was detected for productive tillers, finger number and grain yield. Highly significant difference was observed for important disease of finger millet, head blast. Genotypes*location significantly affected days to heading, plant height, lodging and grain yield. GXE revealed four environments were identifiable from which Haro Sabu had the most discriminating ability and good representative where Lalo Kile had a poor discriminating ability as well as least representative. GGE bi-plot analysis revealed that genotype 8 coded as FMC-33 was identified as ideal genotypes in terms of yielding ability and stability and promoted to Variety Verification Trial for further evaluation to be released as variety.*

Keywords*: Landrace, GXE, Genotype, stability, discriminating ability, representativeness.*

Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn.) is one of the most important food cereals in the sub-Saharan Africa and south Asia. It is the most widely cultivated millet in the semi-arid tropical and subtropical regions of the world after pearl millet (*Pennisetum glaucum*) and foxtail millet (*Setaria italica*). It is also one of the critical plant genetic resources for the agriculture and food security of farmers inhabiting arid, infertile and marginal lands (Barbeau and Hilu, 1993).

Finger millet is the second most widely grown millets on the continent of Africa and it is an important crop grown in low input farming systems by resource poor farmers in eastern and southern Africa (Damar et al., 2016). This is indigenous to the highlands of Uganda and Ethiopia. Finger millet is widely produced by small scale landholders and consumed locally (Adugna et al., 2011). It is well adapted to heat, drought and poor soil stress that succeed in marginal and degraded soils (Okalebo, 1991). It is valued for nutrition, malt, good storability, income and other uses for animal feeds. In Ethiopia, finger millet covered 456 171.54 hectare of land with the productivity of 22.30 qt/ha (CSA, 2017). However, low in yielding due to lack of high yielding cultivars, moisture stress, and lodging effect, diseases and low fertility and poor crop management practices (Degu et al., 2009). Strengthen the seed production and delivery systems for improved varieties also the most bottleneck of the crop in the small scale farmers.

Climatic change also directed to reduce the productivity of many crops around the world. So that a considerable attention should be given to the effect of genotype x environment interaction in the plant breeding programs, the relative performance of cultivars for quantitative traits such as yield and the other characters, which influence yield, vary from an environment to another. Consequently, to develop a variety with high yielding ability and consistency over locations, high attention should be given to the importance of stability performance for the genotypes under different environments and their interactions. The impacts of phenotypic variation principally based on the environmental situation and the genetic constitution of the varieties. Such variation is more complicated by the fact that not all genotypes respond in a similar way to change in the environment and no two environments are exactly the same. The genotype × environment interaction results in genotype rank changes from one environment to another, a dissimilar in scale among environments, or a combination of these two situations.

It is imperative to detect specific genotypes adapted to or stable in environment(s), in that way succeeding quick genetic gain through screening of genotypes for high adaptation and stability under varying environmental conditions prior to release as a variety (Ariyo, 1989; Flores et al., 1998; Showemimo et al., 2000; Mustapha et al., 2001).While, most genotypes show fluctuating yields when grown in different environments or agro-climatic zones. This makes difficulties indicating the superiority of a specific variety. To tackle this challenge, multi- location yield trials are essential to identify adaptable high yielding cultivars and discover sites that best represent the target environment (Yan et al., 2000). Adaptability is the result of genotype, environment and genotype by environment interaction. That means the ability to perform at an acceptable level in a range of environments, stated to as general adaptability, and the ability to perform well only in appropriate environments, known as specific adaptability (Farshadfar and Sutka, 2006). Combined analysis of variance can quantity GxE interactions and express the main effects however, does not explain the interaction effect (Yuksel et al., 2002; Worku et al., 2013). The main reason of additive main effects and multiplicative interactions (AMMI) is appropriate for agricultural research is that the ANOVA part of AMMI can separate the G and E main effects and the G × E interaction effects (Gauch et al., 2008). Besides, its greatest advantage is its ability to take out interaction Principal Component Axis (PCA) along which there is a maximum variation, thus indicated the number of components necessary to explain the pattern in the interaction residual (Girma, 1999). Additive Main Effect and Multiplicative Interaction model and genotype and genotype by environment interaction (GGE) bi-plot analysis are the most frequently used analytical and statistical tools to determine the pattern of genotypic responses across environments (Gauch and Zobel, 1996; Yan et al., 2000; Yuksel et al., 2002).

AMMI and GGE bi-plot (Gauch and Zobbel, 1996; Yan et al., 2000; Yuksel et al., 2002) for graphical display of data and Eberhart and Russell (1966) model are the most commonly used analytical and statistical tools to identify stable, high yielding and adaptable genotype(s) for wider and/or specific environments. Different finger millet landraces were collected from Western Oromia with the objective to evaluate, select and release high yielder, tolerant to diseases, more adapted and stable varieties.

Materials and Methods

Description of the Study Area

The experiment was conducted Haro Sabu, Sadi Chanka, Sayo and Lalo Kile for the last two consecutive years (2019-2021). The locations were situated at Kellem Wollega Zone of Western Oromia, Western Ethiopia. The locations have different agro-climatic conditions. According to the 2016/7 season weather data Haro Sabu and Sadi Chanka had an average of 1100 mm annual rainfall and temperature 30°C, while Sayo and Lalo Kile received an average of 1050 mm. The sites also characterized by different soil types, which range from the Brown sandy-loam soils at Lalo Kile and black clay loam at Sadi Chanka and light red sandy at Haro Sabu. Haro Sabu is found on altitude of 1450 masl while Sadi Chenka and Bellam found on 1449 masl and 1495 masl respectively.

Description of Experimental Materials

Thirteen finger millet genotypes (landraces) promoted from preliminary observation nursery were evaluated with two standard check under Regional Variety Trial .

Table1. Description of finger millet genotypes

No	Acc.name	Region	Zone	Woreda	Village	Altitude(masl)	Soil color
1	FMC-1	Oromia	K. Wollega	Dale Sadi	Mender-19	1477	Red
2	FMC-1	Oromia	K. Wollega	Dale Sadi	A.Gandaso	1477	Red
3	FMC-6	Oromia	K. Wollega	D.Wabera	Iggu	1449	Red
4	FMC-7	Oromia	K. Wollega	D. Wabera	Mender-5	1450	Red
5	FMC -11	Oromia	K. Wollega	H. Galan	Mender-17	1336	Red
6	FMC -23	Oromia	K. Wollega	Sayo	Kure Gayib	1618	Black
7	FMC l-24	Oromia	K. Wollega	Sayo	Bubuka	1573	Black
8	FMC l-30	Oromia	K. Wollega	H. Galan	Mada Jalala	1416	Black
9	FMC -33	Oromia	K. Wollega	Dale Waber	Kombolcha	1470	Red
10	FMC -36	Oromia	K. Wollega	J. Horro	Tibbe	1612	Black
11	FMC -47	B/Gumuz	B.Gumuz	Bambesi	Qashmando	1478	Red
12	FMC -83	Oromia	W.Wollega	Guliso	Seda Birbir	1537	Red
13	FMC -94	Oromia	W. Wollega	Yubdo	Kebele-01	1622	Red

Experimental design and management

Randomized completed block design (RCBD) with three replications was used for the treatments. Each experimental plot had six rows of 2.5 m long and 40 cm apart with a plot size of 2.4m x 2.5m. Seed was drilled by hands at the rate of 15kg/ha while Fertilizer Urea and NPS was applied at a rate of 100 kg/ha for all locations. All NPS and half of Urea were applied during planting while the half Urea was applied at tillering stages.. All agronomic managements were carried out per their requirements. Data considered for analysis was from the candidates of the net plot, thus the four central harvestable rows. The harvested genotypes were sundried before being tested for moisture content where 12% was the preferred average moisture content using moisture tester. Grain yield data was then obtained by weighing the dried grain using a digital scale.

Data collection method: Plants were selected randomly before heading from each row (four harvestable rows) and tagged with thread and all the necessary plant based data were collected from these sampled plants.

Plot basis: Days to heading (DH), Days to maturity (DM), Lodging percentage (LDG), Grain yield (GY), and Head blast (HB) was recorded as an economic important of finger millet diseases.

Plant basis: Plant height (PH), Finger length (FL), Productive tillers (PTR), Finger per main ear (FPME) and Finger weight per plant (FWPP)

Statistical analysis: The collected data were organized and subjected to analyzed using SAS version 9.2 (SAS, 2008) computer software and additive main effect and multiplicative interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 15th edition statistical package (VSN International,2012).

Results and Discussion

Combined analysis of variance

The mean square of analysis of variance (ANOVA) is presented in Table 1. Highly significant differences ($P \leq 0.05$) were detected for finger millet parameters like days to heading, plant height, Finger weight and lodging whereas significant difference was detected for productive tillers, finger number and grain yield. Non- significant difference was observed for days to maturity and flower length. Highly significant difference was observed for important disease of finger millet, head blast. The combined analysis of variance showed that highly significant differences were recorded across location for all parameters..

Table 2: Combined Analysis of variance (ANOVA) for grain yield and yield related traits of finger millet genotypes at Western Oromia

S. V	DF	Mean Squares									
		DH	DM	PH	PT	FL	FN	FW	HB	LD	GY
Genotypes	14	11.63**	37.84	239.06**	17.16*	0.52	1.15*	5.31**	0.65**	2.46**	1630633.6*
Rep	2	0.49	43.81	49.05	43.51*	1.4*	0.54	7.26*	0.07	0.38	397963.2
Loc	5	1448**	1228.2**	5438.84**	1015.02**	12.77**	37.2**	99.44**	5.28**	10.16**	29455262.3**
Geno*Loc	70	8.1*	42.76	67.47*	7.91	0.31	0.65	1.17	0.21	0.62**	1308972.6*

Key: *, **, significant and highly significant respectively, Loc = location, var=variety, DF -degree of freedom, DH- Days to Heading; DM- Days to Maturity; PT- productive tillers, Head Blast (HB), (LD)-lodging, (PH)- Plant Height; Finger length (FL); Finger Weight per plant (FW),Finger number per main ear (FN) and GY= grainYield

Yield Performance of finger millet genotypes across year and environments

The mean performance of the tested finger millet genotypes for grain yield across location and year presented in Table 4. It indicated some genotypes constantly performed best in a group of environments and some are fluctuating across location (Tamene et al.,2013). The average grain yield ranged from the lowest figure 2978.75kg ha^{-1} at Lalo Kile during 200 to the highest mean grain yield 5199.4kg ha^{-1} obtained at Haro sabu during 2020 with grand mean of 3746. kg ha^{-1} (Table 4). The average grain yield across environments ranged from the lowest value of 3255.0 kg ha^{-1} for genotypes FMC-2 to the highest value of 4425.6 kg ha^{-1} for genotype FMC-33. (Table4). The variation might be due to the genetic potential of the genotypes. The difference in yield rank of genotypes across the environments exhibited the high crossover type of GxE interaction (Yan and Hunt, 2001; Asrat et al.,2009).The genotype FMC-33 was the top ranking pipeline at almost all environments and it has a yield advantage of 18.02 % over the best standard check Meba wich has mean grain yield of 3749.8 Kg/ha.

Table 4: Over year and environments mean performance of grain yield (Kg/ha) finger millet genotypes

Genotypes	Grain Yield in Kg/ha						
	2019			2020			
	Haro Sabu	Sadi Chanka	Sayo	Haro Sabu	Sadi Chanka	Lalo Kile	Comb. Mean
FMC-47	3727.7c	3669bc	3319a-e	6072.4ab	3500.8a-c	2599e-g	3814.6b-e
FMC-1	2036.3d	3109.8cd	2668c-e	5834a-c	3752.9a	2826d-f	3371.1ef
FMC-24	4888.7a-c	4762ab	3994ac	4275.3e	3686.5ab	2999c-e	4100.9ab
FMC-36	3936.3bc	3809.8bc	2722c-e	5286.6b-e	3399.5a-c	3501bc	3775.8b-e
Addis-01	4420a-c	2728cd	2316de	5376b-d	3344a-c	2257.5g	3406.9d-f
Local	4386.2a-c	2492.6cd	2077.7e	5178.5b-e	2634.5c	2761e-g	3255f
FMC-83	3843.2c	3777.9bc	3733a-c	5306.5b-e	3187.2a-c	2533e-g	3730b-f
FMC-33	5361.8a	5405.1a	4321ab	5083.5b-e	2785.3bc	3596.9b	4425.6a
FMC-7	4596.4a-c	3160.9cd	3720a-c	4957.8c-e	3615.8ab	2419fg	3744.9b-f
FMC-23	4054.1bc	2783.6cd	3142b-e	4766.2c-e	3423.8a-c	3016c-e	3530.9c-f
FMC-30	5141.5ab	3299.9bc	3599a-d	5110.7b-e	3526.7a-c	3309b-d	3997.8a-c
FMC-6	3862.7c	3923.3bc	4126ab	4851.9c-e	3509.1a-c	2733e-g	3834.4c-e
FMC-11	4223.9a-c	1737.5d	4534.9a	6620a	3305.1a-c	2986c-e	3901.2b-d
FMC-94	4098.5a-c	2532.7cd	3633a-d	4385.1de	3796.5a	2885d-f	3555.1c-f
Meba	3799.3c	3440.8bc	3064b-e	4886.9c-e	3047.4a-c	4260.6a	3749.8b-f
Mean	4158.438	3375.536	3397.8	5199.422	3367.676	2978.75	3746.28
CV	18.30789	25.98773	23.48	12.6	16.87	10.84	20.09
LSD	1273.3	1467	1335	1096.4	950.7	540.1	495.17
F test	*	*	*	*	ns	**	*

Means with the same letters are not statistically different

Key: FMC- Finger Millet Collection, CV-coefficient of variation, LSD- Least significant difference

Agronomic performance

Days to heading: Anova indicates that there is highly significant ($P<0.05$) difference in days to 50 % heading among the genotypes. Highest mean of days to heading (84.27 days) was recorded Meba variety while the lowest days to heading (81.56 days) was recorded for genotype FMC-94

Plant height: Anova reveals that there is significant difference ($P<0.05$) in Plant height among the genotypes. The maximum plant height (67.85cm) was recorded by the genotype FMC-24 while the minimum plant height (56.18cm) was recorded FMC-1.

Productive Tillers: Significant difference ($P<0.05$) was obtained for number of productive tillers per plant among the genotypes evaluated. Highest number (12.39) of productive tillers were registered by the genotype FMC-6 while the lowest number (8.42) of productive tillers were registered by the genotype FMC-47.

Finger Numbers: The results of Anova shows there is a significant difference ($P<0.05$) for number of fingers per plant among the tested genotypes. Highest value of number of fingers per plant (5.42) were obtained for genotype FMC-47 while the lowest value of number of fingers per plant (4.61) were obtained for genotype FMC-2.

Finger weight: Anova result indicates highly significant ($P<0.05$) difference was observed for finger weight among the genotypes. The maximum finger weight (6.8gm) was scored for the genotype FMC-33 while the minimum finger weight (5.13gm) was scored for the genotype FMC-24

Lodging index (1-5 scoring scale):The result of Anova shows that there is highly significant ($P<0.05$) difference in lodging index among the genotypes. The lowest lodging index (1.06) was recorded for the genotype FMC-33 while the highest lodging index (2.39) was recorded for the genotype FMC-24.

Table 2: Combined mean grain yield and other agronomic performances of finger millet genotypes at Western Oromia, 2019-2021

Genotypes	DH	DM	PH	PT	FL	FN	FW	LD	GY(Kg/ha)
FMC-47	83.5a-d	143.5a	62.98b-d	8.42c	5.91b-d	5.42a	5.48e-g	1.67b-d	3814.6b-e
FMC-1	81.78f	144.94a	56.18f	9.05bc	5.98b-d	4.98a-c	5.76c-g	1.56cd	3371.1ef
FMC-24	82.5d-f	143a	67.85a	10.47ab	6.03b-d	4.66c	5.13g	2.39a	4100.9ab
FMC-36	82.278ef	143.39a	59.75d-f	10.68ab	5.98b-d	5.01a-c	6.73ab	1.39de	3775.8b-e
Addis-01	83.78a-c	143.22a	61.35b-e	9.59bc	5.91b-d	5.04a-c	5.71c-g	1.83bc	3406.9d-f
FMC-2	83.28a-e	143.39a	64.61a-c	10.33bc	6.14a-d	4.61c	6.12a-e	1.72bc	3255f
FMC-83	83.38a-e	142.17ab	61.28c-e	9.47bc	5.76d	5.00a-c	5.83c-g	1.39de	3730b-f
FMC-33	82.5d-f	142.11ab	64.68a-c	10.46ab	5.96b-d	5.3ab	6.8a	1.06f	4425.6a
FMC-7	82.67c-f	142.78a	67.46a	8.95bc	6.44a	5.03a-c	6.74ab	2.28a	3744.9b-f
FMC-23	83.05b-e	142ab	65.63ab	10.40a-c	6.3ab	4.70c	5.91c-f	1.89b	3530.9c-f
FMC-30	83.5a-d	143.06a	58.35ef	9.156bc	6.16a-c	4.74c	6.47c-f	1.56cd	3997.8a-c
FMC-6	83.38a-e	138.17b	59.74d-f	12.39a	5.88cd	4.84bc	6.31a-d	1.89b	3834.4c-e
FMC-11	84.11ab	143.17a	56.7f	9.13bc	6.06b-c	4.80c	6b-e	1.22ef	3901.2b-d
FMC-94	81.56f	142.89a	62.03b-e	9.81bc	6.06a-c	5.08a-c	5.6d-g	1.39de	3555.1c-f
Meba	84.27a	142.06ab	64.76a-c	10.37bc	5.98b-d	5.39a	5.16fg	1.39de	3749.8b-f
Mean	83.04	142.66	62.22	9.91	6.04	4.98	5.98	1.64	3746.28
CV	2.20	4.53	10.46	30.73	10.17	14.36	19.85	30.49	20.09
LSD	1.20	4.25	4.28	2.00	0.40	0.47	0.78	0.33	495.17
Ftest	**	Ns	**	ns	ns	*	**	**	*

**Means with the same letters are not statistically different*

Disease reaction with finger millet genotypes across environments

Disease reaction: the result revealed there is highly significant variation in disease resistance among the finger millet genotypes (Table3).

The genotypes coded by FMC-33 scored the lowest figure (1.44) which shows that the genotype is resistant to head blast disease.

Table 3: Disease reactions for finger millet genotypes

Genotypes	HB (1-5 scale)
FMC-47	1.28g
FMC-1	1.33fg
FMC-24	1.94a
FMC-36	1.5c-g
Addis-01	1.44d-g
FMC-2	1.78a-c
FMC-83	1.67a-e
FMC-33	1.44d-g
FMC-7	1.72a-d
FMC-23	1.67a-e
FMC-30	1.67a-e
FMC-6	1.61a-f
FMC-11	1.56b-g
FMC-94	1.39e-g
Meba	1.83ab
Mean	1.59
CV	27.71
LSD	0.29
Ftest	**

Key: 1-5 scoring scale was used for disease reaction where 1= resistant, 5= susceptible CV =coefficient of variation, LSD =least significant different

Comparison plot for genotypes based on the concentric circle

Figure 1: shows the comparison plot for genotypes and an ideal genotype is one which is near or at the center of the concentric circle. Accordingly, the graph shows that genotype 8 (FMC-33) is the most ideal genotype. It also reveals that, this genotype has high mean grain yield and more stable across environments. Concerning locations, the graph shows Haro Sabu is representative and ideal.

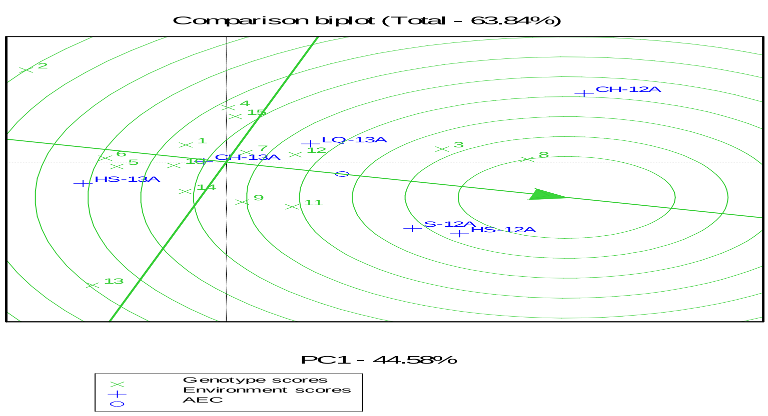


Figure 1: GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability

Key: S-12: Sayo location 2012, HS-12: Haro Sabu location 2012, CH-12 : Chanka location 2012, HS-13: Haro Sabu location 2013, CH-13 : Chanka location 2013, LQ-13: Lalo Qile location 2013, x:Genotypes

Conclusions and Recommendations

Combined analysis of variance (ANOVA) result revealed significant difference among evaluated finger millet genotypes across locations for grain yield and most of yield contributing traits like productive tillers, finger number per plant and finger weight. Among the tested genotypes, FMC-33 has highest mean in grain yield 4425.6 kg/ha with the yield advantage of 18.02% over best standard check 'Meba'. In addition, FMC-33 is resistant to lodging and insect pests.

The graph of GXE interactions shows FMC-33 is near to concentric circle wich shows the genotype is the most ideal and stable. Therefore, FMC-33 was identified as the best genotype in terms of yielding ability and stability, tolerant to diseases and better agronomic performance. The genotype was then promoted to Variety Verification Trial for further evaluation to be released as variety.

Acknowledgement

The authors warmly acknowledge Oromia Agricultural Research Institute (IQQO) for financial support and guidance. The contribution of Haro Sabu Agricultural Research Center staff members are also unforgettable for technical and administrative support. Bako and Melkassa Agricultural Research Centers are also acknowledged for the provision of standard checks.

References

Adugna A, Tesso T, Degu E, Tadesse T, Merga F, Legesse W, Tirfessa A, Kidane H, Wole A &Daba C (2011) Genotype-by-Environment Interaction and Yield Stability Analysis in Finger Millet (Eleusine coracana L. Gaertn) in Ethiopia. American Journal of Plant Sciences 2: 408–415.

Ariyo, J. (1989). Factor analysis of pod yield in Okra (Abelmoschusesculentus).Theoretical and Applied Genetics 64: 82–85.

CSA (2017), The Federal Democratic Republic of Ethiopia, Central Statistical Agency agricultural sample survey 2016/2017 (2009 E.C) volume I report on area and production of major crops (private peasant holdings, *Meher* season). Statistical Bulletin no.584, Addis Ababa, Ethiopia, pp. 118

Damar, W. K., Russom, Z., Garba, A.A., Ibrahim, S. A. & Haggai, P. T (2016) Yield Response of Finger Millet (Eleusine Coracana (L) Gaertn) To Transplanting Date, Intra Row Spacing and Poultry Manure In Bauchi, Nigeria. International Research Journal of Natural and Applied Sciences Vol. 3, Issue 5.

Degu, E., Adugna, A., Tadesse, T. and Tesso, T. (2009). Genetic resources, breeding and production of millets in Ethiopia, In new approaches to plant breeding of orphan crops in Africa. Proceedings of an International Conference, Bern Switzerland, 19-21 September.

Eberhart, S.A. and Russell, W.A. (1966). Stability parameters for comparing varieties, Crop Science 6: 36–40.

Farshadfar, E. and Sutka, J. (2006). Biplot analysis of genotype-environment interaction in durum wheat using the AMMI model. Acta Agronomy Hung. 54: 459-467.

Flores, F.; M.T. Moreno and J.I. Cubero (1998) A comparison of uni-variate and multivariate methods to analysis G × E interaction Field – Crops Res. 56: 271- 286.

Gauch, H. G. and Zobel, R.W. (1996). AMMI analysis of yield trials. In: Genotype by environment interaction. pp. 85-122 (Kang, M. and Gauch, H. eds.). Boca Raton. CRC press, New York.

Gauch, H.G., Piepho, H.P. and Annicchiarico, P. (2008). Statistical analysis of yield trials by AMMI and GGE: Further considerations. Crop Science 48:866–889.165

Girma T, (1999). Modeling Genotype by environment interaction: A Review of procedures In: Proceeding of the Eight Annual Conference of the Crop Science Society of Ethiopia, pp 147 – 158, Addis Ababa, and Ethiopia.

Mustapha, A, A.; F.A. Showemino and A. Aminu – kano (2001). Yield stability analysis of promising maize cultivars in Nigeria. J. Arid Agric 11: 1 -4.

Okalebo JR, Jutto PM & Gathera KW (1991) Effect of form and method of phosphate fertilizer application on maize, sorghum and millet growth in semi-arid environment of Kenya. II. Effect of bulrush and finger millet. East African Forestry Journal 55: 239–248.

SAS Institute Inc. (2008). Statistical analysis Software version 9.2, Cary, NC: SAS Institute

Science 6: 36–40.

Showemimo, F.A., C.A. Echekwu and M.Y. Yeye (2000) Genotype ×environment interaction in sorghum trials and their implication for future variety evaluation in maize growing areas of northern Nigeria the Plt. Scientist 1: 24 -31

VSN International, (2012) "Gen Stat for Windows 15th Edition VSN International, Hemel Hempstead, UK" Available: www.genStat.co.uk

Worku, A., Henry, M., Zewotir, T. and Taye, G. (2013). Additive main effects and multiplicative interactions model (AMMI) and genotype main effect and genotype by environment interaction (GGE) biplot analysis of multi-environmental wheat variety trials. African Journal of Agricultural Research 8(12):1033-1040.

Yan, W., Hunt, L.A., Sheng, Q., Szlavnics, Z. (2000). Cultivar evaluation and mega environment investigation based on the GGE bi-plot Crop Science.40:597-605

Yuksel Kaya, Cetin Palta, SeyfiTaner (2002).Additive main effects and multiplicative interactions analysis of yield performances in bread wheat genotypes across environments. Turkish Journal Agriculture and Forestry 26: 275-279.

Groundnut (*Arachis hypogea* L.) Adaptability and Performance Evaluation at Kellem Wollega Zones of west Oromia, Ethiopia

Dereje Abera*, Firaol Fikadu, Lamesa Emisha, Megersa Terefa and Rata Tamiru
Haro Sabu Agricultural Research Center, P O Box 10, Haro Sabu, West Oromia, Ethiopia
*Corresponding author e-mail: dereaber@gmail.com

Abstract

Eight (8) groundnut varieties collected from Bako and Fadis Agricultural Research Center were evaluated with the standard check (Manipinter) at potential areas of West and Kellem Wollega Zones, West Oromia. An experiment was executed at Haro Sabu (Dale sadi district), Sago (Lalo kile district), Igu (Sadi Chanka district) and Ano Mikael (Sayo district) during 2019-2020 main cropping season. The study was carried out to achieve the main objective of evaluating, selecting and recommending adaptable, high yielding, disease tolerant and stable Groundnut variety. Randomized Complete Block Design (RCBD) with three replications, was used in gross plot area of 2.4mx3m at row and plant spacing of 40cm and 10cm, respectively. Combined analysis of variance (ANOVA) revealed significant main effect of variety, test location, year and their interaction effect on most of agronomic traits observed, indicating the variability of test variety, location and weather conditions. GGE-biplot was used to estimate the stability of variety and location. Significantly larger mean value was recorded from the standard check which is Manipinter (1461.6 kg/ha), Bulki (1411.6 kg/ha) and Shulamiz (1311 kg/ha). These three varieties were ranked as Bulki, Shulamiz and Manipinter in terms of their stability and have more or less similar reaction to foliar disease. The shelling percentage (SP) was the most decisive parameter in groundnut production in views of production cost. With this, better mean value of SP was obtained from Bulki and Shulamiz, however, the high yielding standard check (Manipinter) had significantly lower mean value of SP. Moreover, Bulki and Shulamiz improved SP over Manipinter by 13.36% and 7.22%, respectively. Thus, organized training based demonstration on the special merits of alternative groundnut varieties over the standard check (Manipinter) is paramount important thereby to save the economic production cost for small scale farmers of West and Kellem Wollega Zones of Western Oromia and areas with similar agro-ecology.

Keywords: *Groundnut; Adaptability; Yield; Shelling percentage; Stability*

Introduction

Groundnut (*Arachis hypogea* L.) which is known as peanut, earthnut, monkey nut and goobers is an oil seed and grain legume crop. It is a member of the legume family which is native to South America, Mexico and Central America, though it grows in other parts of the world (Sigmund and Gustav, 1991). Groundnut ranked as the 4th most important oilseed crop and the 13th most important food crop (Surendranatha *et al*., 2011). FAOSTAT (2010) reveals that, groundnut yield in Africa is lower (980 kg ha-1) than the average world groundnut yields. It is primarily cultivated in USA, Nigeria, Senegal, Sudan, China, West Africa, Indonesia and India (Weiss, 2000). Oil crops are the third major crops after cereals and pulses in Ethiopia both in area and in production. Groundnut is the second important lowland oilseed of warm climate, which is relatively new to Ethiopia as compared to sesame. The largest groundnut production areas in Ethiopia are Oromia (32967.8 ha), Benishangul-Gumuz (9968.73 ha), SNNPR (635.04 ha) and in Amhara (344.57 ha) regional states (CSA, 2011). Somalia and Gambela regional states also produce a considerable amount of ground nuts. A variety of oil seeds (e.g. sesame, rapeseed, linseed, groundnut, sunflower, Niger seed, cotton seed, etc.) are grown in Oromia. The demand for sesame has been increasing in the global market making sesame an increasingly important export commodity in Ethiopia. However, Rapeseed, linseed, groundnut, sunflower, Niger seed and cotton seed also serve as raw materials for the domestic edible oil industry.

Groundnut is playing an increasingly important role as an alternative oil crop to an increasing number of small holder farmers. It is high in edible oil (40-50%) and protein (25%) contents and a good source of essential vitamins and minerals (Andrew and Catherine, 2010). In other terms, Groundnut kernel contains 40-50% fat, 20-50% protein, 10-20% carbohydrate and is rich in vitamins and minerals (USDA, 2010). As a legume, groundnut fixes atmospheric nitrogen in soils and thus improves soil fertility and saves fertilizer costs in subsequent crops. This is particularly important when considered in the context of the rising prices of chemical fertilizers which makes it difficult for small scale farmers to purchase. In livestock farming communities, groundnut can be used as fodder for livestock and increases productivity as the groundnut haulm and seed cake are rich in digestible crude protein content (Simtowe *et al*., nd).

Western Oromia has areas, which are most favorable for groundnut production. Though the usage of improved seeds is one of the most efficient ways of raising crop production, in Ethiopia, less than 10 percent of farmers use improved seeds (FAO, 2010). The productivity is not only low but remains static with no or very little changes. The low growth rate obtained overtime is contributed more by area expansion (79%) than by yield (21%) enhancement (Fredu *et .al*, 2015). Groundnut seed yield in Ethiopia is extremely low mainly due to lack of high yielding varieties, low soil fertility and limited access to external inputs (EARO, 2004). Introduction and evaluation of groundnut variety is among intervention approach to alleviate some of Groundnut production constraints such as to lack of high yielding and diseases tolerant varieties

Therefore, present study was developed to achieve the following objectives;

To evaluate, select and recommend adaptable, high yielding and disease tolerant groundnut variety for groundnut producing areas of Kellem Wollega Zones, West Oromia

Materials and Methods

Materials

Eight (8) Groundnut varieties introduced from Bako and Fadis agricultural research center were evaluated with the standard check (Manipinter) at Haro Sabu Agricultural research sites viz; Igu (Sadi Chanka district), Haro Sabu research station (Dale Sadi district) and Sago (Lalo Kile district) for two consecutive main cropping seasons (2019-2020). Description of test materials was presented in appendix.

Experimental Design: The field experiment was executed in randomized complete block design with three replications in gross plot size of 3mx2.4 at the spacing of 40cm and 10cm between row and plant, respectively. The blended and in organic fertilizer (NPS) was applied at recommended rate during planting time. All management agronomic practices including earthing-up were commenced as uniformly as needed.

Data Collection: Performance of Groundnut varieties were evaluated for grain yield and yield attributing agronomic traits by deploying the procedure developed in groundnut descriptor. Stand count at harvesting, days to 50% flowering, days to 50% maturity, disease reaction, plant height (cm), number of pod/plant, number of seed/pod, hundred seed weight (gm), moisture content (%) and adjusted grain yield kg/ha are the major agronomic traits observe.

Data analysis:The collected data were organized and subjected to SAS software. Mean separation was done by using least significant difference (LSD) according to the methods developed by Gomez and Gomez (1984).

Results and Discussions

Combined analysis of variance (ANOVA) showed significant (P<0.05 or p<0.001) main effect of year on number of stand count at harvest (SC), pod/plant (PPP), hundred seed weight (HSW) and grain yield (GY). All observed agronomic traits were affected by the main effect of location (Table 1). The result exhibited variability of test location in terms of their potential and fluctuation of weather condition across year and location. With this, significant and larger mean value was recorded from Haro Sabu research site for all traits excluding hundred seed weight (HSW), grain yield (GY) and shelling percentage (SP) which were better at Sago site. Inversely, the significant and lower mean value was recorded from Ano Mikael site for all agronomic traits except plant height (PH), indicating the poor potential of test location. Moreover, the result found sago as high yielding test location and followed by Haro sabu and Igu presently (Table 2).

Table-1: Combined Analysis of variance (ANOVA) for grain yield and yield components on Groundnut

SV	DF	SC	PH	PPP	SPP	HSW	GY	SP
Year	1.00	1776.33**	52.50	293.34*	0.04	180.70*	1149429.5*	1705.12
Location	3.00	15779.4**	1330.4**	100.63*	0.28**	763.3**	2355376 **	1954.0*
Replication	2.00	201.85	294.84**	53.87	0.02	35.49	33527.28	22.93
Variety	8.00	103.77*	38.42*	58.72*	0.17**	65.85**	517935.7**	543.21*
Yr*Loc	1.00	1858.37**	326.91*	318.92*	0.55*	41.19*	55861.27*	1582.48
Yr*Var	8.00	113.33	17.83	58.34	0.04	21.56	169971.28	492.56
Loc*Var	24.00	113.47	11.96	49.02	0.07*	42.75*	75805.12	243.36
Yr*Lo*Var	8.00	122.37	20.35	29.81	0.09	24.59	141193.64	385.14
Error		89.98	24.85	37.93	0.03	22.48	106054.55	450.05

Key: DF= DF= error degree freedom , GY= grain yield (Kg/ha), HSW= hundred seed weight (gm), Loc*Var= interaction of location by variety, PH= plant height at harvest, PPP= number of pod/plant, SC= number of stand count at harvest, SP= shelling percentage, SPP= number of seed/pod and SV= source of Variance, Yr*Loc= interaction of year by location, Yr*Loc*Var= interaction of year by location by variety and Yr*Var= interaction of year by variety

In other terms; significantly larger mean value of PPP, SPP, HSW, GY and SP was recorded from Haro Sabu and Sago. On the contrary, Ano Mikael revealed significantly lower mean value for all agronomic traits except PH (Table 2).

Table 2: Main effect of location on grain yield and yield components

Location	Sc	PH	PPP	SPP	HSW	GY	SP
Haro Sabu	59.17a	37.38a	20.47a	1.82a	47.82a	1261.35ab	73.01a
Igu	23.94b	26.42b	19.06ab	1.77a	44.95b	1245.19ab	64.26bc
Ano Mikael	22.96b	26.83b	17.78b	1.66b	40.01c	751.51c	60.95b
Sago	53.15a	25.28b	19.47a	1.9a	52.3a	1307.5a	76.88a
Mean	39.81	28.98	19.19	1.79	46.27	1141.39	68.78

Key: GY= grain yield (Kg/ha), HSW= hundred seed weight (gm), PH= plant height at harvest, PPP= number of pod/plant, SC= number of stand count at harvest, SP= shelling percentage in % and SPP= number of seed/pod

Stand count at harvest (SC), plant height (PH) and number of seed/pod(SPP) revealed significantly higher mean value during 2019. Significantly larger mean value of pod number/plant (PPP) and hundred seed weight (HSW) was recorded during 2020. No significant difference observed between the two cropping seasons for grain yield (GY) and shelling percentage (SP), however, the larger mean value was recorded during 2020 for these traits.

Table 3: Main effect of year on grain yield and yield components of groundnut variety

Year	SC	PHT	PPP	SPP	HSW	GY	SP
2019	50.96a	39.81a	17.10b	1.91a	45.63b	1135.45a	64.11a
2020	38.27b	27.98b	19.84a	1.77b	46.44a	1187.33a	69.65a
Mean	44.62	33.90	18.47	1.84	46.04	1161.39	66.88

Key: GY= grain yield (Kg/ha), HSW= hundred seed weight (gm), PH= plant height at harvest, PPP= number of pod/plant, SC= number of stand count at harvest, SP= shelling percentage in %

Interaction Effect of Variety by Location

The interaction effect of variety by location had significant effect PPP, SPP, HSW and GY. In this perspective, no variety showed significantly larger mean value at all test locations consistently. On the contrary, Warer-961 showed lower mean value of PPP at Igu, Ano Mikael and Haro Sabu (after Babile-1 and Senaf). Moreover, larger mean value of PPP was recorded from Bulki followed by Shulamiz and Manipinter (at Haro Sabu), Shulamiz followed by Werer-62 and Manipinter (at Ano Mikael), Shulamiz followed by Babile-1 and Bahatidu (at Igu) and Werer-61 followed Manipinter and Fadis local (at Sago), indicating better mean value of PPP for Shulamiz and Manipenter) over test locations than the rest varieties relatively (Table 4).

Table 4: Interaction effect of variety by location on number of pod/plant

	Test Locations			
Variety	Haro Sabu	Ano Mikael	Igu	Sago
Babile-1	16.26c	15.07a	21.03ab	18.4ab
Bahatidu	20.03a-c	17.73a	20.83ab	17.33ab
Bulki	26.74a	14.2a	15.37b	18.73ab
Flocal	19.01a-c	17.83a	19.57ab	19.6ab
Manipint	20.12a-c	20.13a	17.23ab	23.33ab
Senaf	18.42bc	19.4a	18.4ab	18.67ab
Shulamiz	25.95ab	22.53a	24.23a	16.73b
warer-61	18.57bc	12.13a	15.2b	26.07a
Warer-62	19.15a-c	21a	19.63ab	16.4b
Mean	20.47	17.78	19.06	19.47
CV	33	36.58	32.09	26.97
Lsd	7.93	11.26	7.18	9.09

Significant and larger mean value of SPP was recorded from Bulki and Warer-61 (at Haro Sabu), Fadis local and Senaf (at Ano Mikael) and Senaf (atIgu and Sago). Additionally, significantly lower mean value of SPP was recorded from Manipinter and Senaf (at Haro Sabu), Warer-62 (at Ano Mikael and Igu) and Babile-1 and Bahatidu (at Sago) as presented in table 5.

Table 5: Interaction effect of variety by test location on number of seed/pod

	Test Locations			
Variety	Haro Sabu	Ano Mikael	Igu	Sago
Babile-1	1.8a-c	1.33c	1.63bc	1.8
Bahatidu	1.82a-c	1.6bc	1.87ab	1.8
Bulki	1.98a	1.6bc	1.67a-c	1.87
Fadis local	1.95ab	1.93a	1.83ab	2
Manipinter	1.68c	1.8ab	1.8a-c	1.87
Senaf	1.68c	1.93a	1.9a	2
Shulamiz	1.72bc	1.6bc	1.8a-c	1.87
warar-961	1.98a	1.73bc	1.87ab	2
Warer-962	1.8a-c	1.4c	1.57c	1.87
Mean	1.82	1.66	1.77	1.9
CV	11.24	9.7	11.29092	7.53
Lsd	0.24	0.28	0.23	2.12

Significantly larger mean value of HSW was recorded from Senaf and Manipinter (at Haro Sabu), Warer-62 (at Ano Mikael), Warer-61, Bulki, Bahatidu, Manipiter, Senaf and Babile-1 (at Igu) and Fadis local and Warer-61 (at Sago). Inversely, the significant and lower mean value of HSW was recorded from Warer-961 (at Haro Sabu and Ano Mikael) and Shulamiz (at Igu and Sago) as shown in table 6 below.

Table 6: Interaction effect of variety by location on seed weight (gm)

	Test Location			
Variety	Haro Sabu	Ano Mikael	Igu	Sago
Babile-1	46.8ab	43.43ab	49.05a	53.47a
Bahatidu	42.83b-d	43.5ab	48.52a	53.23a
Bulki	43.45b-d	39.87bc	48.7a	50.97a
Fadis local	41.8cd	38.21bc	46.22ab	54.2a
Manipinter	50.27a	35.13bc	49.88a	51.17a
Senaf	51.42a	41.6a-c	48.08a	50.47a
Shulamiz	43.15b-d	35.17bc	43.23b	49.77a
warar-961	39.63d	33.75c	49.7a	54.13a
Warar-962	45.23bc	49.43a	46.98ab	53.27a
Mean	44.95	40.01	47.81	52.3
CV	9.08	13.3	8.40	10.65
Lsd	4.79	9.21	4.71	9.64

The interaction effect of variety by location imposed highly significant ($P<0.01$ or $p<0.05$) effect on grain yield. With this regards, Manipinter, Shulamiz and Bulki (at Haro Sabu research), Manipinter (at Ano Mikael), Bulki and Manipinter (at Igu) and Babile-1 (at Sago) showed significantly larger mean value of GY. Thus, Manipinter followed by Bulki and Shulamiz relatively exhibited better mean value of GY across most of test locations, most probably indicating higher mean performance and stability of these varieties (Table 7).

Table 7: Interaction effect of variety by location on grain yield (Kg/ha)

Variety	Haro Sabu	Ano Mikael	Igu	Sago
Babile-1	1040.6b	690.95b-d	1187.4ab	1551.3a
Bahatidu	1100.6b	633.66d	972.4b	1229.7bc
Bulki	1566.2a	757.62a-d	1587.8a	1403.8ab
Fadis local	1013.9b	751.74a-d	1115.2b	1304.5ab
Manipinter	1700.2a	876.11a	1576.4a	1339.9ab
Senaf	1284.7ab	851.86ab	1100.6b	911.7c
Shulamiz	1593.8a	735.74a-d	1299.7ab	1343.1ab
warer-961	945.9b	657.02cd	1134.3b	1455.9ab
Warer-962	1106.1b	808.88a-c	1233ab	1227.7bc
Mean	1261.36	751.51	1245.19	1307.5
CV	29.54	12.91	28.56792	14.2
Lsd	437.18	167.87	417.38	321.42

Interaction Effect of Year by Variety

Concerning the interaction effect of variety by year, significantly larger mean value of PH was recorded from Fadis local (2019) and Warer-962 (2020), whereas the significant and lower mean value of PH was recorded from Senaf variety (2019). Warer-962 and Shulamiz showed significantly longer and shorter mean value of PH (2020), respectively. Significantly larger mean value of PPP was recorded from Shulamiz followed by Bulki, Warer-962 and Manipinter (2019). The same variety (Shulamez) attained significantly larger mean value of PPP which was followed by Bahatidu, Warer-961 and Manipinter during 2020. Besides, significant and larger mean value of SPP was recorded from Fadis local (2019 and 2020) as shown in table 8. Babile-1 and Warer-962 showed significantly lower mean value of SPP (2019 and 2020) in the same trend. Inversely, these two varieties showed lower mean value of HSW (2019 and 2020).

Table 8: Interaction effect of variety by year on yield component of evaluated groundnut variety

Variety	Plant height (cm)		Number of pod/plant		Number of seed/pod	
	2019	2020	2019	2020	2019	2020
Babile-1	32.07ab	27.38bc	14.4bc	19.82a	1.67b	1.67de
Bahatidu	33.13ab	29.08a-c	16.03bc	21.18a	1.82ab	1.78a-d
Bulki	33.57ab	29.33ab	20.37ab	19.1a	1.82ab	1.78a-d
Fadis local	35.45a	29.19ab	17.47bc	19.91a	1.95a	1.9a
Manipinter	32.93ab	29.12ab	18.98a-c	20.05a	1.85ab	1.73c-e
Senaf	26.9b	27.45a-c	18.88a-c	18.48a	1.88ab	1.83a-c
Shulamiz	33ab	26.42c	25.48a	22.17a	1.72ab	1.77b-e
warer-961	33.93ab	29.6ab	12.23c	20.32a	1.95a	1.88ab
Warer-962	32.37ab	30.07a	19.19a-c	19.15a	1.7ab	1.65e
Mean	32.59	28.63	18.12	20.02	1.82	1.78
Cv	19.44	11.46	36.3	28.77	12.32	9.2
Lsd	7.43	2.67	7.71	4.69	0.26	0.13

Significantly larger mean value of HSW was recorded Senaf (2019) and Babile-1, Bahatidu, Manipinter and Senaf, Warer-962 (2020). Significantly larger mean value of GY was recorded from Manipinter, Bulki and Shulamiz (2019) and Bulki, Manipinter, Babile-1 and Shulamiz (2020). The result illustrated that Manipinter, Bulki and Shulamiz were relatively stable and high yielder than the rest varieties across the two cropping seasons consistently (Table 9).

Table 9: Interaction effect of variety by year on hundred seed weight and grain

Variety	Hundred seed weight (gm)		Grain yield (Kg/ha	
	2019	2020	2019	2020
Babile-1	48.97a-c	47.67a	791.9c	1278.6a-c
Bahatidu	46.9b-d	46.41a	866.9c	1068.86de
Bulki	47.23a-d	45.17ab	1505.2ab	1364.74a
Fadis local	46.02b-d	44.1ab	981bc	1088.08de
Manipinter	51.27ab	46.02a	1702.8a	1340.96ab
Senaf	52.43a	46.55a	1182.8a-c	1042.17e
Shulamiz	45.68cd	41.58b	1456.9ab	1238.02a-d
warer-961	42.77d	45.25ab	857c	1139.84c-e
Warer-962	47.85a-d	47.86a	1006.5bc	1175.46b-e
Mean	47.68	45.62	1150.11	1192.97
Cv	9.6	10.58	40.14	19.41
Lsd	5.37	3.93	541.62	188.5

Combined Mean Performance of Groundnut Variety

Analysis of variance (ANOVA) detected significant ($p<0.01$ or $p<0.05$) difference of groundnut varieties for all observed agronomic traits, presenting variability among evaluated varieties which is desirable (Table-1). The mean value of SC varied from 36.83 for Fadis local to 44.67 for Bulki with overall mean value of 40.39. PH ranged from 27.27 (Senaf) to 31.04 (Warer-961) with overall mean value of 29.95. The maximum mean value of 23.27 (Shulamiz) and minimum mean value of 17.62 (Warer-961) with grand mean value of 19.38 was recorded for PPP. The mean value of SPP varied from 1.67 (Warer-961 and Babile-1) to 1.92 (Fadis local) with grand mean value of 1.79. HSW ranged from 42.95 (Shulamiz) to 48.1 (Babile-1) with over all mean value of 46.31 gram. The mean value of GY ranged from 1001.6 kg/ha for Bahatidu to 1461.6 kg/ha for Manipinter with over all mean value of 1178.68. Similarly, SP varied from 61.4 for Fadis local to 80.01 for Babile-1 with grand mean value of 68.73 (Table 9).

Significantly larger mean value of SC was recorded from Bulki, however, the significant and lower mean value of SC was obtained from Senaf and Fadis local. Significantly larger mean value of PH was recorded only from Bulki (30.74) and Fadis local (31.28) over Senaf (27.27). Additionally, significantly larger mean value of PPP was recorded from Shulamiz (23.27) over Fadis local (19.1), Babilie-1 (18.01), Senaf (18.62), Warer-961 (17.62) and Warer-962 (19.16). However, numerically larger mean value of PPP was recorded from Manipinter (19.69) and Bulki (19.52) after Shulamiz (23.27). Significantly larger mean value of SPP was obtained from Fadis local, however, the significant and lower mean value of SPP was recorded from Babile-1 and Warer-962. Babile-1 and Senaf exhibited significantly larger mean value of HSW over

Shulamiz and Warer-961. Moreover, Warer-962 (47.86 gm), Manipinter (47.77 gm), Bahatidu (46.57 gm) and Bulki (45.86 gm) showed larger mean value of HSW after Senaf (48.51gm) and Babile-1 (48.1 gm) numerically (Table 9).

Table 10: Combined mean performance of groundnut variety

Entry	Sc	Ph	PPP	SPP	HSW	GY	SP
Babile-1	42.44ab	28.94ab	18.01b	1.67d	48.1a	1116.4bc	80.01a
Bahatidu	42.56ab	30.43ab	19.47ab	1.79bc	46.57a-c	1001.6c	71.79ab
Bulki	44.67a	30.74a	19.52ab	1.79bc	45.86a-d	1411.6a	72.88ab
Fadislocal	36.83b	31.28a	19.1b	1.92a	44.74b-d	1052.4c	61.2b
Manipinter	38.67ab	30.39ab	19.69ab	1.77cd	47.77ab	1461.6a	64.29b
Senaf	37.83b	27.27b	18.62b	1.85a-c	48.51a	1089c	66.15ab
Shulamiz	42.11ab	28.61ab	23.27a	1.75cd	42.95d	1311ab	68.93ab
warer-961	38.89ab	31.04a	17.62b	1.91ab	44.43cd	1045.6c	71.98ab
Warer-962	39.5ab	30.83a	19.16b	1.67d	47.86ab	1119.1bc	62.32b
Mean	40.39	29.95	19.38	1.79	46.31	1178.68	68.73
CV	23.49	16.65	31.77	10.26	10.24	27.63	30.87
Lsd	6.269	3.2947	4.07	0.1215	3.1334	215.22	14.02

Key: CV= coefficient of variation, Lsd= list significant difference, GY= grain yield (Kg/ha), HSW= hundred seed weight (gm), PH= plant height at harvest, PPP= number of pod/plant, SC= number of stand count at harvest, SPP= number of seed/pod

Manipinter (1461.6 kg/ha) and Bulki (1411.6a kg/ha) varieties showed significantly larger mean value of GY over all varieties except Shulamiz (1311 kg/ha). Inversely, the significant and lower mean value of GY was recorded from Bahatidu (1001.6 kg/ha), Warer-961 (1045.6 kg/ha), Fadis local (1052.4 kg/ha) and Senaf (1089 kg/ha). Identified varieties viz. Manipinter, Bulki and Shulamiz deployment can improve groundnut productivity in test area. With this views, the yield advancement of 24 % (Manipinter), 19.76 (Bulki) and 11.23% (Shulamiz) was recorded over the attained grand mean. Shelling percentage (SP) was another desirable trait in groundnut production. In addition to GY, present study also evaluated varietal performance for this desirable trait. With this regards, significantly larger mean value of SP which is desirable was recorded from Babile-1 (80.01) over Manipinter (64.29), Fadis local (61.4) and Warer-962 (62.32). Besides, numerically larger mean value of SP was recorded from Bulki (72.88), Bahatidu (71.79), Warer-961 (71.98) and Shulamiz (68.93) as presented in table 9. The high yielding standard check (Manipinter) had significantly lower mean value of SP which is undesirable. Bulki and Shulamiz which had numerically larger mean value of GY after Manipinter had relatively larger mean value of SP which is desirable. Moreover, Bulki and Shulamiz improved SP over Manipinter by 13.36% and 7.22%, respectively.

Variety and Variety by Environment interaction (GGE) Bi-plot analysis

The test environments and varieties obtained in the central circle are considered as ideal in GGE biplot (Yan, 2002). GGE bi-plot, assumes that stability and mean yield are equally important (Farshadfar et al., 2011). With this perspective, Bulki (1411.6 kg/ha) was the most stable variety across test environments and followed by Manipinter (1461.6 kg/ha) and Shulamiz (1311 kg/ha). These three varieties were also identified for significantly higher and above grand mean value of grain yield. Inversely, Senaf, Bahatidu, Warer-961, Fadis local and Babile-1 were unstable varieties and had below grand mean value of grain yield as depicted in figure 1 below.

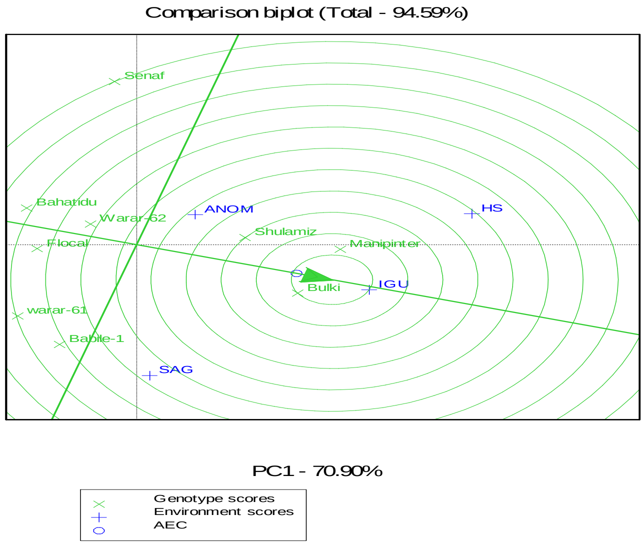


Figure 13. GGE bi-plot based on genotype focused scaling for comparison of genotype for grain yield stability

As the stability of test environment is concerned; Igu (1245.19 kg/ha) was the most ideal and followed by Haro Sabu (1261.36 kg/ha) test location. Sago (1307.5 kg/ha) test environment had above grand mean value of grain yield, however, the site found to be unstable which is not desirable. On the contrary, Ano Mikael (808.88 kg/ha) was also considered for its yield instability and below grand mean value of grain yield, indicating less representativeness of the environment as presented in Figure.2 below.

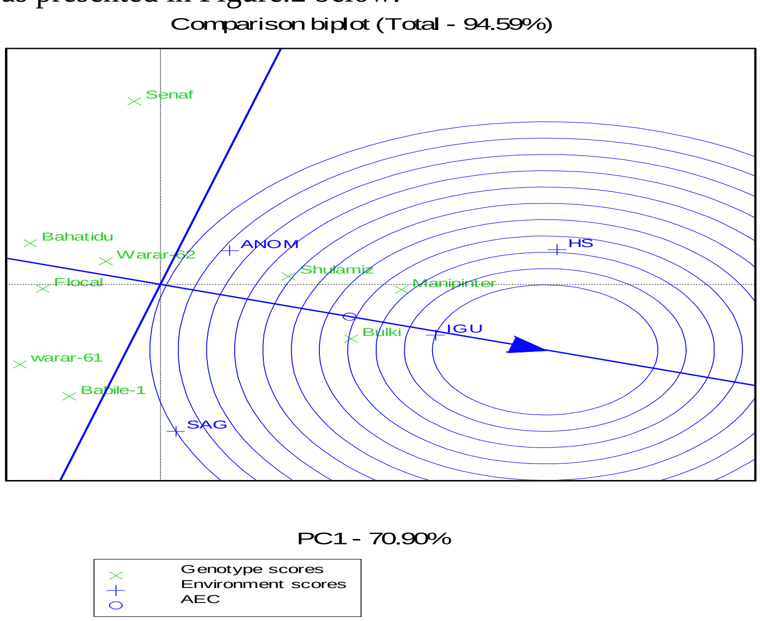


Figure 14. GGE bi-plot based on environment focused scaling for comparison of environment for grain yield stability

Conclusions and Recommendations

Combined analysis of variance illustrated significant variation of the main effect of variety, location, year and their interaction effects on most of agronomic traits observed in the study. Significant GEI reveals difficult selection of superior variety for all test location and their response become unstable with fluctuation of environmental conditions. Thus, Manipinter followed by Bulki and Shulamiz were identified for higher mean value of grain over the rest varieties. Likewise, these three varieties were ranked as Bulki, Shulamiz and Manipinter in terms their stability and have more or less similar reaction to foliar disease. The shelling percentage was the most decisive parameter in groundnut production. With this, perspective, better mean value of SP was obtained from Bulki and Shulamiz, however, the high yielding standard check (Manipinter) had significantly lower mean value of shelling percentage.

The study depicted no statistical difference of grain yield between Manipinter, Bulki and Shulamiz. Moreover, utilization of Bulki and Shulamiz can improve groundnut shelling percentage by 13.36% and 7.22%, respectively over the standard check (Manipinter). Therefore, it is devisable to demonstrate Bulki and Shulamiz with Manipinter by supporting with training on the special merit of these alternative varieties in West and Kellem Wollega Zones of Western Oromia and areas similar agro-ecology.

Acknowledgements

Authors gratefully thank Oromia Agricultural Research Institute for financial grant, Melkasa Agricultural Research Center for permitting access to Groundnut Variety, Haro Sabu Agricultural Research Center for facilitation of research activity and Pulse and Oil Crop Research Case Team for trial management.

Reference

Andrew, E., Catherine, P. 2010. Procurement for development forum: Groundnuts case study Chatham House. 10 St James's square. (Londonwww.chatham house.org.uk) (Accessed on October, 2018).

CSA (Center of Statistical Authority of Ethiopia. Agricultural Sample Survey 2015/16. Reports on area under cultivation, yield and production of major crops for main (Meher) season, Ethiopia; 2015.

EARO (Ethiopian Agricultural Research Organization). 2000. *Lowland pulses research strategy*. Ethiopia: Addis Ababa. pp. 1-39.

FAO/WFP (Food and Agriculture Organization). 2010. Crop and food security assessment mission to Ethiopia Available at:http://www.faostat.fao.org.

FAOSTAT (Food and Agriculture Organization of the United Nations). 2014. In FAOSTAT database: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor. Accessed 03 February 2018.

Gomez, K. A. and A. A. Gomez. 1984. Statistical Procedures for Agricultural Research. 2nd Ed., John Willey and Sons. Singapore.

Adaptability and Performance Evaluation of Improved large pod hot pepper (*Capsicum annum* L.) Varieties in West and Kellem Wollega Zones

Kibiru Kena[1*], Zewdu Tegenu[2*], Alemayehu Latera[2*], Fekadu Adane[2*], Ashenafi Debela[2*]
Corresponding author email: -kibiruk12@gmail.com

Abstract

*Large pod hot Pepper is a seasonal plant of the family Solanaceae. It is grown as an annual crop and produced for its fruits. It is one of the most important vegetable crops for fresh consumption, for processing and as a spice (for making stew). A field experiment was conducted at Haro Sabu Agricultural Research center on station, Sedi Chanka (Egu) and Sayo (Meti) sub sites of Kellem Wollega zone, Western Ethiopia, during the 2019/2020 and 2020/2021 main cropping season. A total of six large pod hot pepper varieties collected from Melkasa and Bako Agricultural Research (Melka Zala, Bako Local, Melka Awaze, Melka Shote, Oda Haro, and Marko fana) were evaluated against one local check. Combined analysis of variance (ANOVA) detected highly significant differences (P ≤ 0.01) among variety for all parameters except pod diameter. Highly significant differences were detected among location (P ≤ 0.01) for all parameters except number of pod per plant and pod weight. Variety * Location effects were significant for all parameters excluding number of primary branches per plant, pod length, pod diameter and pod* weight. *The interaction effect of variety, location and year revealed highly significant (P ≤ 0.01) effect on days to flowering, days to maturity and total dry pod yield. In the present experiment, Melka Awaze, Oda Haro and Marko Fana varieties were found superior in terms of yield, tolerant to major disease and other important parameters. Thus they are recommended for popularization and wider production in test locations and similar agro-ecologies in the Western Oromia in particular and hot pepper producing regions of Ethiopia under main natural rain fed.*

Keywords: adaptation, marko fana, melka awaze, oda haro, dry pod yield

Introduction

Hot pepper (*Capsicum species*) belongs to the Solanaceae family and originated in the new world tropics and subtropics (Mexico, Central America and Andes of South America) over 2000 years ago (Walter, 1986 and Rodriguez *et al.*, 2008). The genus Capsicum consists of approximately 22 wild species and five domesticated species, which include C. *annum* L., C. *frutescens* L., C. *chinenses* L., C. *baccatum* L., and C. *pubescens* L. (Bosland and Votava, 2000, Patricia *et al.*, 2003 and Pickersgill, 1997). Peppers are grown extensively under various environmental and climatic conditions. It is an important cash crop for smallholder farmers in developing countries such as Ethiopia, Nigeria, Ghana, China, India, Pakistan, Bhutan, Indonesia, Cambodia, and Thailand (Lin *et al.,* 2013). In many countries of the world, pepper is a cash crop with high domestic- and export value. According to Lin *et al*. (2013), uses of pepper are generally grouped into five broad market categories: (i) fresh market (green, red, multi-color whole fruits), (ii) fresh processing (sauce, paste, canning, pickling), (iii) dried spice (whole fruits and powder), (iv) industrial extracts (paprika/ oleoresin, capsaicinoids and carotenoids) and (v) ornamental (plants and /or fruits). Peppers are widely grown in various parts of Ethiopia and the fruits are consumed as fresh, dried or processed products, as vegetables, as spices or condiments. Today, the crop has not only attained economical, but also traditional importance. It is one component of the daily diet of Ethiopian people. Peppers are important in the local dishes as 'karia' (green pod), 'berbere' (fine powder from the dry fruits of hot pepper), grinded mature green fruits blended with other spices and 'mitmita', the small very pungent fruits. The powder from dried ripe fruits of hot pepper is used as spice to flavor ‘Wot’, an Ethiopian stew in a daily traditional meal. Mature green pods ('karia') are eaten as salads. Unless the sauce (stew) is 'alcha' (prepared without the use of hot pepper powder), 'berbere' is used daily in almost all Ethiopian house as a culinary spice in the preparation of stew (sauce) to yield the desired color, flavor and pungency. Fine pungent powder of hot pepper ('berbere') is an indispensable flavoring and coloring ingredient in the daily preparation of different types of Ethiopian sauces ('wot'), whereas the green pod is consumed as a vegetable with other food items (MARC, 2004). Green pods ('karia') are not eaten only fresh as vegetables, but also grinded and eaten with 'injera' (Ethiopian flat pancake prepared from grains of 'tef' (Tef *eragrostis*) or bread or with other food items and also used as ingredient of sauce. In all cases, powder of red pepper or grinded green pods is blended with other spices to add more color and flavor. Pepper is a very important crop for spice extraction since it has a lot of Oleoresin for dying of food items and Ethiopia is among few developing countries that have been producing paprika and *capsicum* oleoresins for export market (MoARD, 2007). The crop is exported as dried ripe fruit or as oleoresin extracted from the fruits (Yosef and Yayehu, 1989). Today, small-scale farmers produce the largest proportion of hot pepper in the country. In many areas, pepper is grown predominantly as monocrop, and rotated with cereals or legumes, using the main rainy season. However, pockets of production in the dry season using irrigation can be found, particularly in the rift valley parts of Ethiopia.

Introduction and selection for best adaptable varieties with high yield and quality as well as resistant to biotic and abiotic environmental stresses is therefore a priority and quick approach to contribute towards alleviating major bottlenecks of the existing production system. According to Mskuwa *et al*., (2016), introduction, domestication and commercialization of plants play a major role in improving rural livelihoods through nutritional status, household income, entrepreneurial opportunities and economic empowerment.

The use of unimproved local varieties of low quality and productivity, and soil borne and foliar diseases caused by fungi, bacteria and viruses are among several constraints of the production system for green and dry pod confronted with(Dessie and Birhanu,2017). Hence, production and productivity of hot pepper is declining and farmers are abandoning pepper production in many places around the study area. This adaptability and performance evaluation of large pod hot pepper varieties was therefore undertaken to identify best varieties for disease resistance /tolerance, high dry pod yield and quality around West Wollega and Kellem Wollega zones of western Oromia.

The diverse climatic soil conditions of Ethiopia allow cultivation of a wide range of fruit and vegetable crops including small pod and large pod hot pepper, which is largely grown in the eastern and central parts of the mid- to low-land areas of the country. However, local production of hot pepper in West and Kelem Wellega zones is not able to meet the domestic demand due to lack of improved variety, diseases and another new technological packages for hot pepper.

Therefore, it is important to evaluate different large pod hot pepper varieties to recommend high fruit yielding and disease tolerant variety/ies for the study area. Thus, the objective of this study was to evaluate the adaptability of large pod hot pepper varieties for high yielding and recommend the best performed variety for production in the studied areas and similar agrological zones.

Materials and Methods

Description of study sites: The experiment was conducted in Haro Sabu Agricultural Research Center of three experimental sites for two consecutive years during 2019 and 2020 main cropping season.

Experimental materials: Six improved large pod hot pepper varieties collected from Melkassa and Bako Agricultural Research Centers *viz* Melka Zala, Bako Local, Melka Awaze, Melka Shote, Oda Haro and Mareko Fana varieties were evaluated against one local check.

Experimental Procedure:The six hot pepper varieties which were collected from Melkasa and Bako Agricultural Research center *(*Melka zala, Bako local, Melka awaze, Melka shote, Oda haro, and Marko fana) and Local check from farmer, were evaluated under three locations (HSARC On station, Meti and Egu). Seeds were sown on a seed bed size of 1x10m. The seed bed was covered with a dry grass for 20 days. Then, beds covered by raised shade to protect the seedling from strong sun shine and heavy rainfall until the plants are ready for transplanting. Agronomic practices were done as crop requirement in the nursery. The seedlings were transplanted and planted at spacing of 30 cm x 70 cm between plant and row respectively to the main field after attaining stage for transplanting on (20 to 25 cm height or at 54 days after sowing). Other pertinent agronomic and horticultural practices applicable to hot pepper were also followed in the field based on the recommendation.

Experimental Design and Management: The experiment was carried out in randomize complete block design (RCBD) having three replications in a gross plot size of 3.5mx3m (10.5m2) and net plot size 2.1mx2.4m (5.04m2) with a spacing of 1.5m between replications and 1m between plots. 200 kg/ha NPS as a Hill/Dibble during the transplanting operation and 100 kg/ha for UREA, half of it during the transplanting and half of it one month and half after transplanting was applied. A seeding rate of 0.7kg ha-1 was used. There were five rows per plot and 10 plants per row with a total of 50 plants per plot.

Data collection and Data analyses: Five plants were randomly sampled from middle three rows. Data on plant height, plant canopy, number of primary branches per plant, number of pods per plant, average pod weight (g), pod length (cm), pod diameter (cm) were recorded plant based While measurements such as days to flowering, days to maturity and total dry pod yield ($Kgha^{-1}$) were taken on plot based.

The collected data were subjected to analysis of variance using SAS and Gen Stat computer software (Gen Stat, 2016) and Least Significant Differences (LSD) was used to compare the varieties using the procedures of Fishers protected at the 5% level of significance.

Results and Discussions

Combined Analysis of Variance (ANOVA): The combined analysis of variance (ANOVA) for total yield and other agronomic traits of seven large pod hot pepper varieties grown at three locations in 2019/2020 and 2020/2021 are presented in Table1. Highly significant differences were detected among variety (P ≤ 0.01) for all parameters except pod diameter. Highly significant differences were detected among location (P ≤ 0.01) for all parameters except number of pod per plant and pod weight. Variety * Location effects were significant for all parameters excluding number of primary branches per plant, pod length, pod diamete and pod weight. The interaction effect of variety, location and year revealed highly significant effect (P ≤ 0.01) on days to flowering, days to maturity and total dry pod yield. This might be due to varietal effect since genetic factor can influence yield related parameters.

Table 10.Mean squares of ANOVA for Phenology, Growth, yield and yield related traits of large pod hot pepper Varieties Evaluated in 2019/2020 and 2020/2021 main cropping season.

Source of variation	d.f.	Mean Squares				
		DF	DM	PH	CL	NPrB
Replication	2	27.08	11.01	119.13	88.02	0.80
Variety	6	462.24**	662.23**	437.1**	252.11**	2.06**
Location	2	373.48**	240.1**	276.1*	394.76**	1.85**
Year	1	2605.79**	21790.87**	426.44*	32.31	3.30**
Variety. Location	12	28.85*	41.08*	109.27*	85.41*	0.30
Variety.Year	6	96.88**	315.49**	96.82*	41.13	0.26
Location.Year	2	19.45	4386.44**	274.37*	492.99**	8.38**
Variety.Location.Year	12	90.96**	42.21*	62.9	29.03	0.29
Residual	82	14.29	14.46	37.71	28.8	0.22
CV (%)		5.7	2.6	11.6	13.8	21.7

Table 1. Contd

Source of variation	d.f.	Mean Squares				
		NPPP	PL	PD	PW	TY(Kgha)
Replication	2	116.76	0.358	3.882	0.3027	366382.4
Variety	6	287.56**	9.179**	7.694	0.563*	1264068.01**
Location	2	11.42	8.149*	25.656*	0.2625	4633623.58**
Year	1	45.84	1.522	0.647	0.1283	37743997.23**
Variety. Location	12	91.51*	2.261	4.451	0.2636	873829.62**
Variety.Year	6	62.82	1.621	5.431	0.2113	340524.14*
Location.Year	2	1518.08*	53.706**	2.268	2.1546**	11168476.69**
Variety.Location.Year	12	77.04*	0.564	3.389	0.1185	453463.78**
Residual	82	34.88	1.556	4.157	0.1512	141963.0
CV (%)		31.5	14.3	42.2	23.5	26.59

*Where * **, Loc *Vrt, Yr*Loc*Vrt, DF, DM, PH, CL, NPrB, NPPP, PL, PD, PW and TYQha are significant at 5% and 1%, location by varieties, year by location by varieties, days to flowering, Days to maturity, plant height, plant canopy length, number of primary branches per plant , number of pod per plant, pod length, pod diameter, pod weight and total yield per hectare respectively.*

Yield Performance of large pod hot pepper Varieties across Environments and over years

The interaction effect of variety and year revealed highly significant ($p<0.01$) effect on total yield of large pod hot pepper varieties (Table 1). The result indicated that Melka awaze was the highest dry pod yield than local check in both years. However, all the remaining varieties recorded similar performance with the local check over the two years (Table 2). The interaction of variety and location revealed highly significant ($p<0.01$) effect on total yield of large pod hot pepper varieties (Table 1). The result indicated that Melka awaze (3003.6 kg) was the highest dry pod yield than local check at Onstation . However, the remaining varieties (Melka Zala, Bako Local, Melka Shote and Oda haro) recorded similar performance with the local check at Onstation (Table 3). Oda haro (1822.1kg) was the highest dry pod yield than local check at Egu. However, the remaining varieties (Melka Zala, Bako Local, Melka Shote and Melka awaze) recorded similar performance with the local check at Onstation (Table 3). No significant difference observed among varieties at Meti site (Table 3).

Table 11. Total yield (Kg/ha) of large pod hot pepper over years

	Year	
Variety	2019/2020	2020/2021
Melka awaze	2698.2a	1122.7a
Marko fana	2006.7bc	883.2bc
Malka shote	1958.9bcd	796.7bc
Oda haro	2193.9b	951.3ab
Malka zala	1621.1cd	835.3bc
Bako local	1507.7d	703.3c
Local check	1764.8bcd	796.3bc
Mean	1964.46	869.827
LSD(0.05)	466.88	220.58
CV(%)	24.98	26.65655

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Table 12. Total yield (Kg/ha) of large pod hot pepper over locations

Variety	Location		
	Onstation	Egu	Meti
Melka awaze	3003.6a	1402.2ab	1325.5
Marko fana	2190.8b	930.3d	1213.7
Malka shote	1832.3bc	1161.2bcd	1140
Oda haro	1822.1bc	1589.2a	1306.5
Malka zala	1404.7cd	1120.9cd	1159
Bako local	906.9d	1175.4bcd	1234.1
Local check	1440.3cd	1327.3bc	1074.1
Mean	1800.11	1243.78	1207.55
LSD(0.05)	707.75	259.96	NS
CV(%)	33.24	17.67	15.60

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Phenology and Growth Parameters of large pod hot pepper

Days to flowering and Days to Maturity

The analysis of variance showed that there was a highly significant effect($p<0.01$) on days to flowering and days to maturity due to main factors of variety, location and year; and the interaction effect of variety and year, variety, location and year (Table 1). The result indicated that Local check (57) and Marko fana (63.83) were the earliest, whereas Malka Zala (73.33) and Bako local (69.22) were the latest days to flowering (Table 4). Melka awaze (139.3) and Melka shote (141.4) were the earliest, whereas Melka zala (153.7) and Bako local (153.6) were the latest days to maturity (Table 4) respectively. Earliness or lateness in the days to 50% flowering and days to maturity might be to the inherited characters, early acclimatization to the growing area and environmental conditions such as temperature, moisture and soil fertility which enhance growth and developments plants. This result was in agreement with the finding of Seleshi *et al*. (2014) who reported that days to flowering and maturity of hot pepper which could be due to the temperature of the growing area and due to the transplanting disturbance since it is subjected to loss of feeder roots during uplifting, and consumed their energy to repair damaged organs and thus the process demanded them more time to resume shoot growth.).

Plant height: Analysis of variance showed that there was a highly significant ($P \leq 0.01$) effect on plant height due to main factors of variety and there were a significant effect on location, year and the interaction effect of variety and location, variety and year, location and year (Table 1). The result indicated that Malka Aawaze (58.63cm), Melka zala (58.31cm) and Marko fana (56.07cm) were the longest Plant height than local check. However, Melka shote was recorded similar performance with the local check (Table 4). The significant different of varieties on plant height might be due genetic makeup. This result was in agreement with the finding of MARC (2005), which reported different plant height for different varieties and might be due to the varietal variability to absorb the nutrients from the soil (Vos and Frinking, 1997; El-Tohamy et al., 2006) and climatic condition such as sun light which might influence vertical growth of plant parts.

Plant canopy: Analysis of variance showed that there was a highly significant ($P \leq 0.01$) effect on plant canopy due to varieties, location and interaction of location and year (Table 1). The result indicated that Melka Awaze (45.8cm) was the widest Plant canopy than local check. However, all the remaining varieties recorded similar performance with the local check (Table 4). These variations in canopy diameter between varieties might be due to their inherited traits, the growing environment's soil type, rainfall and soil pH. This variation on the other hand, may determine the yielding potential of the crop, since, varieties with wider canopy diameter could produce more fruit (pods) than varieties with narrow canopy due to increased number of secondary and tertiary branches which are the locations for fruit bud formation. This is in conformity with the work of Faby (1997) who has reported that plants with wider crown produced higher early season yield than those with small crown.

Number of primary branches per plant: Analysis of variance showed that there was a highly significant ($P \leq 0.01$) effect on number of primary branches per plant due to varieties, location, year and interaction of location and year (Table 2). The highest (2.7) and the lowest (1.64) number of primary branches per plant were recorded from Melka Zala and Local Check varieties, respectively (Table 4). This might be due to different plant canopy among varieties of the same crop. This result was online with Seleshi*et al* (2014) who reported different branch number per plant of hot pepper varieties. Generally, the differences observed in branching of pepper plants might have been due to genetic variations existed between varieties and or due to favorable influence of organic and inorganic nutrients present in the soils or the growing environment which goes in line with the findings of (El-Tohamy*et al*., 2006), that stated the presence of adequate amount of organic nutrients in the soil improves growth of pepper plants

Table 13. Combined mean of Phenology and Growth Parameters of large pod hot pepper

Variety	Parameters				
	DF	DM	PH	CL	NPrB
Melka zala	73.33a	153.72a	58.31a	38.67b	2.7a
Bako local	69.22b	153.56a	50.92b	33.56c	2.22b
Melka awaze	66.72bc	139.28d	58.63a	45.8a	2.31b
Melka shote	66.44cd	141.39d	48.78bc	37.63b	2.28b
Oda haro	64.06de	150.28b	50.63b	39.21b	2.28b
Marko fana	63.83e	152.78ab	56.07a	40.8b	1.88c
Local check	57f	144.94c	46c	37.3b	1.64c
Mean	65.80	147.99	52.76	39.00	2.19
LSD(0.05)	2.51	2.52	4.07	3.56	0.31
CV(%)	5.75	2.57	11.64	13.76	21.68

Where DF, DM, PH, CL, NPrB, (0.05) and CV(%) are days to 50% flowering, days to 50% maturity, plant height(cm), canopy length(cm), number primary branches per plant, Least significance difference and coefficient of variation respectively.

Yield and Yield Components of large pod hot pepper

Number of Pod per Plant: Analysis of variance revealed there was a significant ($P \leq 0.05$) difference on pod number per plant of on the interaction effect of variety and location, location and year, variety, location and year and effect of variety showed highly significant effect on pod per plant (Table 1). The result indicated that Malka Awaze (24.36) and Oda haro (22.87) were the highest number of pod per plant than local check followed by Melka shote (20.71). However, all the remaining varieties recorded similar performance with local check (Table 5). This might be due to the highest number of primary branches of Malka Awaze variety and genetic character which influence number of fruits per plant. The highest fruit number in Malka Awaze variety was most likely due to the fruit bearing capacity of the variety and more branch formation nature which leads to contain high number of fruits per plant. In line with this result, Amare *et al*. (2013) found different fruit number per plant due to variety differences. Furthermore, Seleshi *et al* (2014) reported that number of fruits per plant was highly significantly affected by the interaction of variety by location. These authors also stated that fruit number difference might be due to the associated traits like canopy diameter that could limit the number of branches, the temperature stress of the growing environment and the capability of each varieties to with stand the stress especially on the reproductive development, which is more sensitive to high temperature stress (day and night temperature) than vegetative development.

Pod Length: Analysis of variance showed that there was a highly significant ($P \leq 0.01$) effect on fruit length due to varieties and interaction of location and year (Table 1). The result indicated that Malka Zala (9.63cm) and Bako local (9.54cm) were the longest Pod Length than local check . However, the remaining varieties showed lower mean value of Pod Length over the local check (Table 5). The significant difference in fruit length among the hot pepper varieties might be attributed to the inherited traits and adaptability to the environmental condition of the study area. This current result was supported by the findings of Haileslassie *et al*. (2015) and Seleshi *et al.* (2014) who reported significant fruit length for different hot pepper varieties. Further, Setiamihardja and Knavel (1982) indicated that fruit length and fruit diameter were quantitatively inherited and governed by additive gene action in crosses of *Capsicum annuum* Moreover, this finding was supported by the work of Tibebu and Bizuayehu (2014).

Fruit (Pod) Weight: Analysis of variance showed that there was highly significant ($P \leq 0.01$) effect on Fruit (pod) Weight of on the interaction effect of Location and Year and there was a significant effect on variety (Table 1). The result indicated that Mareko Fana (1.91g) was the highest average pod weight than local check. However, the remaining varieties showed lower mean value of average pod weight than local check (Table 5). The varietal different on pod weight might be due to genetic factors and environmental factors such as sunlight and moisture..

Total dry Fruit Yield (Kg/ha):The main effect of variety revealed highly significant ($P<0.01$) effect on total yield of large pod hot pepper varieties (Table 1). The result indicated that Melka Awaze (1910.5Kg/ha) was the highest total yield than local check followed by Oda haro (1572.6kg/ha). However, all the remaining varieties recorded similar performance with the local check (Table 5). The significance difference among varieties on total yield might be due to yield related parameters such as plant canopy length, number of pods per plant and branch number per plants. This is in line with the findings of Haileslassie *et al* (2015) who reported the highest dry yield of Malka Awaze variety at Raya valley of Northern Ethiopia. Similarly Dessie and Birhanu (2018) stated the highest green pod yield of Malka Awaze varity. This is associated with superior vegetative growth including height, plant canopy and tolerance to disease attack. Beside high yielder Malka Awaze and Oda Haro varities was more stable over year and location than other varieties (Fig. 1).

Table 14. Combined mean of Yield and Yield Components of large pod hot pepper

Variety	Parameters				
	NPPP	PL	PD	PWT	TY(Kg/ha)
Melka zala	17.73bc	9.63a	4.66	1.69abc	1228.2cd
Bako local	17.26bc	9.54a	5.94	1.62bcd	1105.5d
Melka awaze	24.36a	7.77c	4.63	1.52cd	1910.5a
Melka shote	20.71ab	8.22c	4	1.38d	1377.8bc
Oda haro	22.87a	8.57bc	4.66	1.64bcd	1572.6b
Marko fana	14.46c	8.26c	5.48	1.91a	1444.9bc
Local check	14.07c	9.111ab	4.47	1.82ab	1280.5cd
Mean	18.78	8.73	4.83	1.65	1417.14
LSD(0.05)	3.92	0.83	NS	0.26	249.84
CV(%)	31.45	14.29	42.18	23.53	26.59

Disease reaction of varieties: The major recorded disease of hot pepper at the studied areas were anthracnose and Cercospora leaf spot (frog eye). The main factor of variety not significantly affected by antracnose. However there were a significant effect of variety on Cercospora leaf spot (frog eye) disease (Table 6). The result revealed that Oda Haro and Bako Local varieties were better tolerance to economically important Cercospora leaf spot (frog eye). However, the remaining varieties were less tolerance to Cercospora leaf spot (frog eye) disease (Table 6)

Table 15. Major disease reaction of large pod hot pepper varieties

Variety	Antracnose	Cercospora leaf spot (frog eye)
Mareko Fana	1.33	2b
Melka Shote	1.22	1.89bc
Bako Local	1.11	1.67c
Melka Awaze	1.11	2.44a
Melka Zala	1.11	2b
Oda Haro	1	1.67c
Local Check	1	1.89bc
LSD(0.05)	NS	0.32
CV (%)	21.9	17.4

Comparison plot for genotypes based on the concentric circle

Figure 1: shows the comparison plot for variety, and an ideal variety is one which is near or at the center of the concentric circle. Hence in this study, the plot reflected that Melka awaze and Oda haro are the most ideal varieties as shown by their position. This also reflects that; these varieties have highest dry pod yield and more stable. Good varieties are those which are closer to the ideal varieties. However, Bako local, Melka zala, Local check, Melka shote and Marko fana are the worst varieties as their position in the plot are located far from the concentric circle.

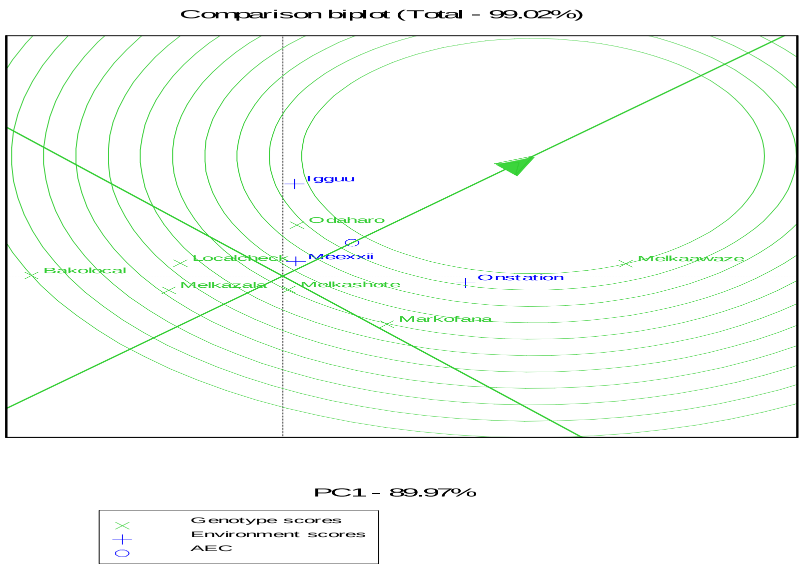


Figure 15. GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability.

Conclusions and Recommendations

The evaluation of large pod hot pepper varieties were done to study the adaptability and performance of improved large pod hot pepper varieties. Significant difference was shown on different yield related traits among varieties. Local check and Marko fana were the earliest, whereas Malka Zala and Bako local were the latest days to flowering. Melka awaze and Melka shote were the earliest, whereas Melka zala and Bako local were the latest days to maturity respectively. Similarly Malka Aawaze, Melka zala and Marko fana were the longest Plant height than local check. However, Melka shote was recorded similar performance with the local check. Generally significant differences for a number of traits among the tested varieties were observed. Evaluation of varieties for adaptation is a fast truck strategic approach to develop and promote agricultural technology. In the present study, Melka Awaze and Oda Haro varieties were found superior in terms of yield and other yield related parameters. These varieties also stable than all other varieties evaluated and tolerant to major hot pepper diseases. Thus they are recommended for popularization and wider production in test locations and similar agro-ecologies.

Acknowledgement

The authors appreciate Oromia Agricultural Research Institute for funding the research budget. Horticulture Department of Haro Sabu Agricultural Research Center is acknowledged for facilitating the field trials. Finally thanks to Bako and Melkasa Agricultural Research Centers for providing the seeds of improved varieties.

References

Amare Tesfaw Nigussie Dechasa and Kebede W/Sadik(2013). Performance of hot pepper (*Cupsicumannuum*) varieties as influenced by nitrogen and phosphorus fertilizers at Bure, Upper Watershed of the Blue Nile in Northwestern Ethiopia. *Int. J. Agric. Sci.*, 3(8): 599-608.

Bosland PW, Votava EJ (2000). Peppers: Vegetable and Spice Capsicums. Crop Production Science in Horticulture, CABI Publishers.Pp.304

El-Tohamy, W.A., Ghoname, A.A. and Abou-Hussein, S.D. (2006). Improvement of pepper growth and productivity in sandy soil by different fertilization treatments under protected cultivation. *J. Appl. Sci. Res.*, 2: 8-12.

Gen Stat. 2016. Gen Stat Procedure Library Release. 18th Edition. VSN International Ltd.

Haileslassie, G., Haile, A., Wakuma, B. and Kedir, J. (2015).Performance evaluation of hot pepper (*Capsicum annum* L.) varieties for productivity under irrigation at Raya Valley, Northern Ethiopia. Basic Res. J. Agric. Sci. Rev., 4(7): 211-216, July 2015.

Lin S WL, Chou Yu, Ching S H, Andreas W, Ebert S K, Ravza M, Albert R, Abdou T, Victor A and Paul A G (2013). Pepper (Capsicum spp.) Germplasm Dissemination by AVRDC – The World Vegetable Center: an Overview and Introspection. CHRONICA HORTICULTURAE, 53 (3)

MARC (Melkasa Agricultural Research Center) (2004). Progress Report, Addis Ababa, Ethiopia

MoARD (2007). Crop Variety Register, Crop Development Department: Issue No. 10, June 2007. Ministry of Agriculture and Rural Development, Addis Abeba, Ethiopia

Msukwa V, Munthali CRY, Missanjo E, Chilima CZ, Simon A, Mng'omba SA, Sagona W, Mkwezalamba I (2016). Growth Performance and Fruit Production of *Sclerocarya birrea* (A. Rich.) Hochst. Provenances in Malawi. International Journal of Scientific Research in Agricultural Sciences, 3(2), pp. 042-049

Patricia T, Rodriguez F, Martinez E, Duque MC, Tohme J (2003). Molecular characterization by AFLPs of *Capsicum* germplasm from the Amazon department in Colombia, characterization by AFLPs of *Capsicum*. *Genetic resources and crop evolution*, 50: 639-647

Pickersgill B (1997). Genetic resources and breeding of *Capsicum* spp. *Euphytica* , 96:129-133

Rodríguez Y, Depestre T, Gómez O (2008). Efficiency of selection in pepper lines (*Capsicum annuum*) from four subpopulations in characters of productive interest. *Cienciae Investigación Agraria*, 35(1):29-40

Seleshi Delelegn, Derebew Belew, Ali Mohammed and Yehenew Getachew, 2014.Evaluation of elite hot pepper varieties (Capsicum spp.) for growth, dry pod yield and quality under Jimma Condition, South West Ethiopia.*International journal of agricultural research*, *9*, pp.364-374.

Tibebu Simon and BizuayehuTesfaye (2014). Growth and productivity of hot pepper (*Capsicum annuum*L.) as affected by variety, nitrogen and phosphorous at Jinka, Southern Ethiopia. Res. J. Agric. Environ. Manage., 3(9): 427-433.

Walter H (1986). Green leaf. In: Breeding Vegetable Crops. Westport, Connecticut: AVI Publishing, Co.

Yosef H, Yayehu Z (1989). Hot pepper and tomato production in Ethiopia. In: Green, SK, Giggs, TD, Mclean, BT (eds.). Tomato and pepper production in the Tropics, Pp 442-451

Registration of Jabdu Common Bean (Phaseolus vulgaris L.) Variety

Dereje Abera*, Lamesa Emisha, Firaol Fikadu, Megersa Tarafa and Rata Tamiru
Haro Sabu Agricultural Research Center, P O Box 10, Haro Sabu, West Oromia, Ethiopia
*Corresponding author e-mail: dereaber@gmail.com

Abstract

Jabdu is a common name given for medium red mottled common bean (Phaseolus vulgaris L.) variety with pedigree name of Ram-20. Jabdu is a bush food bean variety screened from common bean germplasms introduced to Ethiopia (Melkasa Agricultural Research Center) through CIAT program. Jabdu officially verified and released in 2020 by Haro Sabu Agricultural Research Center for large scale production in potential areas of west and Kellem Wollega Zones of West Oromia, Ethiopia and other similar agro- ecologies. It was evaluated in different research sites from 2015 -2017 with Morka variety and further confirmed on farmer's field during 2020 main cropping season with Morka and Ibado. Over all grain yield mean value of 1601 kg/ha, 1538 kg/ha and 1672 kg/ha was attained by Jabdu, Morka and Ibado, respectively on research field. Jabdu out yielded Morka by 4.1% and was lower yielder than Ibado. Never the less, Jabdu was released as the alternative variety for potential areas of west and Kellem Wollega Zones for its special merits such as prevailing disease tolerance, seed colour, growth habit (short, erected and determinant), earliness to maturity, marketability and cooking quality. The wide adaptability, stability, distinctness and uniformity of Jabdu was another concerned issue. Finally, Haro Sabu Agricultural Research Center was recognized for maintenance of breeder seed of Jabdu variety for different research purposes.

***Keywords**: Jabdu; Phaseolus vulgaris; Variety Registration*

Introduction

Common bean (*Phaseolus vulgaris* L; 2n=22) is the world's most important food legume which is used for direct human consumption. Since it is high in nutrient content and commercial potential, common bean holds great promise for fighting hunger, increasing income and improving soil fertility in Sub Saharan Africa. It is the second most important crop next to cow pea in eastern, central, and southern Africa (Negash et. al, 2011 and Lilongwe et al.,2011), ranks first globally and stands second next to faba bean in Ethiopia (Walelign W., 2017). It is one of the major food and cash crops in Ethiopia and it has considerable national economic significance and also traditionally ensures food security in Ethiopia (Asfaw *et al.*, 2009 and PABRA, 2014). It ranks third as an export commodity in Ethiopia, contributing about 9.5% of total export value from agriculture. It is often grown as cash crop by small scale farmers. The majority of common bean producers in Ethiopia are small scale farmers, and it is used as a major food legume in many parts of the country where it is consumed in different types of traditional dishes (Habtu *et al.*,1996). In Ethiopia; Oromia, Amhara and Southern Nations Nationalities and peoples are major common bean producing regions (CSA (2017).

Jabdu (*Ram-20*) is common bean variety released in 2020 by Haro Sabu Agricultural Research Center (HSARC). The newly released variety is medium seed size, bright red mottled seed colour obtained from CIAT/ECABREN breeding lines that had been introduced to Ethiopia by national agricultural research institute, Melkasa Agricultural Research Center. Ram-20 came to HSARC and tested from early breeding stage to variety development. Jabdu (Ram-20) officially approved in 2020 by Ethiopian National Variety Release Committee based on the standard of national variety release and registration policy of the country for common bean potential areas of West and Kellem Wollega Zones of west Oromia and areas with similar agro-ecology. Jabdu (Ram-20) was described by using common bean description suggested by Grafton *et al.* (1993), Kelly *et al.* (1994) and Saindom *et al.* (1996).

Evaluation

The newly released variety (Jabdu) was evaluated under regional variety trial at six environments (6) in western Oromia, Ethiopia between during 2015 and 2017. It was tested with the standard checks (Morka and Ibado). On-farm and research evaluation was conducted during 2020 at Sago (Lalo Kile district), Haro Sabu (Dale sadi district), Ano Mikael (Sayo district) and Igu (Sadi Chanka district) with Morka and Ibado at altitude ranging from 1400-1650 meters above sea level.

Agronomic and Morphological Characteristics

Jabdu (Ram-20) is recognized for light green leaves, determinant, short and erected growth habit. It has bright red mottled seed colour, white flower colour and medium seed size. Jabdu produces 8.4-10 pods per plant, 4-4.2 seeds per pod, 41.2-42.6 gm seed weight and 32.2-36.3 cm plant height, on range base (Table 1). The new variety is a food type/market group preferred by producers mainly because of its high yielding, seed color, disease tolerance and marketability.

Yield Performance

Multi-location yield trial conducted at Haro Sabu research site, Gulliso FTC, Kure Gayib FTC, Sago FTC and Tole FTC between 2015 and 2017. Jabdu showed higher mean value of grain yield than Morka (ECAP-0056) and lower mean value of grain yield compared to Ibado as observed from the mean value recorded in breeding stage (2015-2017) and on farm evaluation of 2020. On combined analysis; Jabdu variety was high yielder than all genotypes (except Ibado), stable, well adapted and disease tolerant. The mean grain yield value of 1601 kg/ha and 1538 kg/ha and 1672 kg/ha were recorded from Jabdu, Morka and Ibado, respectively on research field. On farmers' fields, the grain yield of Jabdu ranged from 14.91-16.58 kg/ha.

Table 1: Mean of some agronomic characters (Jabdu Vs. Morka and Ibado)

Major Agronomic characters	Jabdu	Morka	Ibado
Days to flowering	38-39.5	41-42	42-44
Days to Maturity	69-71	75-77	77-79
Plant height (cm)	32.2-36.3	53-55.2	45-48.2
Pod/plant	8.4-10	10.8-14	8.8-12
Seed/pod	4-4.2	4.4-4.6	4.3-4.4
Hundred seed weight (gm)	41.2-42.6	38.7-40.4	40.2-43.4
Mean Grain Yield (kg/ha):			
Research Field	15.16-19.58	14.47-17.63	17.06-22.74
Farmer Field	14.91-16.58	13.04-15.1	15.02-20.2

Yield Stability Test

Jabdu was tested for its grain yield performance in areas ranging from 1450-`650 meters above sea level. Its yield stability across test locations was analyzed following the AMMI model with twelve medium red mottled bean genotypes. The result of the study showed that Jabdu had the highest interaction principal components, indicating that Jabdu1 is specifically adapted to favorable environments in general.

Disease Reaction

Jabdu was tested for its disease reaction starting from preliminary observation nursery and found to be tolerant to major common bean diseases in the test locations. Disease reaction was scored on the base of the standard rating scale of 1-9, where 1 being highly resistant and 9 highly susceptible. Haro Sabu-1 scored a mean value of 2 for Common bacterial blight (*Xanthomonas campestris pv. Phaseoli)* and 1.75 for anthracnose (*Colletotricum lindemuthianum*).

Table 2: Major common bean disease reaction

Major disease	Jabdu	Morka	Ibado
Common bacterial blight	2	3.25	2.5
Anthracnose	1.75	3	2.75

Quality Analysis: Beside its yielding ability, other desirable agronomic traits such as earliness, short plant statue and disease tolerance; producers preferred Jabdu due to attractive seed physical characteristics like seed color, size, marketability and uniform maturity.

Adaptation: Jabdu is released large scale production in West and Kellem Wollega Zones of West Oromia, Ethiopia, preferably for areas receiving a well distributed total annual rainfall greater than 1000 mm. Moreover, the production of this newly released variety can be extended to other regions having similar agro-ecology after adaptability and performance test.

Conclusions and Recommendations

Jabdu (Ram-20) variety which is a responsive to inputs was released and officially verified in 2020 for West and Kellem Wollega, West Oromia, Ethiopia as alternative variety with Ibado which was already adapted in test areas. Jabdu was considered for its special merits such as disease tolerance, bright red mottled seed colour, determinant, short and erected growth habit and earliness to maturity compared to Ibado which was high yielder than Jabdu. Therefore, Jabdu was suggested for further demonstration and large scale production in West and Kellem Wollega Zones, and other similar agro-ecology on the base of varietal adaptation and performance evaluation.

Acknowledgements

Authors gratefully thank Oromia Agricultural Research Institute for financial grant, Melkasa Agricultural Research Center for permitting access to germplasms, Haro Sabu Agricultural Research Center for facilitation of research activity and Pulse and Oil Crop Research Case Team for trial management.

References

FAOSTAT .2010. Food and Agriculture Organization at www.fao.org

Grafton, K.F., Chang, K.C., Venette, J.R., Wal, A.J. and Vander. 1993. Registration of 'Norstar' navy bean. *Crop Science* 33: 1405-1406.

Kelly, J.D., Hostfield, G.L., Varner, G.V., Uebersax, M.A., Brothers, M.E. and Taylor, J. 1994. Registration of 'Huron' navy bean. *Crop Science* 34: 1408.

Kimani PM.1999. Common Bean in Africa. Its origin, production, and improvement, a brief note, University of Nairobi, Department of Crop Sciences, Nairobi, Kenya.

Mulugeta Atnaf1, Hussein Mohammed and Habtamu Zelleke. 2013. Inheritance of primary yield component traits of common beans (*Phaseolus Vulgaris L.*): Number of seeds per pod and 1000 seed weight in an 8 × 8 diallel cross population. Volume 5(4), pp.42-48.

Negash R.2007. Determinants of adoption of improved haricot bean production package in Alaba special woreda, southern Ethiopia. MSc Thesis, Haramaya University.

Ribeiro ND, Londero PM, Cargnelutti SA, Jost E, Poersch NL, Mallmann CA. 2007. Composition of amino acids of bean cultivars and implications for breeding. Braz. Agric. Res. 42:1393-1399.

Saindom, G. Mundel, H.H. and Huang, H.C. 1996. Registration of 'AC Skipper'navy bean. *Crop Science* 36: 207.

Appendix

1. New Common Bean Variety

1.1 Variety: Jabdu (Ram-20)

1.1.1 Agronomic and Morphological characteristics

Adaptation Areas: Lowland to mid-land areas of West and Kellem Wollega such as Haro Sabu, Kure gayib, Sago, Igu, Didesa and other similar agro ecology of the country

Altitude (m.a.s.l):1400-1650

Rain fall (mm): 1000-2100

Planting date: Early of August

Spacing (cm): -40cm between rows
-10cm between plants

Seed rate(kg/ha): 100 with row planting

Fertilizer rate(kg/ha):
NPS: 100
Urea:-

Days to flowering: 38-39.5

Days to maturity: 69-71

Plant height (cm): 32.2-36.3

Growth habit: Erect and determinate

Flower colour: White

Seed colour: bright red mottled

Number of Pod/plant: 8.4-10

Number of Seed/pod: 4-4.2

Seed size: Medium

Hundred seed weight(gm): 41.2-42.6

Foliar disease; Anthracnose and Common bacterial blight reaction*

Grain Yield (Kg/ha)

-Research Field: 15.16-19.56

-Farmer Field: 14.91-16.58

1.1.2 Year of Release: 2020

1.1.3 Breeder/Maintainer: Haro Sabu ARC/OARI

*Tolerant to foliar disease (Anthracnose and common bacterial blight and moderately tolerant to insect pest on field)

Registration of Jajo (Acc#28) Small Pod Hot Pepper (*Capsicum frutescens* L.) Variety

Kibiru Kena[1*], Zewdu Tegenu[2*], Alemayehu Latera[2*], Fekadu Adane[2*], Ashenafi Debela[2*]

Corresponding author email: -*kibiruk12@gmail.com*

Abstract

Jajo is a common name given for small pod hot pepper (Capsicum frutescens L.) variety with accession name of Acc#28. It is selected out of a local collection done during 2013GC from west wollega and kellem wollega zones and released by Haro Sabu Agricultural Research Center for production in west and Kellem Wollega Zones of West Oromia, Ethiopia and similar agro-ecologies in 2021 in multi-location trial. Jajo gave a mean dry pod yield of 1225.78 kg/ha on research field. Jajo performed better than the standard check, Dinsire, which gave 1010.65kg/ha mean dry pod yield. On farmers' fields a mean yield of 1048.83 kg ha-1 was recorded for Jajo. Jajo is small pod hot pepper variety with sparse growth habit and up right pod orientation. It is a variety with light green at maturity and light red at dry pod color used for market use and domestic consumption. Yield stability study showed that Jajo was stable variety in test locations and requires favorable environments for good pod yield. It is also moderately resistant to major hot pepper disease (anthracnose and cercospora leaf spot) and insect pest. The breeder seed of Jajo is maintained by Haro Sabu Agricultural Research Center for different research purposes.

Keywords*:* calyx, dry pod, jajo

Introduction

Hot pepper (*Capsicum species*) belongs to the Solanaceae family and originated in the new world tropics and subtropics (Mexico, Central America and Andes of South America) over 2000 years ago (Walter, 1986 and Rodriguez *et al.,* 2008). The genus Capsicum consists of approximately 22 wild species and five domesticated species, which include C. *annum* L., C. *frutescens* L., C. *chinenses* L., C. *baccatum* L., and C. *pubescens* L. (Bosland and Votava, 2000, Patricia *et al.*, 2003 and Pickersgill, 1997). It is grown as an annual crop and produced for its fruits. Small pod hot pepper(Chili) (*Capsicum frutescens* L.) is an important vegetable and spice crop cultivated throughout Ethiopia especially in South, Central and South West part of the country. The small fruited chili locally called 'Mitmita' are either prepared as crushed fresh or 18 powder of dry fruits used for special local sauce preparation, to eat raw meat or eaten with local bread/injera for its unique pungency which adds value in local food preparations. In some parts of the country where pepper and chilies are dominantly grown, sales from these crops contribute 50-60% of the household income, as the green fresh fruits fetches good price and sold at Ethiopian Birr $80-100 per kg in the retail market. However, the productivity of chili pepper is below the average yield estimation at national level (CSA, 2018). This yield loss might be due lack of improve variety, sowing methods, use of appropriate plant spacing and environmental conditions. In Ethiopia, chili (small pod hot pepper) has become almost an essential ingredient of the daily diet of the rich and the poor societies. It is an important commercial product supplied to the local market and exported to different countries. In its major area of production, with hot pepper has a huge potential for improving the income and livelihood of thousands of smallholder farmers and can plays a vital role for food security in Ethiopia. In some parts of the country where pepper and chilies are dominantly grown, sales from these crops contribute 50-60% of the household income, as the green fresh fruits fetches good price and sold at Ethiopian Birr $80-100 per kg in the retail market (Gebeyehu and Shimelis, 2018). In Ethiopia, pepper grows under warm and humid weather conditions and the best fruit is obtained in a temperature 21-27^{o}C during the daytime and 15-20^{o}C at night IAR, (1996). It is extensively grown in most parts of the country, with the major production areas concentrated at altitude of 1100 to 1800 m.a.s.l. MoARD, (2009).

Jajo (*Acc#28*) is small pod hot pepper released in 2021 by Haro Sabu Agricultural Research Center (HSARC). It is small pod with light green at green maturity stage and light red at dry pod stage. it is obtained from local collection of small pod hot pepper done during 2013GC of West Wollega and Kellem Wollega zones. Acc#28 was collected and had been evaluated from preliminary to variety development stage at HSARC main station and similar agro ecology of its substation. It was officially approved in 2021GC by Ethiopian National Variety Release Committee in accordance with the national variety release and registration policy of the country to hot pepper producing areas of West and Kellem Wollega, west Oromia and areas with similar agro-ecology.

Evaluation

Jajo was tested under regional variety trial at six environments (location x year) in western Oromia, Ethiopia between 2016 and 2018. Jajo was evaluated along with the standard check, Dinsire. On-farm evaluation was conducted during 2020 at seven sites, with Dinsire at altitude ranging from 1400-1650 meters above sea level.

Agronomic and Morphological Characteristics

The newly released variety; Jajo has light green leaves with sparse growth habit. The pod of Jajo is light green at maturity and light red at dry pod stage with upright pod orientation. Jajo produces 98.29 pods per plant, with 0.44gm average pod weight, 5.26 cm pod length and 63.89 cm plant height (Table 1). The new variety is a food type/market group preferred by producers mainly because of its high yielding, disease moderately resistant and hard persistent calyx on fruit which reduces perishability during harvest.

Yield Performance

Jajo was evaluated for dry pod yield from early breeding stage i.e. 2013 to 2018 and had better mean value than the standard check, Dinsire . Multi-location yield trial carried out at Haro Sabu research station, and sub-stations (Meti) for three consecutive main cropping seasons (2016-

2018). Jajo was found to be high yielder, stable, well adapted, disease moderately resistant. The mean dry pod yield value of 1225.78 kg/ha was obtained from Jajo compared to the standard check; Dinsire which had a mean value of 1010.65kg/ha for dry pod yield. On farmers' fields, the dry pod yield of Jajo was 1048.83 kg/ha (Table 1), which revealed the increment of yield through new variety deployment.

Table 16. Mean of some agronomic characters (Jajo Vs. Dinsire)

Major Agronomic characters	Jajo	Dinsire
Days to flowering	70.14	60.14
Days to Maturity	142.14	124.00
Plant height (cm)	63.89	49.20
Plant canopy (cm)	56.71	44.57
Pod/plant	98.29	34.69
Pod length (cm)	5.26	6.02
Pod weight (gm)	0.44	0.79
Mean dry pod yield (kg/ha):		
Research Field	1225.78	1010.65
Farmer Field	1048..83	872.14

Yield Stability Test

Jajo was tested for its dry pod yield performance in areas ranging from 1400-1650 meters above sea level. Its yield stability across test locations was analyzed following the AMMI model with nine small pod hot pepper genotypes (Gen Stat, 2016).. The result of the study showed that Jajo had the highest interaction principal components, indicating that it is specifically adapted to favorable environments in general.

Disease Reaction

Jajo was tested for its disease reaction starting from preliminary observation nursery and found to be moderately resistant to major hot pepper diseases in the test locations. Disease reaction was scored on the base of the standard rating scale of 1-5, where 1 being highly resistant and 5 highly susceptible. Jajo scored a mean value of 1.29 for pod anthracnose(*Colletotrichum* spp) and 1.57 for cercospora leaf spot *(Cercospora capsici)*.

Table 17. Major hot pepper disease reaction

Major disease	Jajo (Acc#28)	Dinsire
Cercospora leaf spot	1.57	3.14
Pod anthracnose	1.29	1.57

Quality Analysis

Besides its yielding ability, other desirable agronomic traits and disease moderately resistant, producers and consumers preferred Jajo due to hard calyx, attractive pod color for market and local consumption, pod length and high pungency.

Adaptation

Jajo is released for production in West Wollega and Kellem Wollega Zones of West Oromia, Ethiopia, preferably for areas receiving a well distributed total annual rainfall greater than 1000mm and altitude of 1400-1650 masl. Never the less, Jajo production can be extended to other regions having similar agro-ecology after adaptation and performance evaluation.

Conclusion

Jajo (Acc#28) is a responsive variety to inputs which was officially verified and released in 2021 in West and Kellem Wollega, West Oromia, Ethiopia. It is high yielding, highly adaptable, stabile and moderately resistant to major hot pepper diseases prevailing in areas over the standard check. It was also preference by producers for its better dry pod yield performance, high pungency and marketability. Therefore, Jajo was recommended for further demonstration and large scale production in the test locations, and other similar agro-ecology on the base of adaptability study.

Acknowledgements

The authors gratefully thank Oromia Agricultural Research Institute for financial grant, Haro Sabu Agricultural Research Center for facilitation of research activity and Horticulture &Spice team for trial management.

References

Bosland PW, Votava EJ (2000). Peppers: Vegetable and Spice Capsicums. Crop Production Science in Horticulture, CABI Publishers.Pp.304

CSA (Central Statistical Agency). 2018. Agricultural Sample Survey 2018/2019: Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Volume-I, Statistical Bulletin 589, Addis Ababa, Ethiopia.

Gen Stat. 2016. Gen Stat Procedure Library Release. 18th Edition. VSN International Ltd.

Gebeyehu Wondimu and Shimelis Aklilu. 2018. Stability Analysis of Chili(*Capsicum frutescens* L.) Genotypes in the Rift Valley Areas of Ethiopia. *Journal of Agricultural Sciences and Food Research.* 9(208).

IAR (Institute of Agricultural Research). (1996). Progress Report Addis Ababa. *Institute of Agricultural Research*, Addis Ababa, Ethiopia.

MoARD (Ministry of Agriculture and Rural Development). (2009). Variety Register. Issue No. 9. June 2006. Addis Ababa, Ethiopia

Patricia T, Rodriguez F, Martinez E, Duque MC, Tohme J (2003). Molecular characterization by AFLPs of *Capsicum* germplasm from the Amazon department in Colombia, characterization by AFLPs of *Capsicum*. *Genetic resources and crop evolution*, 50: 639-647

Pickersgill B (1997). Genetic resources and breeding of *Capsicum* spp. *Euphytica* , 96:129-133

Rodríguez Y, Depestre T, Gómez O (2008). Efficiency of selection in pepper lines (*Capsicum annuum*) from four subpopulations in characters of productive interest. *Cienciae Investigación Agraria*, 35(1):29-40

Walter H (1986). Green leaf. In: Breeding Vegetable Crops. Westport, Connecticut: AVI Publishing, Co.

Appendices

Appendix 1. Agronomic and morphological characteristics of Small pod hot pepper variety Acc#28(Jajo)

Variety	Jajo(Acc#28)
Agronomic and morphological characteristics	
Adaptation area	Dale Sadi, Sadi Chanqa, Hawagalan ,Sayo and similar agro-ecologies
Altitude (meter above sea level)	1400-1650
Rain fall (mm)	1000-2100
Soil type	Sandy loam
Planting time	Late June – Mid July
Seed rate (kg/ha)	0.7-0.8
Fertilizer rate (Kg/ha)	
NPS	200 at transplanting
Urea	100 (% 50 at transpanting and 50% after 1.5 months
Days to 50% flowering	70.14
Fruit maturity (days)	142.14
Plant height(cm)	63.89
Growth habit	Erect
Color at maturity	Light green
Color of dried pod	Light red
No of fruits/plant	98.29
Plant canopy(cm)	56.71
Pungency	Very high
Crop pest reaction	moderately resistant for major diseases (anthracnose and cercospora leaf spot
Number of pedicle /axis	1
Acceptability/use	Dry pod
Yield (dry)(Qt/ha)	
Research field	10.30-14.33
Farmers field	8.48-12.34
Year of Release:	2021
Breeder/Maintainer:	HSARC/OARI

Keys: HSARC= Haro Sabu Agricultural Research Center, OARI= Oromia Agricultural Research Institute

Release and Registration of AYINAGE (5012 (09BKF$_6$#2007(6) Sorghum (*Sorghum bicolor* L. Moench) Variety for West Hararghe zone

Abubeker Terbush, Gebeyehu Chala, Desu Asegid and Abdela Usmael
Oromia Agricultural Research Institute, Mechara Agricultural Research Center, P.O. Box 19, Mechara, West Hararghe, Ethiopia.
Corresponding author Email: fenan2294@gmail.com

Abstract

AYINAGE (5012(09BKF$_6$#2007(6) was an accession name for this Sorghum (Sorghum bicolor L Moench.) variety with a pedigree designation of (5012 (09BKF$_6$#2007(6). The variety has been developed and released by Mechara Agricultural Research Center for mid lands of West Hararghe and similar agro-ecologies of Ethiopia. It has been tested at Hirna and Mechara on station during 2017-2019 years and showed consistence performances for grain yield over standard checks (Dagim) variety during Regional variety trial and Bonsa during Variety verification trial. Thus, the variety has shown high mean grain yield and consistently stable across locations and years. It also showed better reaction against responses to stalk borer, leaf bight, and loose smut diseases as compared to standard check. The medium maturing and larger head size characteristics of the variety suits to the different cropping systems in the area and give better adoption potential by the local farmers. The result of Genotype and genotype by environment (GGE) demonstrated that this variety was more stable and high yielder than the check and it is released as a new sorghum variety by the approval of national variety release committee for large scale production as improved sorghum variety for major producing areas of west Hararghe Zone and similar agro ecologies in Ethiopia.

Keywords: Disease Reaction, genotype and Disease Reaction

Introduction

Sorghum is the fifth most important cereal crop worldwide after wheat, rice, maize and barley. Ethiopia is the primary center of origin and center of diversity for sorghum. Sorghum is now widely found in the dry areas of Africa, Asia, Americas and Australia (Dickon *et al*., 2006). In lowland areas of Ethiopia, where moisture is the limiting factor, sorghum is one of the most important cereal crops planted as food insurance, especially in the lowlands of eastern Ethiopia and in the north and north-eastern parts of the country where the climate is characterized by unpredictable drought and erratic rainfall (Degu *et al*., 2009). Sorghum is one of the most important cereal crops of the tropics grown extensively over wider areas with altitude range from 400 to 3000 meters above sea level (m.a.s.l) due to its ability to adapt to adverse environmental conditions. This has made sorghum a popular crop in world wide. It is the major source of energy and protein for millions of people living in arid and semi-arid region of the world. It occupied third position in terms of production in Africa after wheat and maize and fifth in the world after wheat, maize, rice and barley (FAO, 2017). The crop is the major food cereal after maize and tef in terms of area coverage and the third after maize and wheat interims of grain production in the country (FAOSTAT, 2017). In Ethiopia, sorghum is the 3rd in area coverage next to maize and Tef accounting to the total area of 1,828,182.49ha and 52,655,800.59Qt in total production as report of 2019/20 Private Peasant Holdings For Meher Season(CSA.2019). The total sorghum production in Oromia was 714,492.91 ha which produces annual production of 21626963.13quintals (30.27 qt ha^{-1}). From Oromia region Eastern and Western Hararghe, most part of West Shoa and East Wolega are among the major producers, that covers 142,385.06, 155,386.13, 62,158.67, and 36,571.80 hectares of land; and 4,190,886.12, 4,879,974.70, 1,989,276.71 and 1,166,347.89quintals of sorghum production, respectively (CSA, 2019).

AYINAGE(5012) (09BKF$_6$# 2007(6) sorghum variety is released on June 5/2021 under Oromia Agricultural Research Institute by Mechara Agricultural Research Center. The material has been evaluated together with other genotypes in different breeding nurseries from 2011-2021 and then advanced to variety trial to see its varietal performance across locations and years in sorghum producing areas of West Hararghe mid lands. The variety was officially released as a new variety in West Hararghe mid lands after approval of the Ethiopian National Variety Release Committee in accordance with the guidelines of the national variety release system and variety registration of the country. Breeder seed and foundation seed of the variety is maintained by McARC.

Varietal Origin and Evaluation

AYINAGE (5012((09BKF$_6$#2007(6) was brought from Melkasa Agricultural Research Center which was originally collected from West Hararghe Zone. It was selected by pure line selection methods at Mechara Agricultural Research Center (McARC) to develop a variety with high yielding potential and other better agronomic traits. It was tested together with 10 sorghum genotypes including checks in regional variety trial at two environments with three years in major sorghum producing areas of West Hararghe during 2017-2020 consecutive years. It was evaluated along with Dagim at regional variety trial and Bonsa as standard check in variety verification trial at altitudinal range of 1720-1768 meter above sea level at Hirna and Mechara on station locations in each year. The variety was consistently performed stable both across years and locations in all parameters.

Varietal Characteristics

Even though the variety is medium in plant height (153cm); erect growth habit. The variety matures with an average of 146 days which is relatively lower maturity period as compared to locally grown sorghum cultivars in west Hararghe. The average days to heading and maturity are 88 and 146 days, respectively. On the other hand, seed color is red brown and has average head weight of 253.5gm .This sorghum variety had a medium plant height and stay green after maturity as the sorghum straw has a high demand for animal feed and home use as fire wood which makes it preferable than those sorghum verities previously developed and released which are characterized by low biomass. AYINAGE sorghum variety is characterized by having larger head size, erect type in growth habit and partially open panicle .It can be produced efficiently with the existing short rainy season received from May to August. It is also characterized by better resistance/tolerance to main biological insect pest stem borer score of (1.8), leaf blight and mold (visual observation) than specially the standard variety (Dagim). (Table 1).Therefore; it is selected for dual purpose (food and feed) at the tested locations.

Yield and Stability Performance

The results of the evaluation indicated important information regarding variety performance and stability. Thus, grain yield performance of the released sorghum variety and checks is described below in Table (1). During evaluation seasons, the overall location mean grain yield of this variety was consistently better than checks in both across locations and years. Beside this, AYINAGE (5012(09BKF6#2007(6)) was higher in mean grain yield over check variety, exceeding by 3.2% over Dagim (standard variety). On research field (5012(09BKF6#2007(6)) gave yield of 41 Qt ha^{-1}, whereas 33 Qt ha^{-1} on farmers' field. In addition, stability analysis was done on grain yield using three years (2017-2019) data. In this regard, AYINAGE (5012(09BKF6#2007(6) is stable variety with high mean grain yield, and stable across locations and years. Therefore, it has shown stable yield performance across locations of evaluation as well as higher mean grain yield over check variety (Dagim).

Table 1. Combined Mean grain yield (Kg ha^{-1}) and agronomic traits of Sorghum genotypes during 2017 to 2019 at Mechara onstation (Daro Lebu) and Hirna (Tulo)

SN	Genotype	Pedigree	DF	PH (cm)	HW (gm)	Insect score (1-5)	MD	GrY kg ha^{-1}	Over all agronomic traits
1	G5003	09BKF$_6$#2002(1)	90.3	164.3	253.2	2.30	153.3	3697	2.02
2	G5014	09BK F$_6$#2001(1)	88.2	150	262.2	2.39	148.2	3628	2.3
3	G5005	09BK F$_6$#2003	85.3	145.6	273.4	2.49	144.6	3378	2.38
4	G5010	09BK F$_6$#2007(7)	87.4	162.7	239.2	2.46	147.1	4078	2.1
5	G5007	09BK F$_6$#2006(1)	79.3	149.9	250.4	2.26	145.8	4513	2.03
6	G5017	09BK F$_6$#2007(3)	84.1	147.2	229.5	2.14	150	3955	2.01
7	G5008	09BK F$_6$#2007(2)	80.4	145.4	239.3	2.58	143.3	4006	2.33
8	G5012	09BK F$_6$#2007(6)	87.9	152.9	253.5	1.88	146.3	4110	1.91
9	G5006	09BK F$_6$#2005(5)	82.2	179.8	230.7	2.10	145.3	3519	2.02
10	Dagim		80.3	177.3	219.5	2.55	147.6	3957	2.21
	Mean		85	157.5	245.0	2.40	147.1	3883	2.13
	LSD		4.1	13.735	83.0	0.31	6.4	1146	0.58
	CV		6	5.4	21.0	27.10	5.4	18.3	16.9

FD=Flowering Date, PH, HW= Head Weight, IS, Insect Score, MD, Maturity Date, GY=Grain Yield, DF= days to flowering, DM= days to maturity, PH= plant height, HW= head weight, DIS= disease, PAS= plant aspect, Yld= Grain yield, GM= grand mean, LSD= Least significant difference, CV= Coefficient of variation.

Table 2. Grain Yield data for sorghum Variety Verification Trial at Mechara and Tulo districts of west Hararghe Zone in 2020 cropping season

Candidates and checks	On station Grain yield kg ha^{-1}	On farm Grain Yield kg ha-^{1}	Overall Average Grain yield kg ha-^{1}
5012(Candidate-2)	3705	3026	3365.5
5017(Candida-1)	4040	3300	3670
Bonsa	2981	2611.7	2796.35

Disease Reaction: Data recording was done for all genotypes including this variety for major sorghum insect pest such as stem borer and for major diseases such as Anthracnoses

(*Colletotrichum graminicola*), leaf blights (*Exserhilum turcicum*), and smut are among the major bottleneck for sorghum production at two environments. Providentially, this variety revealed resistance to the above mentioned insect and diseases throughout the study periods.

Farmers Evaluation of the Variety

During field evaluation of the perception and preferences of the local farmers, Sorghum variety verification trial conducted at five representative sites in West Hararghe mid lands during 2020 cropping season. The national variety releasing committee has made Farmers selection and evaluation individually and in group. In this evaluation, Dagim as well as Bonsa recently released variety were included together with AYINAGE (5012(09BKF6#2007(6)). Among these the candidate variety was almost selected or ranked as first variety preferred by the local farmers mainly due to its better head size, early maturity to even Bonsa which was recently released, tolerant to grain mold, leaf blight and relatively disease free than both standard check.

Adaptation: AYINAGE (5012(09BKF6#2007(6) variety was recommended for production in the mid lands areas of West Hararghe Zone and other regions in the country with annual rainfall amount of 800-1500mm in the altitude rage of 1700 to 2000 m.a.s.l. From know this sorghum variety can be used by different organization NGO's and Research center as check and improved variety for large scale production.

Table 3. Agronomical and Morphological Characteristics of AYINAGE (Acc.5012) Sorghum Variety

Variety Name	IYINAGE
Adaption areas	Mechara, Tulo and similar agro-ecologies
Altitude (m.a.s.l.)	1700-2000
Rain fall(mm)	800-1500
Seed rate (kg ha^{-1})	10-12
Plant spacing	
Row spacing(cm)	55
Row spacing between plant(cm)	20-25
Planting date early to late May	Early to mid-May
Fertilizer rate kg ha^{-1}	
Nitrogen (N)kg ha(urea)	100
NPS/NPSBn(kg)	100
Days to maturity (days)	146
Plant height in (cm)	152
Seed color	Red
Growth Habit	Erect
Crop disease and insect Reaction	
Leaf blight	1.9
Stalk borer	2
Grain Yield(t ha^{-1})	
Research field	4.1
On farm	3.3
Year of Release	June, 2021
Breeder Seed Maintainer	Mechara Agricultural Research Center

m.a.s.l=meter above sea level.

Conclusions and Recommendations

AYINAGE (5012(09BKF6#2007(6) sorghum variety was evaluated in Mechara and Tulo district's for 3 consecutive cropping season and released as new sorghum Variety that can best fit for production in midland areas of Western Hararghe Zone and other regions in the country exhibiting similar agro-ecologies where this variety was developed. This sorghum variety was preferred for its better grain yield, medium maturing and stay greenness it's stalks after maturity and larger head size, relatively tolerant to some insect pest and leaf blight were some of the merits of this variety attracted local community.

References

CSA (Central Statistical Agency). 2019. Agricultural sample survey 2019/2020: report on area and production of crops (private peasant holdings, main season), vol. 1. Addis Ababa: Federal Democratic Republic of Ethiopia, Central Statistical Agency.

Degu, E., Debello, A. and Ketema Belete. 2009. Combining ability study for grain yield and yield related traits of grain sorghum (*Sorghum bicolor* (L.) Moench) in Ethiopia. *Agricultural Crop Science,* 57(2): 175–184.

Dicko, M.H., Gruppen, H., Traore, A.S., Alphons, G.J., Voragen, A.G.J. and Berkel, W.J.H. 2006. Sorghum grain as human food in Africa: Relevance of content of starch and amylase activities. *African Journal of Biotechnology,* 5: 384-395.

FAO (Food and Agriculture Organization). 2017. Sorghum and millet production and nutrition, Chapter 2, www.fao.org/docrep.

FAOSTAT. 2017. Food and Agriculture Organization of the United Nations Data base of AgriculturalProduction.FAOStatisticalDatabases.Availableathttp://faostat.fao.org/site/339 /default. aspx.

Yan, W. and Kang, M.S. 2003. GGE Biplot analysis: A graphical Tool for Geneticist, Breeders and Agronomists. CRC press, Boca Raton, FL., U.S.A.

Registration of ''Ikhulule'' (12AN FMRVT Seed inc. #7)' Finger Millet (*Eleusine coracana* (L.) Gaertn) Variety

Abubeker Terbush, Gabayehu, Desu Asegid and Abdela Usmael,

Oromia Agricultural Research Institute, Mechara Agricultural Research Center, P.O. Box 19, Mechara, West Hararghe, Ethiopia.

Corresponding author Email: fenan2294@gmail.com

Abstract

Ikhulule (12AN FMRVT Seed inc. #7) is a light brown-seeded finger millet (Eleusine coracana sub spp. coracana) variety.Its pedigree is designated by (Acc. Ikhulule). It is a selection from 96 genotypes obtained from Melkasa Agricultural Research Center which had been collected from different parts of Oromia and few were introduced from abroad Ikhulule and other pipeline finger millet genotypes were evaluated against a standard check (Addis-01) for grain yield, disease reaction, and other agronomic traits across two locations (Mechara and Habro districts) for three consecutive years (2017-2019) during the main cropping seasons. Additive main effect and Multiplicative Interaction (AMMI), and Genotype and Genotype by Environment Interaction

(GGI) biplot analysis showed that Ikhulule is stable, disease tolerant, and high yielder (6.3 t ha^{-1}) with 18%.yield advantage over standard check Gute (5.8 t ha^{-1}). Therefore, it was developed and released by Mechara Agricultural Research Center for eastern parts of Oromia and similar agro ecological areas of Ethiopia.
Keywords: Finger millet, productive tiller, Yield Performance

Introduction

In Ethiopia finger millet [*Eleusine coracana* (L.) Gaertn] is one of the most important indigenous cereal crop grown largely by small holder farmers. Finger millet has been mainly grown in Amhara, Benishangul-Gumuz, Oromia, Southern Nations, Nationalities and People's Region of Ethiopia, and Tigray (Figure 1). The cultivation of finger millet covers a total land area of 455,580.47ha and production estimated to 11,259,578.67qt in Ethiopia from private peasant holding data of Meher season 2019/20 (CSA, 2019).The production of finger millet in oromia region covers about 93,098.4 ha of land with production of 2379255.2qt (CSA, 2019).Finger millet is a climate-resilient crop with highly nutritious and antioxidant properties (Gupta *et al*., 2017). It is grown mainly by subsistence farmers in the drier regions of Africa and serves as a food security crop because of its high nutritional value, excellent storage qualities and as a low input-requiring crop (Dida *et al*., 2008). Despite its importance, it is one of the neglected and underutilized crops in Africa (Ayalew, 2015). More emphasize of improvement is often directed towards staple cereal crops such as maize, wheat, rice, barley, etc than finger millet. In Ethiopia, finger millet, which is considered as a poor man's crop, is being grown by the rural poor farmers in marginal lands with low yielding potential, mainly in Amhara and Oromia regions (Adugna *et al*., 2011; Ayalew, 2015). Low grain yield due to lack of stable and high yielding varieties with disease resistance is a major problem constraining widespread cultivation and use of finger millets in Ethiopia (Dagu *et al*., 2009; Dagnachew *et al*., 2015).

Therefore, to address these problems, developing adaptable, stable, high yielding and disease resistant varieties is important.

Varietal Origin and Evaluation: Ikhulule was developed through selection from finger millet landrace collections originally from different parts of Oromia regional state few of them were introduced from abroad from ICRSAT, Ethiopia. Ikhulule and other 96 finger millet pipeline genotypes were evaluated against the standard check (Maba) for three years (2017-2019) across two districts (locations), namely Mechara and Habro districts in west Hararghe Zone.

Agronomical and Morphological Characteristics: The released variety, Ikhulule is characterized by light red brown seed color, medium in plant which is less susceptible to lodging height of 103cm and relatively early maturing in days of 131 as compared to those all standard checks Maba, Axum and Addis 01. Ikhulule finger millet variety showed a better number of finger and productive tiller per plant 7.5 and 5.4 respectively.

Yield Performance: The multi-location and year trial conducted for the evaluation (2017-2019) data records indicated that Ikhulule is a stable and high yield variety which produced 4.2 to 6.3 t ha^{-1} on research station. On-farm (farmers' field) yield evaluation recorded from variety verification plots at Mechara and Habro revealed that Ikhulule gave an average grain yield ranging from 2.8- 3.8 t ha^{-}

Table 1. Mean grain yield (t ha^{-1}) and disease reaction across location over years. Genotypes mean grain yield (t ha^{-1}) and disease reaction (1-5 scale)

No	Genotype	DF	NF/plant	NPT	PH (cm)	DM	Overall agronomic desirability	Gy (tons ha^{-1})
1	Addis 01(ck)	89.33	7.467	4.931	107.9	141	1.8	4.742
2	KNE#814	80.5	7.3	5.431	114.4	130.8	1.6	5.888
3	GBK-008328A	74.89	6.8	5.658	113.5	133.4	1.7	5.422
4	KNE#1124	78.56	5.79	5.594	106	131.6	1.7	5.650
5	ENGENY	76.17	6.3	5.028	115.1	128.9	1.8	5.284
6	KNE#1012	75.5	6.69	5.539	101.8	132.9	1.7	6.050
7	KNE#624	74.89	6.8	4.853	103.7	132.5	1.7	5.498
8	Maba(check)	84.83	6.99	5.292	103.7	134.8	1.7	5.801
9	P224	71.28	6.89	4.997	103.7	128.3	1.6	5.397
10	GBK-000399A	82.72	7.2	5.306	118.7	140.2	1.6	5.854
11	Ikhulule	73	7.14	5.067	103.7	131.5	1.6	6.383
12	Axum(check)	89.28	8.64	4.389	121.7	141.1	1.8	5.262
13	Acc.#14FMB/0	70.56	6.278	4.869	103.7	129.7	1.9	4.907
14	KNE#688	79	6.678	5.203	103.7	131.3	1.5	5.315
15	KNE#622	79	6.667	5.208	103.7	128.5	1.6	4.997
	Grand Mean	78	6.9	5.2	109.5	133	1.7	5.497
	LSD(0.05)	7.8	1.2	1.4	11.8	7.1	0.4	1784.
	CV	6.2	10.6	16	6.7	3.3	16.3	20.1

DF= days to flowering, NF=Number of finger per plant, NPT=number of productive tiller, PH= plant height, GY Grain yield

Table 2. Grain Yield data for Finger millet Variety Verification Trial at Mechara and Tulo districts of west Hararghe Zone in 2020 cropping season

Finger millet Candidates and checks	On station Grain yield tons ha^{-1}	On farm Grain Yield tons ha-$^{-1}$	Overall average Grain yield tons ha-^{1}
Ikhulule/Candidate-1	4.115	3.516	3.816
KNE#1012(Candidate-2)	3.452	2.769	3.110
Kumsa (Check)	3.355	2.452	2.903

Stability and Adaptability Analysis: Ikhulule (12AN FMRVT Seed inc. #7) variety showed more stable and widely adaptable variety than the remaining genotypes. Both GGE biplot and AMMI analysis also indicated that Ikhulule (12AN FMRVT Seed inc. #7) was stable and high yielding, which gave about 18% (6.3 t ha^{-1}) yield advantage over the standard check Maba (5.8 t ha^{-1}). Hence, the variety was officially released and recommended for production in the testing locations and areas with similar agro-ecological conditions to boost production and productivity of the crop. Accordingly, Ikhulule was recommended for eastern parts of Oromia (Mechara and Habro) as well as for other areas of Ethiopia which had resembling agro ecological conditions in the crop variety was developed.

Reaction to diseases and insect: The variety was evaluated in shoot fly and some blast affected areas of west Hararghe Mechara and Habro. Accordingly, Ikhulule (12AN FMRVT Seed inc. #7) is relatively tolerant to blast (*Magnaporthe oryzea*)and shoot fly a devastating major disease and insects of finger millet that affect all above ground parts of the of the plant

Table 3. Agronomic/morphological characteristics of finger millet variety, Ikhulule (12AN FMRVT Seed inc. #7)

Variety name	Ikhulule(12AN FMRVT Seed inc. #7)
Adaption areas	Mechara, Habro and similar agro-ecologies
Altitude (m.a.s.l.)	1700-1900
Rain fall(mm)	800-1200
Seed rate (kg/ha^{-1})	8-10
Row Spacing (cm)	40-10
Planting date early to late May	Earl to late May
Fertilizer rate kg ha^{-1}	
Nitrogen (N)kg ha(urea)	100
NPS/NPSBn(kg ha^{-1})	100
Days to maturity (days)	131
Plant height in (cm)	73
Seed color	Light brow
Growth Habit	Erect
Crop disease and insect Reaction	
Blast	2
Shoot fly	2
Grain Yield(t ha)	
Research field	6.3
On farm	3.8
Year of Release	June, 2021
Breeder Seed Maintainer	Mechara Agricultural Research Center

Note: m a.s.l. = meters above sea level.

Conclusions and Recommendations

Ikhulule finger millet variety was released for its early in maturity, high grain yield, showed better adaptability and stable performance than the standard check. The variety is also tolerant to blast disease and shoot fly. Therefore, it was released and recommended for smallholder farmers of finger millet producer in West Hararghe Zone such as Mechara, Habro and other areas with similar agro-ecologies in the country to boost finger millet productivity.

References

CSA (Central Statistical Agency). 2019. Agricultural sample survey 2019/2020: report on area and production of crops (private peasant holdings, main season), vol. 1. Addis Ababa: Federal Democratic Republic of Ethiopia, Central Statistical Agency.

Adugna, A., Tesso, T., Degu, E., Tadesse, T., Merga, F., Legesse, W., Tirfessa, A., Kidane, H., Wole, A.and Daba, C. 2011. Genotype-by-environment interaction and yield stability analysis in finger millet (*Elucine coracana* L. Gaertn) in Ethiopia. American Journal of Plant Sciences, 2(03): 408-415

Ayalew, B. 2015. Trends, growth and instability of finger millet production in Ethiopia. Research Journal of Agriculture and Environmental Management, 4(2): 078-081.

Dagnachew, L., Kassahun, T., Awol, A., Masresha, F., Kebede, D., Girma, M., Geleta, G., Hailu, F.,Kassa, M., Chemeda,B., Girma, C. and Gudeta, B. 2015. Registration of "Addis-01" Finger Millet Variety. East African Journal of Science, 9 (2): 141- 142.

Degu, E., Adugna, A., Tadesse, T. and Tesso, T. 2009. Genetic resources, breeding and production of millets in Ethiopia, in new approaches to plant breeding of orphan crops in Africa. Proceedings of an International Conference, Bern Switzerland, 19- 21 September, 2007.

Dida, M.M., Wanyera, N., Dunn, M.L.H., Bennetzen, J.L. and Devos, K.M. 2008. Population structure and diversity in finger millet (*Eleusine coracana*) germplasm. Tropical Plant Biology, 1(2): 131-141.

Gupta, S.M., Arora, S., Mirza, N., Pande, A., Lata, C., Puranik, S., Kumar, J. and Kumar, A. 2017. Finger millet: a "certain" crop for an "uncertain" future and a solution to food insecurity and hidden hunger under stressful environments. Frontiers in Plant Science, 8 (643): 1-11.

Genotype by Environment Interaction and Stability Analysis of Sweet Potato (*Ipomoea batatas* (L.) Genotypes in West Hararghe Zone, Eastern Ethiopia

Gezahegn Assefa*, Dereje Deresa and Sintayehu Girma

Oromia Agricultural Research Institute (IQQO), Mechara agricultural research center, P.O. Box.19, Mechara, Ethiopia

*Corresponding author: gezeassefa@gmail.com

Abstract

Abstract: This study was carried out to determine the yield performances of 16 sweet potato genotypes included 3 standard check and one local variety were employed across six environments in Mechara onstation and Habro district in the 2018 - 2020 growing season. The experimental layout was a randomized complete block design with three replications. Additive main effects and multiplicative interactions analysis (AMMI) indicated that the yield performances of genotypes were under the major environmental effects of genotype by environmental interactions. The first two principal component axes (PCA 1 and 2) were significant ($p < 0.01$) and cumulatively contributed to 73% of the total genotype by environment interaction. In GGE bi-plot analysis using genotypic and environmental scores of the first PCA 1 and lower PCA 2 scores gave high yields (stable genotypes), and genotypes with lower PCA 1 and larger PCA 2 scores had low yields (unstable genotypes), as in the sites tested. Besides, genotypes G3 and G5 were optimum stable across tested location and gave higher root yield (40.21t ha^{-1} and 45.87 t ha^{-1}), respectively, However, G5 is recommended for possible release for specific adaptability around Eastern Oromia areas with similar agro-ecology in the country

Keywords*:* Genotypes, GGE, multi-environment, stability analysis

Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam) is a root crop belongs to the *convolvulaceae* family. It belongs to the family *Convolvulaceae*, genus Ipomoea, and, according to Vaeasey *et al*. (2008), the genus has over 600 species, of which *batatas* is the only one with economic value. In many developing countries, sweet potato is reported to be the fifth most important food crop after rice, wheat, maize, and cassava (Aina *et al*., 2012). Over 110 million metric tons of sweet potatoes is produced in 2018, with China producing 53.01 million metric tons representing 65.6% of the world sweet potato production (FAOSTAT, 2018). Africa was responsible for 20.7 million tons which represents about 25.4% of the world production. In Ethiopia, agriculture is the main source of livelihood for about 80% of the population which it contributes to 42% of Ethiopia's gross domestic product (FAOSTAT, 2009). Sweet potato has been cultivated for the last several years and over 95 % of the crop is produced in the southwest, eastern and southern parts. It is one of five most important crops, in terms of production, economic value, and contribution to calories and proteins. But the productivity of sweet potato is limited to both abiotic and biotic constraints, leading to poor yields and quality at farm levels. The crop has a potential of giving over 50 to 60 tons ha^{-1} in Ethiopian conditions, however, yield obtained from farmer's field is lower than 6 to 8 tons ha^{-1}. Thus the yields are ten times lower than the potential sought. One of the main reasons is shortage of improved varieties planting materials in addition to other factors (FAOSTAT, 2006). Therefore, one important way of mitigating against poor root yield in farmers' fields is to develop and release new sweet potato varieties with stable and high root yield potential into the farming system.

Understanding the differential response of crop genotypes to changing environmental conditions is of key importance in plant breeding. One major step toward the development of improved crop genotypes is the assessment of the nature of interactions that exist between genotypes and the production environment for a particular trait (Sabri *et al*., 2020). When genotypes are evaluated across a range of different locations and/or years, their yield performances could differ significantly. The existence of large G × E interaction usually causes serious confounding effects in comparing and recommending good genotypes for wide adaptation (Moussa *et al*., 2011). Previous G × E studies on several traits have demonstrated that sweet potato is sensitive to environmental changes. According to Madawal *et al*. (2015), Fikadu *et al*. (2017), and Ngailo *et al*. (2019), changes in environmental conditions have been reported to affect sweet potato storage root yield and yield components. This makes the analysis for G × E interaction crucial for genotype selection, cultivar release, and identification of suitable production environments for optimum yield. Therefore, having a basic understanding on G × E interactions, stability parameters, and genetic correlations for root yield and yield components are considered necessary for sweet potato breeders in making an informed choice concerning which locations and input systems should be used in their breeding efforts (Gruneberg *et al*., 2005).

Statistical tools such as the Additive Main Effect and Multiplicative Interaction (Gauch, 1992) and genotype and genotype-by-environment interaction (GGE) biplot analyses (Yan and Kang, 2003; Yan and Tinker, 2006) have been reported as appropriate for use in GEI analyses. These statistical tools have then been extensively used in several sweet potato improvement programs by authors such as Caliskan *et al*. (2007) AMMI model analysis for GEI and stability analysis of sweet potato genotypes across different environments(Laurie and Booyse, 2015).

Therefore, the objective of the study was to estimate genotype by environment interaction and to identify the stable and high yielder sweet potato genotypes for West Hararghe Zone and similar agro-ecologies.

Materials and Methods

The field experiment was carried out during 2018-2020 cropping season at Mechara research onstation and Busoytu FTC, Habro districts. Mechara onstation is located in Eastern part of country lying between 8.34 N latitude and 40.20'E longitude. The altitude of the area is about 1760 m.a.s.l., it has annual mean maximum and minimum temperature is 28^0c and 15.1^0c. Habro district is one of West Hararghe Zone in Eastern Ethiopia, it's is located at 8051'N and 400 39' E at an altitude of 1728 meters above sea level. Gelemso town is the administrative seat of the district.

Planting Materials: Sixteen sweet potato accessions along with thee released varieties and one local check were used the trial.

Field Layout and Experimental Design: The experiment was conducted using Randomized Complete Block Design (RCBD) with three replications and with each plot size of $12m^2$ with 1m and 0.3 m inter-row and intra-row spacing, respectively. Data was collected from the 20 plants that were grown in two central rows. Young portion of 30 cm length of the vine cuttings planted where 2/3 of their length covered by soil. The accessions were planted on end July as soon as the rain starts and the soil get sufficient moisture. All plots where receive the recommended cultural practices uniformly. Replanting was done to substitute the dead vine after one week of planting. Harvesting was done after 90 % of the sweet potato leaves changed in to yellowish color. From each plot ten 10 plants were be considered for both storage root yield and yield related traits.

At harvest, the middle two rows were used for data collection. After removing vines, the ridges were opened with a hoe and storage roots were dug. The harvested storage roots were then counted and weighed and average storage root weight (g) and total storage root yield per ha were calculated from these data.

Data Collection:Agronomic data (number and marketable and unmarketable roots yield, sweet potato weevil (*Cylas* spp infestation) were collected and subjected to analysis of variance (ANOVA) using the Generalized Linear Model procedure of SAS 9.2 where genotype was treated as a fixed factor and replication treated as a random variable according to the model of (Steel and Torrie,1980). Number of marketable (saleable) roots represents the number of roots that were more than or equal to 100g (Levette, 1993) or with diameters at the widest point >25mm roots. These were counted and the number recorded per plot.

Statistical Analysis: Analysis of variance (ANOVA) was carried out for each environment (location-year combinations) to check whether significance variation was observed among the test genotypes. This was conducted before combined analysis of variance and other multivariate analysis of G × E interaction across the test environments. Furthermore, homogeneity of variance tests (Bartlett's test) was conducted to determine if data from individual environments could be pooled to conduct a combined ANOVA across environments to analyze G × E interactions. The environments were considered as random and genotypes as fixed effects.

Data analysis and genotype by environment interaction analysis was done using Genstat 18th edition statistical software.

The combined ANOVA method sufficiently identified G × E interaction as a significant source of variation but it is not able to explore the nature of G × E interaction which could not show the true performance of genotypes in certain environments (Cross, 1990). Stability analysis was done using the methods of Additive main effects and multiplicative interaction AMMI (Zobel *et al*., 1988). The AMMI model was done based on the formula suggested by (Cross, 1990).

Yij = μ+ Gi + Ej+ (ΣKnUniSnj) + Qij + eij

Where (i = 1, 2,…35: j = 1, …6); Yij = The performance of the i genotype in the j environment; μ = The grand mean; G = Additive effect of the i genotype (genotype mean minus the grand mean); K = Eigen value of the PCA axis n; E = Additive effect of the jth environment (environment mean deviation); U and S = Scorer of genotype i and environment j for the PCA axis n; Q = Residual for the first n multiplicative components and; e = error.

Results and Discussions

Combined analysis of Variance: The analysis of variance showed highly significant differences among the tested genotypes, location and interaction (P< 0.01) for root yield (Table 1) However; significance variation (P< 0.05) was recorded on genotypes evaluated across years. This indicated that the presence of variability among tested genotypes across tested environments. In the same times, GEI showed that presence of variability among tested genotypes across environments and their interaction shows possibility to do stability analysis i.e to understand the nature of GEI and performance of the genotypes over locations. The analysis of variance revealed that the main effect of genotypes, location and years were significant difference (p<0.05) on root yield

Table 1. Combined mean of ANOVA for root yield of Sweet potato genotypes over six environments in West Hararghe Zone

Source of variation	D.f.	S.S.	M.S.
Genotype(G)	19	20512.16	1079.59**
Rep(Env’t)	4	2386.46	596.62**
Year(Yr)	2	9075.49	4537.75**
Location(Loc)	5	1781.53	356.31**
Genotype.Yr	38	6767.48	178.09*
Loc.Yr	10	904.14	90.35**
G.Loc	95	12676.61	133.44**
G.Yr.Loc	93	12676.61	136.31**
Residual	238	17876.77	75.11
Total	359	64309.02	

df = degree of freedom, ***and ** = Significant at 0.001 and 0.01 probability levels, respectively, ns = non-significant at 5% probability level.

Combined Mean Root Yield and Agronomic Performance of Sweet Potato Genotypes

The mean root yield of the individual environments during 2018 - 2020 main cropping season are highly significant at (p<0.001) and presented in (Table 1). Habro district was the suitable environment for sweet potato production. G5 was the highest root yielder (45.87 t ha^{-1}) across environments followed by G3, which yielded 40.21 t ha^{-1}. The lowest mean root yield (15.26 t ha^{-1}) was recorded for local check (Table 2). This high yielding genotype (G5) produced nearly 2-3 times higher yield than local genotypes. Likewise, the result for the combined mean analysis of yield related traits across environments were showed significance difference among the genotypes in all location (Table 3). The combined mean of tested genotypes indicated that G5 and G3 as better performers followed by Hawasa -09 varieties, while local check was the least performer in a traits. Besides, the highest mean of root numbers (8.29, 7.43 and 7.19) were recorded by G16, G8 and G2 genotypes, respectively. Whereas, Genotypes G5 had the highest root diameter (7.21cm) followed by Hawassa-09 (6.35cm).

Table 2. The combined mean result of root marketable yield across locations and years of Sweet potato Regional Variety Trial at Habro district and Mechara onstation, in 2018-2020

S/n	Gen. Code	Genotypes	Environments							Mean RY (t ha^{-1})
			Habro District				Mechara onstation			
			2018	2019	2020	Mean	2018	2019	2020	
1	G4	CN-1753-4	12.75a-g	34.41cde	24.61b-e	23.92d-h	32.66	36.96abc	17.62b-e	26.5cde
2	G18	Tis-9068-8	31.71a-h	18.52e-h	25.47b-e	25.23d-g	25.45	27.77c-f	15.5b-f	24.07c-g
3	G15	Tis-8441-1	37.16a-d	35.98b-e	27.4bcd	33.51bcd	31.26	19.33d-g	9.66d-g	26.8cde
4	G10	Hawaassa-09	38.15abc	54.17ab	28.47bc	40.26abc	32.36	33.49a-d	23.75b	35.06 b
5	G14	Tis-80/043-3	19.3e-h	21.99d-h	19.67c-f	20.32fgh	26.56	13.21fg	19.58bcd	20.05fgh
6	G8	CN-2065-7	30.34a-g	9.35gh	13.53f	17.74gh	30.24	17.13d-g	10.28d-g	18.48gh
7	G7	CN-2065-15	20.54d-h	39.04bcd	25.2b-e	28.26def	24.35	31.77b-e	13.06c-g	25.66c-f
8	G5	CN-1754-12	41.9a	65.78a	40.07a	49.25a	39.05	48.99a	39.42a	45.87a
9	G3	CN-1753-19	36.62a-d	54.64ab	31ab	40.75ab	36.77	46.3ab	35.91a	40.21ab
10	G1	Barkume	26.77a-h	33.91c-f	24.93b-e	28.54def	26.7	26.78c-f	21.63bc	26.79cde
11	G11	Hawassa-83	34.71a-f	35.18cde	25.17b-e	31.69b-e	27.46	24.89c-g	21.4bc	28.14c
12	G20	Tis-9468-7	19.04fgh	7.77h	15.36ef	14.06h	30.25	17.91d-g	5.52fg	15.98h
13	G6	CN-2059-5	26.7a-h	36.96b-e	27.57bcd	30.41c-f	26.33	28.28c-f	16.98b-e	27.14cd
14	G16	Tis-9065-1	35.9a-e	39.73bcd	11.91f	29.18def	28.42	20.13c-g	13.28c-g	24.89c-f
15	G13	Tis-70357-2	16.53gh	19.51e-h	17.53def	17.86gh	28.61	8.5g	7.81efg	16.42h
16	G12	Local	18.65fgh	15.33fgh	11.27f	15.08gh	25.8	16.52efg	4.01g	15.26h
17	G9	CN-2069-8	22.91b-h	43.5bc	23.93b-e	30.11c-f	33.11	32.94a-e	11.15d-g	27.92c
18	G19	Tis-9465-10	28.95a-h	27.54c-g	18.67c-f	25.05d-g	26.54	12.47fg	9.73d-g	20.65
19	G17	Tis-9068-2	37.28abc	29.6c-f	21.33b-f	29.41def	28.32	26.17c-f	11.15d-g	25.64
20	G2	CN-1752-9	21.04c-h	26.65c-g	19.2c-f	22.3e-h	29.73	16.86d-g	13.44c-g	21.15
		Mean	27.85	32.48	22.61	27.65	29.5	25.32	16.04	25.63
		CV	36.2	34.9	27.5	22.3	10.6	30.5	36.22	14.66
		LSD	16.65	18.74	10.27	10.18	5.18	16.95	10.07	6.20

*, ** significant at 0.05 and 0.01 probability levels, respectively df = degree of freedom, LSD= Least significant difference, CV= Coefficient of variation.

This may be related to genetic potential of the individual genotypes, While G9 had the lowest mean of root number(4.82) while the least mean root diameter (3.60cm) were recorded by (G20) followed G8(4.23cm) genotypes (Table 3). In generally, genotype (G5) showed higher yield related traits are the major components of having larger storage roots produced higher total root yield Similarly, Gezahegn, *et al*. (2020) revealed that root length and number, and root diameter per varied significantly due to varietal difference.

Table 3. The Combined analysis of overall agronomic traits of Sweet potato genotype regional Variety Trial at Habro and Mechara districts, in 2018-2020

Genotypes Name	Genotype	RN	RL (cm)	RD (cm)	RW (kg)	RWP (kg)	My (t ha^{-1}	Unm (t/ha)	TY (t ha^{-1})
CN-1753-4	G4	6.87a-e	16.74e-g	5.31cde	0.53c-f	4.12b-e	26.5cde	2.58	29.08d-g
Tis-9068-8	G18	6.36b-f	17.52b-e	4.99efg	0.49def	3.51c-e	24.07c-g	3.65	27.72d-h
Tis-8441-1	G15	7a-d	15.58gh	5.86bc	0.43efg	2.97efg	26.8cde	6.01	32.81cd
Hawaasa-09	G10	6.35b-f	18.57ab	6.35b	0.91a	5.43b	35.06 b	3.38	38.22bc
Tis-80/043-	G14	6.00b-g	16.70e-g	5.19c-f	0.48efg	4.23b-e	20.05fgh	2.95	23ghi
CN-2065-7	G8	7.43ab	15.00h	4.23hi	0.23h	2.33fg	18.48gh	4.3	22.78hi
CN-2065-15	G7	6.41b-e	15.62hg	4.91e-h	0.40efg	3.14c-g	25.66c-f	3.82	29.48def
CN-1754-12	G5	6.57b-e	17.21c-f	7.21a	0.93a	8.41a	45.87a	3.47	49.34a
CN-1753-19	G3	6.65b-e	18.56ab	4.87fgh	0.48efg	7.34a	40.21ab	3.74	43.94ab
Barkume	G1	5.43e-g	19.91a	5.60cde	0.760b	4.83bc	26.79cde	2.16	28.95d-h
Hawassa-83	G11	4.93fg	18.78ab	5.43cde	0.61cd	4.87bc	28.14c	2.65	30.78de
Tis-9468-7	G20	7.03a-d	17.03e-g	3.60i	0.21h	1.50g	15.98h	3.62	19.59 i
CN-2059-5	G6	5.49efg	18.31bc	5.76bcd	0.75b	4.15b-e	27.14cd	1.54	28.68d-h
Tis-9065-1	G16	8.294a	15.92fgh	5.09def	0.53cd	3.30c-e	24.89c-f	5.2	30.09def
Tis-70357-2	G13	6.32b-f	16.17e-h	4.50fgh	0.41fg	2.01fg	16.42h	3.98	20.4i
Local	G12	4.96fg	18.79ab	4.27gh	0.5cde	1.61g	15.26h	3.33	18.59i
CN-2069-8	G9	4.82g	18.6abc	5.86bc	0.65bc	3.12de	27.92c	2.9	30.83de
Tis-9465-10	G19	5.69d-g	17.19c-f	5.34cde	0.53c-f	2.66efg	20.65	3.2	23.85fghi
Tis-9068-2	G17	5.97c-g	17.22c-f	4.97e-h	0.5cde	3.06efg	25.64	2.48	28.13d-h
CN-1752-9	G2	7.2abc	16.65e-g	4.49fgh	0.36g	3.19c-g	21.15	3.51	24.67e-i
Mean		6.29	17.3	5.19	0.54	3.79	25.63	3.42	29.06
CV		13.9	5.1	8.65	13.53	27.92	14.66	38	13
LSD		1.44	1.45	0.74	0.12	1.75	6.2	2.57	6.24

*, ** significant at 0.05 and 0.01 probability levels, respectively df = degree of freedom, IPCA1=Interaction Principal Component Axis

Response to Major Insect Pest

From analyzed of SP weevil, genotypes CN-1754-12 and CN-1753 -19 were the least *Cylas* spp. damage in environments in both locations. The least mean of SP weevil score value was recorded (1.89) from CN-1754-12 genotypes. The differential expression of tolerance by the genotypes in different environments is unexpected as tolerance to *Cylas* spp. is known to be largely influenced by strong environmental control. SP weevil tolerance, stability, thereby enhances the probability of identifying highly tolerant genotypes that could be deployed across many environments.

Table 4. The mean result of Sweet potato weevil (*Cylas* spp) scores across location for the 20 Sweet potato genotypes in Habro and Mechara, during 2018-2020 cropping season

S/N	Genotypes Name	Gen. Code	Habro district				Mechara onstation			
			2018	2019	2020	Mean	2018	2019	2020	Mean(0-5)
1	CN-1753-4	G4	1.67	1.67	2.33	1.89	2.20	2.13	2.00	2.00
2	Tis-9068-8	G18	2.00	2.00	2.00	2.00	1.96	1.95	1.67	1.95
3	Tis-8441-1	G15	2.00	2.33	2.67	2.33	2.48	2.10	2.00	2.30
4	Hawaassa-09	G10	2.00	2.33	3.33	2.55	2.92	2.16	2.00	2.53
5	Tis-80/043-3	G14	1.67	2.67	3.33	2.56	2.90	2.28	1.67	2.50
6	CN-2065-7	G8	1.67	2.00	3.67	2.45	3.08	1.86	2.00	2.47
7	CN-2065-15	G7	2.00	2.33	2.00	2.11	2.00	1.81	2.00	2.04
8	CN-1754-12	G5	1.67	1.33	2.67	1.89	2.28	1.31	1.67	1.89
9	CN-1753-19	G3	2.33	2.33	2.00	2.22	1.94	1.89	1.33	2.01
10	Barkume	G1	2.00	2.33	3.00	2.44	2.59	1.52	1.67	2.28
11	Hawassa-83	G11	2.00	2.33	2.67	2.33	2.46	1.98	2.00	2.28
12	Tis-9468-7	G20	2.00	2.33	3.00	2.44	2.66	2.10	1.67	2.36
13	CN-2059-5	G6	2.00	3.33	3.33	2.89	2.99	2.63	1.67	2.74
14	Tis-9065-1	G16	2.00	2.67	2.67	2.45	2.41	1.71	1.67	2.26
15	Tis-70357-2	G13	1.67	2.33	3.33	2.44	2.85	2.33	1.33	2.39
16	Local	G12	2.00	2.33	2.33	2.22	2.15	1.64	1.67	2.07
17	CN-2069-8	G9	1.33	2.33	4.33	2.66	3.44	1.52	1.67	2.60
18	Tis-9465-10	G19	1.67	1.67	3.33	2.22	2.79	1.49	2.00	2.24
19	Tis-9068-2	G17	2.00	3.00	2.33	2.44	2.23	2.01	1.67	2.25
20	CN-1752-9	G2	2.00	2.33	2.33	2.22	2.13	1.42	1.67	2.04
	Mean		1.88	1.21	2.83	1.97	1.89	1.89	1.75	1.92
	CV		19.80	31.90	35.20	28.97	32.01	32.00	33.10	30.50
	LSD		0.61	1.21	1.65	1.16	1.06	1.02	0.95	1.09

*, ** significant at 0.05 and 0.01 probability levels, respectively df = degree of freedom, LSD= Least significant difference, CV= Coefficient of variation.

Additive Main Effects and Multiple Interaction (AMMI) Model Analysis

The AMMI analysis of variance of root yield (ton ha^{-1}) of 20 sweet potato genotypes tested in six environments was presented in (Table 6). The analysis showed that sweet potato root yield was significantly ($p<0.01$) affected by genotypes (G), Environment (E) and genotype x environment interaction (GEI). The AMMI of 20 genotypes tested in six environments showed that 31.9% of the total sum of squares was attributable to genotypes effects, 16.9 Environment effects, and 19.7% to GEI effects (Table 5). A large sum of squares for genotypes indicated that the genotypes were diverse with large differences among genotypes means causing most of the variation in root yield. The result is agreed with the previous findings (Mehmet, E *et al*., 2007). The magnitude of the GEI sum of squares showed that there was significance difference, that indicating there were substantial differences in genotypic response across environments.

Table 5. AMMI analysis of variance for root yield (t ha^{-1}) of 20 sweet potato genotypes grown at 6 environments in Mechara onstation and Habro districts

Source	D.F	S.S	M.S	% GXE Explained	Cumulative %
Total	359	64309	179.1	-	
Block	12	4024	335.4**	6.3	
Genotypes	19	20512	1079.6**	31.9	
Environments	5	10857	2171.4**	16.9	
GxE	95	12677	133.4**	19.7	
IPCA 1	23	6750	293.5**	53.2	53.3
IPCA 2	21	2492	118.7*	19.6	19.7
IPCA 3	19	1620	85.2^{ns}	12.8	12.6
IPCA 4	17	1177	69.2^{ns}	9.2	9.2
IPCA 5	15	638	42.6^{ns}	5.0	99.99
Residuals	51	3434	67.3*		
Error	228	16239	71.2		

*, ** significant at 0.05 and 0.01 probability levels, respectively df = degree of freedom, IPCA1=Interaction Principal Component Axis

Results from AMMI analysis revealed that mean square of first and second interaction principal component axis (IPCA1 and (IPCA2) were found to be highly significant (P<0.01). The first principal component axis (IPCA 1) of the interaction captured 53.21% followed by PCA 2 (19.6%), Together (IPCA 1 and PCA 2) they accounted for 73% of the GE interaction SS, the remaining 23% value of IPCA 3, 4 and 5). In addition to genotypes found closer to the origin showed stable performance over the testing environments (Emanuel *et al.*, 2021). Clearly indicates as those genotypes found close to the origin showed general adaptability than those found at far distance away from the origin likewise those environments found in the closet distance to the origin were stable and not changed across seasons. In the present study, G3 and G5, which are found close to the origin showed general stability, whereas, environment Mechara showed less change across seasons allow stability for the genotypes tested in these locations (Figure 1).

GGE Biplot Analysis: The value in table 5 showed that sweet potato genotypes based on the yield character showed in Figure 1-3. Biplot in the AMMI analysis shows the genotype and environmental magnitude that contributed to the interaction. Figure 1-3 illustrated 85.25% of the total GGE variation, where PC1 explained 76.16% and PC2 9.09% of total variation respectively. From Figure 1, it can be seen that G5 and G3 were the closest to the ideal environment; therefore, it was most stable of all genotypes. Genotypes that have a small vector distance from the center of the biplot are considered as stable genotypes (Yan *et al.*, 2007). While G13 and G8 were the least unstable genotypes (Fig 1). Moreover, these ideal genotypes, represented by the small circle with an arrow pointing to its defined as having the highest yield in all environments (Emmanuel C. *et al*., 2021). So, G5 genotype was also capable of producing maximum yield at all environments, so they can be recommended as new superior variety. Similarly, Fikadu *et al.* (2017) revealed that genotypes that fall in the central (concentric) circle are considered as stable genotypes. In this study, there were some genotypes with high stability and low their mean root yields. But, Aim this study was to select stable and high yielder genotype was desirable for the area. Furthermore, the stability analysis aims at helping the breeder to identify which genotypes have specific and/or general adaptability to various production environments. It also helps in the analyses of the test environments for prudent decision making for future evaluation.

Set of concentric lines that serve as a ruler to measure the distance between an environment and the ideal environment. Figure 2 also showed that Ha19 was the closest to the ideal environment, and, therefore, is most desirable of all seven environments. Ha19 is followed by Me19, which are followed in turn by Me18 and Ha18 were the least desirable test environments. However, Me19 and Ha 20 had worst performing environment for fresh root yield. Environments in different sectors show that genotypes located in these locations have unequal yields and that genotypes belong to region-specific genotypes. From ranking of genotypes in (Figure 3) showed that, an ideal genotype should have both high mean performance and high stability across environments. The center of the concentric circle (Figure 3) is the location for the ideal genotype. Among the test genotypes, the one closest to the point is the best. Though G3 and G5 had the highest storage root yield among the 20 genotypes, while, G3 that possessed both high mean root yield and high stability is closest to the ideal genotype for root yield with consistency of performance across environments.

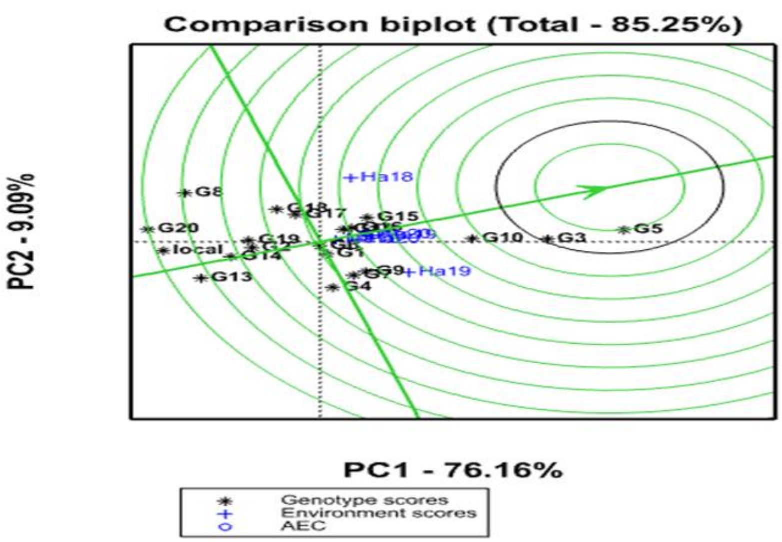


Figure-1. GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability

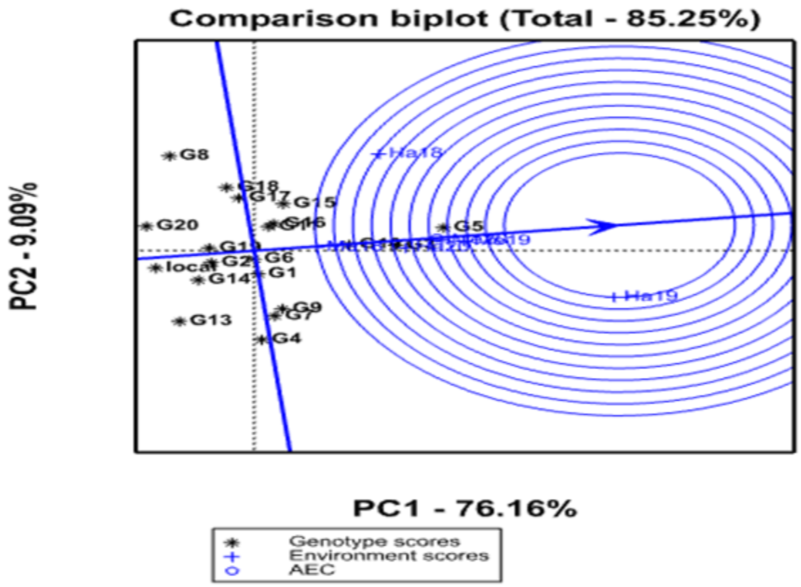


Figure-2. GGE bi-plot based on enviroment-focused scaling for comparison of their ideal enviroment for sweet potato production

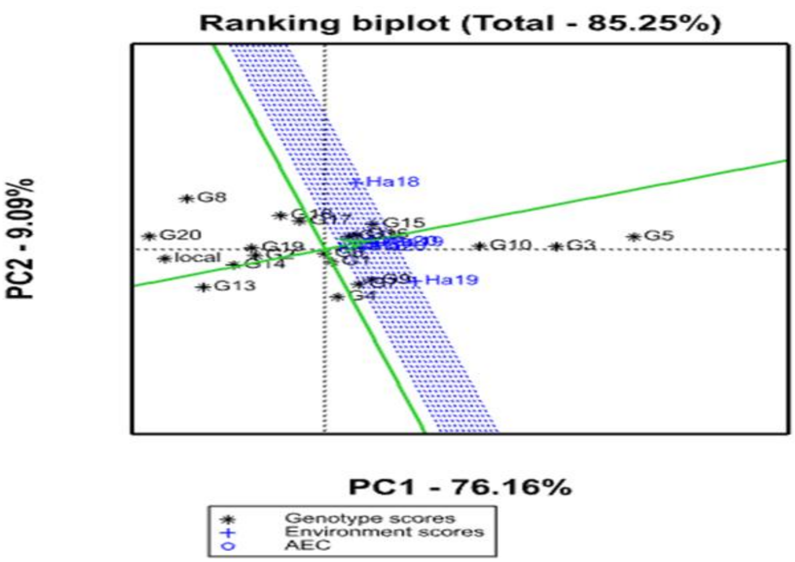


Figure-3. GGE bi-plot based on genotypes ranking of their ''stable'' genotypes and stability performance of eight tested genotypes

Conclusions and Recommendations

In conclusion, AMMI analysis, regression coefficient, deviation from regression and GG biplot results revealed that G3 and G5 were relatively stable genotypes with optimum root yield. However, G5 genotypes was optimum stable across tested locations and high root yield, From the present study it was concluded that G5 which gave the highest mean root yield than the rest of the genotypes with yield advantage of 28% over the checks, and showed moderate stability over the testing sites, is identified as candidate genotypes to be verified in the coming cropping season for possible release after being evaluated by the National Variety Releasing Committee.

Reference

Aina, A. J., Falade, K. O., Akingbala, J. O., and Titus, P. 2012. Physicochemical properties of Caribbean sweet potato (*Ipomoea batatas* (L) Lam) starches. *Food Bioprocess Technol*, 5, 576–583. doi: 10.1007/s11947-009-0316-6.

Caliskan, S. M., Aslan, M., Uremis, I., and Caliskan, M. E. 2007. The effect of row spacing on yield and yield components of full season and double cropped soybean. *Turk. J. Agric*. For. 31, 147–154.

Cross J .1990. Statistical analysis of multi-location trails. *Adv.Agro*.45:56-86.

Ebem EC, Afuape SO, Chukwu SC and Ubi BE. 2021. Genotype × Environment Interaction and Stability Analysis for Root Yield in Sweet Potato [*Ipomoea batatas* (L.) Lam]. *Front. Agron.* 3:665564. doi: 10.3389/fagro.2021.665564.

Fekadu Gurmu, Shimelis Hussein and Mark Laing. 2017. Genotype-by-environment interaction and stability of sweet potato genotypes for root dry matter, β-carotene and fresh root yield. *Open Agriculture*. (2): 473–485. doi.org/10.1515/opag-2017-0052.

Food and Agriculture Organization of the United Nations (FAOSTAT). 2018. Food and Agricultural Organization of the United Nations, Production Statistics. Available online at: http://faostat.fao.org/ (accessed Dec 12, 2021).

Food and Agriculture Organization of the United Nations (FAOSTAT). 2009. Statistical database.

Gauch, H.G., and Zobel R.W.1996. AMMI analysis of yield trails. In: Kang, M.S. and Zobel, H.G. Jr (Eds), genotype by environment interaction, CRC Press, Boca Raton. Pp: 85-120.

Gruneberg, W. J., Manrique, K., Zhang, D., and Hermann, M. 2005. Genotype X environment interactions for a diverse set of sweetpotato clones evaluated across vary-ing eco-geographic conditions in Peru. Crop Sci. 45, 2160–2171. doi: 10.2135/cropsci2003.0533.

Laurie, S.M., Faber,M., Calitz, F. J.,Moelich, E. I.,Muller, N., and Labuschagne,M. T. 2013. The use of sensory attributes, sugar content, instrumental data and consumer acceptability in selection of sweet potato varieties. *J. Sci. Food Agric*. 93, 1610–1619. doi: 10.1002/jsfa.5932.

Levette, M. P. 1993. The effects of methods of plant cuttings of sweet potato (*Ipomoea batatas* (L) Lam) on yield. Tropical Agric. Trinidad 70, 110–115.

Madawal, S. I., Madarakhandi, T. B. S., and Narasannavar, A. 2015. Genetic variability study in sweetpotato (Ipomoea batatas L.) genotypes. Int. J. Trop Agric. 33, 279–282.

Mehmet, E. Çalışkan, E. Tahsin, S. Erkan, B. and Halis, A. 2007. Genotype by environment interaction and stability analysis of sweet potato (*Ipomoea balata's* L) genotypes, *New Zealand Journal of Crop and Horticultural Science*, Vol. 35 Science, Vol. 35: 87–99.

Moussa, S. A. M., Hala, A. A. E., and Nashwa, I. A. E. 2011. Stability study of sweetpotato yield and its component characters under different environments by joint regression analysis. J. Horticult. Sci. Ornamental Plants 3, 43–54. doi: 10.5897/AJMR11.054.

Ngailo, S., Shimelis, H., Sibiya, J., Mtunda, K., and Mashilo, J. 2019. Genotype by environment interaction of newly-developed sweet potato genotypes for storage root yield, yield-related traits and resistance to sweet potato virus disease. *Heliyon*; (5):e01448. doi: 10.1016/j.heliyon.2019.e01448.

Purchase, J.L. 1997. Parametric analysis to describe GXE interaction and stability in winter wheat. PhD thesis, Department of Agronomy, Faculty of Agriculture, University of the Orange Free State, Bloem fonten, South Africa.

Sabri, R. S., Rafii, M. Y., Ismail, M. R., Yusuff, O., Chukwu, S. C., and Hasan, N. 2020. Assessment of agro-morphologic performance, genetic parameters and clustering pattern of newly developed blast resistant rice lines tested in four environments. *Agronomy* 10:1098. doi: 10.3390/agronomy10081098.

Steel, R. G. D., and Torrie, J. A. 1980. Principles and Procedures of Statistics, 2nd Edn. New York, NY: McGraw-Hill, 183–193.

Vaeasey, E. A., Borges, A., Rosa, M. S., Queiroz-Silva, J. R., Bressan, E. A., and Peroni, N. 2008. Genetic diversity in Brazilian sweet potato (*Ipomoea batatas* (L.) Lam., Solanales, *Convolvulaceae*) landraces assessed within microsatellite markers. *Genet. Mol. Biol*. 31, 725–733. doi: 10.1590/S1415-47572008000400020.

Yan W, Tinker NA, 2006. Biplot analysis of multi-environment trial data: principles and application. *Canadian J. Plant Sci*. 86:623-645.

Yan, W., and Kang, M. S. 2003. GGE Biplot Analysis: A Graphical Tool for Breeders, Geneticists, and Agronomists. Boca Raton, FL: CRC Press.

Yan, W., and Ma, B. L. 2006. Model Diagnosis and GGE Biplot Analysis. Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-food Canada.

Zobel, R. W., Wright, M. J. and Gauch, H. G. 1988. Statistical analysis of a yield trial. *Agron. J*. 80: 388-393.

Effects of Inter and Intra Row Spacing on Yield and Yield Components of Erect type Groundnut (*Arachis Hypogeal* L.) in West Hararghe Zone, Eastern Ethiopia

Shanene Haile*, Fantahun Adugna and Ahmed Mohamed

Oromia Agricultural Research Institute, Addis Ababa, Ethiopia

Mechara agricultural research center, P.O.Box.19, Mechara, Ethiopia

Corresponding author: haileshanne@gmail.com

Abstract

*The study was conducted in 2019 and 2020 main cropping season at two locations in West Hararghe Zone, Ethiopia, to determine the optimum inter- and intra-row spacing of ground nut for maximum yield and yield components. The experiment was laid out randomized complete block design with three replications in a factorial arrangement of three inter-rows (50cm, 60cm and 70 cm) and four intra-row (10cm, 15cm, 20cm and 25 cm) spacing were used groundnut Werer-962 variety. The combined mean was observed inter and intra-row spacing significant different for days to flowering, days to maturity, plant height, number of pods per plant and grain yield. While, non-significant different showed for number of seed per pod. The highest grain yield (2722kg ha^{-1}) was obtained at interaction of 60cm * 20cm spacing, followed by 2622* *kgha-^{1} at 60cm*25cm inter and intra-row spacing. while the lowest (1542 ha^{-1} and 1592 ha^{-1}) was obtained from 70cm*25cm and 70cm*20cm inter- and intra-row spacing, respectively. However, based on agronomic performance use of 60cm * 20cm spacing is promising for groundnut production in West Hararghe and similar agro ecologies.*

Keywords*:* Intra-row spacing, Groundnut, Row spacing

Introduction

Groundnut (*Arachis hypogaea L*.) is an important monoecious annual legume used for oilseed, food and animal feed (Upadhyaya *et al.,* 2006). Groundnut was probably introduced to northern Ethiopia by the Portuguese in the 17th century, and somewhat later through the Arab influence to south eastern part of the country (Ahmad, N *et al.*, 2007). It is the main source of food in various forms and used as a component of crop rotation in many countries (Gbehounou and Adengo, 2003). It is the world's thirteenth most important food crop, fourth most important source of edible oil and the third most important source of vegetable protein (Taru *et al.*, 2008). The estimated production area and yield of groundnut in Ethiopia in 2019/2020 cropping season were 87,925.23ha and Oromia shared (50,121.08 ha), However, it is important to note that the national average yield of groundnut (1.71t ha^{-1}), is much lower than the average potential yield for improved groundnut varieties. Plant density and planting arrangement are efficient management tools for maximizing crop yield by optimizing resources utilization such as light, nutrients and water and reduce soil surface evaporation (Amato, G., 1992).

Production of groundnut is influenced by many factors such as climatic factors (rainfall, temperature, humidity, wind, solar radiation, edaphic), soil factors (very low organic carbon and very low available phosphorus) and biological factors (pests and diseases) and agronomic factors (fertilizer, spacing and weed management). Plant spacing plays an important role on growth, yield and quality of groundnut. Establishment of optimum population per unit area of the field is essential to get maximum yield. If the plant population is too high, plants compete with each other for resources and low yield was realized (Aktar, 2015). Furthermore, Egli (1988) also reported that define the relationship between plant spacing, plant densities and yield; two approaches are used commonly. First if the plant produces enough leaf area to maximize isolation interception during reproductive growth, maximum yield can be obtained. Secondly, equidistant row spacing between plants will provide maximum yield since it will minimize inter plant competition. The highest pod number per plant was obtained from wide row spacing (75 cm row spacing) due to less competition among the plants to get enough space for their growth and development (Bihter*et al*., 2017). These results are in agreement with the findings of (Madkour *et al*., 1992; (Patil *et al*., 2007 and Awal and Aktar, 2015).

Plant spacing is one of the most important factors limiting the production of groundnut in West Hararghe Zone. It is important to note one of the factors leading to poor yields in most small scale farms is inappropriate plant spacing practice. Many of groundnut farmers of the Zone have been faced with the problem of using the existing recommended spacing between plant and row. The use of narrow spacing between plant and row may affect the yield of groundnut. West Hararghe is the production belt for groundnut and widely grown by small scale farmers. The nature of groundnut peg development requires light soil for easy peg penetration and enough spacing for earthing up for good vegetative growth and peg development. Earthing up of groundnut where soil is piled up around the stem is important for peg formation. Generally, proper inter and intra-row spacing are imperative in the determination of yield in groundnut production. Therefore, this study was undertaken to study into inter and intra- row spacing to improve the growth and yield of groundnut West Hararghe Zone.

Materials And Methods

Description of the Study Area

The experiment was conducted at Daro Lebu district (Mechara on station and Milkaye on FTC). Mechara is located 434 km to the East of Addis Ababa in Daro Lebu District of West Hararghe Zone in Oromia Regional State. It is 110 km from Zonal Capital city Chiro to the south on a gravel road that connects to Arsi and Bale Zones. Located at latitude $8^0$36'N and longitude 40^0 18'E. Its' altitudes is 1750 m.a.s.l. with annual average temperature and rainfall 16 ^{0}c and 963 mm in the same order. The major soil type of the center is sandy loam clay which is reddish in color. Milkaye is located 38km to the east of Mechara town in Daro Lebu District of West Hararghe Zone. Located at latitude $06^0$69'03.8''N and longitude 09^0 30'96.9'' E. Its' altitudes is 1656 m.a.s.l.

Treatments and Experimental Design

The experiment was consisting of two factors. Seven levels of spacing were 50cm*10cm (194,444plants ha^{-1}), 50cm*15cm (126,388plants ha^{-1}), 50cm*20cm (97,222plants ha^{-1}), 50cm*25cm (77,777plants ha^{-1}), 60cm*10cm (166,666plants ha^{-1}), 60cm*15cm (108,333plants ha^{-1}), 60cm*20cm (83333 plants ha^{-1}), 60cm*25cm (133,333 plants ha^{-1}),70cm*10cm(138,888plantsha^{-1}), 70cm*15cm(90277plant ha^{-1}),70cm*20cm(69444plant ha^{-1}), 70cm*25cm(55,555plant ha^{-1}) and Werer-962 variety were used. The experiment was laid out in Randomized complete Block design with three replications in factorial arrangement. The gross plot area was 12.5m x 29.5m (368.75m^2) and five, six and seven rows were planted depending on the row spacing in each plot. Net Plot size was used 3.5m x 2m (7m^2).The distance between each blocks and plot will be 1m and 0.5m respectively.

Table 1. Treatments arranged as follows

S.N	Treatments	S.N	Treatments
1	50cm*10cm	7	60cm*20cm
2	50cm*15cm	8	60cm*25cm
3	50cm*20cm	9	70cm*10cm
4	50cm*25cm	10	70cm*15cm
5	60cm*10cm(control)	11	70cm*20cm
6	60cm*15cm	12	70cm*25cm

Experimental Procedures

The experimental field was ploughed and harrowed by a tractor to get a fine seedbed and leveled manually before the field layout was made. Two seeds per hill were planted and thinned to one plant per hill two week after emergence. At planting full dose of NPS fertilizer at the rate of 100 kg ha^{-1} was applied uniformly into all plots. It was harvested from the net plot after they attained their normal physiological maturity.

Data collected

Day to flowering was recorded number of days from planting to the time when 50% of the plants produced at least one flower. Days to physiological maturity were recorded number of days from planting to the time when 95% of pods reached maturity. Plant height was measured from the base of plant to the tip of the main stem at the stage of physiological maturity. Number of pods per plant was determined by counting total number of pods from five randomly selected plants from each net plot at the time of harvesting. Number of seeds per pod was counted from 10 pods from net plot at harvested from each net plot. Grain yield was recorded by weighted of harvested grain yield from each net plot

Data Analysis: Data analysis of variance was carried using General Linear Model of ANOVA using SAS version 9.1 software (SAS, 2002). Mean separation was carried out using Least Significance Difference (LSD) test at 5% probability level.

Results and Discussion

Adjusted Yield: The combined analysis showed that main effect and their interaction effect of inter- and intra-row spacing which was highly significantly ($P < 0.01$) affected on grain yield of groundnut (Table 2). Combined mean Seed yield range from 1542kg ha^{-1} to 7222kg ha^{-1} at inter- and intra-row spacing 60cm * 20cm and 70cm * 25cm, respectively. The highest adjusted grain yield of 7222kg ha^{-1} was obtained at 60cm*20cm inter- and intra-row spacing followed by 2262 kg ha^{-1} at (60cm*25cm) while the lowest adjusted grain yields of 1542kg ha^{-1} and 1592kg ha^{-1} were obtained at interaction of and 70cm*25cm and 70cm*20cm inter- and intra-row spacing, Respectively (Table 3) The grain yield at the optimum plant densities might be due to efficient utilization of growth resources. Whereas, the lowest grain yield at the largest inter row spacing might be attributed to the more comfortable growth because of the more resources at the lower plant density initiated more pod thickness than the grain yield. This result is in line with (Bihter *et al*., 2017 and Virk *et al.,* 2005).

Days to flowering: The combined main effect of inter- and intra-row and their interaction had spacing was highly significant ($P < 0.01$), effect on days to 50% flowering (Table 3). The longest days to 50% flowering (38.16 cm) were recorded at inter-row spacing and intra-row spacing of 60cm*25cm and 50cm*15cm, respectively. While the shortest days to 50% flowering (35.33) were recorded at inter-row spacing and intra-row spacing 50cm*10cm (Table 3).

The longest days to flowering with a wider inter- and intra-row spacing might be due to the fact that more nutritional area available in the wider row spacing might have caused the crop to flower later than the narrower spacing. Furthermore, this result might be because wider spacing had a better light interception as compared to the narrow row spacing, resulting in more number of days to flowering of mung bean. This result is in line with Samih A., (2008) and Birhanu et al.,(2018) who reported that when beans are planted at the lower planting densities, the plants required more number of days for flowering.

Days to 90% maturity: The combined main effect of inter- and intra-row spacing and their interaction was highly significant ($P < 0.05$) on days to 90% maturity (Table 1). The longest days to 90% maturity (156.08 days) were recorded at interaction of 60 cm inter- and 10 cm intra-row spacing, while the shortest days to 90% maturity (151.91 cm) was recorded at 70 cm inter- and 10 cm intra-row spacing (Table 3).

Plant height (cm): The combined main effect of inter-spacing was highly significant ($P < 0.01$), while intra spacing and their interaction had no significant effect on plant height (Table 2). The maximum plant height (38.45cm and 38.58cm) were recorded at inter and intra row spacing of 60cm*10cm and 70cm*10cm, respectively (Table 3).while the shortest plant height was measured (33.41cm) from inter and intra row spacing of 50cm*25cm.

Number of Pod per Plant: Results from the analysis of variance indicated that intra row space was high significant ($P < 0.01$) but both inter row space and their interaction effect non-significant on the number of pods per plant (Table 2). The highest number of pods per plant (40.86 and 40.18) was obtained from 60cm*25cm and 60cm*20cm inter- and intra-row spacing, respectively this indicated that due to less competition among the plants to get enough space for their growth and development. These results are agreement with the findings of Bihter et al. (2017), Patil et al. (2007) and Awal and Aktar (2015). While the lowest number of pods per plant (28.45) was found at 50cm*10cm spacing.

Number of Seed per Pod: The combined analysis showed that both main effect and their interactions effect of inter and Intra-row spacing was not significant on number of seeds per pod (Table 1). This result was in line with the finding of Ihsanullah et al.,(2002) who reported no significant effect of row spacing on number of seeds per pod of mung bean. The present result was in line with Lemlem (2011) who obtained no significant effect of plant density on hundred seeds weight of soya bean.

Table 2: The combined mean square values of ANOVA for phenology, growth and yield components of groundnut inter and intra-rows spacing at density at both location in 2019 and 2020

Source Variation	DF	DF	DM	PH	NPPP	NSPP	YLD(kg ha^{-1})
Rep	2	0.35ns	10.58ns	4.45ns	426.17ns	0.02ns	324596.89ns
Intra row	3	6.37**	20.65*	84.55**	684.11**	0.01ns	433137.24ns
Inter row	2	1.66**	31.23*	13.3ns	64.43ns	0.11ns	3346985.51**
Location	1	24.63**	9648.61**	49.47**	891.03**	0.73**	4687607.93**
Inter row * Intra row	6	11.22**	20.12*	5.86ns	47.38ns	0.03ns	954125.64**
Mean		36.85	153.16	35.94	36.29	1.67	2039.851
CV %		2.19	3.94	12.06	29.51	10.61	41.79

Means in the same column and the same letters are non-significantly different at 5% level of probability, ns= non-significant, LSD= least significant difference at 5% level of significant, CV= coefficient of variation in percent, DF=Days to Flowering, DM=Days to maturity, PH= plant height (cm), NPPP=Number of pod Per plant, NSPP=Number of seed per pod, and YLD= Grain Yield (kg/ha)

Table 3: Combined mean phenology, growth and yield components of ground nut inter and intra-rows spacing at density at both location in 2019 and 2020

Spacing	**Plant Density**	**DF**	**DM**	**PH**	**NPPP**	**NSPP**	**YLD(t ha^{-1})**	**YLD AD%**
(50cm*10cm)	194,444	35.33e	154.33a-c	36.61bc	28.45c	1.7	1945.83cd	
(50cm*15cm)	126,388	36.08a	155.08ab	36.00b-d	35.18a-c	1.71	2020.83c	1.92
(50cm*20cm)	97,222	36.50dc	153.58a-c	35.73c-e	36.82ab	1.75	2239.28bc	12.93
(50cm*25cm)	77,777	36.41dc	152.66bc	33.41f	36.35ab	1.68	1891.66cde	
(60cm*10cm)	166,666	37.75a	156.08a	38.45a	32.18bc	1.76	1982.73cd	
(60cm*15cm)	108,333	36.00d	152.91a-c	35.60c-e	36.63ab	1.75	2140.47c	7.95
(60cm*20cm)	83,3333	37.08b	155.41c	34.91c-f	40.18a	1.78	2722.61a	37.31
(60cm*25cm)	66,666	36.75bc	153.66a-c	34.25ef	40.86a	1.71	2622.02ab	32.24
(70cm*10cm)	138,88	36.58bc	151.91bc	38.58a	29.00c	1.7	1842.85cde	
(70cm*15cm)	90,277	36.66bc	152.16bc	37.48ab	35.15a-c	1.76	1934.76cde	
(70cm*20cm)	69,444	36.91bc	152.33bc	35.43c-e	37.46ab	1.76	1592.85de	
(70cm*25cm)	55,555	38.16a	154.83bc	34.88d-f	36.24ab	1.76	1542.26e	
Mean		36.85	153.16	35.94	35.33	1.73	2039.85	
CV%		1.67	1.87	4.14	17.21	6.54	16.87	
LSD 0.05		0.87**	3.31*	1.72*	7.03*	NS	397.7**	

Table 4: Combined Mean grain yield and agronomic traits of groundnut plant density at Mechara on station in 2019 and 2020

TRT	DM	PH	NPPP	NSPP	YLD(Kg ha-^{1})	YLD AD%
(50cm*10cm)	163.33ab	37.06ab	27.26d	1.50b	1969.04bd	
(50cm*15cm)	163.33ab	34.66de	31.80b-d	1.56ab	1654.76cd	
(50cm*20cm)	162.33a-c	34.36de	31.65b-d	1.60ab	1855.95cd	
(50cm*25cm)	160.50bc	33.13e	36.56a-c	1.50b	1666.66cd	
(60cm*10cm)	166.00a	37.43a	2963cd	1.66ab	2042.85a-c	
(60cm*15cm)	161.83a-c	35.46b-d	32.63b-d	1.56ab	2042.85a-c	
(60cm*20cm)	158.33c	35.10cd	41.56a	1.66ab	2600.76a	27.31
(60cm*25cm)	162.00a-c	34.20de	39.76ab	1.66ab	2495.23ab	22.24
(70cm*10cm)	159.16bc	37.23a	26.80d	1.56ab	1425d	
(70cm*15cm)	161.16a-c	3653a-c	33.80a-d	1.70a	1573.81cd	
(70cm*20cm)	159.50bc	34.40de	37.56a-c	1.70a	1594.04cd	
(70cm*25cm)	159.16bc	34.50de	37.10a-c	1.60ab	1438.09d	
Mean	161.4	35.34	33.84	1.6	1863.59	
CV	1.81	2.83	15.38	6.57	18.31	
LSD 0.05	4.96*	1.69*	8.79*	0.17*	576.43**	

DF=Days to Flowering, DM=Days to maturity, PH= plant height (cm), NPPP=Number of pod Per plant, NSPP=Number of seed per pod, and YLD= Grain Yield kg ha)

Table-5: Combined Mean grain yield and agronomic traits of groundnut plant density at Milkaye FTC in 2019 and 2020

TRT	DM	PH	NPPP	NSPP	YLD(Kg ha^{-1})	YLD AD%
(50cm*10cm)	145.33	36.16b-e	29.63b	1.9	1922.61def	
(50cm*15cm)	146.83	37.33a-c	38.56ab	1.86	2386.905a-d	
(50cm*20cm)	144.83	37.10a-d	42.00a	1.9	2622.61a-c	
(50cm*25cm)	144.83	33.70e	36.13ab	1.86	2116.66c-e	
(60cm*10cm)	146.16	39.46a	34.73ab	1.86	1922.61def	
(60cm*15cm)	144	35.73b-e	40.63ab	1.93	2238.09b-d	
(60cm*20cm)	144.5	34.73c-d	42.80a	1.9	2840.47a	47.74
(60cm*25cm)	145.33	34.30de	41.96a	1.8	2748.81ab	42.97
(70cm*10cm)	144.5	39.93a	30.23b	1.83	2260.71b-d	
(70cm*15cm)	143.16	38.93ab	36.50ab	1.83	22295.71b-d	
(70cm*20cm)	145.16	36.46b-e	33.36b	1.83	1591.66f	
(70cm*25cm)	144.5	35.26c-e	35.38ab	1.93	1646.42ef	
Mean	144.93	36.55	36.82	1.87	2216.1	
CV	2.11	4.79	18.22	6.36	13.65	
LSD 0.05	NS	2.96*	11.33*	NS	511.19***	

DF=Days to Flowering, DM=Days to maturity, PH= plant height (cm), NPPP=Number of pod Per plant, NSPP=Number of seed per pod, and YLD= Grain Yield(qt/ha)

Conclusion and Recommendation

Generating reliable information on agronomic management practices such as appropriate row and plant spacing is quite important to come up with profitable and sustainable ground nut production and productivity. In view of this, an experiment was conducted to determine the effect of intra- and inter-row spacing on the yield and yield components of groundnut variety. This study provides evidence that inter- and intra-row spacing has influence on the phenology, growth, yield and yield components of groundnut. The combined mean was observed inter- and intra-row spacing significant different for days to flowering, days to maturity, plant height, number of pods per plant, grain yield. While, non-significant different showed for number of seed per pod. The highest grain yield (2722kg ha^{-1}) was obtained at interaction of 60cm * 20cm spacing. While the lowest (1542 ha^{-1} and 1592 ha^{-1}) were obtained at 70cm*25cm and 70cm*20cm inter- and intra-row spacing, respectively. Therefore, 60cm * 20 cm is recommend as the optimum spacing for the high yield production of ground nut in west Hararghe zone and similar agro ecologies.

References

Upadhyaya, H.D, Reddy, L.J., Gowda C.L.L., Singh, S. 2006. Identification of diverse groundnut germplasm: Sources of early maturity in a core collection. Field Crops Res. 97(23): 261-271.

Pande S, Bandyopadhyay R, Blümmel M, NarayanaRao J, Thomas D, Navi S.S., 2003. Disease management factors influencing yield and quality of sorghum and groundnut crop residues. Field Crops Res. 84(1-2): 89-103.

Alessi, J., Power, J.F. and Zimmerman, D.C. 1977.Sunflower yield and water use as influenced by planting date, population and row spacing. *Agronomy Journal*, 69:465-469.

Amato, G., Cibella, R., Giambalvo D. and Gristina, L.1992. Observations of the reproductive development in faba bean (*Vicia faba* L. var. equina) in relation to plant density pp. 245-246. In: Proceedings of the 1st European Conference on Grain Legumes 1- 3 June, Angers, France.

Ahmad, N., Mohammad, R. and Ulas, K. 2007.Evaluation of different varieties, seed rates and row spacingof groundnut, planted under agro-ecological conditions of Malakand Division. *Journal of Interacademia*, 9(4):178-183.

Bell, M.J., Muchow, R.C., Wilson, J.L. 1987. The effect of plant population on peanuts (*Arachis hypogaea* L.) in a monsoonal tropical environment. *Field Crop Research,*17: 91-107.

Brereton, R.G. 1980. Groundnuts: Ethiopian Grain Review. Addis Ababa, Ethiopia. By AGORA on 10/20/07.

Annadurai, K., Puppala , N. Angadi, S. and Masilamani, P. 2009. Agronomic management technologies for peanut production: a review. *Indian Agricultural Review*, 30 (4): 235 - 261.

Donald, C.M. 1963. Competition among Crops and Pasture Plants.Advances in Agronomy, 15: 17-27. Madkour, M.A., S.I. El- Mohandes, A.M.El-wakil 1992.Effect of Row-Spacing, Phosphorus, Potassium and Born Application on Some Peanut Cultivars. Egypt J. Agron., 17:127-140. Patil, H.M., P.T.

Kolekar and B.T. Shete. 2007. Effect of Layouts and Spacing on Yield Quality of Bold Seeded Summer groundnut (Arachis hypogaea L.). Int'l J. Agric. Sci., 3 (2): 210-213.

Bihter ONAT, Halil BAKAL, Leyla GULLUOGLU, Halis ARIOGLU,2017 . the effects of row spacing and plant density on yield and yield components of peanut grown as a double crop in mediterranean environment in turkey. 22(1), 71-80

Patil, H.M., P.T. Kolekar and B.T. Shete. 2007. Effect of Layouts and Spacing on Yield Quality of Bold Seeded Summer groundnut (*Arachis hypogaea* L.). Int'l J. Agric. Sci., 3 (2): 210-213.

Awal, M.A, L. Aktar. 2015. Effect of Row Spacing on the Growth and Yield of Peanut (*Arachis hypogaea* L.) Stands. International Journal of Agriculture, Forestry and Fisheries. Vol. 3, No. 1, 2015, pp. 7-11.

Sternitzke, D.A, M.C. Lamb, J.I. Davidson, Jr.R.T. Barron and C.T. Bennet, 2000. Impact of Plant Spacing and Population on Yield for Single-Row Non irrigated Peanuts (*Arachis hypogaea* L.). Peanut Science: July 2000, Vol. 27, No. 2, pp. 52-56.

Ahmad, A., M. Rahim and U. Khan. 2007. Evaluation of Different Varieties, Seed Rates and Row Spacing of Groundnut, Planted Under Agro-Ecological Conditions of Malakand Division. Journal of Agronomy, 6(2):385-387

Gbehounou, G. and Adengo, E., 2003. From a crop rotation experiment at Akron. Effect of citric acid on aflatoxin degradation and on functional and textural. *Food Research International*, Volume 42, Issue 8

Konlan, S., J. Sarkodie-addo, E. Asareand and M.J. Kombiok. 2013. Groundnut (*Arachis hypogaea* L.) Varietal Response to Spacing in the Guinea Savanna Agro-Ecological Zone of Ghana. Growth and Yield. *African J. of Agriculture Research*, 8(22): 2769-2777.

Samih A. Effect of plant density on flowering date, yield and quality attribute of bush beans (*Phaseolus Vulgaris* L.) under center pivot irrigation system. *Am J Agric Biol Sci.* 2008; 3(4):666–8.

Asaye Birhanu, Tilahun Tadesse and Daniel Tadesse. 2018, Effect of inter‑ and intra‑row spacingon yield and yield components of mung bean(*Vigna radiata* L.) under rain‑fed condition at Metema District, northwestern Ethiopia. Agric & Food Secur (2018) 7:84

Lemlem HG. Effect of N fertilizer and plant density on yield, seed quality,and oil content of soybean (*Glycine max* L. Merr) at Hawassa, southernEthiopia. M.Sc. thesis presented to Haramaya University, Ethiopia; 2011.

Ihsanullah F, Taj H, Akbar H, Basir A, Noor U. Effect of row spacing on the agronomic traits and yield of mung bean (*Vigna radiata* L. Wilczek). *Asian J Plant Sci.* 2002;1(4):328–9.

Amato, G., Cibella, R., Giambalvo D. and Gristina, L. 1992. Observations of the reproductive development in faba bean (*Vicia faba* L. var. equina) in relation to plant density pp. 245-246. In: Proceedings of the 1st European Conference on Grain Legumes 1- 3 June, Angers, France.

Performance of Improved Bread Wheat Varieties (*Triticum aestivum* L) for Highland Areas of West Guji, Southern Oromia

Ibsa Jibat*[1], Ejigu Ejara[1], Belda Idao[1] and Natol Bakala[2]

[1]Oromia Agricultural Research Institute, Yabello Pastoral and Dryland Agricultural Research Center, Ethiopia

[2]Oromia Agricultural Research Institute, Bako Agricultural Research Center, Ethiopia

*Corresponding author: Email: ibsawabek@gmail.com , phone: +251 910128618

***Abstract**: Bread wheat is the most important cereal crops grown worldwide. It is one of the cereal crops grown in southern Ethiopia including West Guji zone. The area has potential to the production of cereal crops in general and bread wheat in specific for food and nutrition security. However, insufficiency of varieties that fit to the prevailing location is one of the major production challenges. Therefore, this experiment was conducted to evaluate five bread wheat varieties against one local check and recommend the best performing varieties for the study areas and similar agro ecologies. The field experiment was therefore conducted for three years at Bule hora in 2017, 2018 and 2019 cropping season and the varieties were planted in Randomized Complete Block Design (RCBD). Data were collected on yield and important agronomic traits. Combined analysis of variance over three years revealed significant variations among varieties for grain yield, phenological traits and important yield related traits. Moreover, Varieties showed a grain yield as low as 2753.23kg/ha (local check) and as high as* 4037.45*kg/ha with pooled mean of* 3284kg/ha. *Sanate (*4037.45*kg/ha) variety is significantly*

high yielding variety followed by Mandoyo (3475.14kg/ha) with yield advantage of 31.8% and 20.77% over local check respectively. Therefore, those two varieties are suggested for production around the study area and locations with similar agro ecologies until new high yielder varieties will be developed through selection/breeding program.
***Keywords**: Adaptability, Bread wheat*

Introduction

Bread wheat (*Triticum aestivum* L.) is the world's leading cereal grain and more than one-third of the population of the world uses as a staple food and contributes more calories and proteins to the world diet than any other cereal crops. In Sub-Saharan African countries, the consumption of wheat increased from time to time (Mason *et al*., 2012; Negassa, *et al*., 2013; Chimdesa, 2014). Ethiopia is the second wheat producer in sub-Saharan after South Africa (FAO, 2019). Wheat is the fourth largest cereal crop grown in Ethiopia and about 56 million smallholder farmers engaged on wheat production, which makes about 40 percent of all small farmers in the country (Gebreselassie *et al*., 2017; Rashid, *et al*., 2019). Bread wheat is a staple food in the diets of several Ethiopian, providing about 15% of the caloric intake for the countries over 90 million population (FAO, 2019; Minot *et al*., 2019).

Wheat is grown at an altitude ranging from 1500 to 3000 m.a.s.l. in Ethiopia. The most suitable agro- ecological zones, however, fall between 1900 and 2700 m.a.s.l. (Abu, 2012; Shibeshi, 2019). In Ethiopia, bread wheat improvement has started in 1949 and up to now many varieties have been released by the national and regional research institutes (Tarekegne *et al*., 1995). However, those varieties are not widely distributed to all parts of the country. This is because of several constraints including the remoteness and in accessibilities of the growing areas that limited to test the adaptability and yields of the varieties in such areas. It is necessary to evaluate varieties for the intended growing regions since varieties were recommended as high yielding after evaluating a few representative wheat growing areas, in other words the varieties were not evaluated in wider wheat growing areas.

In west Guji were this experiment was conducted, the productivity of wheat has remained low mainly because of lack of improved varieties. There is no detail information indicating the adaptability and production status of the bread wheat varieties in the area. Therefore, this experiment was conducted with the following objective

Objective: To select and recommend high yielding Bread wheat varieties for the study area and similar agro ecologies.

Materials and Methods

Description of the Study Area: Field experiment was conducted at west Guji of Bule hora woreda, for three consecutive years (2017 to 2019). The study sites were recognized with an elevation of 2000 m.a.s.l. having bimodal rainfall distribution pattern. The area is located at 447 km far from Addis Ababa city to the southern part of the country.

Experimental Materials and design

Five released varieties (Sanate, Mandoyo, Madawalabu, sofumer and Dure) collected from Sinana Agricultural Research Center were evaluated against local check. Randomized Complete

Block Design (RCBD) with three replications, having a plot size of 1.2mx2m was used at the spacing of 1.5m, 0.75m and 0.2m between replications, plot and row, respectively. Seed was sown at the rate of 125 kg/ha with drilling method. Fertilizer was calculated at the rate of 100kg/ha of Urea and 100kg/ha NPS and applied uniformly to the plots. All recommended other management and agronomic practices were applied uniformly.

Collected data

Plot base data

Days to 50% heading (DTH): The number of days from date of sowing to the stage where 75% of the spikes have fully emerged.

Days to 90% maturity (DTM): The number of days from sowing to the stage when 90% of the plants in a plot have reached physiological maturity.

Grain yield (GY): Grain yield in grams obtained from the central four rows of each plot and converted to kilograms per hectare at 12.5% moisture content.

Thousand seed weight (TSW): Weight of 1000 seeds in gram.

Above ground biomass (BM): The plants within the four central rows were harvested and weighted in grams.

Plant base collected data

Ten plants were randomly selected from the four central rows excluded two rows left as border effect:

Number of productive Tillers (TN): The average number of productive tillers with heading

Plant height (PH): The average height in centimeters from ground level to the tip of the spike.

Spikelet per spike (SPS): The average number of spikelet per spike.

Spike length (SL): The average spike length in centimeters from its base to the tip.

Data Analysis

The collected data were organized and analyzed using SAS statistical package (SAS, 2006 version 9.03). Mean separation was done by using Duncan Multiple Range Test (DRMT) at 5% probability level

The mathematical model used for analysis of variance was:

$$Yijk = \mu + Gi + Yj + GYij + Bk(j) + Eijk$$

Where: $Yijk$ = observed value of genotype i in block k of year j, μ= grand mean = Gi= effect of genotype I, Yi=effect of year j, GYij=the interaction effect of genotype i, year j, Bk (j)= effect of block k in location/environment, $Eijk$ = random error or residual effect of genotype in block k of location j

Results and Discussions

Analysis of Variances (ANOVA)

The combined Analysis of variance (ANOVA) computed indicated that variation among varieties were highly significant ($P<0.01$) for flowering dates, maturity dates, spike length, thousand seed weight and grain yields. But, the number of productive tilers and number of spikelet per spike ware significantly different ($P\leq 0.05$) in bread wheat varieties (table 1). The presence of variations among varieties under experiment for traits studied indicated the presence of sufficient variability among bread wheat varieties. Significant variations in bread wheat varieties for plant height and spike length were reported by other authors (Kebede *et al*, 2019; Gedifew *et al*. (2020). Very highly significant variation of year effect (P<0.01) for all traits except in plant height which showed significant (P≤ 0.05) indicated the presence of variability in all years for those traits. On the other hand, performance of bread wheat varieties for grain yield and other related traits were significantly influenced by year effect. The interaction effect of variety by year was not significant for traits like plant height, spike length, number of spikelet's per spike and biomass indicating similar performance of varieties in different year for those traits. Other authors also reported the existence of significant variation in bread wheat genotypes, growing season and interaction of year by genotype (Abay and Bjornstad, 2009; Gebru and Abay, 2013; Chimdesa *et al.*, 2017; Tulu and Wondimu, 2019).

Mean performance of Varieties

Crop phenology

Days to 50% heading and Days to 90% physiological maturity: Days to flowering and days to maturity were ranged from 59.60 to 70.00 and 108.56 to 122.33 days respectively. Dure variety (108.56 days) was the earliest while local check was takes longer time to mature. On the other hands, Dure and Sanate variety was early maturing varieties (108.56) and (116.22) days respectively. The variation in days to heading and days to maturity were also reported by other authors (Asaye *et al*. 2013; Ferede, 2016; Baye *et al*. 2018)

Growth traits, Yield and yield components: Bread wheat varieties showed significant variations for plant height. Sofumer (87.82cm) was the longest plant height followed by Sanate (86.78cm) while Mandoy (73.09cm) was the shortest variety. Significant variation among bread wheat Varieties for plant height was also reported by many authors including Demelash *et al*. (2013), Chimdesa *et al*. (2017), Baye *et al*. (2018). In contrast, nonsignificant variation among bread wheat varieties was reported by Dargo and Shiferaw (2017). The heist spike length was recorded for Sanate (12.00cm), followed by Madawalabu (11.32cm) while the lowest spike length was recorded from Local check (8.11cm). Bread wheat varieties also showed variation on number of productive tiller. The highest tiller number was recorded for Madawalabu (3.44) variety while the lowest was recorded for Dure (2.78). Similar findings were also reported by (Zerga *et al*. 2017; Wardofa *et al*. 2019) in bread wheat for number of productive tiller. The thousand grain weights bread wheat varieties were significantly different. The highest thousand grain weight was recorded in Mada walabu (37.85g) followed by Sofumar (36.38g). But, the lowest thousand grain weight was recorded for the variety Mandoyo (29.78g). Other authors also reported similar findings in bread wheat varieties (Baye *et al*. 2018; Wardofa *et al*. 2019; Semahegn *et al*. 2020). Variation for mean grain yield in tested bread wheat were also observed. The highest mean grain yield was recorded from Sanate variety (4037.45kg ha^{-1}) followed by Mandoyo (3475.75kg ha^{-1}) and Dure (3210.64kg/ha). The highest spike length and good number of Seed per Spike for Sanate may be contributed for having highest grain yield. But, the lowest mean grain yield were recorded from Local variety (2753.23kg ha^{-1}) followed by Mada walabu (3098.56kg ha^{-1}). The highest biomass was recorded for Mandoyo (7449.10 kg/ha) while the lowest biomass was recorded for local check (5353.70 kg/ha). This result is concise with the finding of other authors (Baye *et al*. 2018; Alemu *et al*. 2019; Wardofa *et al*. 2019)

Conclusions and Recommendations

From experiment conducted at Bule hora for three consecutive year (2017, 2018 and 2019), variation among bread wheat varieties for grain yield and other yield related traits were observed except for biomass. Significant variation among varieties for grain yield and other yield related traits indicated that the possibility of selecting varieties for the study areas. From the pooled mean performance of varieties, Sanate (4037.45kg ha^{-1}) followed by Mandoyo (3475.14 ha^{-1}) provided better yield than other varieties with about 31.8% and 20.77% yield advantage over local check and selected as promising varieties. Therefore, farmers and Bread wheat producers of the study areas and similar agro ecologies are suggested to use Sanate and Mandoyo varieties for production. In case of disease occurrence, bread wheat producers could use registered commercially available chemicals for disease control.

Acknowledgments

The authors sincerely acknowledge Oromia Agricultural research Institute for providing Research fund, Yabello Pastoral and Dryland Agricultural research center for logistic and budget facilitation and Cereal research team members for field management and data collection.

Table 1. Combined Analyses of Variance of Bread wheat varieties for 9 traits at Bule hora during 2017, 2018 and 2019

Source of variation	DF	FD	MD	PH	SL	TN	SPS	BM	TSW	GY
Year (Y)	2	92.13***	1233.17***	241.83*	41.19***	13.91***	4168.79***	130.44***	468.05***	41116055***
Variety(V)	5	104.25***	178.40***	270.06***	19.53***	0.88*	268.76*	4.96ns	85.78***	1708103***
Rep(Year)	6	2.63ns	10.39ns	56.66ns	0.61ns	0.33ns	123.39ns	3.034ns	1.46ns	46004ns
Y *V	10	17.55***	17.97**	21.71ns	0.85ns	0.84*	127.46ns	1.11ns	37.48***	248602***
Error	30	1.19	5.10	45.93	0.59	0.31	102.01	3.81	3.12	24264.07
cv		1.67	1.96	8.36	7.65	17.32	23.04	30.60	5.17	4.74

DF= degree of freedom, FD=days to heading, DM=days to physiological maturity, PH=plant height in centimeter, SL=spike length in centimeters, TN=number of productive tillers, SPS= number of spikelet's per spike, BM=biomass in kg/ha, GY= grain yield in kg/ha, TSW= thousand seed weight in gram

Table2. Combined Mean Performance of Bread Wheat Variety at Bule hora during 2017, 2018 and 2019

Varieties	FD	MD	PH	SL (cm)	TN (no)	SPS (no)	BM	TSW	GY
Local	70.00a	122.33a	80.02b	8.11d	2.89bc	34.78b	5353.70b	35.81b	2753.23d
Madawalabu	66.22b	116.67b	79.93b	11.32a	3.44a	42.13ab	6328.70ab	37.85a	3098.56c
Sanate	65.88b	116.22cd	86.78a	12.00a	3.31ab	51.22a	6859.10ab	33.53c	4037.45a
Sofmer	65.77b	114.22c	87.82a	10.54b	3.22abc	46.22a	6463.00ab	36.38ab	3131.56c
Mandoyo	64.11c	114.67bc	73.09c	9.06c	3.58a	42.96ab	7449.10a	29.78e	3475.14b
Dure	59.55d	108.56d	78.67bc	9.39c	2.78c	45.67a	5814.80ab	31.55d	3210.64c
Mean	65.26	115.44	81.05	10.07	3.20	43.83	6.38	34.15	3284.43

FD=days to heading, DM=days to physiological maturity, PH=plant height in centimeter, SL=spike length in centimeters, TN=number of productive tillers, SPS= number of spikelet's per spike, BM=biomass in kg/ha, GY= grain yield in kg/ha, TSW= thousand seed weight in gram

References

Abay, F., Bjørnstad, A. and Smale, M., 2009. Measuring on farm diversity and determinants of barley diversity in Tigray, northern Ethiopia. *Momona Ethiopian Journal of Science*, *1*(2).

Abu, T, (2012). Grain and feed annual report. Grain report number: ET1201, Addis Ababa, Ethiopia (Triticum aestivum L.). Research in Plant Biology, 3(1): 33-36.

Adhiena, M. (2015). Genetic variability and association among seed yield and yield related traits in bread wheat (Triticum aestivum L.) Varieties at Ofla District, Northern Ethiopia. M.Sc. Thesis, Haramaya University, Haramaya, Ethiopia

Baye, A., Berihun, B., Bantayehu, M. and Derebe, B., 2020. Genotypic and phenotypic correlation and path coefficient analysis for yield and yield-related traits in advanced bread wheat (Triticum aestivum L.) lines. *Cogent Food & Agriculture*, *6*(1), p.1752603.

Chimdesa, O., Mohammed, W. and Eticha, F., 2017. Analysis of genetic variability among bread wheat (Triticum aestivum l.) Varieties for growth, yield and yield components in Bore district, Oromia regional state. *Agriculture, Forestry and Fisheries*, *6*(6), pp.188-199.

Demelash, A., Desalegn, T. and Alemayehu, G., 2013. Participatory Varietal Selection of Bread Wheat (Triticum aestivum L.) Varieties at Marwold Kebele, Womberma Woreda, West Gojam, Ethiopia. *International Journal of Agronomy and Plant Production*, *4*, pp.3543-3550.

Ferede, M., 2016. Stability analysis in bread wheat (Triticum aestivum L.) Varieties in north-western Ethiopia. *East African Journal of Sciences*, *10*(1), pp.15-22.

Gebreselassie, S., Haile, M. and Kalkuhl, M., 2017. The wheat sector in Ethiopia: Current status and key challenges for future value chain development.

Gebru, H. and Abay, F., 2013. Evaluation of bread wheat Varieties for their adaptability in wheat growing areas of Tigray Region, Northern Ethiopia. *Journal of Biodiversity & Endangered Species*, *1*.

Gedifew, S., 2020. *Genetic diversity and association of traits in sesame (sesamum indicum l.) Varieties at northwestern Ethiopia* (Doctoral dissertation, Bahir Dar University).

Kebede, D., Dagnachew, L., Megersa, D., Chemeda, B., Girma, M., Geleta, G. and Gudeta, B., 2019. Genotype by environment interaction and grain yield stability of Ethiopian black seeded finger millet Varieties. *African Crop Science Journal*, *27*(2), pp.281-294.

Mason, Nicole M., Thomas S. Jayne, and Bekele A. Shiferaw. *Wheat consumption in Sub-Saharan Africa: trends, drivers, and policy implications*. No. 1096-2016-88381. 2012.

Mehari, M., Tesfay, M., Yirga, H., Mesele, A., Abebe, T., Workineh, A. and Amare, B., 2015. GGE biplot analysis of genotype-by-environment interaction and grain yield stability of bread wheat Varieties in South Tigray, Ethiopia. *Communications in Biometry and Crop Science*, *10*(1), pp.17-26.

Minot, N., Warner, J., Lemma, S., Kasa, L., Gashaw, A. and Rashid, S., 2019. The wheat supply chain in Ethiopia: Patterns, trends, and policy options. *Gates Open Res*, *3*(174), p.174.

Misganaw Ferede (2016). Stability Analysis in Bread Wheat (Triticum aestivum L.) Varieties in North-western Ethiopia. East African Journal of Sciences, Volume 10 (1) 15-22

Muez, M., Mizan, T., Haddis, Y., Adhiena, M., Teklay, A., Assefa, W. and Birhanu, A., 2015. GGE biplot analysis of genotype-by-environment interaction and grain yield stability of bread wheat Varieties in south Tigray, Ethiopia. *Communications in Biometry and Crop Science*, *10*(1), pp.17-26.

Mwadzingeni, L., Shimelis, H., Tesfay, S. and Tsilo, T.J., 2016. Screening of bread wheat Varieties for drought tolerance using phenotypic and proline analyses. *Frontiers in plant science*, *7*, p.1276.

Rashid, S., Getnet, K. and Lemma, S., 2019. Maize value chain potential in Ethiopia: Constraints and opportunities for enhancing the system. *Gates Open Res*, *3*(354), p.354.

Semahegn, Y., Shimelis, H., Laing, M. and Mathew, I., 2020. Evaluation of bread wheat (Triticum aestivum L.) Varieties for yield and related traits under drought stress conditions. *Acta Agriculturae Scandinavica, Section B—Soil & Plant Science*, *70*(6), pp.474-484.

Shibeshi, S., 2019. Performance evaluation of released bread wheat varieties at mid altitude areas of Southern Ethiopia. *Ukrainian Journal of Ecology*, *9*(4).

Tadesse, W., Bishaw, Z. and Assefa, S., 2019. Wheat production and breeding in Sub-Saharan Africa: challenges and opportunities in the face of climate change. *International Journal of Climate Change Strategies and Management*.

Tarekegne, A., Tanner, D.G. and Gebeyehu, G., 1995. Improvement in yield of bread wheat cultivars released in Ethiopia from 1949 to 1987. *African Crop Science Journal*, *3*(1).

Tulu, L. and Wondimu, A., 2019. Adaptability and yield stability of bread wheat (Triticum aestivum) varieties studied using GGE-biplot analysis in the highland years of South-western Ethiopia. *African Journal of Plant Science*, *13*(6), pp.153-162.

Wardofa, G.A., Mohammed, H., Asnake, D. and Alemu, T., 2019. Genotype x environment interaction and yield stability of bread wheat Varieties in Central Ethiopia. *Journal of Plant Breeding and Genetics*, *7*(2), pp.87-94.

Zerga, K., Mekbib, F. and Dessalegn, T., 2017. The Mean Performance of Different Bread Wheat (Triticum Aestivum. L) Varieties in Gurage Zone, Ethiopia. *Landscape Architecture and Regional Planning*, *2*(1), pp.29-35.

Performance evaluation of lentil varieties at Bule hora, Southern Ethiopia

Ejigu Ejara*, Kemal Kitaba and Gutema Idosa

Yabello Pastoral and Dryland Agriculture Research Centre, Oromia Agricultural Research Institute, Yabello, Ethiopia. *Corresponding author. E-mail: ehordofa@gmail.com

***Abstract**: Lentil (Lens culinaris Medik) is one of the most important highland food legumes grown in many parts of the world as food crops. It is one of the pulse crops grown in southern Ethiopia including West Guji zone. The area has potential to the production of Lentil for food and nutrition security as well as export commodity. However, scarcity of varieties that fit to the environment is one of the major production challenges. Therefore, this experiment was conducted to evaluate nine Lentil varieties and recommend the best performing varieties for the study areas and similar agro ecologies. The field experiment was therefore conducted for three years at Bule hora in 2018, 2019 and 2020 and the varieties were planted in Randomized Complete Block Design (RCBD). Data were collected on yield and important agronomic traits. Combined analysis of variance over three years revealed significant variations among varieties for grain yield, flowering dates, maturity dates and number of seeds per plants. Moreover, Varieties showed a grain yield as high as* 1104*kg/ha with pooled mean of* 894.84kg/ha*. Derash (*1104*kg/ha) variety is relatively high yielding variety followed by Chackol (1099.999kg/ha) with yield advantage of 18.95% and 18.65% over variety mean respectively. Therefore, those two varieties are suggested for production around the study area and locations with similar agro ecologies until new high yielder varieties will be developed through selection/breeding program.*

Key words: Adaptability, Grain yield, Yield related traits

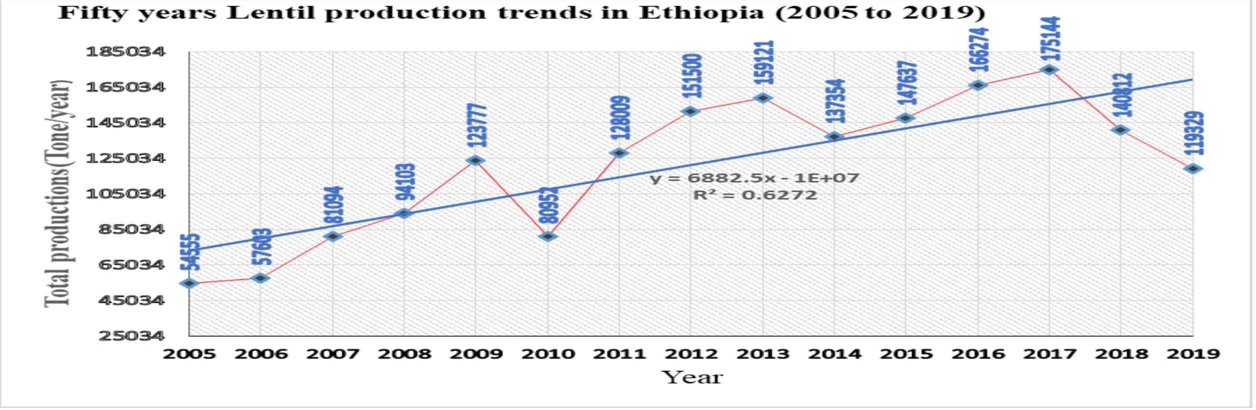
Introduction

Lentil (*Lens culinaris* Medik) is one of the most ancient annual food crops that have been grown as an important food source for over 8,000 years (Dhuppar et al, 2012 and Oplinger, 1990). It is one of the most important highland food legumes grown in many parts of the world as food crop (Erskine et al., 2011). Globally lentil production ranking sixth in production among pulses after dry bean, pea, chickpea, faba bean, and cowpea (FAO, 2010). Lentil is one of the high land crops widely grown in Ethiopia. It is largely produced in the high land and semi-highland regions of the country mainly on clay soil. In Ethiopia, the production of Lentil is increasing from year to year (figure 1). Currently, in 2019, 87444 hectares of land is covered with lentil and about 119329 tones are produced with national average yield of 1.3646 tone/ha (FAOSTAT, 2020). The area coverage, production and productivity were simultaneously increased when compared with that of 1993. The national average yield was also increased by more than double from 0.556 tons in 1993 to 1.365 tons in 2020.

In southern part of Oromia, the production of Lentil is still very low. Moreover, there is a need for selecting high yielding and adaptable varieties and capacitating farmers and agricultural investors in the study areas. This experiment was therefore conducted with the following objective

Objective: To select and recommend adaptable Lentil varieties for the study areas

Figure 1



Source: FAOSTAT (2020) at http://www.fao.org/faostat/en/#home

From this, it is expected that Lentil production is increasing rapidly in the future due to its demand for consumption and other purposes.

Materials and Methods

Descriptions of the study area: The experiment was conducted at Bule hora during 2018, 2019 and 2020 cropping season. The experimental areas are located in the Southern part of the country in the Oromia Regional State, West Guji zone, Bule hora district (Garba). The area is located at 447 km far from Addis Ababa city.

Experimental Materials: A total of 9 Lentil varieties were collected from Debre zeyit Agriculture research Center and evaluated at Bule hora for three consecutive years (2018, 2019 and 2020).

Table 1: List of Lentil varieties used in this experiment

S.No	Variety	Year of release	Breeder/ Maitainer
1	Chalew (NEL 358)	1984	DZARC /EIAR
2	Alemtena (FLIP 96-49L)	2004	DZARC /EIAR
3	Gudo (FLIP 84-78L)	1995	DZARC /EIAR
4	Denbie(El-142xr-186-3)	2013	DZARC /EIAR
5	Teshale (FLIP 96-46L)	2004	DZARC /EIAR
6	Derash	-	-
7	Alemeya	-	-
8	EL		
9	Chekol (ENAL-2704)	1984	DZARC /EIAR

Experimental Design and Managements

The experiment was laid out in Randomized Complete Block Design. Each variety was planted in a plot having 6 rows of 2 meter length. Four rows were harvested and two border rows were left to exclude border effect. Individual plot size was 1.8 m x 2m=3.6 m^2 and 1m between each block. All other agronomic managements were applied uniformly in all experimental plots as per national recommendation for the lentil varieties.

Data Collection

Data recorded on plant basis

Plant height at harvest (cm): Height of five randomly taken plants during harvest period from each experimental plot was measured in centimeter from the ground level to top of the plants and the average height was recorded.

Number of primary branches: Number of productive branches extending from the main stem was recorded from five randomly selected plants and average branch number was taken.

Data recorded on plot basis

Days to Flowering: The numbers of days from the date of emergence to the date on which about 50% of the plants in each plot produce flowers.

Days to maturity: The number of days from planting to maturity period

Stand count at harvest: This was recorded by counting the total number of plants from the four middle rows of each plot at harvest.

Grain yield (g/plot): Grain yield in grams obtained from the central four harvestable rows of each plot was harvested, threshed and weighted by using sensitive balance

Grain yield (kg/ha): Grain yield obtained from each plot was used to estimate grain yield (kg) per hectare.

Number of pods per plant: this was recorded as average total number of pods of five randomly selected plants from each experimental plot at harvest.

Number of seeds per plant: This was recorded as average total number of seeds of five randomly selected plants from each experimental plot.

Data Analysis

Analysis of variance

Analysis of variance (ANOVA) was computed for grain yield and other traits as per the methods described by Gomez and Gomez (1984) using R and R-Studio for Randomized complete block design. Comparison of treatment means was made by using Duncan multiple range test (DMRT) at 5% level of significance test. Analyses of variance (ANOVA) were computed using the following mathematical model:

$$Yijk = \mu + Gi + yj + Bk + Gyij + \varepsilon ijk$$

Where: $Yijk$ = is the observed mean of the ith variety (G_i) in the jth year (y_j), in the kth block (B_k) μ= General mean of trait Y, Gi = Effect of the ith variety, yj= Effect of the jth year, Bk = Block effect of the ith variety in the jth year, $Gyij$ = The interaction effects of the ith variety and the jth year, εijk= The error term

Results and Discussions

Analysis of variance

The combined over three years Analysis of variance (ANOVA) computed shown that variation among varieties were highly significant (P<0.01) for all traits except plant height, number of primary branch and pod per plant (Table 3). The presence of variations among varieties under experiment for traits studied indicated the presence of sufficient variability among Lentil varieties. Significant variation among grain yield, days to flowering, days to maturity and seeds per plant were also reported by Geje, 2019, Omar *et al*., 2019 and Mihiretu *et al*., 2019. Other author (Mukerem and Shimelis 2019) also reported the existence of variation in grain yield and maturity date for lentil varieties.

Source of var.	df	GY(kg/ha	FD	MD	Pht	NPB	PPP	SPP
Year (Y)	2	101168	258.235*	161.370*	499.10**	22.312***	8621.6***	562964.0**
Variety(V)	8	222461**	13.559***	66.111**	25.65	1.408	1597.4	17543.0***
Rep(Y)	6	173471*	2.111	15.432	27.47	3.149	279.5	935.0
V*Y	16	90804	11.235***	30.606	7.50	1.265	574.0	11416***
Pooled error	48	74678.39	2.417	17.168	15.50	1.391	316.9	1258.600
CV		30.54	2.69	3.38	12.05	24.36	26.57	21.27

Table 3: Mean squares from combined analyses of variance over three years for 8 traits of Lentil varieties grown at Bule hora in 2018, 2019 and 2020

ns, ,**&***,non-significant, significant and highly significant at P<0.05, P<0.01 and P<0.001, respectively. DF= degree of freedom, FD= days to flowering, MD= days to maturity, PH (cm) = plant height in centimeter, NPB= number of primary branch, GY (kg/ha) = Grain yield in kilogram per hectare, PPP=Pods per plants, SPP=Seeds per plant.*

Very highly significant variation of year effect (P<0.01) for all traits except grain yield were observed indicating the presence of variability in all years for those traits. On the other hand, performance of Lentil varieties for grain yield was not significantly influenced by year effect. The interaction effect of variety by year was not significant for all traits except flowering date and grain yield indicating similar performance of varieties in different year for those traits. Similar findings were also reported by Mukerem and Shimelis, 2019

Mean performance of varieties

Crop phenology

Flowering duration of 9 Lentil varieties ranges from 55.77-59 days while the maturity duration of varieties ranges from 117.44-126.33 days. The pooled mean performances of these traits are presented in Tables 4. The earliest flowering variety was chakol (55.77 days) followed by EL (56 days) and Alemaya (56.55days) while the late flowering varieties were Chalew (59 days) followed by Alamtena and Gudo (58.667 days each). The top three early maturing varieties are Chekol (117.44 days), EL (120.11 days) and Alemaya (121.778 days) while the three top late maturing varieties are Gudo (126.33 days), Chalew (126), Alemtena and Dembie (122.667 days each.

Growth traits, Yield and yield components

The combined over year analyses indicated that there are no significant variation among 9 Lentil varieties for number of primary branches, plant height and number of pods per plants. Mean performances of varieties for plant height ranged from 30.58cm to 35.89cm. About 55.55% of varieties were taller than the grand mean (32.676). Geja, 2019 also reported variation of lentil varieties ranged from 26.3cm to 36.4 which is in line with this finding. Other author Mukerem and Shimalis reported variation from 35cm to 40.49cm. Varieties showed considerable variations for number of seeds per plants that ranged from 99.867 to 219.62 (table 4). Similar result was also reported by Geja, 2019 for number of seeds per plants, seeds per pods and thousand seeds weight in lentil varieties.

Table 4: Mean value of yield and yield related traits of 9 Varieties of lentil tested at Bule hora in 2018, 2019 and 2020 cropping season

var. name	FD	MD	Pht	NPB	PPP	SPP	GY(kg/ha
Chalew	59a	126a	32.689a	3.311a	80.11a	209.1ab	726.62cd
Alemtena	58.7ab	122.667ab	30.933a	5.133a	60.267a	126.4cd	815.277bcd
Gudo	58.7ab	126.333a	35.889a	4.711a	57.733a	99.8d	737.963bcd
Denbie	58.2ab	122.667ab	33.267a	4.600a	80.111a	204.8ab	976.621abc
Teshale	58.2ab	122.556ab	32.978a	4.356a	51.244a	124.1cd	893.751a-d
Derash	57.3bc	122.444b	34.289a	4.733a	82.289a	219.6a	1104.398a
Alemeya	56.6cd	121.778ab	31.4a	5.422a	87.911a	184.1b	993.867ab
EL	56cd	120.111c	32.067a	4.322a	54.739a	192.2ab	705.093d
Chekol	55.8d	117.444bc	30.578a	4.967a	65.756a	140.6c	1099.999a
mean	57.61	122.44	32.676	4.84	69.99	166.76	894.84
Range	56-59	117-126	30.5-35.9	3.3-5.1	51.2-87.9	99.8-219.6	705-1104

Means with the same letters in the same columns are not significantly different, FD= flowering date, MD= Maturity date, PH= plant height in centimeter, NPB= number of primary branch, GY= Grain yield per hectare, PPP=Pods per plants, SPP=Seeds per plant

Highest mean grain yield was recorded from Derash (1104.4kg ha^{-1}) followed by Chakol (1099.99kg ha^{-1}) and Alemaya (993.87kg/ha). But, the lowest mean grain yield were recorded from EL (705.09kg ha^{-1}) followed by Chalew (726.62kg ha^{-1}) and Gudo (737.96kg ha^{-1}). Variation of mean grain yield ranged from 650kg ha^{-1}to 1590/ha in lentil varieties were also reported by Geja, 2019

Conclusions and Recommendations

From the experiment conducted at Bule hora for three consecutive years (2018, 2019 and 2020), the variation among lentil varieties for grain yield, flowering date, maturity date and seed per plants were observed. The existence of significant variation among varieties for grain yield and other yield related traits indicated the possibility of selecting varieties for the study areas. The mean of flowering and maturity date in this experiment ranged from 55.778-59 days and 117.44-126.33 days respectively. The early flowering and maturing varieties was Chekol with 55.7 and 117.4 days respectively while the late maturing varieties are Gudo and Chalew with 126.33 and 126 days respectively. The mean grain yield ranged from 705kg to 1104kg.The highest mean grain yield were exhibited by Derash (1104.4kg ha^{-1}) followed by Chekol (1099.99 kg ha^{-1}) and Alemaya (993.87kg ha^{-1}). The high yielding capacity of these varieties may be due to the presence of high number of seeds per plants and pods per plants. Therefore, farmers and Lentil producers around the study area and similar agro ecologies can alternatively use those varieties until new high yielder varieties will be recommended for the study areas.

References

Dhuppar P, Biyan S, Chintapalli B, Rao S (2012) Lentil Crop Production in the Context of Climate Change: An Appraisal. Indian Research Journal of Extension Education 2(Special Issue): 33-35.

FAOSTAT, 2020 accessed on 9th October,2021

Geja, M.M. 2019. Evaluation of lentil varieties for adaptation and yield performance under midland ecology of kaffa zone, south-west Ethiopia. *Int. J. Agril. Res. Innov. Tech.* 9(2): 9-14. DOI: 10.3329/ijarit.v9i2.45404.

Gomez, K. A. and Gomez, A. A., 1984. *Statistical procedures for agricultural research*. 2nd ed. New York,USA.: John Willey and Sons Ltd., p. 680.

Mihiretu, A., Asresu, M. and Wubet, A. (2019). Participatory assessment of lentil (*Lens culinaris* Medik.) production practices in marginal dry lands of Wag-lasta, Ethiopia. *Archives of Agriculture and Environmental Science*, 4(3): 288-294, https://dx.doi.org/10.26832/24566632.2019.040305

Mukerem Elias and Shimelis Mohammed(2019): Participatory Variety Selection of Lentil (*Lens culinaris* M.) in Siltie and Hadiya Zones. *International Journal of Plant Research,* 9(2): 19-22

Omar Idrissi, Ali Sahri, Chafika Houasli, and Nasserelhaq Nsarellah, (2019). Breeding Progress, Adaptation, and Stability for Grain Yield in Moroccan Lentil Improved Varieties. *Crop Sci*. (59):925–936.

Oplinger ES, Hardman LL, Kaminski AR, Kelling KA, Doll JD (1990) Departments of Agronomy and Soil Science, College of Agricultural and Life Sciences and Cooperative Extension Service, University of Wisconsin-Madison and Department of Agronomy and Plant Genetics, University of Minnesota.

Performance of Mung bean varieties (*Vigna radiata* (L.) Wilczek.) at Yabello and Abaya, Southern Ethiopia

Ejigu Ejara[1]*, Kemal Kitaba[1], Gutema Idosa[1] and Zinash Misganaa[1]

[1]Yabello Pastoral and Dryland Agriculture Research Centre, Oromia Agricultural Research Institute, Yabello, Ethiopia.

*Corresponding author. E-mail: ehordofa@gmail.com

***Abstract**: Mung bean is an important short duration, self-pollinated diploid legume crop with high nutritive values and nitrogen fixing ability. In southern part of Oromia, the production of Mung bean is still low or neglected. Moreover, there is a need for selecting high yielding and adaptable Mung bean varieties for the study areas. Therefore, this experiment was conducted to evaluate fife Mung bean varieties and select adaptable varieties with high yield and agronomic traits. The field experiment was therefore conducted in two location for three years (2017, 2018 and 2019 at Abaya) and (2018, 2019 and 2020 at Yabello). Varieties were planted in Randomized complete block design (RCBD) with three replications. Data were collected on yield and important agronomic traits and analyzed by SAS software. The computed analysis of* *variance at both locations over three years revealed significant variations among varieties for days to flowering, days to maturity, number of primary branches, plant height, pods number per plants, seeds number per plants and Grain yield at Yabello. But, the variation was not statistically significantly different for number of primary branches and plant height at Abaya. MH-1 variety is significantly high yielding (1079.3kg/ha) variety at Yabello with 29.697% yield advantage over pooled mean and Rasa is high yielding variety (621.66 kg/ha) with 23.91% yield advantage over pooled mean at Abaya and therefore recommended for production in moisture stress areas of Yabello, Abaya and location with similar agro ecologies.*

***Keywords**: Mean, grain yield, performance, yield related traits*

Introduction

Mungbean (*Vigna radiata* (L.) Wilczek) belongs to the order Leguminosae and Papilionoideae family (Rachie and Roberts 1974). It is originated in India and Central Asia. It has green skin and is also called green bean. It is sweet in flavor and cold in nature (EPP, 2004). Mungbean is an annual food legume belonging to the subgenus *Ceratotropis* in the genus *Vigna*. Mung bean is an important short duration, self-pollinated diploid legume crop with high nutritive values and nitrogen fixing ability. Hence, it is an eco-friendly food grain leguminous crop of dry land agriculture with rich source of proteins, vitamins, and minerals (Ketinge at al., 2011). Mung bean contains 51% carbohydrate, 24–26% protein, 4% mineral, and 3% vitamins (Afzal at al., 2008). Mung bean seeds contains about ~24% easily digestible protein, is rich in fibre, antioxidants, and phytonutrients, and are consumed whole or split, ground into flour, or used as sprouts (Tang et al., 2014). Besides providing protein in the diet, mungbean has the remarkable quality of helping the symbiotic root rhizobia to fix atmospheric nitrogen and hence to enrich soil fertility (Anjum et al., 2006). As a legume, the crop fixes most of its own nitrogen requirement and contributes significantly to improving the sustainability of farming systems (Ebert et al., 2014). Smallholder farmers in drier marginal environments in Ethiopia grow mung bean. Mung bean is a relatively drought-tolerant and low-input crop that can provide green manure as well as livestock feed and thus is favored by smallholder farmers. Mung bean is recent introduced in Ethiopian pulse production and grown in the north eastern part of Amhara region (North Shewa, and Southern Wollo), Oromiya special zone, SNNPR (Gofa area) and pocket areas in Oromiya region (mostly Hararge zone) (Teame et al., 2017). In southern Ethiopia, Farmers in some moisture stress areas (Gofa, Konso, south Omo zone and Konta) have been producing mung bean to supplement their protein needs and also effectively use short period rainfall (Asrate et al., 2012). In southern part of Oromia, the production of Mung bean is still very low, even neglected. Moreover, there is a need for selecting high yielding and adaptable varieties and capacitating farmers/agro pastoralist and agricultural investors in the study areas. This experiment was therefore conducted by Yabello Pastoral and Dryland Agriculture Research Center with the following objective

Objective: To investigate and select the best adapted mung bean variety for the study area.

Materials and Methods

Description of the study area

The experiment was conducted at Yabello during 2018, 19, 2020 and Abaya during 2017, 2018 and 2019 cropping season. The two locations are the research sites and sub- sites of Yabello Pastoral and Dryland Agriculture Research Center, respectively. The experimental areas are located in the Southern part of the country in the Oromia Regional State. Yabello and Abaya are located at 561 and 365 km far from Addis Ababa city, respectively. The detail description of the study areas are listed in the Table 1.

Table 18: Description of the study area

Variables	Yabello	Abaya
Soil type	sandy	Sandy clay loam
Altitude (m.a.s.l.)	1631	1442
Latitude	02°88’006"N	06°43’520"N
Longitude	038°14’761"E	038°25’425"E
Annual Temperature ^{0}C		
Minimum	14.5	12.6
Maximum	26.3	29.9
Annual rainfall (mm)		
Minimum	400	500
Maximum	700	1100

Experimental Materials

For this study, five released Mung bean varieties were obtained from Melkassa Agriculture Research Centre (MARC) and evaluated for adaptability of the varieties

Table 2: Released Mung bean varieties used in the experiment

S.No	Variety	Year of release	Breeding center
1	NVL-1	2014	Nirmal plc/EAR/MARC
2	Rasa (N-26)	2011	MARC/EAR
3	MH-97-6(Borda)	2008	SARI/AWRC
4	Hardeke	-	
5	Chinese	-	MARC/EAR

Experimental Design and Managements

The experiment was laid out in Randomized Complete Block Design. Each entry was planted in a plot having 6 rows of 3 meter length. Four rows were harvested and two border rows were left to exclude border effect. The row and plant spacing was kept at 40 cm and 10 cm, respectively. Plot size was 2.4 m x 3 m=7.2 m^2 and 1m and 1.5m between plot and block, respectively. 100kg NPS/ha fertilizer was calculated to plot and applied at the time of planting. All other agronomic managements were applied uniformly in all experimental plots as per national recommendation for the crop.

Data Collection

The following data were collected during the experiment time both from the whole plot, net plot and sampled plants by random selection method from the middle of four rows of each plot.

Data recorded on plant basis

Plant height at harvest (cm): Height of five randomly taken plants during harvest period from each experimental plot was measured in centimeter from the ground level to top of the plants and the average height was recorded.

Number of primary branches: Number of productive branches extending from the main stem was recorded from five randomly selected plants and average branch number was taken.

Number of pods per plant: this was recorded as average total number of pods of five randomly selected plants from each experimental plot at harvest.

Seeds per plant: Average number of seeds counted from five randomly selected plants.

Data collection on plot basis

Days to Flowering: The numbers of days from the date of emergence to the date on which about 50% of the plants in each plot produce flowers.

Days to maturity: The number of days from planting to the date when 90% of the morphological observation of the plant turned to yellow straw color.

Stand count at harvest: This was recorded by counting the total number of plants from the four middle rows of each plot at harvest.

Grain yield (g/plot): Grain yield in grams obtained from the central four harvestable rows of each plot was harvested, threshed and weighted using sensitive balance.

Grain yield (ton/ha): Grain yield obtained from each plot was used to estimate grain yield (tons) per hectare.

Data Analysis

Analysis of variance

Analysis of variance (ANOVA) was computed for grain yield and other traits as per the methods described by Gomez and Gomez (1984) using SAS software (Version 9) for Randomized Complete Block Design. Comparison of treatment means was made using Duncan Multiple Range test (DMRT) at 5% level of significance.

Individual locations ANOVA were computed using the following mathematical model:

Individual locations ANOVA model

$$Xijkl = \mu + Gi + Bjk + Y + GYi + Eijk$$

Where, $Xijkl$ = Observed value, μ = general mean, Gi = effect of variety, Bjk = effect of replication (block), Y= effect of year, GYi = variety x Year, $Eijk$ = residual effects or experimental error. Additionally, g, r, y are numbers of geneotypes, replications, locations and years, respectively

Results and Discussions

Analysis of Variance

The experiment was conducted at two locations viz. Yabello and Abaya. The analysis of variance were computed for days to flowering, days to maturity, plant height, number of primary branches, pods per plant, seeds per plant and grain yield per hectare.

Analysis of variance computed for both locations over three years revealed that variation among varieties were highly significant (P<0.01) for all traits at both locations except plant height and number of primary branches were not statistically significantly different at Abaya (Table 3 and Table 4). Other authors (Asfaw *et al*., 2012, Melese, 2018, Teame *et al*., 2017 and Fantaye *et al*., 2019) also reported similar findings in Mung bean varieties. The existence of variations among varieties under experiment for all the traits studied indicated the presence of sufficient variability among Mung bean varieties that would be exploited through selection. Statistically significant variation for interactions of year by variety was also observed for all traits except number of primary brunches and plant height at Abaya. But the interaction of variety by year effect was significant for traits like flowering date, maturity date and grain yield at Yabello. The presence of significant variation for verities x year interaction at each location (Table3 and 4) suggested that varieties had differential performance during growing years for these traits. Other authors also reported the significant influence of genotype by year interaction on the performance of Mung bean (Fantaye *et al*., 2019 and Asfaw *et al*., 2012). The year effect was highly significant (P<0.01) at both location, indicated that the performance of varieties are different in different year.

Table 3. Mean squares from combined analyses of variance over two years for 7 traits of Mung bean varieties grown at Abaya in 2017, 2018 and 2019

S.V	DF	FD	MD	NPB	PH (cm)	PPP	SPP	GY (kg/ha)
Year (Y)	2	464.3**	1184.3**	7**	339**	151.7**	657169.6**	1002807.5**
Varieties(V)	4	22.97**	50.31**	1.62	3.654	47.9**	134389.1**	147139.234**
Rep(Y)	6	5.044**	5.577	0.562	25.382	5.373	14349.067	20208.547
V*Y	8	18.044**	24.628**	0.458	37.124	19.564*	58501.622*	94854.101*
Pooled error	24	1.239	4.272	0.718	25.31	7.847	22567	36175
CV		2.406	2.303	28.21	17.3	23.29	28.61	40.21
mean		46.266	89.73	3.00	29.07	12.03	525.1	473

ns,* &,** non-significant, significant at P<0.05, and P<0.01 respectively. DF= degree of freedom, FD= days to flowering, GY (kg/ha) = Grain yield in kilogram per hectare, MD= days to maturity, PH (cm) = plant height in centimeter, NPB= number of primary branch, PPP= pods per plant, SPP= Seeds per plants

Table 4. Mean squares from combined analyses of variance over three years for 7 traits of Mung bean varieties grown at Yabello in 2018, 2019 and 2020 G.C

S.V	DF	FD	MD	NPB	PH (cm)	PPP	SPP	GY/ha
Year (Y)	2	249.9***	1358.4***	5.2**	1792.676***	2105.754***	297594 **	1240258 **
Var.	4	20.3***	58.756***	1.92**	74.515**	170.146**	87045 **	810871.7**
Rep(Y	6	4.489	9.733	0.514	52.994*	99.641*	34570*	181821 ***
year*V	8	7.983*	13.089*	0.319	37.187	50.474	25632.49	251808 ***
Error	24	2.933	4.594	0.325	19.7888	39.0156	12374.09	45352.99
CV		3.81	2.38	20.77	13.088	42.109	31.089	28.067

ns, *, **&***, non-significant, significant, highly significant and very highly significant at P<0.05, P<0.01 and P<0.001, respectively. DF= degree of freedom, FD= days to flowering, GY (kg/ha) = Grain yield in kilogram per hectare, MD= days to maturity, PH (cm) = plant height in centimeter, NPB= number of primary branch, PPP= pods per plant, SPP= Seeds per plants

Mean performance of varieties

Crop phenology

Flowering duration of five varieties of Mung bean ranges from 44.33-47.89 and 43-47 days at Abaya and Yabello respectively while the maturity duration of varieties ranges from 86.11-91.67 and 86.22-92.667 days at Yabello and Abaya respectively. Fantaye *et al*., 2019 reported days to flowering and maturity in Mung bean variety ranged from 39-50 days and 64-76 days respectively. Habte (2018) also reported the range of flowering and maturity date in Mung bean varieties from 37.33-41.33 and 72.83-74.67. The pooled mean performances of these traits over year at both locations are separately presented in Tables 5 and 6. The earliest maturing varieties was Chinese (86.22 days) followed by Hareke (89.44 days) while MH-97-6 (Borda) (92.667 days) was the late maturing variety at Yabello (Table 5). On the other hand, Hardeke (86.11days) was early maturing variety followed by Chinise (88.56 days) at Abaya (Table 6). Two varieties exhibit lower number of days to maturity than over all mean at both locations.

Growth traits

Varieties showed considerable variations for number of primary branches that ranged from 2.489 for NVL-1 to 3.578 for Rasa at Abaya (table 6); and 2.017 for Hardeke to 3.233 for MH-97-6 (table 5). Rasa and MH-97-6 varieties recorded superior number of primary branches than the mean performance of varieties pooled over three years at Abaya (Table 6); while Rasa, MH-97-6 and NVL-1 provided better number of primary branches than the pooled mean of three years at Yabello (table 5). Existence of significant variations among Mung bean varieties for number of primary branches was also reported by Yehuala *et al* 2018. He also reported different performance of Mung bean varieties at different locations for branch bearing.

Mean performances of varieties for plant height at Abaya ranged from 28.44 to 29.978cm with location mean of 29.07cm; whereas 28.9cm to 35.91cm with location mean of 33.988cm at Yabello (table 5 and 6). Reported the performance of mung bean varieties for plant height ranged from 30.00cm to 34.67cm (Teame *et al*., 2017). Mung bean varieties attained higher plant height at Yabello than at Abaya.

Yield and yield components

The variation of varieties for pods number per plant and seeds number per plant ranged from 9.11 to 14.267; and 364.44 to 680.67, respectively at Abaya. The variation of these two traits ranged from 11.00 to 21.018 and 219.67 to 452.11, respectively at Yabello. Rasa had significantly higher pods number per plant and seeds number per plant at Abaya while MH-97-6 had higher pods number per plant and seeds number per plant at Yabello (Table5 and 6). Other Authors (Aklilu *et al*., 2020, Fantaye *et al*., 2019 and Habte, 2018) also reported similar findings for number of pods per plant and seeds per plants in mung bean varieties. The pooled over two years mean grain yield of Mung bean varieties ranged from 267 kg to 1079.3kg; 286.34 kg - 621.66kg at Yabello and Abaya, respectively (table 5 and 6). At Yabello, significantly highest mean grain yield was recorded from MH-1 (1079.3kg/ha) followed by NVL (872.1kg/ha) and the lowest mean grain yield was obtained from Hardeke (267 kg /ha). At Abaya the highest grain yield was obtained from variety Rasa (621.66kg/ha) followed by NVL (555.67kg/ha) and the lowest grain yield was measured from Hardeke (286.34kg/ha). Three varieties gave grain yields greater than mean grain yield of varieties at Yabello and two varieties had grain yield greater than mean yield of varieties at Abaya (table 5 and 6). In Ethiopia, Teame *et al*., 2017 was previously reported the performance of Mung bean varieties for grain yield from 379.7kg/ha to 1362.5kg/ha.

Table 5: Mean value of yield and yield related traits of 5 Varieties of Mung bean tested at Yabello in 2018, 2019 and 2020 G.C cropping season

Varieties	FD	MD	NPB	PHT(cm)	PPP	SPP	GYHakg
Rasa	45.22b	91.556ab	2.972ab	35.4a	17.716ab	427.11a	762.6b
MH-1	47.00a	92.667a	3.233a	35.911a	21.018a	452.11a	1079.3a
NVL	44.00bc	91.556ab	2.872ab	34.906a	11.631bc	397.89ab	872.1ab
Hardeke	45.22b	89.444b	2.017c	28.9b	11.002c	219.67c	267c
Chinese	43.00c	86.222c	2.622b	34.822a	12.8bc	292.22bc	812.9b
mean	44.89	90.29	2.743	33.988	14.833	357.8	758.777
Ranges	43.00-47.00	86.22-92.667	2.017-3.233	28.9-35.91	11.00-21.018	219.67-452.11	267-1079.3

Means with the same letters in the same columns are not significantly different ns,* ,**&***,non-significant, significant at P<0.05, P<0.01 and P<0.001, respectively. DF= degree of freedom, FD= days to flowering, GY (kg/ha) = Grain yield in kilogram per hectare, MD= days to maturity, PH (cm) = plant height in centimeter, NPB= number of primary branch, PPP= pods per plant, SPP= Seeds per plants

Table 6: Mean value of yield and yield related traits of 5 Varieties of Mung bean tested at Abaya in 2017, 2018 and 2019 G.C cropping season

Varieties	FD	MD	NPB	PHT	PPP	SPP	GYHakg
Rasa	47.89a	91.11a	3.578a	29.978	14.267a	680.67a	621.66a
MH	47.22a	91.22a	3.267ab	28.444	13.822a	559.78ab	468.53ab
NVL	47.11a	91.67a	2.489b	28.489	10.067b	446.78bc	555.67a
Hardeke	44.78b	86.11c	2.889ab	29.333	12.867a	573.89ab	286.34b
Chinese	44.33b	88.56b	2.8ab	29.111	9.111b	364.44c	432.99ab
Mean	46.266	89.73	3.00	29.07	12.03	525.1	473
Range	44.33-47.89	86.11-91.67	2.489-3.578	28.44-29.978	9.11-14.267	364.44-680.67	286.34-621.66

Means with the same letters in the same columns are not significantly different ns,* ,**&***,non-significant, significant at P<0.05, P<0.01 and P<0.001, respectively. DF= degree of freedom, FD= days to flowering, GY (kg/ha) = Grain yield in kilogram per hectare, MD= days to maturity, PH (cm) = plant height in centimeter, NPB= number of primary branch, PPP= pods per plant, SPP= Seeds per plants

Conclusions and Recommendations

The results of this investigation showed significant variation among varieties for all traits as well as significant effect of varieties by year interaction at both location for grain yield and most yield related traits, which indicated the differential performance of varieties across years. The highest Mung bean mean grain yield was showed by MH-1 (1079.3kg/ha) followed by NVL (872.1kg/ha) at Yabello and Rasa had significantly highest mean grain yield ((621.66kg/ha)) at Abaya with about three varieties provided mean grain yield greater than grand mean at Yabello and two varieties provided greater grain yield than pooled mean over years at Abaya. MH-1 variety is significantly high yielding variety at Yabello with 29.697% yield advantage over pooled mean and Rasa is high yielding variety (621.66 kg/ha) with 23.91% yield advantage over pooled mean at Abaya. The prominent Mung bean varieties MH-1 and NVL at Yabello and Rasa at Abaya are promising varieties due to their relatively good yield advantages and some considerable traits. Therefore, farmers, agro pastoralist, investors and other mung bean producers around study areas and similar agro ecologies can use those varieties for production.

References

Afzal MA, Murshad AN, Bakar MA, Hamid A, and Salahuddin ABM. Mungbean Cultivation in Bangladesh, Pulse Research Station, Bangladesh Agricultural Research Institute, Guipure, Bangladesh. 2008.

Anjum MS, Ahmed ZI, and Rauf CA. “Effect of Rhizobium inoculation and nitrogen fertilizer on yield and yield components of moonbeam,” International Journal of Agriculture and Biology, 2006;8(2):238– 240.

Asfaw A., F. Gurum1, F. Alemayehu1, and Y. Rezene, 2012. Analysis of Multi-environment Grain Yield Trials in Mung Bean *Vigna radiate* (L.) Wilczek Based on GGE Bipot in Southern Ethiopia. *Journal of Agricultural Science Technology. Vol. 14: pg. 389-398*

Ebert, A.W. Potential of underutilized traditional vegetables and legume crops to contribute to food and nutritional security, income and more sustainable production systems. Sustainability 2014, 6, 319–335.

EPP (Ethiopian Pulses Profile), "Ethiopian export promotion agency, product development & market research directorate, May 2004 Addis Ababa, Ethiopia," 2004.

Fantaye Belay, Hintsa Meresa, Shambel Syum and Atsbha Gebresilasie, 2019. Evaluation of improved mung bean (*Vigna radiata* L.) varieties for yield in the moisture stress conditions of Abergelle Areas, Northern Ethiopia. *Journal of Agricultural Science and Practice*. 4(4), pg 139-143

Gomez, K. A. and Gomez, A. A., 1984. *Statistical procedures for agricultural research*. 2nd ed. New York,USA.: John Willey and Sons Ltd., p. 680

Habte Umata. 2018. Evaluation of Adaptability of Mung Bean Varieties in Moisture Stress of Eastern Harerghe Zone. Agri Res & Tech: Open Access J. 13 (2). Pg. 49-52

Ketinge J, Easdown W, Yang A, Chadh R. and Shanmugasundaram M.S. Euphytica, 2011;180:129-141.

Melese Lema,Bililign Mekonnen and Getachewu Gudero, 2018. Performance and Growth Analysis of Three Mungbean (*Vigna Radiate* (L.) Wilczek) Genotypes at Hawassa, Ethiopia. *International Journal of Horticulture and Agriculture*. Pp. 1-4

Mequannit Aklilu and Tefera Abebe. 2020. Adaptation study of mung bean (*Vigna radiata*) varieties in tepi, south wester Ethiopia. *Asian Journal of Plant Science and Research*, 2020, 10(5):58-61

Rachie KO, Roberts LM. Grain legumes of the lowland tropics. Adv. Agron. 1974;26:1-132.

Teame Gereziher, Ephrem Seid, Lemma Diriba and Getachew Bisrat. 2017. Analysis of Multi-environment Grain Yield Trials in Mung Bean *Vigna radiate* (L.) Wilczek Based on GGE Bipot in Southern Ethiopia. Adaptation Study Of Mung Bean (Vigna Radiate) Varieties

In Raya Valley, Northern Ethiopia. Current Research in Agricultural Sciences. *Vol. 4(4,) pp. 91-95*

Yehuala Kassa, Daneil Admasu, Abiro Tigabe, Amsalu Abie and Dejene Mamo. 2018. Participatory on farm evaluation of improved mungbean technologies in the low land areas of North Shewa Zone Amhara Region, Ethiopia. *Journal of Agricultural Extension and Rural Development*. pp. 158-164

Tang, D.; Dong, Y.; Ren, H.; Li, L.; He, C. 2014.A review of phytochemistry, metabolite changes, and medicinal uses of the common food mung bean and its sprouts (Vigna radiata). Chem. Cent. J., (8) (4).

Registration of a Newly Released Lentil (*Lens Culinaris. M*) Variety "Debine" for Highland Areas of Bale, Southeastern Ethiopia and other similar agro-ecologies in the country.

Amanuel Tekalign*, Tadele Tadesse, and Belay Asmare

Oromia Agriculture Research Institute, Sinana Agriculture Research Center, Bale-Robe, Ethiopia

Abstract

The development of new varieties with high yield and acceptable levels of stability is an important in breeding program. The performance of a given genotype depends on its genetic potential and the environment upon which it is grown. Debine is a commercial name given for a newly released Lentil (Lens culinaris) variety with pedigree designation of 'DZ -2012-LN-0051' was released in 2021 for highland areas of Bale, Southeastern Ethiopia, and similar agro ecologies. The variety has been registered by Sinana Agricultural research center and it was tested at better representative environments (Sinana and Agarfa) representing highland (2300 to 2600) meter above sea level) agro-ecologies during 2016 to 2018 main cropping season. The variety is mainly characterized by its superior mean grain yield as compared from standard check Asano based on different yield measurement and stability testing parameters across locations and over years. It also had comparable resistance/tolerant level to major Lentil diseases such as Aschocyta blight, Rust and Root Rot. Debine has dark gray seed color and could be cultivated across a number of locations in the highlands of Bale and other similar agro-ecologies for increasing productivity of the crop.

Keywords: Disease resistance, Grain yield, Lentil (*Lens culinaris*), stability, Variety Registration

Introductioon

Lentil (*Lens Culinaris* Medikus.; Fabaceae) is an autogamous, diploid (2n = 2x = 14), self-pollinated and annual cool season grain legume with ~4 Gbp genome size (Toklu *et al*., 2009; Ates *et al*., 2016). It is one of the first agriculture crop grown more than 8500 years ago (Aghili *et al*., 2012). Its annual production is ~5 million ton globally and Canada, India, Turkey, USA, Nepal, Australia, Ethiopia, Bangladesh, Kazakhstan is the major lentil producing countries of the world sequentially. Approximately 50% of world's lentils are grown in South Asia, and nearly 1.5 billion people in this area consume ~70% of the global lentil supply (Ates *et al*., 2018a;

Shrestha *et al.*, 2018). Lentil is recognized as one of the most nutritious pulse crops ranking next to chickpea among cool-season food legumes. It contains 57-60% carbohydrate, 24-26% protein. It is also a rich source of minerals containing calcium (69 mg per 100g), phosphorus (300 mg per 100g) and Iron (7 mg per 100gm) of seed (Erskine *et al.*, 2004). Lentil seed contains lysine, an essential amino acid, found only at low levels in cereal protein. Lentil is a valuable human food, mostly consumed as dry seed as well as used as fodder, and generally grown as a crop rotation after cereals to enrich the soil by their nitrogen fixing ability (Duran *et al.*, 2004).

Because of its significant economic role and social conditions, lentil production has recently been expanding in both stressed and non-stressed environments. In Ethiopia in 2017 cropping season, the total area of production of pulse crops is about 2,092,357.57 hectares and the total production was 328,734.78ton. Among these pulse crops, lentil covered 124,915.16 hectares with production of 170.09ton. The national productivity of lentil was 1.35 t ha^{-1} (CSA, 2018), which was far below the potential yield of the crops and productivity in different parts of the world. The reason for this yield gap is mainly due to poor genetic makeup of the available cultivars, and other biotic and abiotic factors. Therefore, the objective of this study was to register stable high yielding and disease resistant/tolerant Lentil variety for highlands Bale and other similar agro-ecologies in Ethiopia.

Materials and Methods

Descriptions of Experimental sites

The experiment was conducted at two potential areas of Bale Zone, Sinana and Agarfa in South Eastern Ethiopia. Description of the study sites at Regional Variety Trail is given below.

Table 1 Description of the test locations for geographical position and physico-chemical properties

	Location	
Parameter	Sinana	Agarfa
Geographical position		
Latitude	07º 07’ N	07º15’44’’N
Longitude	40º 10’00’’E	039º50’38’’E
Altitude (m.a.s.l.)	2400	2509
Soil property		
pH	6.2	6.3
Texture	Clay	Clay loam
OMC (%)	3.9	3.4
Total N (%)	0.24	0.2
Pav(ppm)	30.4	32.41
K(mg/Kg)	240	572
CEC (meq/Kg)	64.4	71.5
Moisture Regime	SH2	SH2

Key: OMC = Organic matter content, N = Nitrogen, Pav = Phosphorus availability, K = Potassium, CEC = Cation exchange capacity, SH2 = Sub-humid tepid to cool sub-humid mid-highlands.

Breeding Procedures

Adapted Lentil line “Dz-2012-Ln-0051, which was selected from the last stage of variety trial. The crossing was done at Debre Zeit Agricultural Research Center. Screen houses were routinely used in the early generations, i.e., F1, F2, F3 and F4, of a breeding cycle. During these phases, selection for traits with high heritability such as; seed size, grain yielding ability, plant habit, time of flowering and resistance to major diseases were undertaken. Thirty-six individual lines selected from the F5 generation were evaluated for yielding ability, large seed size, disease reaction and stability in preliminary yield trial (PYT) conducted at Sinana Agricultural Research Center. From this trial, 15 promising genotypes were promoted and evaluated in a regional variety trial (RVT) along with standard checks 'Asano' at multi-locations (Sinana and Agarfa) during 2016 to 2018 main cropping seasons. Lastly, Dz-2012-Ln-0051 and Dz-2012-Ln-0085 were selected as the most promising candidate varieties and verified along with best standard checks 'Asano' on 10 m x 10 m plots, and evaluated by the national variety release technical committee, each one on-station and two on-farm fields during the 2020/21 cropping season. Finally, the committee decided the first genotypes coded as Dz-2012-Ln-0051, and named "Debine", for official release.

Results and Discussions

Agronomic and Morphological Characteristics

In an attempt to develop Debine, higher yield, and resistance to major lentil diseases were important traits of consideration. The newly released Lentil variety 'Debine' is characterized by an erect growth habit. Its flower color is light Pink. The seed coat and cotyledon colors are dark gray and light red, respectively. The average number of days required to reach its 50% flowering and 95% physiological maturity were 62 and 122, respectively, with the average plant height being 32 cm (Table 2). The average number of pods per plant is 33 (Table 4). It has good general acceptance for lentil with high quality. The appropriate planting date for this variety would range from end of July to early August (Table 2).

Yield and Quality Performance

Highly significant variations among Lentil genotypes were observed throughout the trial evaluation. Debine consistently out-yielded other tested Lentil genotype over three years. Combined location over years analysis revealed that it had produced an average yield of 22-25 Q/ha at Research field and 14-16 Q/ha on farm yield. This means that the grain yields of Debine was found to be 29.76% yield advantage over standard check Asano (Table 4). Debine offers new hope for resource poor farmers in study areas and other similar agro ecology.

Reaction to Major Diseases

Developing Lentil cultivars with high yielder, resistant or tolerant varieties to major lentil diseases such as Ascochyta lentis *(ascochyta blight)*, Rust (Uromyces viciae-fabae) and Root Rot is among the major objectives of the Lentil breeding program. Accordingly, above mentioned disease is among the major bottleneck for Lentil production in Southeastern part of the country, Bale. Disease data across location and years were scored and analyzed. Debine variety showed resistance to moderate resistance to the above-mentioned diseases throughout the field evaluation periods (Table 5).

Performance Stability and Adaptation Domain

The variety 'Debine' was released for high altitude agro-ecologies of the country receiving 750-to-1000 mm average annual rainfall. It is well adapted to an altitude range of 1800 – 2600 meters above sea level such as Sinana, Goba, Agarfa, Gassera, Goro (Meliyu), Adaba, Dodola and other similar agro-ecologies (Table 2). Based on most stability parameters, 'Debine' showed relatively comparable performance stability across a range of environments (Table 4).

Variety Maintenance

The breeder and foundation seed will be maintained by Sinana Agricultural Research Center/ Oromia Agricultural Research Institute.

Table 2. Agronomical and Morphological Characteristics and Agro-ecological Zones of Adaptation of Debine, Lentil variety

No	Variety name:		Debine (DZ-2012-LN-0051)
1	Adaptation area		Sinana, Goba, Agarfa, Gassera, Goro (Meliyu), Adaba, Dodola and other similar agro-ecologies
2	Altitude (m.a.s.l.)		1800 – 2600
3	Rainfall (mm)		750 – 1000
4	Seed Rate (Kg/ha)		65
5	Planting date		End of July to Early August
6	Days to Flower		62
7	Days to Maturity		122
8	Plant Height (cm)		32
9	Growth habit		Erect
10	1000 Seed Weight (gm)		3.7
11	Seed Color		Dark gray
12	Cotyledon Color		Light red
13	Seed size		Large
14	Flower Color		Light Pink
15	Yield	Research Field	22-25
	(Qt/ha)	On-farmer's field	14-16
16	Disease reaction		Tolerant to rust, wilt and Aschochyta blight
17	Yield advantage over Asano (%)		29.76
18	Year of Release		2021
19	Breeder and Maintainer		SARC/ IQQO

Table 3. Mean grain yield(kg/ha) of 17 Lentil genotypes across locations and years

Entry	Sinana			Agarfa			Mean	Yield Adv. over St. check
	2016	2017	2018	2016	2017	2018		
DZ -2012-LN-0051	1810	2404	3364	1690	1458	1623	2058	29.76%
DZ -2012-LN-0057	916	2018	3441	766	933	2113	1698	
DZ -2012-LN-0059	1363	2375	3308	614	694	861	1536	
DZ -2012-LN-00118	1484	2581	3089	1574	1412	1640	1963	
FLIP-96-49L	1384	2347	3278	1498	1272	1142	1820	
DZ -2012-LN-0038	1480	2360	3084	1991	1036	1338	1881	
DZ -2012-LN-00107	1408	2195	3300	2003	987	1175	1845	
DZ -2012-LN-0058	1220	1857	2853	1425	884	993	1539	
DZ -2012-LN-0048	1505	2542	3457	1195	916	1461	1846	
FLIP-97-33L	1194	2398	3021	1467	1138	1870	1848	
DZ -2012-LN-0065	1621	2329	3003	1173	611	1118	1643	
FLIP-86-38L	1635	2289	3614	1939	1135	1170	1964	
FLIP-89-19L	1284	1788	2323	1569	675	1885	1587	
DZ -2012-LN-0095	1715	2746	2678	1648	1019	2055	1977	

DZ -2012-Ln-0085	1882	2836	3237	1838	1582	2496	2311
Asano (St. check)	1211	1634	2020	1525	1032	2095	1586
Local check	1805	1901	1345	1544	763	574	1322
Means	1466	2271	3136	1498	1032	1506	1790
LSD (<0.05)	479.5	590.0	907.5	565.2	634.6	716.1	291.9
C.V	23.0	18.0	20.0	22.5	23.0	23.0	20.6

Table 4. Mean Seed yield and other agronomic traits for 17 lentil genotypes tested in regional Variety Trial combined over two locations (Sinana and Agarfa) over three years (2016-2018)

Entry	DF	DM	Stand %	PH (cm)	NPP	NSP	HSW (g)	SY (kg/ha)
DZ -2012-LN-0051	62	122	76	32	33	1	3.7	2058
DZ -2012-LN-0057	64	126	77	34	31	1	4.0	1698
DZ -2012-LN-0059	63	125	75	33	37	1	3.1	1536
DZ -2012-LN-00118	61	122	78	31	33	1	3.6	1963
FLIP-96-49L	62	123	75	31	36	1	3.5	1820
DZ -2012-LN-0038	62	123	78	31	33	1	3.6	1881
DZ -2012-LN-00107	62	123	79	31	33	1	3.6	1845
DZ -2012-LN-0058	61	125	74	31	35	1	2.7	1539
DZ -2012-LN-0048	61	124	76	32	37	1	3.2	1846
FLIP-97-33L	62	123	76	32	35	1	3.4	1848
DZ -2012-LN-0065	61	125	77	35	36	1	3.0	1643
FLIP-86-38L	62	122	77	32	31	1	3.6	1964
FLIP-89-19L	61	125	79	32	30	1	3.6	1587
DZ -2012-LN-0095	63	125	78	34	39	1	2.7	1977
DZ -2012-LN-0085	62	125	79	34	37	2	2.8	2311
Asano (St. Check)	61	124	77	31	32	1	3.7	1586
Local check	62	122	74	33	33	1	2.4	1322
Mean	62	124	77	32	34	1	3.3	1790
LSD (<0.05)	0.8	1.2	3.3	2.0	7.7	0.2	0.1	291.9
CV%	2.4	1.7	7.5	10.8	23.9	22.6	7.1	20.6

Table 5. Mean seed yield, agronomic traits and disease reaction of 'Debine' along with standard and Local checks tested in two environments at varietal verification levels during 2015-2017cropping seasons.

	Agronomic traits								Disease Reaction (1-9)		
Entry	DF	DM	Stand %	PH (cm)	NPP	NSP	HSW (g)	SY (kg/ha)	ASB	Rust	RR
DZ -2012-LN-0051	62	122	76	32	33	1	3.7	2058	4	3	3
Asano	61	124	77	31	32	1	3.7	1586	5	3	4
DZ -2012-LN-0085	62	125	79	34	37	2	2.8	2311	4	3	3
Local check	62	122	74	33	33	1	2.4	1322	5	5	4

Note: DF = days to 50% maturity, DM, days to 90% maturity, PH = plant height(cm), NPP = Number of pods per plant, NSP =Number of seed per plant, HSW = Hundred seed weight(g), GY = grain yield(kg), ASB = Aschocyta Blight, RR = Root Rot

Conclusions and Recommendations

Grain yield is the primary trait of interest and a prime objective in Lentil breeding programs for many decades. “Debine” produced high yield, and it had a more stable performance in seed yield over locations and years than the standard check variety. The current variety, Debine has 29.76% yield advantages over the widely cultivated lentil varieties, Asano. Therefore, wide cultivation of Debine variety will boost productivity and marketability of the crop and improve farmers’ income. Debine was resistant to major diseases of Lentil that prevailed in the growing areas. Farmers also preferred the variety for its superior performance over the existing local variety, which is manifested by good plant height, better pods load and number of branches per plant. Hence, Debine was verified and officially released for large scale production in major Lentil growing areas of Bale highland and other similar agro-ecologies.

Acknowledgement

The authors would like to thank Oromia Agricultural Research Institute for funding the research throughout the varietal development process. They also thank all staff members of the Pulse and Oil crops research case Team of the Sinana Agricultural Research Center for their unreserved efforts in field trail management and data collection during the experimental period.

References

Aghili, Parisa. "Study of correlation and relationships between seed yield and yield components in Lentil (Lens culinaris Medik)." *Ann. Biol. Res* 3.11 (2012): 5042-5045.

Ates, D., S. Aldemir, B. Yagmur, A. Kahraman, H. Ozkan, A. Vandenberg and M. B. Tanyolac. 2018a. QTL Mapping of Genome Regions Controlling Manganese Uptake in Lentil Seed. G3: Genes, Genomes, Genetics 8(5):1409-1416.

Ates, D., T. Sever, S. Aldemir, B. Yagmur, H. Y. Temel, H. B. Kaya, A. Alsaleh, A. Kahraman, H. Ozkan, A. Vandenberg and B. Tanyolac. 2016. Identification QTLs controlling genes for se uptake in lentil seeds. PLoS One 11: e0149210.

Central Statistical Agency (CSA), "Report on area and production of major crops (private peasant holdings, meher season)," Statistical Bulletin, vol. 532, pp. 15-17, 2018.

Duran Y, Fratini R, Garcia P, De La Vega MP. An inter subspecific genetic map of Lens. Theoretical and Applied Genetics. 2004; 108: 1265- 1273

Erskine W, Sarker A. Lentil. In Corke H, Walker CE, editor. Encyclopedia of Grain Sciences. London. UK: Elsevier; 2004. Pp. 142- 150

Shrestha, R., Rizvi, A. H. Sarkar, A. Darai, R. Paneru, R. B. Vandenberg, A. and Singh, M. 2018. Genotypic Variability and Genotype x Environment Interaction for Iron and Zinc Content in Lentil under Nepalese Environments. Published in Crop Sci. 58:2503–2510 (2018).

Toklu, F., T. Karakoy, E. Haklı, T. Bicer, A. Brandolini, B. Kilian and H. Ozkan. 2009. Genetic variation among lentil (Lens culinaris Medik) landraces from Southeast Turkey. Plant Breeding 128: 178-86.

Stability Analysis of Durum Wheat (*Triticum durum* Desf.) Genotypes at Southeastern Oromia

Tilahun Bayisa[1]*, *Mulatu Abera*[1]

[1]Sinana Agricultural Research Center, P.O.Box: 208, Bale Robe, Ethiopia

Abstract

The improved genotypes evaluated in multi-environment trials to test their performance across different environmental conditions. Yield stability has been described as yield consistency across years and locations. AMMI analysis allow characterizing the environment according to more variables and explaining a larger portion of the GxE The objective of this study was to select and identify stable and high yielding durum wheat genotypes for highland to mid-altitude of Bale and similar agroecololgy. The field experiment was conducted at three locations including Sinana, Agarfa and Ginnir during 2019 and 2020 main cropping seasons. The experimental materials comprised of twenty durum wheat genotypes including three checks. The result shows that genotype had the largest effect, explaining 44.2% of total variability, while environment and GE interaction explained 32.8% and 23.0% of total sum of squares. Mean comparison for the tested genotypes indicated that maximum grain yield was obtained from Genotype-2 (4.13 tha^{-1}) followed by Genotype-11 (4.07 tha^{-1}). The first two principal component axis of genotype by environment interaction (G×E) accounts 59.4% and 21.7% of the genotype by environment interaction (G×E), respectively, together explaining 81.1% of the total variation. The AMMI model IPCA1 and IPCA2 scores of grain yield for each durum wheat genotypes and the corresponding AMMI stability value (ASV) shows that test genotypes Genotype-10, Genotype-8 and Genotype-2 were the most stable genotypes with AMMI stability values (ASV) of 0.11, 0.13 and 0.16, respectively. Based on Genotype Selection Index (GSI) in the present study the most stable and high yielding exhibited by genotypes Genotype-2, Genotype-8 and Genotype-11. Therefore Genotype-2 and Genotype-11 were identified as candidate genotypes to be verified for possible release.

Keywords: AMMI; ASV; Durum wheat; Stability; Grain Yield;

Introduction

Durum wheat (*Triticum durum* Desf.) produced in most parts of Ethiopia. Durum wheat is among the diversified crop species, about 12% (about 7000 accessions) of the Ethiopian national gene bank holding constituted durum wheat (Mengistu & Pè, 2016). Ethiopia is among very few countries endowed with highly suitable environmental conditions to produce durum wheat (Legesse, 2017). The Ethiopian farmers have cultivated durum wheat for long years. Durum wheat is traditionally grown by small-scale farmers on heavy black soils (vertisols) at altitudes ranging from 1800 to 2800 meters above sea level, exclusively under rain-fed conditions.

The grain of durum wheat is mainly required for the manufacturing of pasta products (macaroni, spaghetti and semolina). Recently, with the current privatization policy and booming of agro industries in the country (Eshetie, 2018), there is a rising demand for durum wheat grains for the manufacturing of pasta and macaroni products. Due to the shortage of durum wheat grains in the country, pasta and macaroni-processing factories imported durum wheat grains from abroad to satisfy their annual durum wheat grains demand, costing the country a lot of foreign currency.

The improved genotypes evaluated in multi-environment trials to test their performance across different environmental conditions. In most trials, crop yield fluctuates due to suitability of genotypes to different conditions which is known as genotype × environment interaction (G×E) (Kang, 1998). Yield stability has been described as yield consistency across years, while adaptation refers to the ability of genotype to perform well across locations (Lin and Binns, 1988). Information regarding crop stability is applicable for selection of genotypes with constant yield across environments. Many of researchers have been reported to depict the responses of genotypes to the different condition of environments for simultaneous selection of yield and stability. These techniques are using statistical parameters to estimate stability of genotypes to variation in environments. Linear regression approach is used widely for identifying of high yielding and stable genotypes (Alberts, 2004).

Several approaches have been proposed to dissect the genotype ´ environment (GxE) interaction to better understand it. One of the most used methods to simplify the environment component of the GxE is to characterize the environments according to the average yield of the genotypes tested in it. Linear regression models can then be fitted with the yield of every genotype at each environment and the average yield of the set of genotypes at each environment. This method, called Finlay–Wilkinson regression (Finlay and Wilkinson, 1963), is widely used to characterize the yield response to good environments of a set of genotypes. However, it allows only one type of environment characterization based on average yield. On the other hand, approaches such as the additive main effects and multiplicative model (AMMI) allow characterizing the environment according to more variables (Gauch and Zobel, 1997), such as climatic or pedological data (Sanchez-Garcia *et al.,* 2012), therefore explaining a larger portion of the GxE (Malosetti *et al.,* 2013). Additionally, the most explanatory products of the environmental and genotypic sensitivity scores can also be represented in a biplot to simplify discovery. These approaches to the GxE analysis allow characterizing the genotypes as “widely adapted” or as “specifically adapted” to one environment, group of environments, or to specific environment. A wider adapted genotype performs consistently over a wider range of environment. Therefore, the objective of this study was to select and identify stable and high yielding durum wheat genotypes for highland to mid-altitude of Bale and similar agroecololgy.

Materials and Methods

Description of Experimental Areas

The field experiment was conducted at three locations including Sinana, Agarfa and Ginnir during 2019 and 2020 main cropping seasons. Sinana is characterized by bimodal rainfall pattern and annual total rainfall ranges from 750 to 1400 mm (Table 1). The main season receives 270 to 842 mm rainfall, while the short season receives from 250 to 562 mm. Agarfa is located at 07°26′ N latitude and 39°87′ E longitude with an elevation of 2510 m.a.s.l. Its total annual rainfall ranges from 1000 to 1451 mm. The mean annual minimum and maximum temperatures

7.3 and 22.8°C, respectively. The experiment at both locations was conducted during the main cropping season. Ginnir is 519 km away from Addis Ababa, 86 km away from capita of Bale zone, Robe town. Ginnir is located at 07º 15'N latitude and 40º 66'E longitude at 1972 m above sea level. The seasonal rainfall is 531 mm and its mean annual minimum and maximum temperature 13.4 and 25.5ºC, respectively. Year by location combination is being considered as environment.

Table 1. Environmental description of the study area of 20 durum wheat Genotypes

Locations	Geographical position			Temperature		Annual Rainfall (mm)	
	Latitude	Longitude	Altitude	Min.	Max.	Min.	Max.
Sinana	07°07′ N	40°10′ E	2400	9.6	20.7	750	1400
Agarfa	07°26′ N	39°87′ E	2510	7.3	22.8	1000	1451
Ginnir	07º 15'N	40º 66'E	1972	13.4	25.5	700	1200

Experimental Materials and Design

The experimental materials comprised of twenty durum wheat genotypes including two released durum wheat varieties *viz.* Dire, Bullala, Local check (Inglize) and 17 advanced durum wheat genotypes. The experiment was laid out in Randomized complete block design with three replications having plot size of six rows of 0.2 m spacing and 2.5 m length (total area of the plot was $3m^2$). Four central rows were harvested for grain yield computations. For statistical analysis, yield from net plot area of $2m^2$ was harvested and converted into ton ha^{-1} base at 12% standard grain moisture content. Seed rate of 150 kg ha^{-1} and fertilizer rates of 100 kg/100 kg ha^{-1} were used.

Statistical analysis

Mean grain yield data of the experiment were statistically treated by AMMI model analysis. This analysis consists in the sequential fitting of a model of analysis of experiments, initially by ANOVA (additive fitting of the main effects) and then by analysis of principal components (multiplicative fitting of the effects of interaction). The model AMMI equation is:

$$Y_{ij}=\mu+g_i+e_j+\sum_{n=1}^{h}\lambda_n\alpha_{ni}.Y_{nj}+R_{ij}$$

Where ij Y is the yield of the ith genotype in the jth environment; μ is the grand mean; i g and je are the genotype and environment deviations from the grand mean, respectively; λ_n is the square root of the eigen value of the principal component Analysis (PCA) axis, α_{ni} and Y_{nj} are the principal are the principal component scores for the PCA axis n of the ith genotype and jth environment, respectively and R_{ij} is the residual. The analysis was done using R software (R for windows) version 4.1.

AMMI Stability Value (ASV)

The ASV is the distance from the coordinate point to the origin in a two dimensional of IPCA1 score against IPCA2 scores in the AMMI model (Purchase *et al.,* 2000). Because of the IPCA1 score contributes more to the GE interaction sum of square, a weighted value is needed. This weight is calculated for each genotypes and environment according to the relative contribution of IPCA1 to IPCA2 to the interaction SS as follows:

$$ASV = \sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA\ Score)\right]^2 + [IPCA2]^2}$$

Where, SSIPCA1/SSIPCA2 is the weight given to the IPCA1 value by dividing the IPCA1 sum squares by the IPCA2 sum of squares. The larger the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller IPCA score indicate a more stable genotype across environment.

Genotype Selection Index (GSI)

Based on the rank of mean grain yield of genotypes (rYSI) across environments and rank of AMMI Stability Value (rASV) a selection index GSI was calculated for each genotype which incorporate both mean grain yield and stability index in a single criterion (GSI) as suggested by Bose *et.al*., (2014) and Bavandpori *et.al*., (2015).

GSI = rASV + rYSI

Results and discussions

Genotype Evaluation

Homogeneity of variance tests indicated homogenous error variance for grain yield in the six environments allowed for a combined analysis across environments. The combined analysis of variance indicated that the main effects of random environments and fix genotypes were significant for grain yield that exhibiting the presence of variability in genotypes and diversity of growing conditions at different environments. The combined analysis of variance was conducted to determine the effects of environment (location), genotype, and their interactions on grain yield of durum wheat genotypes (Table 3). The main effects of environment (E), genotypes (G) and GE interaction were highly significant at $P < 0.01$. Genotype had the largest effect, explaining 44.2% of total variability, while Environment and GE interaction explained 32.8% and 23.0% of total sum of squares, respectively (Table 3). A large contribution of the genotype indicated that genotypes were diverse, with large difference among genotype means causing most of the variation in grain yield and higher differential in discriminating the performance.

Mean grain yield of genotypes was highest at Ginnir in 2020 cropping season followed by Agarfa 2020 and Sinana in 2019 cropping season. Similarly, the lowest mean grain yield of genotypes was observed at Agarfa in 2019 (Table 2). The average grain yield of genotypes across location and year ranged from the lowest 0.2 t ha^{-1} at Sinana 2019 to the highest 5.4 t ha^{-1} at Ginnir 2020, with a grand mean of 3.0 t ha^{-1} (Table 2). The observed genotypes means grain yield across environments ranged from the lowest 2.2 t ha^{-1} for Agarfa to 4.0 t ha^{-1} for Ginnir 2020 (Table 2). Mean comparison for the tested genotypes indicated that maximum grain yield was obtained from Genotype-2 (4.13 tha^{-1}) followed by Genotype-11 (4.07 tha^{-1}) and Genotype-12 (3.53 tha^{-1}), whereas the least mean grain yield was obtained from Genotype-1 (1.55 t ha^{-1}). The result showed that only five genotypes had higher mean grain yield than standard check Dire (3.23 tha^{-1}).

Table 2. Mean performance of 20 durum wheat genotypes in 6 Environments in $tonha^{-1}$

SN	Genotype Code	Year 2019			Year 2020			Mean
		Sinana	Agarfa	Ginnir	Sinana	Agarfa	Ginnir	
1	G1	0.2	0.5	1.6	1.4	2.8	2.8	1.55
2	G2	4.5	3.6	4.0	3.9	3.9	4.9	4.13
3	G3	2.1	2.0	3.0	3.4	3.1	4.5	3.02
4	G4	1.5	1.8	2.4	2.6	2.5	4.1	2.48
5	G5	2.0	1.3	2.8	2.5	2.8	4.5	2.65
6	G6	3.4	2.5	2.8	2.0	2.6	3.9	2.87
7	G7	3.3	2.4	3.8	3.0	2.7	4.9	3.35
8	G8	3.4	2.7	3.0	2.8	3.2	4.5	3.27
9	G9	3.9	2.7	2.7	3.4	3.3	3.5	3.25
10	G10	2.8	2.1	2.8	3.0	3.4	4.1	3.03
11	G11	4.3	3.4	3.9	3.8	3.6	5.4	4.07
12	G12	4.0	2.6	3.4	3.6	2.8	4.8	3.53
13	G13	3.9	2.0	2.9	3.1	2.9	3.7	3.08
14	G14	2.6	1.8	3.1	3.0	3.2	4.1	2.97
15	G15	2.8	2.4	2.8	3.7	3.5	3.9	3.18
16	G16	3.4	2.2	2.6	2.7	3.4	4.0	3.05
17	G17	0.8	0.4	1.9	0.7	2.2	3.4	1.57
18	G18	3.8	3.1	3.0	3.3	3.4	2.8	3.23
19	G19	3.6	2.5	3.2	3.0	3.2	3.4	3.15
20	G20	4.2	2.3	2.8	3.6	3.2	3.4	3.25
Mean		3.0	2.2	2.9	2.9	3.1	4.0	3.0
LSD 0.05		0.895	0.749	0.721	0.832	0.965	1.282	0.370
CV (%)		21.50	24.67	17.92	20.71	22.69	23.10	22.19

AMMI Analysis

The combined analysis of variance and AMMI analysis is shown in Table 3. The first two principal component axis of genotype by environment interaction (G×E) accounts 59.4% and 21.7% of the genotype by environment interaction (G×E), respectively, together explaining 81.1% of the total variation (Table 3). This was in agreement with Mattos *et al.* (2013); Regis *et al.* (2018) suggested that G×E pattern is collected in the first two principal components of analysis. Similarly, previous studies were also suggested the importance of capturing most of the genotype by environment interaction (G×E) sum squares in the first two principal component axis to attain accurate information (Crossa *et al*., 1990; Purchase *et al*., 2000).

Table 3. ANOVA for grain yield of Durum wheat genotypes for the AMMI model

Source	d.f.	SS	MSS	Explained SS%
Genotypes	19	138.0674	7.2667**	44.2
Environments	5	102.5213	20.5043**	32.8
Replication	12	11.14137	0.9284*	
Interactions	95	72.0561	0.7585**	23.0
IPCA 1	23	42.7729	1.8597**	59.4
IPCA 2	21	15.6212	0.7439*	21.7
IPCA 3	19	7.6240	0.4013	10.6
IPCA 4	17	3.7846	0.2226	5.3
Residuals	240	114.5190	0.4772	

d.f.=degree freedom, SS= Sum of square, MSS= Mean Sum of square, SS%= Percentage of sum of square, IPCA 1, 2, 3 and 4= first, second, third and fourth principal component

The first interaction principal component axis (IPCA) and mean grain yield t ha^{-1} were used to construct a AMMI biplot graph to gain sufficient information on the stability of individual genotypes in different test environments (Figure 1). The result of AMMI Biplot analysis with IPCA1 against mean grain yield (t ha^{-1}) indicated that most test genotypes were showed good stability for grain yield in most test environments. However, Genotype-1 and Genotype-17 were the most unstable genotypes. Previous studies showed that, the IPCA scores approximate to zero, the more stable the genotype is all over the test environments (Purchase *et al.*, 2000). The ideal genotype is one with high productivity and IPCA1 values close to zero, whereas the undesirable genotype has low stability associated with low productivity (Gauch and Zobel, 1988). Moreover, in this study test environment Ginnir 2020 was the most productive environment, while Agarfa 2019 was the least productive environments of durum wheat genotypes in Bale highland and mid-altitude. In the AMMI1 biplot display, genotypes or environments that fall on a perpendicular and horizontal line of the graph had similar mean yield and similar interaction, respectively. On the other hand, genotypes or environments on the left and right-hand side of the midpoint line have less and higher yield than the grand mean, respectively. Twelve genotypes including three checks found at the right side of midpoint line (above mean yield). The score and sign of IPCA-1 reflect the magnitude of the contribution of both genotypes and environments to genotype by environment interaction (G×E), where scores near zero are the characteristic of stability and a higher score (absolute value) designate instability and specific adaptation to a certain environment (Gollob, 1968).

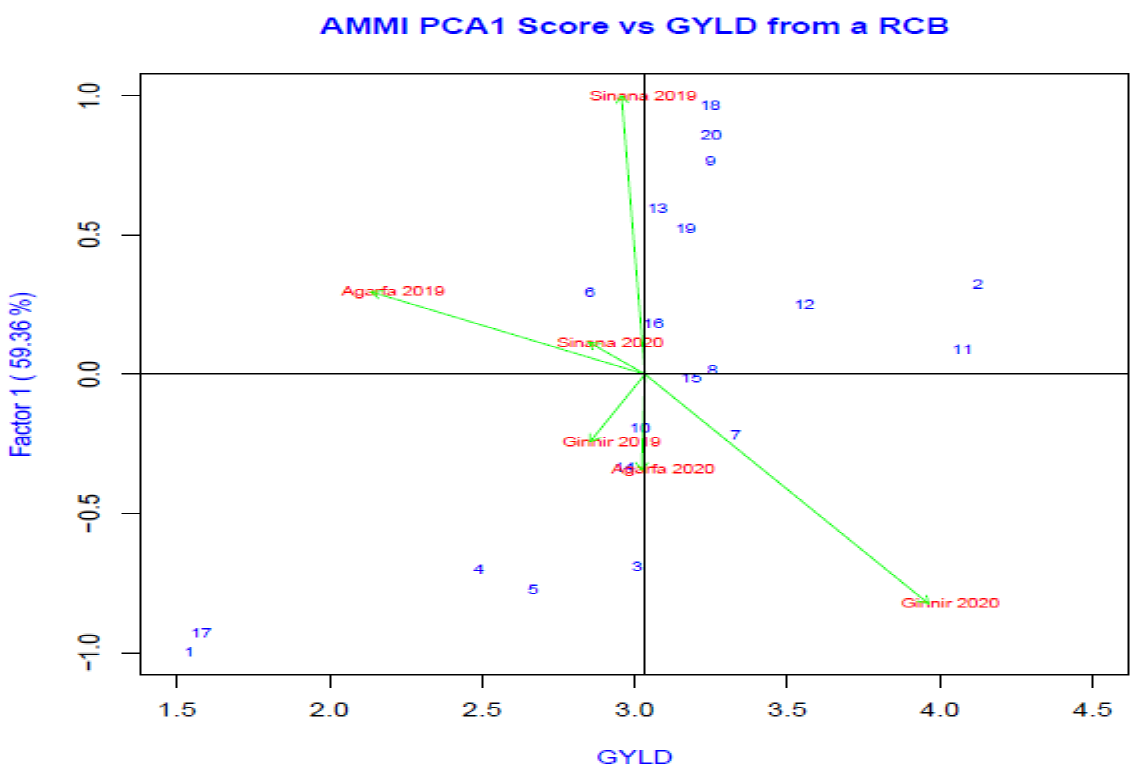


Figure 1. First interaction principal component axis (IPCA) and mean grain yield t ha^{-1}

AMMI Stability Analysis:

ASV is the distance from zero in a two dimensional scatter diagram of IPCA1 scores against IPCA2 scores. Since the IPCA1 score contributes more to the GE sum of square, it has to be weighted by the proportional difference between IPCA1 and IPCA2 scores to compensate for the relative contribution of IPCA1 and IPCA2 total GE interaction sum squares. According to this stability parameter, a genotype with least ASV score is the most stable. The high interaction of genotypes with environments was also confirmed by high ASV and rank, suggesting unstable yield across environments. In general the importance of AMMI model is in reduction of noise even if principal components don't cover much of the GE SS (Gauch, 1992; Gauch and Zobel 1996).

Table 4 Mean grain yield of 20 Durum wheat Genotypes, AMMI stability values, Genotypic selection index and coefficient of variation

Genotype	Mean	ASV	rASV	rYSI	GSI	IPCA 1	IPCA 2
G1	1.54	2.14	20	20	40	-0.7447	0.6824
G2	4.12	0.16	3	1	4	0.2414	-0.1446
G3	3.01	0.88	13	14	27	-0.5143	0.1025
G4	2.49	0.89	14	18	32	-0.5227	0.0343
G5	2.67	0.92	16	17	33	-0.5764	-0.1645
G6	2.85	0.74	12	16	28	0.2176	-0.4516
G7	3.33	0.72	11	4	15	-0.1616	-0.6168
G8	3.25	0.13	2	5	7	0.0130	-0.1930
G9	3.25	0.9	15	7	22	0.5708	0.2454
G10	3.02	0.11	1	13	14	-0.1448	0.2236
G11	4.07	0.34	6	2	8	0.0649	-0.4551
G12	3.55	0.61	9	3	12	0.1845	-0.5008
G13	3.07	0.65	10	11	21	0.4430	-0.1214
G14	2.96	0.21	4	15	19	-0.2492	0.0620
G15	3.18	0.49	8	9	17	-0.0119	0.4902
G16	3.06	0.23	5	12	17	0.1346	0.0469
G17	1.58	1.57	18	19	37	-0.6927	-0.0876
G18	3.25	1.8	19	8	27	0.7190	0.4755
G19	3.16	0.48	7	10	17	0.3899	0.1512
G20	3.25	1.19	17	6	23	0.6396	0.2213

ASV= AMMI stability value, rASV=Rank of AMMI stability value, rYSI=Rank of yield index, GSI=Genotypic selection index and CV%=coefficient of variation in percentage

The AMMI model IPCA1 and IPCA2 scores of grain yield for each durum wheat varieties and the corresponding AMMI stability value (ASV) are shown in Table 4. Based on this analysis, test genotypes Genotype-10, Genotype-8, Genotype-2 and Genotype-14 were the most stable varieties with AMMI stability values (ASV) of 0.11, 0.13, 0.16 and 0.21, respectively. Test genotypes with least AMMI stability value (ASV) from the origin are regarded as the most stable. This analysis also confirmed that Genotype-1, Genotype-18, Genotype-17 and Genotype-20 were the most unstable genotypes with AMMI stability value 2.14, 1.80, 1.57 and 1.19, respectively in the present study. The quantitative stability value called AMMI Stability Value (ASV), developed by Purchase et al. (2000) to rank genotypes through the AMMI model was considered to be the most appropriate single method of describing the stability of genotypes (Bose *et.al*., 2014; Bavandpori *et.al*., 2015; Esayas *et al.*, 2019)

However, stable genotypes would not predictably provide the best yield performance and therefore identifying genotypes with high grain yield together with consistent stability across growing environments has importance. Therefore, Genotype Selection Index (GSI) which combine both mean yield and stability in a single index have been introduced to further detect high yielding genotypes with stable yield performance, through diverse growing environments (Mohammadi and Amri, 2008). Genotype Selection Index (GSI) showed that in the present study the most stable and high yielding exhibited by genotypes Genotype-2, Genotype-8 and Genotype-11, whereas, Genotype-1, Genotype-37 and Genotype-5 were the least stable and low yielding genotypes with GSI value of 40, 37 and 33, respectively.

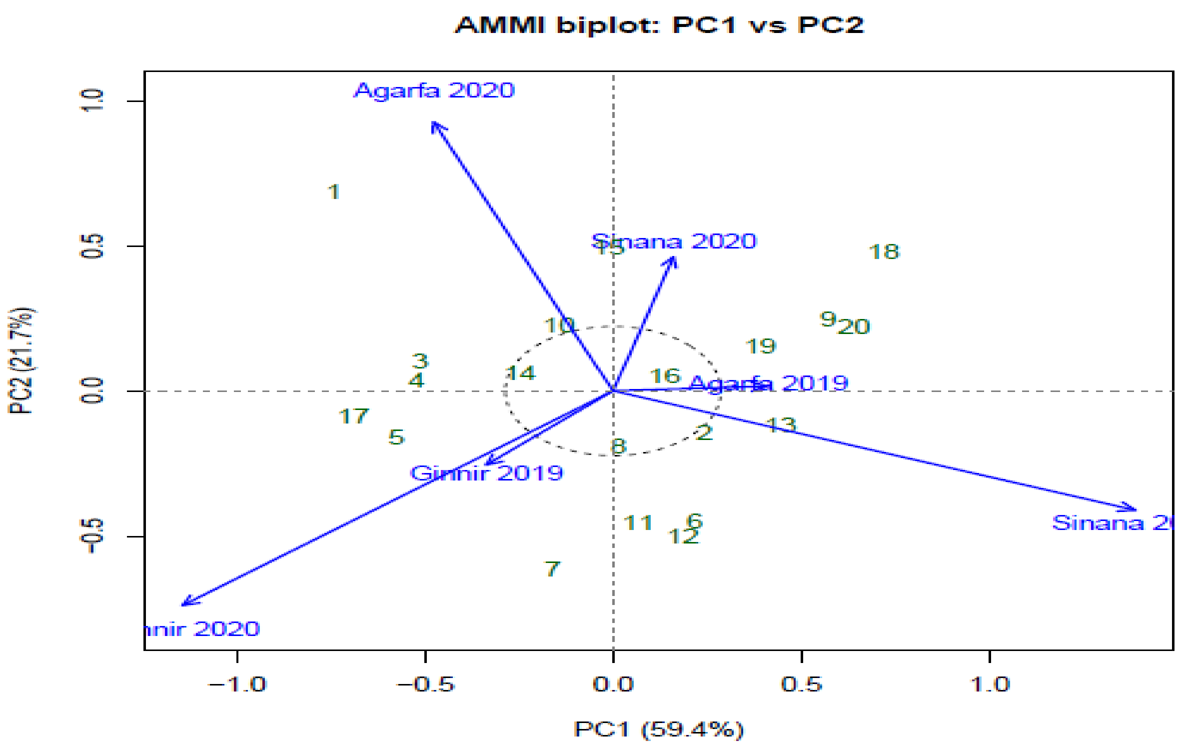


Figure 2. Two dimensional scatter diagram of IPCA1 scores against IPCA2 scores

Evaluation of environments

The concentric circles on the GGE biplot help to visualize the length of the environment vectors, it measure of the discriminating ability of environments. Sinana 2019 and Ginnir 2020 were the most discriminating, where as Agarfa 2020 was least discriminating environment for evaluation of durum wheat genotypes. Environments (locations) that are both discriminating and representative are good test environments for selecting generally adapted genotypes. A test environment that has a smaller angle with the Average-Environment Axis (AEA) is more representative of other test environments (Yan *et al*, 2011). Based on this, Sinana 2020 was the most representative followed by Ginnir 2019 and Agarfa 2019 while, Ginnir 2020 was the least representative of all test environments.

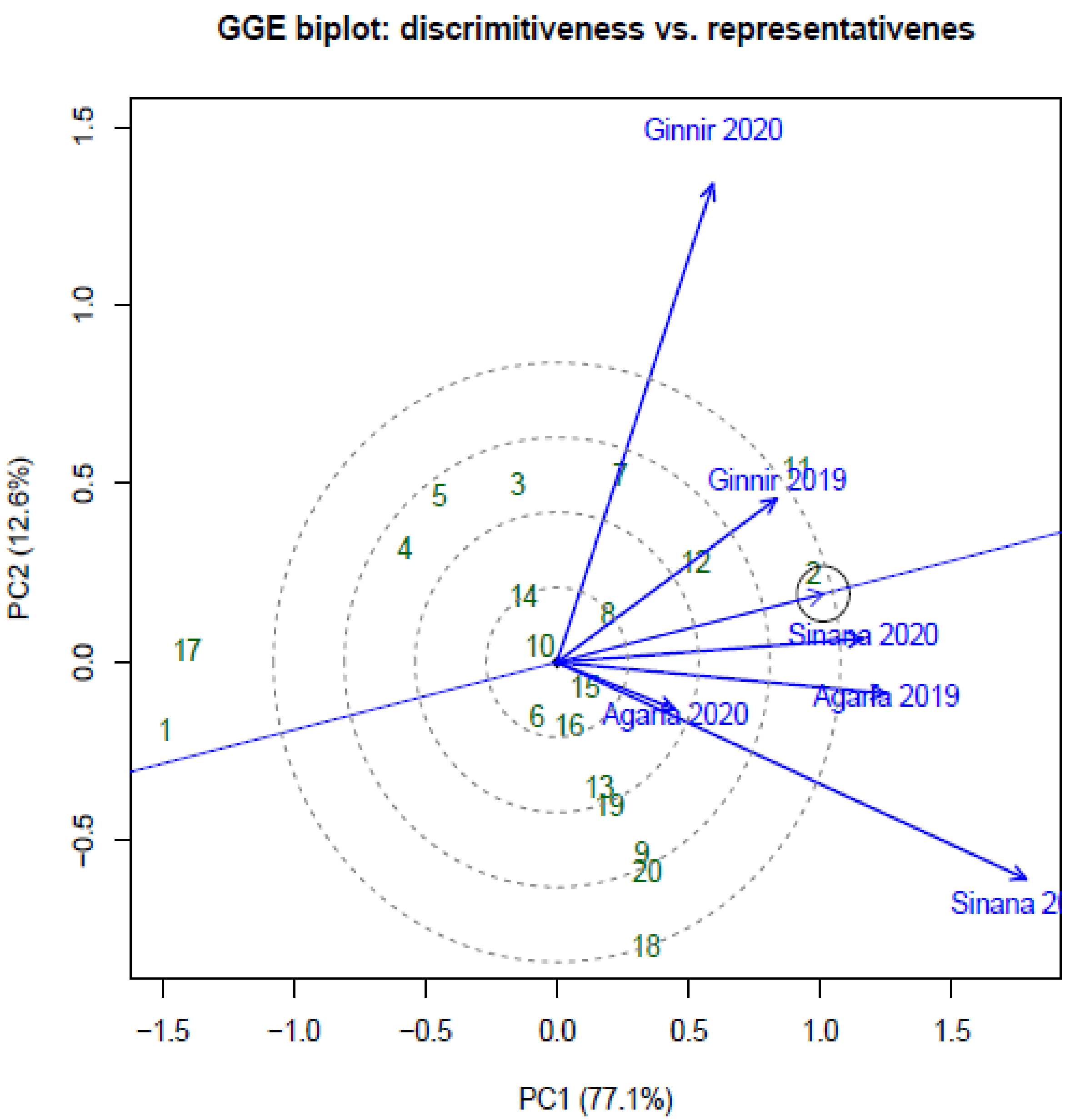


Figure 3. GGE biplot discrimitiveness vs representative

Mega-environment Analysis

The "which-won-where" view of the GGE biplot, which consisted of an irregular polygon formed by connecting vertex genotypes and a set of lines drawn from the biplot origin and intersecting the sides of the polygon at right angles, was indicated in Figure 4. The vertex genotypes in this case were G-1, G-17, G-5, G-11, G-2 and G-18. In Figure 4 help to seek opportunities to sub-divide the target environment into sub-regions (mega-environments). It classified the environment markers into two sectors (i.e., two mega-environments). This revealed that no single genotype had highest yield in all environments. Four environments including Sinana 2019, Sinana 2020, Agarfa 2019 and Agarfa 2020 were grouped into the same mega-environment. Ginnir 2019 and Ginnir 2020 were grouped into second mega-environment. The first mega-environment the highland of Bale whereas, environments grouped in to the second mega-environment is mid-altitude of Bale. The genotype on the vertex of the polygon, contained in a mega-environment, had the highest yield in at least one environment and was one of the best performing genotypes in the other environments (Yan & Rajcan, 2002). All other genotypes are contained within the polygon and have smaller vectors, and they are less responsive in relation to the interaction with the environments within that sector.

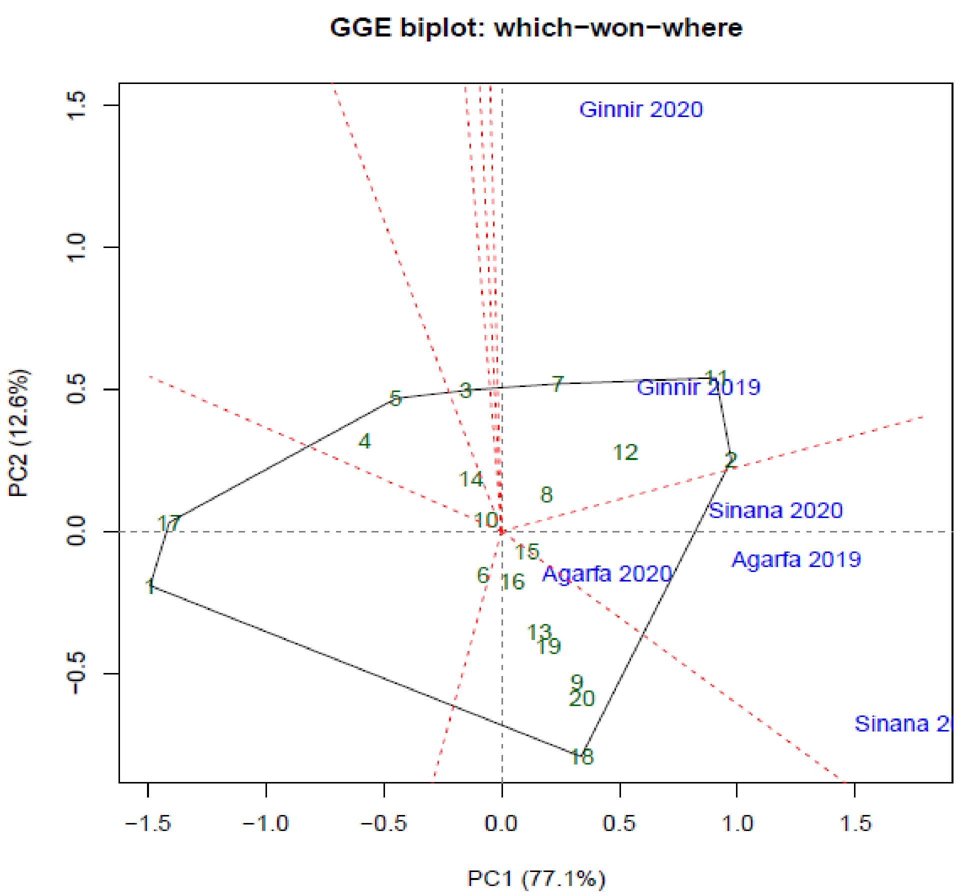


Figure 4. GGE biplot which-won-where

Conclusions and Recommendations

Regarding the AMMI model, the results of the analysis of variance indicated significant genotype × environment interaction. Based on the result of data analysis the highest combined mean yield was observed for G-2, G11 and G12. ASV analysis, test genotypes Genotype-10, Genotype-8 and Genotype-2 were the most stable. GSI showed that the most stable and high yielding exhibited by genotypes Genotype-2 and Genotype-11. Therefore Genotype-2 and Genotype-11 were identified as candidate genotypes to be verified for possible release.

References

Alberts, M.J.A. (2004): A comparison of statistical methods to describe genotype × environment interaction and yield stability in multi-location maize trials. Plant Breeding MSc Thesis, University of the free state Bloemfontein. Pp.100

Bavandpori F, Ahmadi J, Hossaini SM (2015) Yield Stability Analysis of Bread Wheat Lines using AMMI Model. Agricultural Communications 3(1): 8-15.

Bergh, K., A. Chew, M.K. Gugerty, and C.L. Anderson. 2012. Wheat value chain: Ethiopia. Brief 204. Univ. of Washington, Evans School Policy Anal. Res., Seattle, WA.

Bose, L. K., Jambhulkar, N. N. Pande Kanailal, O. N. Singh, and Mohapatra Trilochan. "Yield stability for selecting stable rice genotypes under diverse environments using univariate and multivariate statistical approaches." *Journal of Food, Agriculture & Environment* 12, no. 2 (2014): 334-339.

Crossa, J., Gauch, H.G. & Zobel, R.W. (1990): Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. Crop Science 44:55-85

Esayas Tena, Frehiwot Goshu, Hussein Mohamad, Melaku Tesfa, Diribu Tesfaye, and Abebech Seife. "Genotype× environment interaction by AMMI and GGE-biplot analysis for sugar yield in three crop cycles of sugarcane (Saccharum officinirum L.) clones in Ethiopia." *Cogent Food & Agriculture* 5, no. 1 (2019): 1651925.

Eshetie, T. (2018). Ethiopia's manufacturing industry opportunities, challenges and way forward: A sectoral overview. Novel techniques in nutrition and food science. Crismson Publishers.

Gauch GH, Zobel RW. AMMI Analysis of Yield Trials. In: Genotype-by Environment Interaction, Kang MS, Gauch HG. (Eds.). Taylor and Francis, Boca Raton, FL., 1996; 85-122.

Gauch H.G.,1992. Statistical anlyis of regional yield trials. AMMI analysis of factorial designs. 1st edn, Elsevier, New York, ISBN: 0-444-89240-0

Gauch, H. G., & Zobel, R. W. (1988). Predictive and postdictive success of statistical analyses of yield trials. *Theoretical and Applied genetics*, *76*(1), 1-10.

Gollob, H.F. (1968). A statistical model which combines features of factor analytic and analysis of variance techniques. Psychometrika 33(1):73-115.

Gauch, H.G., and R.W. Zobel. 1997. Identifying mega-environments and targeting geno- types. Crop Sci. 37:311–326. doi:10.2135/cropsci1997.0011183X003700020002x

Kang M. S. 1998. Using genotype-by-environment interaction for crop cultivar development. Advanced Agronomy 62: 199–252, DOI: 10.1016/S0065- 2113(08)60569-6

Legesse,W. (2017). Fast truck variety development and participatory variety selection approach for climate smart agriculture in Shebel Berenta District, Eastern Gojam, Ethiopia. International Journal of Current Research, 9(5), 50179–50183. Retrieved from https://www.journalcra. com/sites/default/files/issue-pdf/22620.pdf

Lin, C. S., Binns, M. R. 1988. A superiority measure of cultivar performance for cultivar x location data. *Canadian J. Plant Sci*., 68: 193–198.

Mattos, P. H. C., Oliveira1, R. A. J., Filho, C. B., Daros, E., and Verissimo, M. A. A. (2013). Evaluation of sugarcane genotypes and production environments in Parana by GGE biplot and AMMI analysis. Crop Breeding and Applied Biotechnology, 13, 83–90. doi:10.1590/S1984- 70332013000100010

Mengistu, D. K., & Pè, M. E. (2016). Revisiting the ignored Ethiopian durum wheat (Triticum turgidum var. durum) landraces for genetic diversity exploitation in future wheat breeding programs. Journal of Plant Breeding and Crop Science, 8(4), 45–59. https://doi. org/10.5897/JPBCS2015.0542

Malosetti, M., J.M. Ribaut, and F.A. van Euwijk. 2013. The statistical analysis of multi-environment data: Modeling genotype-by-environment interaction and its genetic basis. Front. Physiol. 4:1–17. doi:10.3389/fphys.2013.00044

Mohammadi, R., Amri A. (2008). Comparison of parametric and non-parametric methods for selecting stable and adapted durum wheat genotypes in variable environments. Euphytica 159(3):419-432.

Purchase, J.L, Hatting, H. & van Deventer, C. (2000). Genotype x environment interaction of winter wheat (Triticum aestivum L.) in South Africa: I. AMMI analysis of yield performance. *South African Journal of Plant and Soil*, *17*(3), 95-100.

Regis, J. A. V. B., Andrade, J. A. C., Santos, A., Moraes, A., Trindade, R. W. R., Henriques, H. J. R., … Oliveira, L. C. (2018). Adaptability and phenotypic stability of sugarcane clones. Pesquisa Agropecuária Brasileira, 53(1), 42–52. doi:10.1590/S0100-204X2018000100005

Sanchez-Garcia, M., F. Álvaro, J.A. Martín-Sánchez, J.C. Sillero, J. Escribano, and C. Royo. 2012. Breeding effects on the genotype ´ environment interaction for yield of bread wheat grown in Spain during the 20th century. Field Crops Res. 126:79–86. doi:10.1016/j.fcr.2011.10.001

Yan, W, "GGE Biplot vs. AMMI Graphs for Genotype-by-Environment Data Analysis," *Journal of Indian Society Agricultural Statistics*, 65(2), 181-193, (2011).

Yan, W., Rajcan, I., "Biplots analysis of the test sites and trait relations of soybean in Ontario," *Crop Science*, 42, 11-20, (2002).

Registration of Fenugreek Variety "Arganne" for mid altitude of Bale, South Eastern Ethiopia

GetachewAsefa*, Mohammed Beriso, Mohammedamin A/Rezaq and GemmechuIjigu
Sinana agricultural Research Center, P.O.Box 208, Bale- Robe, Ethiopia
Corresponding Author: *fenetgeach@gmail.com*

Abstracts

Arganne with the accession nameAcc. 202209sno3-5)is a fenugreek variety released by Oromia Agricultural Research Institute, Sinana Agricultural Research center in 2021. The trial was conducted at Sinana Agricultural research centre from observation nursery to preliminary yield trial and promising fenugreek genotypes were selected from yield trial based on seed yield and reaction to diseases especially powdery mildew . These promising genotypes were evaluated against standard check Hunda'ol and Ebisa across three locations for three years (2017 to 2019). Arganneshowed superior yielding ability, producing a mean seed yield yield of 17-26 Qt ha-1 on research field and 15-21 Qt ha-1 on farmers' field.The seed yield of the new variety exceeded that of the standard check Hunda'ol and Ebisavarieties by about 12% and 11.23% respectively

Keywords:- Fenugreek, Variety verification, Registration

Introduction

Fenugreek(*Trigonellafoenumgraecum* L.) is produced as spice, medicinal, animal feed and as pulse crop for rotation and mainly for export which is used for sustains livelihoods incomes and earning foreign exchange. As a medicinal herb the seed of fenugreek is an official drug according to the European dispensatories. Almost all farmers in some parts of Ethiopia like 'Hararghe' use fenugreek in the major food called'Lafiso' which is either made from maize or sorghum 'Injera'served as baked in mixture of fenugreek flour boiled either with meat or alone. The 'Harari' people also use fenugreek as their best dish known as 'HulbatMeraq' where they use fenugreek cooked with meat, mixed with 'Injera' (Jemal, 1998).The production and distribution of fenugreek in Ethiopia isnearly similar to those of other cool season food legumes (Million*etal* 2012) . Fenugreek stands as generating cash in study area. Thus, improving this crop meansopening a new market opportunity in the face ofthe ever expanding world trade for the country in generaland for the resource-poor farmer in particular. Oneadditional advantage of fenugreek is the wide variety ofits uses at different crop stages such as green manuring,leaf vegetable and seed production for the internationalmarket of spices.

Fenugreek is the major seed spices produced in Bale mid altitude viz… Gindhir, Goro, Gololcha and some part of sawwena and Sinana districts. However, its production and productivity is low. Among the factors contributing to low production and productivity, even if many varieties were released before, high yielding and resistance/tolerant to disease with wide adaptability results in low yield. Hence, the objectives of the study is to register releasedfenugreek variety that are high yielding and adaptable to bale mid altitude and similar agro ecologies.

Varietal Origin/Pedigree and Evaluation

'Arganne' with the accession name of (Acc. 202209sno3-5)is landrace material which collected from Arsi Bale and developed through selection. 75 genotypes were evaluated at Sinana Agricultural research centre from observation nursery to preliminary yield trial. 14 fenugreek genotypes were selected from yield trial based on seed yield and reaction to major fenugreek diseases. These promising genotypes were evaluated against standard check Hunda'ol and Ebisawhich was released from Sinana Agricultural Research Centre across three locations(Sinana, Goro and Gindhir) for three years (2017 to 2019). Promising genotypes and standard checks were planted on $10x10m^2$ at nine environments for variety verification trial in 2020 and evaluated by Ethiopian Variety Releasing Committee, finally Arganne approved as superior Variety for Bale mid lands and similar agro ecologies.

Morphological Characteristics of Arganne

The released variety Arganneexhibited congenial morphological and agronomic characteristics compared to the standard check Hunda'ol and Ebisa. It has deep green foliage, yellow seed colour and a medium of day to flowering, days to maturity and plant height(46.17, 121.22 and 65.42cm) respectively(Table 1).

Yield Performance

Arganne *(*Acc. 202209sno3-5) showed superior yielding ability, producing a mean seed yield of 17- 26Qt ha-1 at research field and 15 – 21Qt ha-1 on farmers' field. In fact, the seed yield of the new variety exceeded that of the standard check Hunda'ol and Ebisavariety by about 12% and 11.23% respectively.

Adaptation and Agronomic recommendation

Arganne is fenugreek variety released for Bale midlands, south eastern Ethiopia. It is well adapted in similar agro ecologies with altitude of 1650 – 2400m.a.s.lwith annual rainfall of 550-750mm. Recommended fertilizer rate for Arganne is 100kg of NPS which isapplied at planting while the spacing between rows is 30cm.

Conclusions and Recommendations

The newly released fenugreek variety 'Arganne' was found to be superior to the commercial variety of Hundaol and Ebisa which were used as a standard check, in terms of seed yield and reaction to major fenugreek disease in the area (powdery mildew). The variety was also found to be stable over seasons and locations. It is, thus, concluded that, 'Arganne' fenugreek variety could be produced sustainably and profitably by smallholder farmers and investors in mid lands of Bale and similar agro ecologies in the country

Acknowledgement

Theauthors are acknowledged OromiaAgricultural Research Institute andSinana Agricultural Research Center for financing and facilitate this research work to release fenugreek variety Arganne.

Table 1. Agronomic and Morphological descriptors for newly released Fenugreek variety

Variety Name	Arganne (Acc.202209sno3-5)
Agronomic and Morphological Characteristics	
Adaptation Area	Sinana, Goro, Ginnir and similar agro ecology
Altitude(masl)	1650 – 2400
Rain fall(mm)	550-750
Seed Rate(kg/ha)	Row planting -20 Broadcasting - 25
Planting date	End of August to late September (for Bale mid altitude)
Fertilizer rate(kg/ha)	NPS = 100
Days to flowering	46.17
Days to Maturity	121.22
Plant Height(cm)	65.42
Growth habit	Erect
Seed Color	Yellow
Flower Color	White
Yield (Qt/ha)	
Research field	17-26
Farmers field	15-21
Year of Release	2021
Breeder/Maintainer	SARC/IQQO

References

JemalAbdulahi, 1998. Determination of Spacing of fenugreek(TrigonellafoenumgraecumL.) and Effect of Intercropping Fenugreek with Sorghum (Sorghum bicolor L., Moench) on yield and Soil Nitrogen. M. Sc. Thesis presented to the Schoolof Graduate Studies of Alemaya University, Ethiopia.

Million Fikreselassie, HabtamuZeleke and NigussieAlemayehu.Genetic variability of Ethiopian fenugreek landraces.Journal of Plant Breeding and Crop Science Vol. 4(3), pp. 39-48, 23 February, 2012.Available online at http://www.academicjournals.org/JPBCS , DOI: 10.5897/JPBCS11.078, ISSN 2006-9758 © 2012 Academic Journals

Genotype by Environment Interaction for grain yield stability using AMMI analysis of Ethiopian Mustard (Brassica *carinata* A. Braun) Genotypes studied in the Highlands of Bale, Southeastern Ethiopia

Tadele Tadesse*, Amanuel Tekalign and Belay Asmare
Oromia Agriculture Research Institute, Sinana Agriculture Research Center, Bale-Robe, Ethiopia
Email address:
tadyeko20@gmail.com/tadeleta20@yahoo.com
* Corresponding author

Abstract

The purpose of this study was to investigate grain yield stability and genotype X environment interaction for fifteen Ethiopian Mustard genotypes (Brassica carinata A. Braun) conducted in the highlands of Bale, Southeastern Ethiopia for three consecutive years (2018 to 2020) at two locations, Sinana and Agarfa. Randomized Complete Block Design with four replications was used. The combined analysis of variance for grain yield indicated highly significant interaction (P<0.01%) for genotypes, genotype X environment interaction, and environment. The analysis of variance for AMMI for grain yield revealed highly significant interaction for genotypes, genotypes X environment interaction, and environment. It was observed that 44.84% of the variation in grain yield was accounted by environment, 37.54% for genotypes by environments, and, 17.62% was for genotypes. The first and the second IPCA components with degree freedom of 34 was accounted for 67.64% of the interaction effect and revealed the two models were fit. Genotype G12, G11, G8, and G1 showed the lowest AMMI Stability Value (ASV) indicating stability. Simultaneously Genotype Selection Index (GSI) Genotype G11, G12, G5, and G8 have the lowest GSI value indicating high stability. However, out of these genotypes, G11 showed a high mean grain yield with a yield advantage of 25.8% and showed the lowest GSI value compared to overall genotypes and the checks used in the study. Therefore, G11 was identified as a candidate genotype to be verified in the coming main season of 2022/23 for possible release for the highlands of bale zone, Southeastern Ethiopia, and similar agro-ecologies.

Keywords: AMMI, Genotypes, Genotype by environment interaction, Grain yield, Stability

Introduction

Ethiopian mustard (*Brassica carinata* A. Braun) is mainly originated in the highlands of Ethiopia (Getinet *et al., 1994)*. It is locally known as "Gomenzer". This crop is well adapted in the Mediterranean areas and it is a heat and drought-tolerant oilseed crop (Cardone*et al.*, 2003). It is believed to have originated from the Ethiopian highlands and its cultivation is thought to have started about 4000 years B.C. (Alemayehu and Becker, 2002; Schippers, 2002). It is cultivated as an oil and leafy vegetable crop in the Ethiopian highlands at altitudes between 1500 and 2600 m.

Genotype and environment interaction plays a key role in phenotypic expression and must be estimated and considered when indicating cultivars for the breeding program (Prado et al. 2001). G×E is defined as a phenomenon in that phenotypes respond to genotypes differently according to different environmental factors (Kim. et al., 2014). The presence of significant G*E for quantitative traits such as yield can seriously limit the feasibility of selecting superior genotypes

(Flores et al. 1998). However, the G*E can be properly exploited to advantage through various approaches (Gauch and Zobel, 1996; Kang, 1998). Therefore, identification of yield contributing traits and knowledge of the G*E interactions and yield stability is important for breeding new cultivars with improved adaptation to the environmental constraints prevailing in the targeted environments.

Gene-environment interactions are situations in which environmental factors affect different individuals differently, depending upon genotype, and in which genetic factors have a differential effect, depending upon attributes of the environment (Kenneth W. e*t al*., 2009).

Understanding the implications of GEl structure/nature is important in crop improvement programs because a significant GEl can seriously impair the selection of superior genotypes in new crop introduction and cultivar development programs. The stability of varieties over environments is closely linked with GxE interaction. When the interaction is present, it indicates that the genotype is statistically non-additive, indicating that the genotypic performance is largely depending on the environment (Cotes et al., 2002). Genotype by environment interaction may occur in both the short and long terms (several years and several locations) for crop performance trials. Therefore, analysis of genotype by environment interaction is very necessary in any variety performance evaluation to interpret the genotypic or environmental main effects (Yan et al., 2006; Huhn, 1996) so that one can make an informed decision when making variety selections (Cooper and Delacy, 1996). Several statistical approaches are available to understand GxE interactions, but the most powerful of these is additive main effects and multiplicative interaction (AMMI) analysis (Gauch, 2006). AMMI uses analysis of variance (ANOVA) and principal component analysis to study GxE interactions. Therefore, this study was conducted to identify high-yielding stable genotypes with other desirable traits with tolerant and/or resistant to major Ethiopian mustard diseases in the highlands of Bale, Southeastern Ethiopia.

Materials and Methods

Twelve Ethiopian mustard genotypes were evaluated along with two standard checks, Yellow dodola and Shay, and local check at two locations in Sinana and Agarfa, in the highlands of Bale zone Southeastern Ethiopia for three consecutive years, 2018 to 2020. The experiment was laid out in RCBD with four replications having a plot size of 4.8m2 (4rows at 0.3m spacing with 4m long) was used. Recommended fertilizer rate was also used at all locations. A list of genotypes along with their sources is presented in (Table 1). Crop stat program was used to compute the combined ANOVA and LSD for mean separation. AMMI analysis was also analyzed using the model suggested by Cross *et a*l., 1990.

The AMMI Stability Value (ASV): was calculated for each genotype according to the relative contributions of the principal component axis scores (IPCA1 and IPCA2) to the interaction sum of squares. It is calculated using the model suggested by (Purchase et al., 2000). This weight is calculated for each genotype and environment according to the relative contribution of IPCA1:

$$ASV=\sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1score)\right]^2+[IPCA2]^2}$$

Where, $\frac{SSIPCA1}{SSIPCA2}$ the weight given to the IPCA1 value by dividing the IPCA1 sum squares by the IPCA2 sum of squares. The larger the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller IPCA score indicates a more stable genotype across environments.

Stability per se does not give much information about the level of yield so Farshadfar *etal.*, 2011, and Tumuhimbise *et al.*, 2014 used yield stability index (YSI) and genotype stability index (GSI) which combined high yield performance with stability. Both the YSI and the GSI are based on the sum of the ranking due to ASV scores and yield or performance ranking. Lower YSI and GSI values indicate genotypes that combine high yield or performance with stability (Baraki *et al.*, 2014), and it is calculated as follows:

GSIi= RYi +RASVi, where GSI = genotype selection index, RYi = rank of genotypes for mean grain yield across environment, RASV = rank of the genotypes based on the AMMI stability value.

Table 1 Lists of Genotypes used for the study

Genotypes	Source of the genotypes
ACC 241902	Brought from Holetta, Ethiopia
ACC 241895	Brought from Holetta, Ethiopia
ACC 243738	Brought from Holetta, Ethiopia
ACC 242852	Brought from Holetta, Ethiopia
ACC 242854	Brought from Holetta, Ethiopia
ACC 241906	Brought from Holetta, Ethiopia
ACC 242855	Brought from Holetta, Ethiopia
ACC 241916	Brought from Holetta, Ethiopia
ACC 241909	Brought from Holetta, Ethiopia
ACC 20133	Brought from Holetta, Ethiopia
ACC 20131	Brought from Holetta, Ethiopia
ACC 241904	Brought from Holetta, Ethiopia
Yellow dodola	Released from Holetta
Shaya	Released From Sinana
Local check	Local cultiva

Results and Discussions

The combined analysis over location and years for mean grain yield revealed that highly significant variation at ($P<0.01$) was observed among genotypes, environments, genotypes x environment interaction (Table 2). The same result was reported by Mohammed *et al.*, 2018, Tadele *et al.*, 2018). This significant variation happened due to the change in the magnitudes of difference between genotypes from one environment to another. Furthermore, the significant variation of the GEI revealed that as there are factors that are of economic relevance that can be related to complex or polygenic characteristics, and show a high influence on the environment. Because of this, in breeding programs, various experiments are conducted in several locations to evaluate grain yield. Deitos et al., (2006), indicated that genotype x environment interaction is important for plant breeding because it affects the genetic gain and recommendation and selection of cultivars with wide adaptability.

Table 1. Combined ANOVA for grain yield of 15 Ethiopian Mustard genotypes combined over two locations and three years

Source of Variation	Degree freedom	Sum Squares	Mean Squares
YEAR (Y)	2	24.39	12.19**
Location (L)	1	28.77	28.77**
Genotype (G)	14	1.11	0.37**
Replication	3	3.43	0.24
Y X L	2	19.11	9.55**
G X L	14	4.9	0.35**
Y X L X G	56	13.75	0.25**
RESIDUAL	267	83.5	0.31
TOTAL	359	178.96	0.5

The highest mean grain yield obtained from genotypes G11 (1.94t/ha) followed by G12 (1.56t/ha), G10 (1.55t/ha) and G14 standard check, (1.54t/ha) whereas the mean grain yield across locations was ranged from 1.82t/ha for Sinana 2018 to 0.96t/ha for Agarfa 2018 (Table 3). The grand mean for grain yield across locations and years was 1.45t/ha (Table 3).

Table 3. Mean grain yield (t/ha) of for 15 Ethiopian Mustard (Brassica *carinata)* genotypes tested across locations

Entry	Treat code	Sinana 2018	Agarfa 2018	Sinana 2019	Agarfa 2019	Sinana 2020	Agarfa 2020	TRT MEANS
ACC 241902	G1	1.71	0.8	1.63	1.12	1.7	1.63	1.43
ACC 241895	G2	1.62	0.95	1.24	1.7	1.04	1.42	1.33
ACC 243738	G3	1.71	0.68	1.58	1.31	1.02	1.85	1.36
ACC 242852	G4	1.89	1.04	1.42	1.06	1.74	1.58	1.45
ACC 242854	G5	1.8	0.98	1.38	1.2	1.79	1.96	1.52
ACC 241906	G6	1.76	0.87	1.11	1.39	1.35	1.75	1.37
ACC 242855	G7	1.77	0.78	1.11	1.85	1.34	1.72	1.43
ACC 241916	G8	1.93	1.08	1.25	1.03	1.49	1.89	1.45
ACC 241909	G9	2.01	0.69	1.19	1.54	1.11	1.8	1.39
ACC 20133	G10	1.74	1.27	1.31	1.57	2.33	1.09	1.55
ACC 20131	G11	2.77	1.69	1.8	1.41	2.28	1.65	1.94
ACC 241904	G12	2.22	0.65	1.37	1.38	1.93	1.79	1.56
Yellow Dodola	G13	1.66	0.7	1.59	0.8	1.82	1.42	1.33
Shaya	G14	1.69	1.32	1.65	1.23	1.87	1.46	1.54
Local check	G15	1.01	0.97	1.12	0.84	1.04	1.55	1.09
Mean		1.82	0.96	1.38	1.3	1.59	1.64	1.45
LSD 5%		0.76	0.51	0.5	0.62	0.96	0.99	0.34
CV%		21.9	21.3	21.4	23.2	21.5	22.7	21.2

AMMI Analysis

The AMMI method combines the traditional ANOVA and PCA into a single analysis with both additive and multiplicative parameters (Gauch, 1992). The first part of AMMI uses the normal

ANOVA procedures to estimate the genotype and environment main effects. The second part involves the PCA of the interaction residuals (residuals after the main effects are removed). In this study, the combined analysis of variance and AMMI analysis is shown in Table 4. It was observed that there are highly significant differences in the environment, genotype, and their interactions. The combined ANOVA showed that grain yield was significantly affected by the environment because of significant variance at 1% level (Table 4), which explained 44.84% of the total variation whereas the GEI accounted for 37.54%, and the genotypes captured 17.62% of the total sum square. Similar significant variation for the genotypes, genotypes by environment interaction, and the environments were reported by Esayas *et al.*, 2019; Bocianowski *et al.*, 2020. The two principal components of GE interaction accounted jointly for 67.64 % of the whole $G \times E$ interaction effect variation of grain yield and were significant. The first principal interaction component (IPCA 1) accounted for 46.56 % of the variation caused by the interaction, while IPCA 2 accounted for 21.08 % of this variation. The first two bilinear terms jointly accounted for 67.64% of the G x E sum of squares and used 34 of the total 70 degree freedom available in the interaction indicating the model is fit to describe stability.

Table 4. ANOVA for the Additive Main effect and Multiplicative Interaction (AMMI) for grain yield of 15 Ethiopian Mustard genotypes over environment

Sources	DF.	SS	MS	TSS explained %
Genotypes	14	2.681	0.191	17.62**
Environment	5	6.821	1.364	44.84**
G X E	70	5.71	0.082	37.54**
AMMI COMPONENT 1	18	2.659	0.148	46.56
AMMI COMPONENT 2	16	1.204	0.075	21.08
AMMI COMPONENT 3	14	0.978	0.07	6.43
AMMI COMPONENT 4	12	0.512	0.043	3.36
GXE RESIDUAL	10	0.359		
TOTAL	89	15.21		

AMMI Stability Value (ASV)

ASV, which is the distance from the coordinate point to the origin in two-dimensional scattergram of IPCA1 (Interaction Principal Component Analysis) against IPCA2 scores is used to discriminate stable genotypes. In this ASV method a stable variety is defined as one with ASV value close to zero (Purchase *et al*. 2000). Accordingly genotypes G12 (0.1) followed by G11 (0.22), G5 (0.22), G8 (0.27), and G1 (0.34) were the most stable whereas G10, G9, G7, G3, and G2 with the highest ASV indicate unstable (Table 5).

Genotype Selection Index (GSI)

As stability per se is not a desirable selection criterion, because the most stable genotypes would not necessarily give the best yield performance, hence, simultaneous consideration of grain yield and ASV in a single non-parametric index entitled. Accordingly in this study, Genotypes G11, G12, G5, and G8 showed lowest GSI indicating general stability however, only genotype G11 showed higher mean grain yield than the checks (Table 5).

Table 5. Mean grain yield, Stability parameters, ASV and GSI for 15 Ethiopian mustard genotypes tested across location over years.

Trt	Genotypes	Mean	Rank Yi	Slope (bi)	MS-DEV (S^2di)	IPCA1	IPCA2	ASV	Rank ASV	GSI
1	ACC 241902	1.43	8	1.15	0.27	0.12	-0.22	0.34	4	12
2	ACC 241895	1.33	13	0.48	0.45	-0.38	0.37	0.92	10	23
3	ACC 243738	1.36	12	1.09	0.5	-0.43	-0.27	0.99	11	23
4	ACC 242852	1.45	6	1.08	0.22	0.21	-0.12	0.47	6	12
5	ACC 242854	1.52	5	1.2	0.24	0.02	-0.21	0.22	2	7
6	ACC 241906	1.37	11	1.04	0.27	-0.25	0.07	0.55	7	18
7	ACC 242855	1.43	8	0.96	0.52	-0.42	0.4	1.01	12	20
8	ACC 241916	1.45	6	1.15	0.31	-0.04	-0.26	0.27	3	9
9	ACC 241909	1.39	10	1.31	0.47	-0.47	0.1	1.03	13	23
10	ACC 20133	1.55	3	0.54	0.69	0.55	0.6	1.36	15	18
11	ACC 20131	1.94	1	1.01	0.06	0.48	0.1	0.22	2	3
12	ACC 241904	1.56	2	1.8	0.15	0.04	0.02	0.1	1	3
13	Yellow Dodola	1.33	13	1.26	0.45	0.37	-0.31	0.87	9	22
14	Shaya	1.54	4	0.51	0.31	0.32	-0.01	0.7	8	12
15	Local check	1.09	15	0.32	0.38	-0.12	-0.27	0.38	5	20

AMMI Biplots

The AMMI biplot provide a visual expression of the relationship between the First Interaction Principal Component Axis (IPCA1) or AMMI component 1 and Mean of genotype and environment (Figure 1). As a result, biplots generated using genotypic and environmental scores of the AMMI 1 components can help breeders have an overall picture of the behavior of the genotypes, the environments and G x E (Manrique and Hermann, 2002; Tarakanovas and Ruzgas, 2006). In Figure 1 the IPCA1 scores for both the genotypes and the environments were plotted against the mean yield for the genotypes and the environments, respectively. By plotting both the genotypes and the environments on the same graph, the associations between the genotypes and the environments can be seen clearly. The IPCA scores of genotypes in the AMMI analysis are an indication of the stability or adaptation over environments. The greater the IPCA scores, negative or positive (as it is a relative value), the more specific adaptation of a genotype to certain environments whereas the more the IPCA scores approximate to zero, the more stable or adaptation of the genotype in overall environments sampled.

Accordingly, in this study genotypes G5, G12, G14, G10 and G11 were the highest yielding genotypes while environment Sinana 2020, Sinana 2018 and Agarfa 2020 gave the highest mean grain yield (Figure 1).

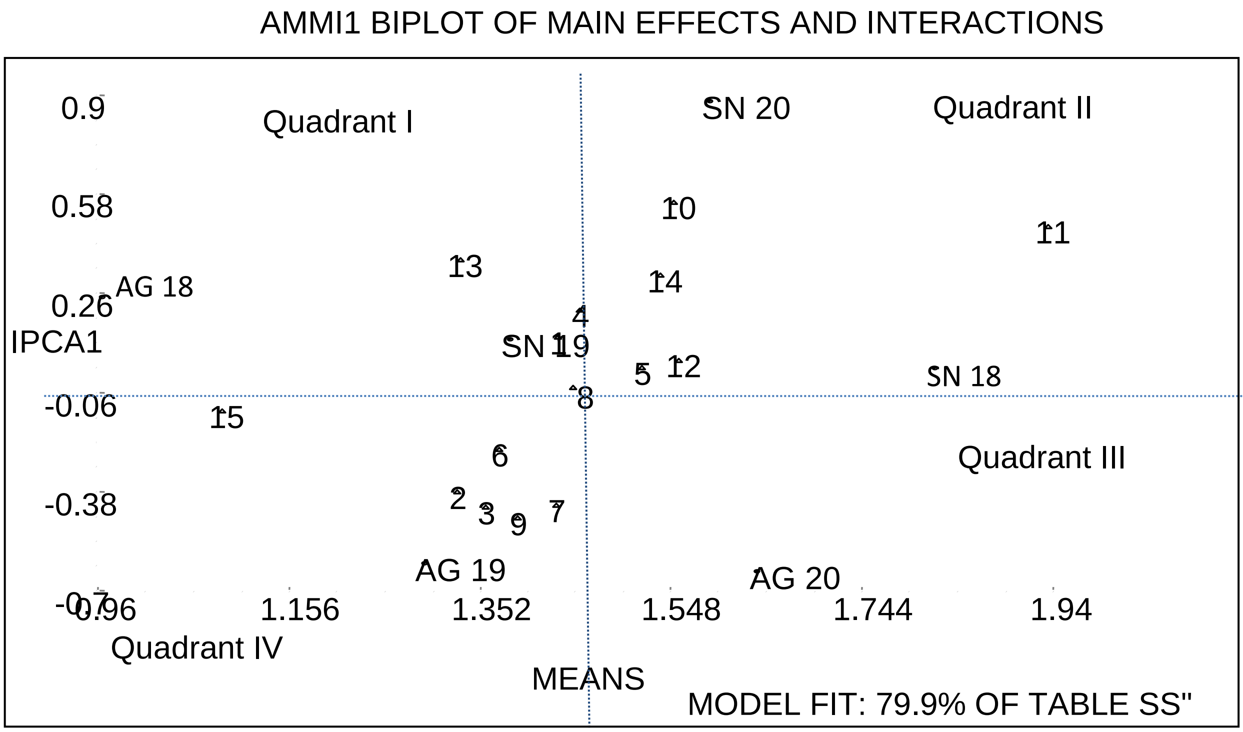


Figure 1. Interaction biplot of AMMI1 where IPCA1 score (y-axis) plotted against mean yield (x-axis) for fifteen genotypes of Ethiopian mustard

AMMI Biplot II: this biplot was constructed using both the IPCA scores. i.e. Since IPCA 2 scores also play a significant role in explaining the GEI, the IPCA 1 scores were plotted against the IPCA2 scores to further explore adaptation (Figure 2). In this biplot graph, those genotypes found near the origin are considered as more stable whereas those genotypes and environments which are found far from the origin, by having the longest vertex are considered as unstable, and well adapted to the specific locations. Accordingly, G11, G12, G14, G4 G1, and G5 were found to be stable in their grain yield when tested across sites whereas the environment A B and C were less responsive to the environmental factors. However, out of those above-mentioned genotypes which showed stable performance, only G11 gave a mean grain yield higher than the checks used in the trial. The other genotypes, though they have stable performance, they gave lower mean grain yield than the checks.

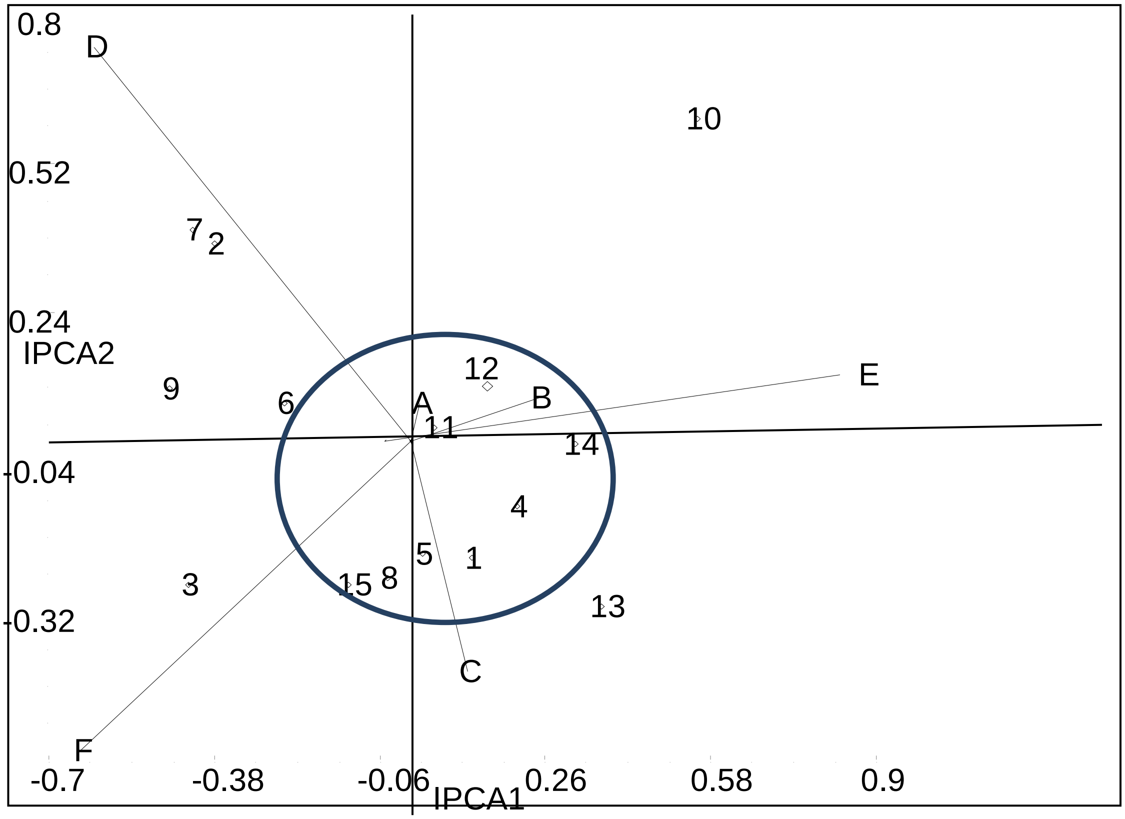


Figure 2. Biplot analysis of GE interaction based on AMM2 model for the first two interactions principal component score

Conclusions and Recommendations

From this study it was concluded that genotypes having better yield with stable performance over the testing sites with tolerant/resistant types of reaction to major Ethiopian mustard diseases compared to the previously used varieties was selected to be verified for possible release. Accordingly, G11 was identified as a candidate genotype to be verified in the highlands of Bale, Southeastern Ethiopia for possible release in the coming bona 2022 cropping season.

Acknowledgement

The authors would like to thank Oromia Agriculture Research Institute for financial support. Besides, the authors also thank Sinana Agriculture Research Center for providing the necessary support and Pulse and Oil Crops research case team staff for the entire trial management and data collection.

References

Alemayehu H, Becker H (2002). Genotypic diversity and patterns of variation in a germplasm material of Ethiopian mustard (Brassica carinata A. Braun). Genet. Resour. Crop Evol. 49(6): 573 – 58

Baraki F, Y. Tsehaye, and F. Abay,(2014). AMMI analysis of genotype * environment interaction and stability of sesame genotypes in Northern Ethiopia. Asian Journal of Plant Sciences, vol. 13, no. 4, pp. 178–183, 2014

Bocianowski J., Liersch A., and Nowosad K. (2020). Genotype by environment interaction for alkenyl glucosinolates content in winter oilseed rape (*Brassica napus* L.) using additive main effects and multiplicative interaction model. Elsevier ,Current Plant Pathology Volume 21

Cardone, M.; Mazzoncini, M.; Menini, S.; Rocco, V.; Senatore, A.; Seggiani, M.; Vitolo, S.(2003) Brassica carinata as an alternative oil crop for the production of biodiesel in Italy: Agronomic evaluation, fuel production by transesterification and characterization. Biomass Bioenergy, 25, 623–636.

Cotes MJ, Nustez EC, Martinez R, Estrada N (2002). Analyzing Genotype by Environment Interaction in potatoes using Yield- stability Index. Am. J. Potato Res. 79:211-218

Crossa, J., Fox P. N., Pfeiffer, W. H., Rajaram, S., and Gauch, H. G. 1991 AMMI adjustment for statistical analysis of an interactional wheat yield trial. Theor. App Gent, 81: 27-37.

Delacy IH, Cooper M, Basford KE (1996). Relationship among analytical methods used to study genotypes-by-environment interactions and evaluation of their impact on response to selection. In:

Deitos A, Arnhold E, Miranda GV (2006) Yield and combining ability of maize cultivars under different eco-geographic conditions. Crop Breeding and Applied Biotechnology 6: 222-227

Esayas Tena, Frehiwot Goshu, Hussein Mohamad, Melaku Tesfa, Diribu Tesfaye & Abebech Seife. (2019) Genotype × environment interaction by AMMI and GGE-biplot analysis for sugar yield in three crop cycles of sugarcane (*Saccharum officinirum* L.) clones in Ethiopia, Cognet Food & Agriculture *Volume 5, 2019* - *Issue 1*

Farshadfar,E. N. Mahmodi, and A. Yaghotipoor (2011). AMMI stability value and simultaneous estimation of yield and yield stability in bread wheat (Triticum aestivum L.), Australian Journal of Crop Science, vol. 5, no. 13, pp. 1837–1844, 2011.

Farshadfar E., (2008). "Incorporation of AMMI stability value and grain yield in a single non parametric index (GSI) in bread wheat," Pakistan Journal of Biological Sciences, vol. 11, no. 14, pp. 1791– 1796,

Flores, F., M. T. Moreno, and J. I. Cubero. 1998. A comparison of the univariate and multivariate methods to analyze G*E interaction. Field Crop Res. 56:271-286.

Gauch HG (2006). Statistical analysis of yield trials by AMMI and GGE. Crop Sci. J. 46(4):1488-1500

Gauch, H. G. (1992). *Statistical analysis of regional yield trials*. Amsterdam: Elsevier

Gauch, H.G. and R.W. Zobel.1996. AMMI Analysis of Yield Trials. In: Genotype-by-Environment Interaction, Kang, M.S. and H.G. Gauch (Eds.). Boca Raton CRC, New York, USA. pp: 85-122 Kang, M.S.1998. Using genotype-by-environment interaction for crop cultivar development. Adv. Agron. , 35: Getinet, A.; Rakow, G.; Raney, J.P.; Downey, R.K.(1994). Development of zero erucic acid Ethiopian mustard through an interspecific cross with zero erucic acid Oriental mustard. Can. J. Plant Sci. 74, 793–795.

Huhn M (1996). Nonparametric analysis of genotype X environment interactions by ranks. In: Kang, M.S., and H.G. Gauch (eds), Genotype -by-environment interaction. CRC press, New York pp. 235-271.

Kang, M.S., and H.G. Gauch (eds), genotype-by-environment interaction. CRC press, New York pp. 51-84

Kenneth W., Marshall D. Lindheimer, (2009). In Chesley's Hypertensive Disorders in Pregnancy (Third Edition), 200). Chapter 4 - Genetic Factors in the Etiology of Preeclampsia/Eclampsia

Kim, J, Taeheon Lee, Hyun-Jeong Lee and Heebal Kim, 2014. Genotype-environment interactions for quantitative traits in Korea Associated Resource (KARE) cohorts. Genetics 15: 18, http://www.biomedcentral.com/1471-2156/15/18.

Manrique, K. and Hermann, M. (2002). Comparative study to determine stable performance in Sweet potato. Acta Hortic. 583, 87-94

Mohammad J., Ashwani K. and S.K. Gupta SK. (2018). Phenotypic Stability for Yield and Some Quality Traits in Brassica juncea L. *Int.J.Curr.Microbiol.App.Sci* 7(2): 479-485

Prado, E.E., D. M. Hiromoto, V. P. C. Godinho, M. M. Utumi and A. R. Ramalho. 2001. Adaptabilidade e estabilidade de cultivares de soja em cinco épocas de plantio no cerrado de Rondônia. Pesquisa Agropecuária Brasileira 36: 625-635.

Purchase, J. L., Hatting H., and Vandenventer, C. S. 2000. Genotype x environment interaction of winter wheat in South Africa: II. Stability analysis of yield performance. South Afr J Plant Soil, 17: 101-107.

Schippers RR (2002). African Indigenous vegetables, An Overview of the Cultivated Species 2002. Revised version in CD – ROM. Natural Resources International Limited, Aylesford, UK

Tadele Tadesse*, Gashaw Sefera and Amanuel Tekalig (2018). Genotypes × Environment interaction analysis for Ethiopian mustard (Brassica carinata L.) genotypes using AMMI model. *Journal of Plant Breeding and Crop Science*Vol. 10(4), pp. 86-92

Tarakanovas P., and Ruzgas V.(2006). Additive main effect and multiplicative interaction analysis of grain yield of wheat varieties in Lithuania. Agronomy Research 4(1), 91–98,

Tumuhimbise, R., R. Melis, P. Shanahan, and R. Kawuki, "Genotype * environment interaction effects on early fresh storage root yield and related traits in cassava," The Crop Journal, vol. 2, no. 5, pp. 329–337, 2014

Yan W, Tinker NA (2006). Biplot analysis of multi-environment trial data: Principles and applications. Can. J. Plant Sci. 86(3):623-645

Grain Yield Stability in Linseed (*Linum usitatissimum* L.) genotypes in the highlands of Bale, Southeastern Ethiopa

Tadele Tadesse*, Amanuel Tekalign and Belay Asmare

Oromia Agriculture Research Institute, Sinana Agriculture Research Center, Bale-Robe, Ethiopia

Email address:

tadyeko20@gmail.com/tadeleta20@yahoo.com

* Corresponding author
Abstract
Linseed (Linum usitatissimum L.), or also known as flax, has been cultivated for many years. Its oil is rich in omega-3 fatty acids, especially Alpha-Linolenic Acid (ALA) (C18:3) that was beneficial for heart disease, inflammatory bowel disease, arthritis and a variety of other health conditions. Twelve linseed (Linum usitatissimum L.) genotypes were evaluated at two Southeastern Ethiopia, Sinana, and Agarfa locations for three consecutive seasons in order to estimate grain yield stability. A randomized complete block design with four replications was used. Grain yield was studied for genotype by environment interaction (GEI) using stability parameters. Analysis of variance showed highly significant variation for genotypes, environment, and genotypes by environment interaction. The highest mean grain yield was recorded from ACC 230826 (2.48t/ha) followed by EH) 10007-7 (2.42t/ha) whereas the highest mean grain yield for environments was recorded from Sinana 2020 (2.38t/ha) followed by Agarfa 2020 (2.11t/ha), and Sinana 2018 (1.96t/ha). Based on the stability parameter using Eberhart and Russell's model, genotype, ACC230826 had a slope value of 0.96, and deviation from regression 0.04, and genotype EH010007-7 had slope value 1.03 with deviation from regression 0.73 indicates as both genotypes were stable. Since these two genotypes gave mean grain yield higher than the checks with yield advantage of 16.8%, and 13.8% over the checks, and also satisfied the stability principles of Eberhart and Russell's model thus, we identified these two genotypes to be verified for possible release in the highlands of Bale, Southeastern Ethiopia, and similar agro-ecologies.
Keywords: Deviation from regression grain yield, Linseed, Stability, Slope,

Introduction

Linseed (*Linum usitatissimum L.)* is a multipurpose oilseed crop, cultivated for oil and fiber, which belongs to the family Linaceae having 14 genera. It has somatic chromosome number 2n = 30. In Ethiopia, among the highland oilseeds, linseed stands second next to Niger seed in total production and areas coverage (Adefris *et al*., 1992, Adugna, 2000). It is an annual field crop that is largely grown in temperate climates (Mansby *et al.*, 2000) and cool tropics including the highlands (>2500m asl) of Ethiopia. In Ethiopia, linseed has been cultivated for two primary purposes, seed and oil use. It has been used for food and as a cash crop since ancient times (Seegler, 1983). Every part of the plant is utilized commercially either directly or after processing. Linseed contains about 35-45% oil which is high in unsaturated fatty acids, especially linolenic acid (Khan *et al*., 2010) and 20-25% protein (Gill, 1987; Arora *et al*., 2003). The oil primarily goes to industries for the manufacturing of paints, varnish, oilcloth, linoleum, pad-ink and printing-ink. Oilcake is a good feed for milch cattle.

Breeding cultivars that adapted reasonably larger geographical area with varying degree of stability from year to year has been a major problem confronting plant breeders. The only effective control might be to reduce environments by grouping them on the basis of their similar responses and subsequently evaluating genotypes in representative environments from each group (Compbell and Lafever, 1977). The existence of genotype-environment interaction (GEI) complicates the identification of superior genotypes for a range of environments and calls for evaluating genotypes in many environments to determine their true genetic potential (Yaghotipoor*et al.,* 2007). Yield is a complex quantitative character and is greatly influenced by environmental fluctuations; Hence, the selection for superior genotypes based on yield per se at a single location in a year may not be very effective, Eberhart and Russell (1966). Lack of high yielding varieties adapted to diverse agro-ecological conditions is the major reason of low productivity. Thus the present study aimed to identify linseed genotypes that are high yielder with stable performance across the testing sites in the highlands of Bale, Southeastern Ethiopia. .

Materials and Methods

Twelve linseed genotypes (Table 1) were evaluated along with two standard checks (Dibene, and Jitu), and a local cultivar in the highlands of Bale, Southeastern Ethiopia, at Sinana and Agarfa for three consecutive years (2018 to 2020). Randomized Complete Block Design with four replications with a plot size of $3.2m^2$ (4 rows at 20cm spacing, and 4m long) was used at all environments. Analysis of variance for each environment and combined analysis of variance was done for grain yield and other traits, using the Crop Stat, ver. 7.2 computer programs. Mean data from each location was used to analyze the combined analysis of variance to create the means data for the different statistical analyses. For the stability analysis, the method of Eberhart and Russell (1966) was used to calculate the regression coefficient (bi), and deviation from regression (S2di). It was calculated by regressing the mean grain yield of individual genotype/environments on the environmental/genotypic index. The linear model proposed by Eberhart and Russell's (1966) is Yij = μi +biIj +S2dij, where Yij is the mean performance of the ith variety (I = 1, 2, 3…, n) in the jth environment; μi is the mean of the ith variety over all the environments; bi is the regression coefficient which measures the response of ith variety to varying environments; S2dij is the deviation from regression of ith variety in the jth environment and Ij is the environmental index of the jth environment.

Table 1. Lists of linseed genotypes used in the study along with their source

Genotype code	Genotypes	Source
G1	EH010004-7	HARC
G2	EH0100010	HARC
G3	EH01000-3	HARC
G4	ACC230660	HARC
G5	ACC233994	HARC
G6	EH010004-5	HARC
G7	ACC 242594	HARC
G8	ACC234005	HARC
G9	ACC 230826	HARC
G10	EH010007-7	HARC
G11	EH010001-4	HARC
G12	ACC 230822	HARC
G13	Jitu	Released from SARC
G14	Dibane	Released from SARC
G15	Local	Local cultivar

HARC= Holetta Agricultural Research Center, SARC= Sinana Agricultural Research Center

Results and Discussions

The combined analysis of variance revealed highly significant variation (P<0.01) for mean grain yield among genotypes, environment, and genotype by environment interaction (Table 2). The genotypes, genotypes by environment interaction, and environment accounted for 22.81%, 2.94%, and 0.77% of the total sum squares. This implies that the genotypes were highly diverse and responsible for the variation observed for grain yield. A similar result of highly significant interaction in linseed was reported by Adane *et al.*, 2018; Tadele *et al.*, 2017; Devender *et al.*, 2016. .

Table 2. Combined Analysis of Variance for mean grain yield of 15 Linseed genotypes over locations and years

Source of Variation	Degree freedom	Sum Squares	Mean Squares	% of variation
YEAR (Y)	2	16.6143	8.30716**	8.93
Location (L)	1	1.43152	1.43152*	0.77
Replication	3	1.1747	0.391567	0.63
Genotype (G)	14	42.4348	3.03106**	22.81
Y X L	2	1.63083	0.815416*	0.88
G X L	14	5.46624	0.390446**	2.94
Y X L X G	56	35.0189	0.625337**	18.83
RESIDUAL	67	82.5499	0.309176	44.38
TOTAL	359	186		8.93

The highest mean grain yield was obtained from genotypes G9 (2.48t/ha), followed by G10 (2.42t/ha), G4 (2.28t/ha), and G12 (2.11t/ha) whereas the highest yielding environments were Sinana 2020 (2.38t/ha) followed by Agarfa 2020 (2.11t/ha), Sinana 2018 (1.96t/ha) and Agarfa 2018 (1.80t/ha) (Table 3).

Table 3. Mean grain yield of 15 linseed genotypes over locations and years

Entry	Treat code	Sinana 2018	Agarfa 2018	Sinana 2019	Agarfa 2019	Sinana 2020	Agarfa 2020	TRT MEANS
EH010004-7	G1	2.12	1.41	1.37	1.43	2.3	3.06	1.95
EH0100010	G2	2.06	2.03	2.03	1.4	2.45	2.01	2.00
EH01000-3	G3	1.82	1.51	1.55	1.54	2.24	1.57	1.70
ACC230660	G4	1.99	2.05	2.08	2.08	3.14	2.35	2.28
ACC233994	G5	1.86	1.72	2.05	1.75	2.72	1.69	1.96
EH010004-5	G6	1.91	1.84	1.6	1.88	2.27	1.46	1.82
ACC 242594	G7	1.94	1.61	2.23	1.65	2.81	2.9	2.19
ACC234005	G8	2.07	1.72	1.25	1.75	2.32	1.11	1.70
ACC 230826	G9	2.59	2.57	2.02	2.32	2.68	2.72	2.48
EH010007-7	G10	2.63	1.96	1.76	1.99	2.14	3.15	2.42
EH010001-4	G11	1.56	1.59	1.51	1.69	2.77	2.1	1.87
ACC 230822	G12	2.13	2.31	1.34	2.35	2.91	1.63	2.11
Jitu (St.check)	G13	2.08	2.18	2.2	1.82	2.5	2.16	2.12
Dibane	G14	1.32	1.51	1.42	1.67	1.49	1.69	1.52
Local	G15	1.25	1.05	1.21	1.06	1.01	1.12	1.12
MEANS		1.96	1.8	1.71	1.76	2.38	2.11	1.95
5% LSD		0.35	0.82	0.62	0.82	0.98	0.9	0.34
C.V.		12	21.6	21.7	23.1	24.1	21.5	21.20

From the combined analysis, it was observed that all the traits studied showed highly significant variation. From the combined mean data, the linseed genotypes needed 64 to 69 days to flower, and to reach physiological maturity they need 141 to 146 days, and also have plant height of 82 to 94cm (Table).

Table 4 Mean Seed yield and other agronomic traits for 15 linseed genotypes tested at six environments in the highlands of Bale, Southeastern Ethiopia.

Entry	Stand%	Days to Flower	Days to Mature	Plant ht. (cm)	Diseases (0-5 scale)			1000 seed wt. (g)	Seed yield t/ha)
					Pasmo	Powder Mildew	Wilt		
EH010004-7	81	66	145	93	5	5	5	5.7	1.95
EH0100010	81	67	145	92	4	5	5	5.7	2.00
EH01000-3	69	64	141	87	5	5	5	5.3	1.70
ACC230660	76	68	144	89	5	5	5	5.1	2.28
ACC233994	70	64	142	82	5	5	5	5.1	1.96
EH010004-5	70	65	141	83	5	5	5	5.3	1.82
ACC 242594	70	67	144	89	5	5	5	5.4	2.19
ACC234005	68	67	141	84	5	5	5	5.1	1.70
ACC 230826	82	69	145	93	3	2	3	5.1	2.48
EH010007-7	81	67	146	90	3	3	3	5.9	2.42
EH010001-4	77	60	142	85	5	5	5	5.3	1.87
ACC 230822	79	66	144	90	5	5	5	5.2	2.11
Jitu	83	68	146	94	5	4	4	5.9	2.12
Dibane	82	68	145	96	5	5	5	5.9	1.52
Local	81	67	144	94	5	4	5	5.6	1.12
Mean	77	66	144	89				5	1.95
5%LSD	6.2	1.2	5.7	8.8				0.2	0.34
CV%	14.2	3.3	7	17.4				6.8	21.2

GEI refers to inconsistent phenotypic performance of genotypes across environments. When it is associated with a significant genotypic rank change over environments, it potentially presents limitations on selection and recommendation of varieties for target set of environments (Navabi *et al*. 2006) as it attenuates the association between phenotype and genotype, reducing genetic progress in plant breeding programs. Eberhart and Russell's 1966, model provide a mean of partitioning the genotype-environment interaction for each genotype into two parts. These are variations due to the response of genotype to different environmental index (sum of squares due to regression), and the unexplainable deviation from the regression on the environmental index. They added that a stable genotype could have high mean performance with a slope value close to unity, and deviation from regression near to zero. Thus, in the present study Genotype, G9 gave a mean grain yield of (2.48t/ha) with a slope value of 0.96, and deviation from regression value close to zero (0.04) whereas G10 gave the second-highest mean grain yield (2.42t/ha) with slope value of 1.03 and its deviation from regression was 0.73. Therefore, these two genotypes were identified as stable genotypes over the tested environment. On the other hand, though genotypes G4, and G7 gave mean grain yield of 2.28t/ha, and 2.19t/ha, respectively that is higher than the yield of the check varieties; they had slope values of 1.53, and 1.70, and deviation from regression of 0.04 and 0.73, respectively. These two genotypes, G4, and G7 since they have bi>1, were responsive to favorable environments and showed unstable performance (Table 5)

Table 5. Mean grain yield, and Stability parameters for 15 linseed genotypes tested over environments

Trt C0	Genotypes	Mean	Rank Yi	Slope (bi)	MS-DEV (S2di)
G1	EH010004-7	1.95	9	1.96	0.26
G2	EH0100010	2.00	7	0.91	0.07
G3	EH01000-3	1.70	12	0.94	0.03
G4	ACC230660	2.28	3	1.53	0.05
G5	ACC233994	1.96	8	1.04	0.1
G6	EH010004-5	1.82	11	0.54	0.07
G7	ACC 242594	2.19	4	1.7	0.16
G8	ACC234005	1.70	13	0.84	0.21
G9	ACC 230826	2.48	1	0.96	0.04
G10	EH010007-7	2.42	2	1.03	0.73
G11	EH010001-4	1.87	10	1.79	0.04
G12	ACC 230822	2.11	6	1.16	0.28
G13	Jitu (St.check)	2.16	5	0.61	0.03
G14	Dibane	1.52	14	0.03	0.03
G15	Local	1.11	15	0.14	0.01

Where bi = slope/correlation coefficient, MS-DEV (S2di) = deviation from regression

Conclusions

Generally, the present study entails the presence of significant variations among environments, genotypes, and GEI interaction for mean grain indicating as genotypes were more variable and highly responsible for the variation. Having high yielder genotypes with stable performance across the testing site is very crucial to boos crop production. Accordingly, based on their yield advantages over the checks, their stable performance across the testing sites, and due to their tolerant reaction for major linseed diseases, two genotypes G9, and G10 were identified as candidate genotypes to be verified for possible release for the highlands of Bale, Southeastern Ethiopia, and similar agro-ecologies.

Acknowledgement

We would like to thank Oromia Agriculture Research Institute for financial support and Sinana Agriculture Research Center for providing the necessary support, and Pulse and Oil Crops research case team staff for the entire trial management and data collection.

References

Adane C. and bebe D. (2018). AMMI and GGE biplot analysis of linseed (*Linum usitatissimum* L.) Genotypes in central and south-eastern highlands of Ethiopia. *J. Plant Breed. Genet*. 06 (03). 117-127

Adefris TW, Getinet A, Tesfaye G (1992). Linseed breeding in Ethiopia. In: Oilseeds Research and Development in Ethiopia. Proc. of the First National Oilseeds Workshop 3-5 Dec. 1991. IAR, Addis Ababa, Ethiopia, pp. 41-50.

Adugna W (2000). Assessment of tissue culture drived regenerants of linseed (Linum usitatissimum L.) in Ethiopia. M.S.c. Thesis. Department of plant breeding, faculty of Agriculture, University of the Free State, Bloemfontein, South Africa.

Arora, S., Modgil, R., Sood, S. and Bhateria, S. (2003). Physio-chemical and nutritional qualities of different cultivars of linseed (Linum usitatissimum L.). J. Food. Sci. Tech., 40: 324-327

Compbell, H.G. and Lafever, H.N. (1977). Cultivar x environment interaction in soft and red winter wheat yield tests. Crop Sci., 17: 604–608

Devender Sharma and Satish Pau. (2016). Genotype × Environment Interaction and Phenotypic Stability analysis of Linseed (Linum usitatissimum L.) in Mid-Hills of North-West Himalayas. *Journal of Applied and Natural Science* 8 (4): 2040-2048

Eberhart SA, Russell WA (1966). Stability parameters for comparing varieties. Crop Sci. 6:36-40.

Gill, K.S. (1987). Linseed, ICAR Publication, New Delhi, India.

Khan, M.L., Sharif, M. and Sarwar, M. (2010). Chemical composition of different varieties of linseed. Pak. Vet. J., 30 (2): 79-82

Mansby E, Díaz O, von Bothmer R (2000). Preliminary study of genetic diversity in Swedish flax (Linum usitatissimum). Genet. Res. Crop Evol. 47:417-424.

Navabi, A., Yang, R .C., Helm, J. and Spawer, D. M. (2006). Can spring wheat growing mega environments in the northern great plain be dissected for representative locations or niche adapted genotypes. Crop Sci. 46:1107-16

Seegler CJP (1983). Oil plants in Ethiopia, their economy and agriculture. M. H. Thijssen, Zewde B, Beshir A, de Boef WS (2008). (eds) farmers seed and varieties: supporting informal seed supply in Ethiopia. Wagningen, Wagenningen International.

Tadele Tadesse, Amanuel Tekalign, Gashaw Sefera, Behailu Muligeta (2017). AMMI Model for Yield Stability Analysis of Linseed Genotypes for the Highlands of Bale, Ethiopia. Plant. Vol. 5, No. 6, 2017, pp. 93-98. doi: 10.11648/j.plant.20170506.12

Yaghotipoor A , and Farshadfar E. 2007. Non-parametric estimation and component analysis of phenotypic stability in chickpea (Cicer arietinum L.) Pak J Biol Sci, 10: 2646-2649

Registration of Hora, Small-red Seed Food Type Common Bean (*Phaseolus vulgaris*) Varieties for Midland areas of Bale and East Bale, Southeast Ethiopia.

Amanuel Tekalign*, Tadele Tadesse, Belay Asmare

Oromia Agriculture Research Institute,

Sinana Agriculture Research Center, Bale-Robe, Ethiopia

Abstract

Ethiopia has suitable environmental condition for common bean production. However, the productivity of common bean is very low as compared with world average due to lack of stable, high yielding, and disease resistant genotypes. Therefore, the objective of this study was to register stable high yielding and disease resistant/tolerant common bean variety for midlands areas of Bale and other similar agro-ecologies in the country. The experiment was carried out at two locations from 2015 to 2017 main cropping season using 15 genotypes including standard checks. Eventually, two promising genotypes, "SCR-28 and SCR-8" were selected and promoted to variety verification trail with the standard check ''SCR 1 and Nasir" during the 2020/21 cropping season. The National Variety Release technical Committee evaluated the two candidate varieties at Goro and Ginner on research stations and farmers' fields. Among the two evaluated varieties, SRC-28, 'Hora', is well adapted to altitudes ranging between 1600 and 1950 meters above sea level and gave high seed yield (1587 kg ha^{-1}) and stable performance across years and locations. It has about 29.3% yield advantage over the standard check variety, "Nasir". Hora is also resistant/ Tolerant level of reactions to Alternaria Leaf Spot, Common Bacteria Blight and Rust. Hence, Hora is released for Midland Areas of Bale and East Bale and similar agro-ecologies for its stable and high grain yield, and resistant to major diseases. Therefore, farmers could be cultivated Hora for increasing productivity of the crop with its full recommended packages.

Keywords: Disease resistance, Grain yield, Hora, Phaseolus vulgaris, stability.

Introduction

Common beans (*Phaseolus vulgaris* L) are annual pulse crop with considerable variation in habit, vegetation characters, flower color and the size, shape of pods and seeds (Onwueme and Sinha, 1999). Beans need up to four months of warm weather and are not frost tolerant. They do poorly in very wet or humid tropical climates because of susceptibility to bacterial and fungal diseases. They need well-drained soils with a pH between 6.5 and 7.0 and are sensitive to deficiencies or high levels of minerals in the soil (Broughton *et. al*., 2003).

It is one of the major food and cash crops in Ethiopia and it has considerable national economic significance and also traditionally ensures food security in Ethiopia. It ranks third as an export commodity in Ethiopia, contributing about 9.5% of total export value from agriculture. It is often grown as cash crop by small scale farmers. The majority of common bean producers in Ethiopia are small scale farmers, and it is used as a major food legume in many parts of the country where it is consumed in different types of traditional dishes (Habtu *et al* 1996).

Pulses covered 10.38% (about 2,671,843.040 tons) of the grain production. Out of this, red and white seeded common beans were planted to, 1.95% (about 244,049.94 ha) and 0.91% (about 113,249.95 ha) of the grain crop area respectively. The production obtained from common bean red and white seeded were 1.43% (380,499.453 tons) and 0.60% (159,739.484 tons) of the grain production respectively. Therefore, the total area devoted for common bean crop production and the yield obtained in Ethiopia are 357,299.89 ha and 540,238.94 tons respectively (CSA., 2016). Even though the crop has tremendous importance in country economy such as for home consumption, soil fertility improvement and etc., its improvement is highly challenged by low yield, diseases, insect pests, and prolonged drought in Ethiopia. Therefore, the objective of this study was to register the released stable high yielding and disease resistant/tolerant common bean variety for midlands areas of Bale, East Bale and other similar agro-ecologies in the country.

Materials and Methods

Description of the Study Area

The field experiments were carried out at two locations, i.e., Goro and Ginner, South-Eastern Ethiopia, and 490 and 568 km, far from capital city, Addis Ababa. Description of the test locations for geographical position and physico-chemical properties are summarized and tabulated hereunder (Table 1).

Table 1 Description of the test locations for geographical position and physico-chemical properties

	Location	
Parameter	Goro	Ginner
Geographical position		
Latitude	6° 59’20.97” N	$7^0$10’42.02” N
Longitude	$40^0$29’45.16” E	$40^0$42’58.64” E
Altitude (m.a.s.l.)	1771	1972
Soil Property		
pH (by 1:2:5 soil Water)	6.89	6.82
OMC (%)	1.19	1.18
Pav(ppm)	8.43	10.23
CEC (cmol. (+) kg soil^{-1})	49.46	47.46
Soil texture	Clay	Clay

Key: OMC = Organic matter content, Pav = Phosphorus availability, CEC = Cation exchange capacity

Experimental Design and Field Management

In multi-location trials, total of 15 Small-Seeded red Bean genotypes including the standard check “SCR 1 and Nasir” were evaluated at Goro and Ginner for three years (2015 to 2017). The experimental layout was arranged in RCBD designs with 4 replications across testing site. The experimental plots have 4(four) rows and 40(cm) inter-rows spacing, and have a total of 3.2 (m^2) net harvesting plot size Fertilizer was applied at the rate of 100 kg ha^{-1} diammonium phosphate

(18 kg N ha^{-1}, 46 kg P2O5 kg ha^{-1} and 0 k) and all other crop management practices were carried out as recommended. Finally, Hora (SCR-28) was selected and verified along with two standard checks. The verification trial was evaluated by the National Variety Releasing Committee at field condition and was released fully for the midland of Bale, East Bale, and similar agro-ecologies.

Results and Discussions

Varietal Origin and Evaluation

Hora (SCR-28) along with 14 genotypes were obtained from Melkasa Agriculture Research Center of the Ethiopian Institute of Agriculture Research. The genotypes were evaluated along with the standard check variety, "SCR 1 and Nasir", across two locations (Goro and Ginner) from 2015-2017. Two genotypes "SCR-28 and SCR-8" were selected as candidate varieties based on a combined data analysis of variance and mean performances comparison of genotypes (Table 2 and 3). The two most promising candidate varieties and the standard check variety were eventually promoted to a variety verification trial. The candidate varieties and standard check variety were planted in plots with a size of 10 m x 10 and evaluated by the national variety release technical committee at two locations during the 2020/21 cropping season. Finally, the national variety release technical committee selected "SCR-28" genotype for release. SCR-28 has better yield advantage, and good resistance/ Tolerant to Alternaria Leaf Spot, Common Bacteria Blight and Rust (Table 4).

Agronomic and Morphological Characteristics

Hora variety has an average plant height of 68 cm and maturity date of 94 days. The variety has high grain yield (1587kg ha^{-1}). The flower color and cotyledon colors of the variety is pink and Light white respectively, with thousand seed weight of 223.1 gm (Table 1).

Yield Performance

The average grain yield of Hora combined over locations and years were 1587kg ha^{-1}, which is higher than SCR-1 (best standard check), 1245 kg ha^{-1}. Under research field, Hora gave grain yield ranging from 2200-2600 kg ha^{-1} while on farmers' field it ranges from1300-1800 kg ha^{-1}(Table 3).

Reaction to Disease: The diseases score for the new variety and the checks are summarized in Table 4. The resistance level of the new variety was better than the standard checks for Alternaria Leaf Spot, Common Bacteria Blight and Rust.

Performance Stability and Adaptation Domain

Hora is released for the midland areas of Bale, East Bale and similar agro-ecologies. It performs very well in area having an altitude of 1600 to 1950 m a.s.l and annual rainfall of 550-650 mm. The appropriate planting date for this variety would range from end of September to early October (Table 1). For a better harvest the variety must receive 18 kg N ha^{-1}, 46 kg P2O5 kg ha^{-1} at sowing and seed rate of 100 kg/ha. Hora variety showed stable yield performance across tested years over location (Table 4).

Variety Maintenance

The breeder and foundation seed will be maintained by Sinana Agricultural Research Center/ Oromia Agricultural Research Institute.

Table 2. Agronomical and Morphological Characteristics and Agro-ecological Zones of Adaptation of Hora, Small red type common bean variety

Variety name:		Hora (SCR-28)
Agro-ecological Zones of Adaptation		Goro, Ginner, Dellomena, Berbere and other similar agro-ecologies
Altitude (m.a.s.l.)		1600 – 1950
Rainfall (mm)		550 –650
Seed Rate (Kg/ha)		90
Planting date		End of September to Early October
Fertilizer Rate (NPS kg/ha)		100
Days to Flower		52
Days to Maturity		94
Plant Height (cm)		68
1000 Seed Weight (gm)		223.1
Growth habit		Portrait
Seed coat Color		Red
Seed size		Small
Cotyledon Color		Light white
Flower Color		Pink
Yield (Qt/ha)	(Research Field	22-26
	On-farmer's Field)	13-18
Disease reaction		Tolerant to Alternaria Leaf Spot, Common Bacteria Blight and Rust
Year of Release		2021
Breeder and Maintainer		SARC(IQQO)

Table 3. Mean grain yield(kg/ha) of 15 Small Red bean genotypes (Set-II) across locations and years

Entry	Goro			Ginner			Mean	Yield Adv. over St. check
	2015	2016	2017	2015	2016	2017		
SCR 7	2328	1192	614.4	1623	853	1160	1295	
SCR 36	2618	1223	707.3	2120	837	1298	1467	
SCR 15	2486	1711	645	1733	833	1309	1453	
SCR 8	2776	1575	656.7	1764	843	1186	1467	
SCR 16	2276	1121	490.1	1697	722	1275	1263	
SCR 13	2345	1294	440.8	1705	831	1250	1311	
SCR 35	2289	1016	529.1	1730	805	1201	1262	
SCR 18	2476	1197	662.5	1754	1028	1196	1386	
SCR 9	2328	1913	424	1672	864	1487	1448	
SCR 29	2235	1131	657.5	1736	895	1508	1360	
SCR 2	2266	1246	582.5	1344	884	1133	1243	
SCR 17	2340	1739	626.5	1229	814	1828	1430	
SCR 28	2664	2112	686.7	1277	966	1818	1587	29.3%
SCR 1	1976	1212	453	1571	798	1457	1245	
Nasir	2270	815	690.5	1585	774	1235	1228	
Means	2378	1367	591.1	1636	850	1356	1363	
LSD (<0.05)	452.3	633.7	372.9	459.7	187.6	560.3	287.1	
CV	13.0	24.3	24	20.0	15.0	24.1	20.1	

Table 4. Mean seed yield and other agronomic traits of 15 Small Red bean genotypes tested regional variety trial (Set-II) combined for two locations (Ginner and Goro) over three years (2015-2017)

Entry	DF	DM	Stand %	PH (cm)	NPP	NSP	TSW(g)	GY (kg/ha)
SCR 7	51	94	75	63	15	4	245.1	1295
SCR 36	52	94	78	67	16	4	232.6	1467
SCR 15	52	94	75	67	17	4	242.8	1453
SCR 8	53	94	74	66	15	4	245.3	1467
SCR 16	52	93	74	64	12	4	233.8	1263
SCR 13	52	94	73	64	15	4	248.7	1311
SCR 35	52	94	72	69	16	4	235.1	1262
SCR 18	52	93	74	65	12	4	234.5	1386
SCR 9	52	94	75	62	13	5	236.4	1448
SCR 29	52	94	74	66	14	4	236.6	1360
SCR 2	52	94	73	64	14	4	256.4	1243
SCR 17	52	94	74	63	13	4	244.1	1430
SCR 28	52	94	78	68	14	4	223.1	1587
SCR 1	52	93	73	66	15	5	223.4	1245
Nasir	52	95	78	65	14	4	193.4	1228
Mean	52	94	75	65	14	4	235	1363
LSD (<0.05)	1.1	1.9	9.4	6.2	4.3	0.4	13.0	287.1
CV%	3.8	3.6	22.1	16.8	22.7	16.9	9.7	20.1

Note: DF = days to 50% maturity, DM, days to 90% maturity, PH = plant height(cm), NPP = Number of pods per plant, NSP =Number of seed per plant, TSW = Thousand seed weight(g), GY = grain yield(kg)

Table-5. Mean grain yield, agronomic traits and disease reaction of ‘Hora’ along with standard checks tested in two environments at varietal verification levels during 2015-2017cropping seasons.

Entry	Agronomic traits								Disease Reaction (1-9 scale)		
	DF	DM	Stand %	PH (cm)	NPP	NSP	TSW (g)	GY (kg ha^{-1})	ALS	CBB	Rust
SCR 28	52	94	78	68	14	4	223.1	1587	4	3	3
SCR 8	53	94	74	66	15	4	245.3	1467	4	4	3
Nasir	52	95	78	65	14	4	193.4	1228	5	3	3
SCR 1	52	93	73	66	15	5	223.4	1245	6	4	4

Note: DF = days to 50% maturity, DM, days to 90% maturity, PH = plant height(cm), NPP = Number of pods per plant, NSP =Number of seed per plant, TSW = Thousand seed weight(g), GY = grain yield(kg), ALS = Alternaria Leaf Spot, CBB = Common Bacteria Blight

Conclusions

Hora is the superior variety compared with the standard checks in grain yield performance in multilocation trails across the testing environments and yield stability. It has better agronomic performance with tolerance level of reactions to Alternaria Leaf Spot, Common Bacteria Blight and Rust as compared to the standard checks. Hence, cultivation of the new variety is recommended in mid altitudes of the major common bean growing areas of the country having similar agro-ecologies with the testing sites.

Acknowledgement

We thank staff members of the pulse Technology generation research team, Sinana Agricultural Research Centers for their unreserved efforts in field trail management and data collection during the experimental period. We are thankful to Oromia Agricultural Research Institute for funding the research throughout the varietal development process. We also to thank the Melkasa Agricultural Research Center for providing us with the germplasm.

References

Broughton, 2003. 'Bean (Phaseolus spp.) – model food legumes.' Plant & Soil, 252.

CSA (Central Statistics Agency of Ethiopia) (2016) Report on area and crop production of major crops for 2016 Meher season, 1: 125.

Habtu, A., Sache, I. and Zadoks, J.C., 1996. A survey of cropping practices and foliar diseases of common beans in Ethiopia. *Crop protection*, *15*(2), pp.179-186.

Onwueme, I.C. and T.D. Sinha, 1999. Field Crop Production in Tropical Africa. CTA. Wageningen, Netherlands.

Registration of Mieso, a Newly Released Field Pea (*Pisum sativum*) Varieties for Highlands of Bale, Southeast Ethiopia

Amanuel Tekalign*, Tadele Tadesse, Belay Asmare
Oromia Agriculture Research Institute,
Sinana Agriculture Research Center, Bale-Robe, Ethiopia

Abstract

Field pea (Pisum sativum L.) variety named Mieso with the pedigree designation of Acc 32003-2 has been officially released by Sinana Agricultural Research Center in 2021. The variety is best adapted to altitudes ranging between 2300 to 2600 meters above sea level in the country. The variety was evaluated under a regional variety trial for three years (2016 to 2018) at Sinana, Sinja and Agarfa districts. This Field pea variety showed superior performance particularly in terms of productivity and resistance/ tolerance level to disease across the years and locations. The released variety out-yielded the other tested Field pea genotypes on both research plots and farmers' fields. Based on most stability parameters, Mieso showed relatively better grain yield performance(3570kg/ha) and stability across a range of environments and years than the standard checks (Harena and Tulu Shenene) and could be cultivated across a number of locations in the highlands of Bale and other similar agro-ecologies for increasing productivity of the crop.

Keywords: Disease resistance, Grain yield, Out-yielded, Pisum sativum L, stability

Introduction

Field pea (*Pisum sativum* L.) is diploid species (2n= 2x=14) belonging to the Leguminosae family. Field pea is a self-pollinating cool season crops and an annual climbing, herbaceous plant, showing very considerable variation in form and habit (Ben Ze'ev *et al*., 1993). It is the fourth most important legume crop in Ethiopia in terms of both area and total amount of production accounts for 13% of the total grain legume production (Yirga., 2013). According to CSA., 2017 report field pea is grown by 1,639,756 households on 212,530.56 hectares of land from which produced 3,481,44.631 tons of grain with the national average of 1.638 t/ha. It requires evenly distributed a rainfall (800-1000 mm/annual) with altitudes ranges 1800-3000 m.a.s.l and cultivated in wide range of soil type with PH range 5.5- 6.5 provided that the drainage is good (Kay., 1979).

Field pea is nutritious food staff when fully matures and they are valuable food legume in different forms particularly in Ethiopia (CSA., 2017). The crop has important ecological and economic advantages in the highlands of Ethiopia, as it plays a significant role in soil fertility restoration and also serves as a break crop suitable for rotation especially with barley and wheat, which serves to restore soil nitrates and minimize weeds, insect pest and disease of cereals (Asfaw *et al*., 1993).

Despite its Ecological and its Economic importance, the productivity of the crop was low 1.6 t/ha and even if the potential yields of the crop extends up to 2.5-7.5 t / ha (CSA., 2017). The reason for low productivity of field pea in Ethiopia is due to less improved technology available which is widely adopted, lack of emphasis and other factors resulted for less field pea productions and economic benefits. Therefore, the development of cultivars, which are adapted to a wide range of diversified environments, is the ultimate aim of plant breeders in a crop improvement program (Bekele *et al*., 2003). The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is grown. A variety is considered to be more stable if it has a high mean yield but a low degree of fluctuation in yielding ability when planted over diverse environments (Purchase *et al*., 1997). Therefore, the objective of this study was to register stable high yielding and disease resistant/tolerant Field pea variety for highlands areas of Bale and other similar agro-ecologies in the country.

Materials and Methods

After conducting of multi-location trials for Sixteen Field pea collections from Ethiopian Biodiversity Institute for three consecutive years at Sinana, Sinja and Agarfa from 2016 to 2018 using RCBD designs with 4 replications across testing site with plot size of $3.2m^2$, one Field pea genotype, Acc 32003-2 were selected due to significantly better mean grain yield and reaction to Field pea disease (Powdery mildew, Downey Mildew and Aschocyta Blight) across all test environments, as a candidate genotype and verified along with check varieties, Harena' and Tulu Shenene at nine locations (at on-station and two on-farms at each location) in 2020/21 for official release. Farmers and NVRC evaluated all trials across on stations and on-farms and the committee decided the Acc 32003-2 and named "Mieso", for official release for production in the highlands of Bale, Southeastern Ethiopia and similar agro-ecologies.

Results and Discussions

Varietal Characteristics and Descriptions

Mieso is a commercial name given for a newly released Field pea variety with the pedigree name Acc 32003-2. Mieso is characterized by its gray and Light-yellow seed coat and cotyledon colors, respectively and that was evaluated for its agronomic traits across test locations and years. The average number of days required by the variety to reach its 50% flowering and 95% physiological maturity were 66 and 136, correspondingly, with the average plant height being 131 cm (Table 3). The average thousand seeds weight of 151.1g. On average, it produces 16 pods with medium length (Table 3). The appropriate planting date for this variety would range from end of July to early August. For a better harvest the variety must receive 46 kg P2O5 ha^{-1} and 18 kg ha^{-1} N at sowing (Table 1).

Yield and Quality Performance

The mean grain yield of Mieso combined over locations and over years is 3570kg/ha which is higher than standard checks, Harena (3226kg/ha), and Tulu Shenene (3226kg/ha) (Table 2). The variety gives grain yield of 48 to 50 Qt/ha on the research field whereas it gives 30 to 32Qt/ha on farmer's field. This variety has grain yield advantages of the new variety over the high yielder standard checks, Harena variety of the respective locations were 10.67%. Mieso variety is preferred to a greater extent for shiro rather than kiki.

Reaction to Major Diseases

The major field pea diseases according to their importance in the growing areas are powdery mildew (*Erysiphe polygoni*), Downey mildew (*Peronospora pisi*) and Aschochyta blight (*Mycosphaerella pinnodes*) (Asfaw *et al*., 1993). Accordingly, above mentioned disease is among the major bottleneck for Field pea production in Southeastern part of the country, Bale. Disease data across location and years were scored and analyzed. Mieso variety showed resistance to moderate resistance to the above-mentioned diseases throughout the field evaluation periods (Table 4).

Performance Stability and Adaptation Domain

The variety 'Mieso' was released for high altitude agro-ecologies of the country receiving 750-to-1000 mm average annual rainfall. It is well adapted to an altitude range of 1800 – 2600 meters above sea level such as Sinana, Goba, Agarfa, Goro (Meliyu), Gassera, Adaba, Dodola (west Arsi) other similar agro-ecologies (Table 2). Mieso variety showed stable yield performance across tested location over years. It performs best if it is produced with recommended fertilizer, seed rate and other recommended fertilizer rate in the recommended ecologies. The grain yield performance and stability parameters of Mieso (Acc 32003-2) and the checks are summarized in Table 4.

Variety Maintenance

The breeder and foundation seed will be maintained by Sinana Agricultural Research Center/ Oromia Agricultural Research Institute.

Table 1. Agronomical and Morphological Characteristics and Agro-ecological Zones of Adaptation of Mieso, Field pea variety

Variety name:		Mieso (ACC 32003-2)
Adaptation area		Sinana, Goba, Agarfa, Goro (Meliyu), Gassera, Adaba, Dodola (west Arsi) other similar agro-ecologies
Altitude (m.a.s.l.)		2300-2600
Rainfall (mm)		750-1000
Seed Rate (Kg/ha)		75
Planting date		End of July to early August
Days to Flower		66
Days to Maturity		136
Plant Height (cm)		131
Purpose		Shiro
1000 Seed Weight (gm)		151.1
Seed Color		Dark gray
Cotyledon Color		Light yellow
Flower Color		Pink
Yield	Research Field	48-50
(Qt/ha)	On-farmer's field	30-32
Disease reaction		Tolerant to Aschochyta blight, Powdery Mildew, Downey Mildew
Year of Release		2021
Breeder and Maintainer		SARC/IQQO

Table 2. Mean grain yield(kg/ha) of 16 Field pea genotypes across locations and years

	Agarfa			Sinja			Sinana				Yield Adv. over
Entry	2016	2017	2018	2016	2017	2018	2016	2017	2018	Means	St. check
ACC 32518-1	787	3564	1791	3401	3862	3557	2460	4084	3788	3033	
ACC32021-2	900	3722	1583	2759	2465	3203	2152	3705	4062	2728	
ACC 32197-4	945	3393	1758	2332	3840	3748	3129	3652	4226	3003	
ACC32003-2	1734	3727	1993	3129	3542	4414	3741	4828	5021	3570	10.67%
ACC 32509-1	1254	3840	1965	2857	3923	4311	3304	4283	4678	3379	
ACC 32399-4	736	3360	1588	2272	2637	4144	2581	3991	4422	2859	
ACC 32225-1	828	3268	1094	2164	3127	3533	2718	4112	4101	2772	
ACC32178-4	517	3186	1176	1834	3225	3288	2049	3314	3596	2465	
ACC 32512-4	490	2745	1196	2186	3530	3118	1765	3511	2933	2386	
ACC 32487-3	999	3356	1048	2876	3449	3207	2249	3244	3863	2699	
ACC 32180-4	840	3196	1267	2251	2612	3767	2020	3527	3615	2566	
ACC32488-4	845	2750	1342	1836	3297	2754	2345	3063	3550	2420	
ACC 32363-3	855	3418	1362	3077	3203	3146	2261	3789	3802	2768	
Harena	1181	3600	1867	3309	3505	3655	3480	3979	4454	3226	
T/Shenene	961	3944	1526	2624	3937	2901	3111	3735	4847	3065	
Local check	880	3122	1943	1842	3166	3293	2649	3151	3375	2602	
MEANS	922	3387	1531	2547	3333	3502	2626	3748	4021	2846	
LSD (<0.05)	458.3	530.9	659.8	723.4	1180.0	883.0	578.5	831	624.5	276.6	
C.V.	21.5	11.0	23.0	20.0	25.0	18.0	15.0	16	11.0	21.0	

Table 3 Mean seed yield and other Agronomic traits of 16 field pea genotype tested in Regional Variety Trial combined at four sites (Agarfa, Sinja and Sinana) over three years from 2016 to 2018

Entry	DF	DM	Stand %	PH (cm)	NPP	NSP	TSW (g)	GY (kg/ha)
ACC 32518-1	67	133	82	133	14	4	148.9	3033
ACC32021-2	66	136	82	139	13	4	155.4	2728
ACC 32197-4	63	135	83	131	15	4	148.9	3003
ACC32003-2	66	136	83	131	16	4	151.1	3570
ACC 32509-1	66	135	83	126	15	4	148.9	3379
ACC 32399-4	67	136	83	135	12	4	152.2	2859
ACC 32225-1	66	136	82	131	15	4	128.9	2772
ACC32178-4	67	136	83	134	15	4	140.9	2465
ACC 32512-4	67	136	83	139	12	4	143.3	2386
ACC 32487-3	66	136	81	125	18	4	130.9	2699
ACC 32180-4	65	136	83	131	12	4	150.6	2566
ACC32488-4	66	137	81	134	12	4	161.3	2420
ACC 32363-3	66	136	82	137	13	4	143.3	2768
Harena	64	135	83	132	13	4	184.1	3226
T/Shenene	64	135	81	128	13	4	152.8	3065
Local check	62	135	82	137	15	4	137.2	2602
Mean	66	135	82	133	14	4	148.7	2846
LSD (<0.05)	0.9	2.7	2.0	8.0	3.1	0.4	5.1	276.6
C.V.	3.0	4.2	5.3	13.0	24.7	24.1	7.4	21.0

Note: DF = days to 50% maturity, DM, days to 90% maturity, PH = plant height(cm), NPP = Number of pods per plant, NSP =Number of seed per plant, TSW = Thousand seed weight(g), GY = grain yield(kg)

Table-4. Mean grain yield, agronomic traits and disease reaction of 'Mieso' along with two standard checks tested in three environments at varietal verification levels during 2016-2018 cropping seasons.

	Agronomic traits								Disease Reaction (1-9 scale)		
Entry	DF	DM	Stand %	PH (cm)	NPP	NSP	TSW(g)	GY (kg/ha)	PM	DM	AsB
ACC32003-2	66	136	83	131	16	4	151.1	3570	4	4	4
Harena	64	135	83	132	13	4	184.1	3226	6	4	4
T/Shenene	64	135	81	128	13	4	152.8	3065	6	5	6
Local check	62	135	82	137	15	4	137.2	2602	6	5	6

Note: DF = days to 50% maturity, DM, days to 90% maturity, PH = plant height(cm), NPP = Number of pods per plant, NSP =Number of seed per plant, TSW = Thousand seed weight(g), GY = grain yield(kg), PM = Powdery mildew, DM = Downey Mildew, AsB = Aschocyta Blight

Conclusions and Recommendations

The development of cultivars, which are high yielder and adapted to a wide range of diversified environments, is ultimate aim of breeders in crop improvement program. A variety is considered to be more stable if it has high mean yield but a low degree of fluctuation in yielding ability when planted over diverse environments. The field pea varieties, Mieso, had above average grain yield performance in all environments out yielding the standard check, Harena, Tulu Shenene and local check. Mieso is characterized by its gray and light-yellow seed coat and cotyledon colors respectively with better yield stability. These varieties are resistance to moderate resistance powdery mildew, Downey mildew and Aschochyta blight. Hence, Mieso was verified and officially released for large scale production in major Field pea growing areas of Bale highland and other similar agro-ecologies.

Acknowledgement

The authors would like to thank Oromia Agricultural Research Institute for funding the research throughout the varietal development process. They also thank all staff members of the Pulse and Oil crops research case Team of the Sinana Agricultural Research Center for their unreserved efforts in field trail management and data collection during the experimental period.

References

Bekele, B., Muhammad, G., Galano, T. and Belayneh, T., 2003. Faba bean and field pea diseases research in Ethiopia. *Food and Forage Legumes of Ethiopia: Progress and Prospects*, p.221.

Central Statistical Agency (CSA), "Report on area and production of major crops (private peasants holdings, meher season)," Statistical Bulletin, vol. 532, pp. 15-17, 2017.

Kay, D.E., 1979. Food legumes. *Food legumes*., (3).

Yirga, H. and Tsegay, D., 2013. Characterization of dekoko (Pisum sativum var. abyssinicum) accessions by qualitative traits in the highlands of Southern Tigray, Ethiopia. *African Journal of Plant Science*, *7*(10), pp.482-487.

Purchase, J.L., 1997. *Parametric analysis to describe genotype x environment interaction and yield stability in winter wheat* (Doctoral dissertation, University of the Free State).

Ben Ze'ev, N. and Zohary, D., 1973. Species relationships in the genus Pisum L. *Israel Journal of Botany*.

Asfaw, T., Tesfaye, G. and Beyene, D., 1993, December. Genetics and breeding of faba bean. In *Coos-season Food Legumes of Ethiopia. Proceeding of the first national cool-season food legumes review conference* (pp. 16-20).

Registration of Milkesa, Large-red Seed Food Type Common Bean (*Phaseolus vulgaris*) Varieties for Midland areas of Bale and East Bale, Southeast Ethiopia.

Amanuel Tekalign*, Tadele Tadesse and Belay Asmare

Oromia Agriculture Research Institute,

Sinana Agriculture Research Center, Bale-Robe, Ethiopia

Abstract

The name Milkesa was given to Large-red seed Food Type Common Bean (Phaseolus vulgaris) variety with the pedigree of DAB-523. Total of sixteen Large-red Seed Common Bean genotypes including the standard check “Melka dima and Red kidney” were evaluated across two locations (Goro and Ginner) for three years (2015 to 2017). One promising genotype, “DAB-523” were selected and promoted to variety verification trail with the standard check during the 2020/21 cropping season. The national variety release technical committee evaluated the candidate varieties both at Goro and Ginner. Milkesa is characterized by large-seeded with red grain color and gave high seed yield (1626kg ha^{-1}) and stable performance across years and locations. It has *about 10.03% yield advantage over the best standard check variety, "Melka dima". The variety is also resistant/ Tolerant level of reactions to Alternaria Leaf Spot, Common Bacteria Blight and Rust. Milkesa is released for the Midland Areas of Bale, East Bale, and similar agro-ecologies. Therefore, farmers could be cultivated Milkesa for increasing productivity of the crop with its full recommended packages.*

Keywords: Disease resistance. Grain yield, Milkesa, Phaseolus vulgaris, stability,

Introduction

Common bean (*Phaseolus vulgaris* L., 2n = 22), also referred to as dry bean, is to genus *Phaseolus*, species *vulgaris,* family *Leguminosae* (Gepts., 2001). Common bean is grown throughout Ethiopia and is increasingly an important commodity in the cropping systems of smallholder producers (the average farm size for smallholder farmers is between 0.25 to 0.5 hectares) for food security and income.

The area covered by common bean production in Ethiopia was 113,249.95 ha and 244,049.94 ha for white and red common bean respectively with total area of 357,299.89 ha and total production of about 540,238.94 tons/ha and national average yield was 1600 kg/ha (CSA, 2016). There is a wide range of common bean types grown in Ethiopia, including white, mottled, red, and black varieties. The most commercial varieties are pure red and pure white colored beans and these are becoming the most commonly grown types with increasing market demand (Ferris and Kaganzi, 2008). Common bean production is constrained by several biotic and abiotic environmental stresses. Biotic (field and post-harvest pests and plant diseases) and a biotic (drought, excessive rain/flooding, poor soil fertility, heat and cold stressors) factors are known to cause significant reductions in grain yields (Wortmann *et al*., 1998). Bean anthracnose [Colletotrichum lindemuthianum (Sacc. & Magnus) Briosi & Cavara] poses a major constraint on the production of dry bean in Ethiopia. A study by Tesfaye B (1997) stated that yield loss up to 62.8% due to anthracnose was recorded in Ethiopia on susceptible cultivars of common bean like Mexican-142, Awash-1 and Awash Melka.

The development of cultivars, which are Resistant/ Tolerant to major biotic and abiotic environmental stresses, and adapted to a wide range of diversified environments, is the ultimate aim of plant breeders in a crop improvement program. The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is grown. The objective of this study was to register stable high yielding and disease resistant/tolerant common bean variety for midlands areas of Bale and other similar agro-ecologies in the country.

Materials and Methods

Description of the Study Area

The field experiments were carried out at two locations, i.e., Goro and Ginner, South-Eastern Ethiopia, and 490 and 568 km, far from capital city, Addis Ababa. Description of the test locations for geographical position and physico-chemical properties are summarized and tabulated hereunder (Table 1).

Table 1 Description of the test locations for geographical position and physico-chemical properties

Parameter	Location: Goro	Ginner
Geographical position		
Latitude	6° 59'20.97" N	$7^0$10'42.02" N
Longitude	$40^0$29'45.16" E	$40^0$42'58.64" E
Altitude (m.a.s.l.)	1771	1972
Soil Property		
pH (by 1:2:5 soil Water)	6.89	6.82
OMC (%)	1.19	1.18
Pav(ppm)	8.43	10.23
CEC (cmol. (+) kg soil^{-1})	49.46	47.46
Soil texture	Clay	Clay

Key: OMC = Organic matter content, Pav = Phosphorus availability, CEC = Cation exchange capacity

Experimental Design and Field Management

Total of 16 Large-red Seed Common Bean genotypes including the standard check "Melka dima and Red kidney" were evaluated at Goro and Ginner for three years (2015 to 2017). The experimental layout was arranged in RCBD designs with 4 replications across testing site. The experimental plots have 4(four) rows and 40(cm) inter-rows spacing, and have a total of 3.2 (m^2) net harvesting plot size. Fertilizer was applied at the rate of 100 kg ha-1 diammonium phosphate (18 kg N ha^{-1}, 46 kg P2O5 kg ha^{-1} and 0 k) and all other crop management practices were carried out as recommended. Finally, Milkesa (DAB-523) was selected and verified along with two standard checks. The verification trial was evaluated by the National variety releasing committee at field condition and was released fully for the midlands of Bale, East Bale, and similar agro-ecologies.

Results and Discussions

Varietal origin and evaluation

Milkesa (DAB-523) along with 16 genotypes were obtained from Melkasa Agriculture Research Center of the Ethiopian Institute of Agriculture Research. The genotypes were evaluated along with the standard check variety, "Melka dima and Red kidney", across two locations (Goro and Ginner) from 2015-2017. Genotype "DAB-523" were selected as candidate variety based on a combined data analysis of variance and mean performances comparison of genotypes. The promising candidate variety and the standard check variety, "Melka dima and Red kidney", were eventually promoted to a variety verification trial. The candidate variety and standard check variety were planted in plots with a size of 10 m x 10 and evaluated by the National Variety Release technical Committee (NVRC) at two locations during the 2020/21 cropping season. Finally, the national variety release technical committee decided "DAB-523" genotype for release.

Agronomic and Morphological Characteristics

Milkesa was adapted to mid-agro-ecologies of Bale ana East Bale, southeast Ethiopia, in the range of altitude 1600 m.a.s.l. to 1950 m.a.s.l. It gives a high yield under the range of 550 mm to 650. In an attempt to develop Milkesa, higher yield, and resistance to major Haricot bean diseases were important traits of consideration. Milkesa was taken 49 days for heading and 93 days for maturing. Milkesa variety is relatively shorter in height than the standard varieties than Melka dima and red kidney. Milkesa has large seed size with red grain color and it has good general acceptance for Haricot bean with high quality.

Yield Performance

Highly significant variations among large red common bean genotypes in seed yield in all study years and locations were observed. The average grain yield of Milkesa combined over locations and years were 1626kg ha^{-1}, which is higher than Melka dima (best standard check), 1477kg/ha^{-1}. The grain yield performance and stability parameters of Milkesa (DAB-523) and the checks are summarized in Table 5. Under research field, Milkesa gave grain yield ranging from 23-25 Qt ha^{-1} while on farmers' field it ranges from 12-18 Qt ha^{-1}. The combined mean grain yield over locations and years of the newly released variety 'Milkesa' exceeded the average yield of best standard checks 'Melka dima' by 10.03% seed yield advantage (Table 4).

Reaction to Disease

The major Common Bean diseases according to their importance in the growing areas are Alternaria Leaf Spot, Common Bacteria Blight and Rust. On the standard rating scale of 0-9, Milkesa variety is characterized by resistance/Tolerance types of reaction to these major diseases at all sites (Table 2). The resistance reaction of the variety could be integrated with other disease management methods such as crop rotation, managing infested debris, and fungicide seed treatments for better results.

Stability performance

Milkesa variety showed stable yield performance across tested years over location (Table 4). It performs best if it is produced with recommended fertilizer, seed rate and other recommended fertilizer rate in the recommended ecologies.

Variety Maintenance

The breeder and foundation seed will be maintained by Sinana Agricultural Research Center/ Oromia Agricultural Research Institute.

Table 2. Agronomical and Morphological Characteristics and Agro-ecological Zones of Adaptation of Milkesa, Large red type Common Bean variety

Variety name:	Milkesa (DAB-523)
Adaptation area:	Goro, Ginner, Dellomena, Berbere and other similar agro-ecologies
Altitude (m.a.s.l.)	1600 – 1950
Rainfall (mm)	550 –650
Seed Rate (Kg/ha)	90-100
Planting date	End of September to Early October
Fertilizer Rate (NPS) kg/ha)	100
Days to Flower	49
Days to Maturity	93
Plant Height (cm)	58
Growth habit	Portrait
1000 Seed Weight (gm)	298.2
Seed Color	Red
Seed seize	Large

Cotyledon Color		Light white
Flower Color		Pink
Yield	Research Field	23-25
(Qt/ha)	On-farmer's Field	12-18
Disease reaction		Tolerant to Alternaria Leaf Spot, Common Bacteria Blight and Rust
Year of Release		2021
Breeder and Maintainer		SARC/IQQO

Table 3. Mean grain yield(kg/ha) of 16 Large Red bean genotypes (Set-I) across locations and years

	Goro			Ginner				
Entry	2015	2016	2017	2015	2016	2017	Mean	Yield Adv. over St. check
DAB-525	1875	1767	918	1524	1070	1146	1383	
DAB-531	1886	1014	469	1316	762	626	1012	
DAB-538	2264	1737	840	1583	942	934	1384	
DAB-523	2507	2315	1136	1807	1037	952	1626	10.03%
DAB-498	1933	1555	1217	1699	903	1272	1430	
DAB-504	1472	1432	838	1685	866	1059	1225	
DAB-491	1736	1497	741	1485	704	870	1172	
DAB-537	1891	1268	712	1499	550	734	1109	
DAB-488	1761	1901	917	1626	914	974	1349	
DAB-518	2313	1605	626	1765	980	974	1377	
DAB-496	2112	1784	1104	1682	1041	1152	1479	
DAB-526	1829	1594	977	1241	864	766	1212	
DAB-507	1826	1463	507	896	560	485	956	
DAB-522	2034	1317	933	1586	890	840	1267	
Melka dima	1745	1726	1212	1480	1231	1470	1477	
Red kidney	1389	1327	694	901	822	773	984	
Means	1911	1581	865	1486	884	939	1278	
C.V.	23.0	21.8	20.1		18.0	22.7	20.3	
LSD (<0.05)	616.2	717.1	314.8	481.9	230.6	365.1	219.5	

Table 4. Mean seed yield and other agronomic traits of 16 Large Red bean genotypes tested regional variety trial (Set-I) combined for two locations (Ginner and Goro) over three years (2015-2017)

Entry	DF	DM	Stand %	PH (cm)	NPP	NSP	TSW (g)	GY kg/ha
DAB-525	49	94	82	59	14	4.2	408.3	1383
DAB-531	50	94	78	58	14	4.2	338.0	1012
DAB-538	50	93	80	60	14	4.0	401.4	1384
DAB-523	49	93	83	58	12	4.5	298.2	1626
DAB-498	49	93	83	58	12	4.2	399.8	1430
DAB-504	50	95	80	58	13	4.3	408.4	1225
DAB-491	49	94	82	60	11	4.2	377.6	1172
DAB-537	49	94	82	60	14	4.1	368.6	1109
DAB-488	50	94	82	58	13	4.2	346.0	1349
DAB-518	50	94	82	59	12	4.1	394.4	1377
DAB-496	50	93	81	58	12	4.1	409.8	1479
DAB-526	50	94	84	59	16	4.0	368.8	1212
DAB-507	50	95	81	61	13	4.2	392.1	956
DAB-522	50	94	81	60	12	4.1	385.5	1267
Melka dima	50	94	81	60	13	4.1	405.2	1477

Red kidney	50	95	81	59	12	4.0	379.8	984
Mean	50	94	81	59	13	4.2	380.1	1278
LSD (<0.05)	1.0	2.2	3.7	6.2	4.2	0.4	27.7	219.5
CV%	3.4	4.2	8.0	18.4	21.6	16.6	12.8	20.3

Note: DF = days to 50% maturity, DM, days to 90% maturity, PH = plant height(cm), NPP = Number of pods per plant, NSP =Number of seed per plant, TSW = Thousand seed weight(g), GY = grain yield(kg)

Table-5. Mean grain yield, agronomic traits and disease reaction of 'Milkeessa' among two standard checks tested at two environments at varietal verification levels during 2015-2017cropping seasons.

	Agronomic traits								Disease Reaction (1-9)		
Entry	DF	DM	Stand %	PH (cm)	NPP	NSP	TSW (g)	GY (kg/ha)	ALS	CBB	Rust
DAB-523	49	93	83	58	12	4.5	298.2	1626	4	3	4
Melka dima	50	94	81	60	13	4.1	405.2	1477	5	3	4
Red kidney	50	95	81	59	12	4.0	379.8	984	6	4	4

Note: DF = days to 50% maturity, DM, days to 90% maturity, PH = plant height(cm), NPP = Number of pods per plant, NSP =Number of seed per plant, TSW = Thousand seed weight(g), GY = grain yield(kg), ALS = Alternaria Leaf Spot, CBB = Common Bacteria Blight

Conclusions and Recommendations

Milkesa produced high yield, and it had a more stable performance in seed yield over locations and years than the standard check variety. The variety also showed a higher Tolerant to Alternaria Leaf Spot, Common Bacteria Blight and Rust. Therefore, it was released and recommended for cultivation in southeast Ethiopia, but could be adopted for production in similar agro ecologies in the country.

Acknowledgement

We thank staff members of the Pulse and Oil crops research case Team of the Sinana Agricultural Research Center for their unreserved efforts in field trail management and data collection during the experimental period. We are thankful to Oromia Agricultural Research Institute for funding the research throughout the varietal development process. We also to thank the Melkasa Agricultural Research Center for providing us with the germplasm.

References

CSA (Central Statistics Agency of Ethiopia) (2016) Report on area and crop production of major crops for 2016 Meher season, 1: 125.

Ferris, S. and Kaganzi, E. 2008. Evaluating marketing opportunities for haricot beans in Ethiopia. Paper 7. In: IPMS (Improving Productivity and Market Success) of Ethiopian Farmers Project Working ILRI (International Livestock Research Institute), Nairobi, Kenya. 68.

Purchase J.L. "Parametric analysis to describe genotype x environment interaction and yield stability in winter wheat," University of the Free State, Doctoral Dissertation, 1997.

Tesfaye, B. 1997. Loss assessment study on haricot bean due to Anthracnose. Pest Management Journal of Ethiopia 1: 69-72.

Wortmann, C.S., Kirkby, R.A., Eledu, C.A. and Allen, D.J. 1998. Atlas of common bean production in Africa, CIAT, Cali, Colombia.

Registration of Black cumin Variety “Urgesa” for mid altitude of Bale, South Eastern Ethiopia

Mohammed Beriso*, Getachew Asefa, Mohammedamin A/Rezaq and Gemmechu Ijigu
Sinana agricultural Research Center, P.O.Box 208, Bale- Robe, Ethiopia
Corresponding Author: *mbariis2008@gmail.com*

Abstract

Urgesa' (Acc. 205167-2) a medium height deep black seed variety of black cumin was selected and developed by Sinana Agricultural Research Center, eastern Oromia, Ethiopia. The variety was released in 2020/2021 EC for Bale midlands and similar agro-ecologies. This variety was selected from variety trial tested together with 14 other test genotypes and checks (local and the previously released varieties for comparison) at 3 locations (Sinana, Goro and Ginnir) for 3 consecutive years (2017 to 2019 G.C). After the trial was conducted for the above three consecutive years, this variety was selected and verified for one more season at 9 locations to see performance across locations. Finally due to its superior performance, Urgesa was selected and verified during 2020/2021 G.C cropping season and thereby released for production. This variety is characterized by deep black seed color, having high yield with yield advantage 16.5% and 24.69% than standard checks (Darbera and Dirshaye). It is stable, best adapted, having large number of capsule per plant, stem number and thousand seed weight.

Key words:- Black cumin, Variety verification, Registration

Introduction

Spices are well known for their flavoring, culinary uses, medicinal values, and essential oil derivatives. They have high prices at domestic as well as international market. Having considerable demand at home and on the international market; spices have considerable importance to the Ethiopian economy. Bale mid and lowlands are well known for the production of the important cash spices such as Fenugreek, Black cumin and Coriander.

In Ethiopia, fenugreek-growing regions are the high plateaus (1800-2300m a.s.l.) characterized by subtropical climate of wet and dry seasons. It is also one of the crops selected for specialization at the national level for their export potential. The evaluation of fenugreek genotypes in Ethiopia has been infant and on a small-scale. Only some variety development efforts have been reported from Sinana and Debreziet Agricultural Research Center in the country (DZARC, 2004; SARC, 2005). Hence, in Ethiopia there have only been limited research efforts up to this time. The importance of these crops was not fully utilized by the farmers due to the shortage of improved technologies that increase their yield and improve their market quality. Lack of improved variety, even in the country as a whole, is one the factors constraining farmers from exploiting the potential of this crop. Hence, generating, releasing and registering superior varieties of fenugreek available in the country is very crucial.

Specific objective:

To register the newly released variety “Urgesa” for wide production under Bale mid lands and similar agro ecologies of the country

Materials and Methods

The experiment was carried out at three locations. One of the experiments was conducted at the research farm of Sinana Agricultural Research Center, Oromia Agriculture Research Institute, Sinana and the others at the farmers' field, Goro and Ginnir. The experiments were conducted from the screening nursery till varification trial (2014 to 2019 GC) under rain fed conditions at each location. Sinana Agricultural Research Center (7^0 N latitude and 40^0 E longitudes; and 2400 m.a.s.l) is located 463km south east of Addis Ababa and east of Robe, the capital of Bale zone. The other location 'Goro' is located 20 km from sinana east direction; 'Ginnir' is located about 56 km from sinana south east direction.

Varietal Evaluation

Urgesa (Acc. 205167-2) is developed through selection. In 2016 G.C fourteen (14) genotypes were selected from yield trial based on seed yield and reaction to major diseases. These promising genotypes were evaluated against standard check Derbera and Dirshaye for three years (2017 to 2019). Promising genotypes and standard checks were planted on 10mx10m at nine environments for variety verification trial in 2020 G.C and evaluated by national variety release committee (NVRC). Finally "Urgesa" was approved as superior Variety for Bale mid lands and similar agro ecologies

Morphological Characteristics of Urgesa

Urgesa has medium plant size with deep black seed color and basal branching growth habit. On average this variety needs 81.58 days to flowering and 135.5 days to physiological maturity and plant height of 50.90cm (Table 1).

Yield Performance

Urgesa (Acc. 205167-2) showed superior yielding ability, producing a mean seed yield of 16.6-26.6Qt/ha. The seed yield of the new variety exceeded that of the standard check Darbera and Dirshaye variety by about 16.5% and 24.69% respectively.

Adaptation and Agronomic recommendation

Urgesa is Black cumin variety released for Bale midlands, south eastern Ethiopia. It is well adapted in similar agro ecologies with altitude of 1650 – 2400 m.a.s.l with annual rainfall of 120-500mm. Recommended fertilizer rate for Urgesa is P_2O_5 = 46 kg/ha, N= 60 kg/ha which is applied at planting while the spacing between rows is 30cm.

Variety maintenance

Breeder and foundation seed of the variety is maintained by Sinana Agricultural Research center

Table 1. Agronomic and Morphological descriptors for newly Black cumin released variety

Variety Name	Urgesa (Acc. 205167-2)
Agro. and Morph. Characteristics	
Adaptation Area	Sinana, Goro, Ginnir and similar agro ecology
Altitude(masl)	1650 – 2400
Rain fall(mm)	120-500
Seed Rate(kg/ha)	Row planting -15 Broadcasting - 20
Planting date	End of August to late September (for Bale mid altitude)
Fertilizer rate(kg/ha)	P_2O_5 = 46, N= 60
Days to flowering	81.58
Days to Maturity	135.5
Plant Height(cm)	50.90
Growth habit	Erect
Seed Color	Black
Flower Color	White
Oleoresin content	47.03
Crop pest reaction	Not observed
Yield (Qt/ha)	16.6-26.6
Year of Release	2021
Breeder/Maintainer	SARC/IQQO

Conclusion and Recommendation

The development of cultivars, which are adapted to a wide range of diversified environments, is ultimate aim of breeders in crop improvement program. The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is grown. A variety is considered to be more stable if it has high mean yield but a low degree of fluctuation in yielding ability when planted over diverse environments (Becker, 1988). The newly released Black cumin variety 'Urgesa' was found to be stable and superior to the commercial varieties (Darbera and Dirshaye) which were used as a standard checks. Farmers were invited to evaluate the varieties using their own criteria such as number of pod per plant, seed per pod, branch number, and earliness and seed color. Accordingly the farmers were select "Urgessa" as superior variety in almost all location. Thus, it is concluded that, 'Urgesa' Black cumin variety could be registered and widely produced by smallholder farmers and investors in mid and lands of Bale and similar agro ecologies in the country

Acknowledgements

We thank Oromia Agricultural Research Institute (OARI) for financing the development of the varieties. We also thank the staff of Sinana Agricultural Research Centre (SARC) for facilitating the necessary requirements during the trial. we acknowledge Ato Guta Lagasa, Habtamu Lagasa , Buzinesh Asefa and Shimalis Mokonnin and all horticulture research team of Sinana agriculture research center for trial management and appropriate data collection.

References

Becker, 1988. . Stability analysis in plant breeding. Plant Breeding,101, 1-23

DZARC, 2004. Annual report on highland food and forage legumes research program, DebreZiete Agricultural Research Center. Ethiopian Agricultural Research Organization.
SARC, 2005. Annual report on seed spices crop research at Sinana. Horticultural crop Research Division, Sinana Agricultural Research Center. OARI.

Registration of Coriander Variety "Derara" for mid altitude of Bale, South Eastern Ethiopia

Mohammed Beriso*, Getachew Asefa, Mohammedamin A/Rezaq and Gemmechu Ijigu
Sinana agricultural Research Center, P.O.Box 208, Bale- Robe, Ethiopia
*Corresponding Author: *mbariis2008@gmail.com*

Abstract

Derara' (Acc. 240574-1) a medium height brown seed variety of coriander was selected and developed by Sinana Agricultural Research Center, eastern Oromia, Ethiopia. The variety was released in 2020/2021 EC for Bale midlands and similar agro-ecologies. This variety was selected from variety trial tested together with 14 other test genotypes and checks (local and the previously released varieties for comparison) at 3 locations (Sinana, Goro and Ginnir) for 3 consecutive years (2017 to 2019 G.C). After the trial was conducted for the above three consecutive years, this variety was selected and verified for one more season at 9 locations to see performance across locations. Finally due to its superior performance, Derara was selected and verified during 2020/2021 G.C cropping season and thereby released for production. This variety is characterized by brown seed color, having high yield with yield advantage 21.60% than standard check (Walta'I). It is stable, best adapted, having large number of capsule per plant, stem number and thousand seed weight.

Keywords:- *Coriander, Variety verification, Registration*

Introduction

Spices are well known for their flavoring, culinary uses, medicinal values, and essential oil derivatives. They have high prices at domestic as well as international market. Having considerable demand at home and on the international market; spices have considerable importance to the Ethiopian economy. Bale mid and lowlands are well known for the production of the important cash spices such as Fenugreek, Black cumin and Coriander.

In Ethiopia, fenugreek-growing regions are the high plateaus (1800-2300m a.s.l.) characterized by subtropical climate of wet and dry seasons. It is also one of the crops selected for specialization at the national level for their export potential. The evaluation of fenugreek genotypes in Ethiopia has been infant and on a small-scale. Only some variety development efforts have been reported from Sinana and Debreziet Agricultural Research Center in the country (DZARC, 2004; SARC, 2005). Hence, in Ethiopia there have only been limited research efforts up to this time. The importance of these crops was not fully utilized by the farmers due to the shortage of improved technologies that increase their yield and improve their market quality. Lack of improved variety, even in the country as a whole, is one the factors constraining farmers from exploiting the potential of this crop. Hence, generating, releasing and registering superior varieties of fenugreek available in the country is very crucial.

Specific objective: To register the newly released variety "Derara" for wide production under Bale mid lands and similar agro ecologies of the country

Methodology

The experiment was carried out at three locations. One of the experiments was conducted at the research farm of Sinana Agricultural Research Center, Oromia Agriculture Research Institute, Sinana and the others at the farmers' field, Goro and Ginnir. The experiments were conducted from the screening nursery till varification trial (2014 to 2019 GC) under rain fed conditions at each locations. Sinana Agricultural Research Center (7^0 N latitude and 40^0 E longitudes; and 2400 m.a.s.l) is located 463km south east of Addis Ababa and east of Robe, the capital of Bale zone. The other location 'Goro' is located 20 km from sinana east direction; 'Ginnir' is located about 56 km from sinana south east direction.

Varietal Evaluation

Derara' (Acc. 240574-1) is developed through selection. In 2016 G.C seventeen (17) genotypes were selected from yield trial based on seed yield and reaction to major diseases. These promising genotypes were evaluated against standard check Walta'I for three years (2017 to 2019). Promising genotypes and standard checks were planted on 10mx10m at nine environments for variety verification trial in 2020 G.C and evaluated by NVRC. Finally "Derara" was approved as superior Variety for Bale mid lands and similar agro ecologies

Morphological Characteristics of Derara

Derara has medium plant size with deep green foliage and basal branching growth habit. On average this variety needs 80.67days to flowering and 128.56 days to physiological maturity and plant height of 78 cm (Table 1).

Yield Performance

Derara (Acc. 240574-1) showed superior yielding ability, producing a mean seed yield of 19.38-30.25 Qt/ha. In fact, the seed yield of the new variety exceeded that of the standard check Walta'I variety by about 21.60%.

Adaptation and Agronomic recommendation

Derara is Coriander variety released for Bale midlands, south eastern Ethiopia. It is well adapted in similar agro ecologies with altitude of 1650 – 2400 m.a.s.l with annual rainfall of 120-500 mm Recommended fertilizer rate for Derara is 100kg of NPS which is applied at planting while the spacing between rows is 30cm.

Variety maintenance

Breeder and foundation seed of the variety is maintained by Sinana Agricultural Research center

Table 1. Agronomic and Morphological descriptors for newly released coriander variety

Variety Name Agro. and Morph. Characteristics	Derara (Acc. 240574-1)
Adaptation Area	Sinana, Goro, Ginnir and similar agro ecology
Altitude(masl)	1650 – 2400
Rain fall(mm)	550-750
Seed Rate(kg/ha)	25
Planting date	End of August to late September (for Bale mid altitude)
Fertilizer rate(kg/ha)	NPS = 100
Days to flowering	80.67
Days to Maturity	128.56
Plant Height(cm)	78.00
Growth habit	Erect
Seed Color	Brown
Flower Color	White
Oleoresin content	22.56
Crop pest reaction	Not observed
Yield (Qt/ha)	19.38-30.25
Year of Release	2021
Breeder/Maintainer	SARC/IQQO

Conclusion and Recommendation

The development of cultivars, which are adapted to a wide range of diversified environments, is ultimate aim of breeders in crop improvement program. The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is grown. A variety is considered to be more stable if it has high mean yield but a low degree of fluctuation in yielding ability when planted over diverse environments (Becker, 1988). The newly released Coriander variety 'Derara' was found to be stable and superior to the commercial variety of Walta'I which were used as a standard check. Farmers were asked to evaluate the varieties using their own criteria such as number pod per plant, seed per pod, branch number, and earliness and seed color. Accordingly the farmers were select "Derara" as superior variety in almost all location. Thus, it is concluded that, 'Derara' Coriander variety could be registered and widely produced by smallholder farmers and investors in mid and lands of Bale and similar agro ecologies in the country

Acknowledgements

We thank Oromia Agricultural Research Institute (OARI) for financing the development of the varieties. We also thank the staff of Sinana Agricultural Research Centre (SARC) for facilitating the necessary requirements during the trial. we acknowledge Ato Guta Lagasa, Habtamu Lagasa , Buzinesh Asefa and Shimalis Mokonnin and all horticulture research team of Sinana agriculture research center for trial management and appropriate data collection.

References

Becker, 1988. . Stability analysis in plant breeding. Plant Breeding,101, 1-23

DZARC, 2004. Annual report on highland food and forage legumes research program, DebreZiete Agricultural Research Center. Ethiopian Agricultural Research Organization.
SARC, 2005. Annual report on seed spices crop research at Sinana. Horticultural crop Research Division, Sinana Agricultural Research Center. OARI.

Stability Analysis of Food Barley (*Hordeum vulgare L.)* Genotypes for high potential Areas of Oromia

Hiwot Sebsibe[1]*, Endeshaw Tadesse[1], Kasahun Tadesse[1], Ermias Teshome[1], Geleta Gerema[2] and Aliyi Kedir[3]

[1]Sinana Agricultural Research Center, P.O.Box 208, Bale-Robe, Ethiopia,[2]Bako, Ethiopia, Oromia Agricultural Research Institute , P. O. Box 81265, Finfinne, Ethiopia,

[3]Bore Agricultural Research Center, P. O. Box 021, Bore, Ethiopia

*Corresponding author email: hiwotsebsibe@yahoo.com

Abstract

Barley (Hordeum vulgare L.) regional variety trial was conducted to evaluate the performance of twenty breeding lines and released varieties at three locations over two growing seasons under rain fed condition to assess the magnitude of the genotype x environment (G x E) for grain yield and also to determine yield stability. The experiment was arranged in RCBD with three replications. Additive Main Effect and Multiplicative Interaction (AMMI) model was used to measure the performance of genotypes and their interaction with environment. Mean grain yield of the genotypes were ranged from 2.9 t/ha to 4.7t/ha. The IPCA1 and IPCA2 scores were explained 46.5% and 20.4%, of the interaction effects, respectively. Based on the stability analysis, genotype G10 and G6 are stable across all environments with high grain yield and recommended for possible released.

Keywords: GxE interaction, stability analysis, IPCA.

Introduction

Barley (*Hordeum vulgare* L.) is a cool-season crop which grows at altitudes of about 3000 meter above sea level and commonly cultivated in stressed areas where soil erosion, occasional drought or frost limits the growth of other crops (Bekele et al., 2005). Ethiopia is the second largest barley producer in Africa, next to Morocco, accounting for about 25 percent of the total barley production in the continent (FAO, 2017). Barley production and consumption has a longstanding tradition in Ethiopia where the country is considered the centre of diversity or secondary origin of the crop with more than 15,000 accessions conserved in the gene bank.

Genotype x Environment Interaction (GEI) is commonly observed by breeders as differential ranking of variety yields among locations or years. A multi location trial was conducted in order to identify superior cultivars for a target region. In multi-environment trials usually results in genotype-by-environment interactions that often complicate the interpretation of results obtained and reduce efficiency in selecting the best genotypes (Annicchiarico and Perenzin, 1994). This interaction is due to the changes in genotype's relative performance across environments, as a result of differential responses of the genotypes to various abiotic and biotic factors (Dixon and

Nukenine, 1997). Hence, a significant Genotype by Environment (GE) interaction for a quantitative trait like grain yield can complicate the identification of superior genotypes for both improved crop development and new crop introduction.

The AMMI model analysis is useful in visualizing the main effects of genotype x environment interactions. It can estimate the genotype responses and separate noise from real source of variation through partitioning of the GxE. IPCA scores of genotypes in AMMI analysis are the key to interpret the pattern of genotype response across environments (Gauch and Zobel, 1997). The model is important for cultivar evaluation, recommendations and selection of test sites (Gauch and Zobel, 1997). It provides a graphical representation or biplot to summarize information on the main effects and the first principal component scores of the interactions (IPCA1) of both genotypes and environments simultaneously (Crossa, 1990). Although the AMMI biplot can be very effective in summarizing the variation and in visualizing main effects, it does not show which variety is high yielding in which environment (Yan *et al.* 2000) and also identify which environment is most representative (Yan, 2001).

Materials and Methods

Including three standard checks (Adoshe, Abdane and Aruso), twenty food barley genotypes were evaluated under rain fed condition at three locations for two consecutive years (2019-2020) during bona main cropping season at Sinana main station, Bore and Shambu on farmers' field. The experiment was conducted at each location on vertisoils, texturally classified as clay loam soil. Sinana Agricultural Research Center is geographically situated at 07º 07'10.837"N latitude and 040º13'32.933"E longitude7ºN latitude and 40ºE longitude; with altitude of 2400m a.s.l. It is located 463 km away from Addis Ababa and 33km East of Robe, the capital of Bale zone in the Southeast direction. A Randomized Complete Block Design with three replications was used at all locations. The plot size was 3 m^2 (six rows with 2.5m length) at 20 cm inter spacing. Recommended fertilizer rate of 100 kg/ha NPS at planting and seed rate of 125 kg/ha was used. All agronomic practices were done uniformly as recommended for barley production in the area.

Data analysis

Data analysis was computed by using R-statistical software version 3.4.5 (R software, 2018) and Genotype by Environment analysis was done using R (GEA-R version 4.0) (Pacheo *et al.,* 2016). Additive Main effect and Multiplicative Interaction AMMI (Zobel *et al.,* 1988) models were used to compute stability in the AMMI model, the magnitude obtained in the first principal component (IPCA1) of each genotype was used as indicator stability. The lower the absolute value of IPCA1indicated the stable genotype (Purchase et al,. 2000).

$Yij=\mu+gi+ej+\Sigma\lambda knk=1aikyjk+\mathrm{R}ij$

Where, Yij is the mean yield of the i^{th} genotype in j^{th} environment; μ is the general mean g_i is the i^{th} genotypic effect; ej is the j^{th} location effect; λk is the eigenvalue of the PCA axis k; αik and γjk are the i^{th} genotype j^{th} environment PCA scores for the PCA axis k; *R*ij is the residual; k' is the number of PCA axis retained in the model.

Eberhart and Russell Regression Model

The Eberhart and Russell Regression Model was used and is represented by: Yij= μi+biIj+S^2dij; Where: Yij is the mean performance of the i^{th} variety (I=1,2,3…,n)in the i^{th} environment; μi is the mean of the i^{th} variety over all the environment; bi is the regression coefficient which measures the response of i^{th} variety to varying environments; S^2dij is the deviation from regression of i^{th} variety in the i^{th} environment; and Ij is the environmental index of the i^{th} environment.

Genotype and genotype by environment interaction (GGE) biplot

To determine genotype by environment interaction and stability analysis, different methods were used. The genotype and genotype by environment (GGE) biplot analysis is the most common currently utilized (Yan and Tinker 2005; Yan et al., 2007). GGE biplot analysis was carried out using the method proposed by Yan (2001) for multi environment data.

Table 1. List of food barley genotypes used in the study along with and their codes

Genotype	Genotype code	Genotype	Genotype code
ICB09-1291-0AP-0TR-0AP-0TR-0TR	G-1	ICB97-0930-0AP-18AP-3TR-7AP-0AP-4AP-0AP-0TR-0TR	G-11
ICB09-1308-0AP-0TR-0AP-0TR-0TR	G-2	ICB05-0487-0AP-30AP-0AP	G-12
ICB98-0908-0AP-13AP-0AP-6TR-1AP-0AP-0TR-0TR	G-3	ICB02-1104-0AP-21AP-0AP	G-13
ICB09-1329-0AP-0TR-0AP-0TR-0TR	G-4	ICB02-1104-0AP-13AP-0AP	G-14
ICB05-0238-0AP-5AP-0AP-0TR-0TR	G-5	ICB05-0467-0AP-1AP-0AP	G-15
ICB09-1290-0AP-0TR-0AP-0TR-0TR	G-6	ICB91-0343-0AP-0AP-0AP-9AP-0AP	G-16
ICB09-1437-0AP-0TR-0AP-0TR-0TR	G-7	ICB01-0018-0AP-32AP-7AP-0AP	G-17
ICB09-1433-0AP-0TR-0AP-0TR-0TR	G-8	Abdane	G-18
CMB87.643-2A-0AP-0AP-0TR-0TR	G-9	Adoshe	G-19
CBSS04Y00226S-12Y-2M-1Y-1M-0Y-0AP-0TR-0TR	G-10	Aruso	G-20

Results and Discussions

Analysis of variance

The result of the combined analysis of variance across locations revealed there was a significant variation at ($p<0.01$) for genotypes, environment and genotype by environment interaction (GE). This result indicated there was wide range of genetic variability among barley genotypes across testing environments. The large variation due to the environment is an indication of diversity among environments and the highly significant variation of GEI is an indication of changes in the rank of genotype performance across environments. This result was in agreement with result of Girma et al. (2018), Kendal et al (2016) and Hiwot et al (2020) who reported that significant variation of genotypes, environments and GE of grain yield by barley genotypes.

Table 2. Combined ANOVA for barley genotype over tested environments

Source of variation	Df	Sum Sq	Mean Sq
Environment (E)	5	437.37	87.474**
Replication/E	12	93.66	7.805 **
Genotype (G)	19	68.74	3.618 **
GxE	95	159.56	1.680 **
Residuals	228	344.57	1.511

Table 3. Mean grain yield of 20 barley genotypes tested at three locations for two years

Genotype	Bore-19	Bore-20	Shambu-19	Shambu-20	Sinana-19	Sinana-20	Mean
G1	4.5	4.4	2.6	2.9	4.4	5.0	4.0
G2	5.5	4.8	2.9	3.3	4.2	5.0	4.3
G3	3.2	5.3	1.9	2.3	2.8	6.4	3.6
G4	6.7	3.0	2.2	1.4	4.4	5.0	3.8
G5	4.2	3.8	1.0	2.3	3.3	3.0	2.9
G6	5.3	4.5	2.8	4.8	3.6	6.4	4.6
G7	4.5	3.9	2.8	2.7	2.4	5.1	3.6
G8	4.9	5.1	2.0	1.8	3.9	5.6	3.9
G9	3.8	4.5	1.9	2.5	3.5	5.9	3.7
G10	6.4	5.4	3.2	2.9	4.7	5.3	4.7
G11	3.6	3.7	2.0	3.3	2.8	3.7	3.2
G12	5.1	4.3	2.3	3.0	4.2	4.4	3.9
G13	5.5	5.9	2.1	2.6	3.2	4.6	4.0
G14	5.7	5.6	1.5	2.5	3.8	4.5	3.9
G15	3.6	4.6	1.3	2.6	4.5	5.5	3.7
G16	4.4	5.2	1.4	3.3	3.2	4.4	3.6
G17	4.9	5.5	2.2	2.5	4.1	4.6	4.0
G18	5.1	4.5	2.0	2.7	3.3	5.1	3.8
G19	6.6	6.4	2.7	3.0	4.0	5.1	4.6
G20	6.7	3.3	1.7	2.3	3.0	2.9	3.3
Mean	5.0	4.7	2.1	2.8	3.7	4.9	3.9
LSD 0.05	2.9	1.3	1.2	1.2	1.5	1.3	0.7
CV (%)	32.4	20.3	28.0	31.5	30.2	19.2	31.9

The highest combined mean grain yield was obtained from G-10 (4.7 ton ha$^{-1)}$ followed by G-6 and Adoshe (4.6 ton ha^{-1}). While among the environments maximum grain yield was obtained from Bore 2019 (5 ton ha^{-1}) followed by Sinana in 2020 (4.9 ton ha^{-1}) and Bore in 2020 (4.7 ton ha^{-1}).

AMMI analysis

The result of the AMMI analyses of variance showed that there is a significant effect for genotype (G), environment (E), and GxE interaction (Table 2). Overall, 65.7 % of the total sum squares (SS) was attributed to environment effects; only 10.3% and 24 % were attributed to genotypes and GxE interaction effects, respectively. The large sum square of the environment implying that the environment was with higher differential effect in discriminating the performance of the genotype and caused most of the variation in grain yield. Therefore, tested locations in this experiment were diverse for the barley grain yield and a large part of variation in barley grain yield might have resulted from change in environment. In previous study, there is a report which indicated that in multi location yield trials, the variation captured by the environment is 80% and genotype and genotype by environment interaction explained 10% (Sabaghnia *et al.,* 2013). Large environmental sum square was reported by Abay *et al.*, 2009 and Gebremedhin *et al.,* 2014 in food barely and by Bantayehu, 2009 in malt barley and they reported that there was a large environmental variance. Several other researchers were also reported high environmental effects in different crops such as wheat and oilseeds (Brar *et al.* 2010; Mohammadi and Amir 2011; Letta *et al.* 2008; Dash and Pandey 2009; Sing et al. 2009).

Table4. ANOVA for th AMMI model

Source of variation	**DF**	**SS**	**MS**	**Ex SS %**
ENV	5	437.37	87.47	65.70
GEN	19	68.74	3.62	10.33
ENV*GEN	95	159.56	1.68	23.97
PC1	23	74.17	3.22	46.48
PC2	21	32.60	1.55	20.43
PC3	19	28.66	1.51	17.96
PC4	17	17.59	1.03	11.02
PC5	15	6.55	0.44	4.10
Residuals	240	438.23	1.83	0.00

The first two interaction principal components were highly significant ($p<0.01$) which implied that the interaction of barley genotypes with six environments was predicted by the first two components of genotypes and environments. The results further indicated that the first two interaction principal components (IPCA1 and IPCA2) were very important in explaining the interactions while the rest IPCA's were not significant. IPCA1 explained 47 % of the variability relating to GEI while IPCA2 explains 20.4% of the GE interaction. Both IPCA1 and IPCA2 comprise 67.4 % variations in the GE interactions.

The AMMI Stability value (ASV) and Genotype selection Index (GSI)

The Additive Main effect and Multiplicative Interaction effect stability analysis (ASV) is used to decompose the interaction effect. The interaction Principal Component one (IPCA1) scores and the interaction principal component two in the AMMI model are indicators of stability (Saad, 2013). The Genotype with lower ASV value is considered as stable and genotype with higher ASV is considered as unstable. According to the ASV ranking, the genotype G18 (0.04), G2 (0.36), G3 (0.39), G12 (0.53), G16 (0.55) and G17 (0.57) were among genotypes with lower ASV values in order of importance. This revealed that these genotypes are relatively more stable than others. However, G5 (0.6), G13 (0.84), G8 (0.88), G7 (0.96) and G10 (0.97) were classified moderately stable genotypes.

Stability in itself should, however, not be the only parameter for selection, as the most stable genotype would not necessarily give the best yield performance (Mohammadi *et al*., 2007). The other stability parameter which can consider both grain mean yield and stability is incorporated and the used to discriminate the stability the genotypes over diverse environment. Based on GSI, genotypes G2, G1, G17, G10, G12, G13 and G6 are the best and top-ranking genotypes integrated both stability and grain yield performance parameters. Thus, G10 and G 6 showed more stable to different environment and gave higher mean grain yield than checks were identify and proposed as candidate variety to be verified for possible released for the highlands of Bale and similar agro ecologies.`

Table 5. Combined mean grain yield (tons ha^{-1}), stability parameters, ASV, GSI of barley

Genotype	Gm	rYi	bi	S^2di	IPCA1	IPCA2	ASV	rASV	GSI
G1	4.0	7	0.75	-0.35	0.12	0.23	0.39	3	10
G2	4.3	4	0.84	-0.48	-0.12	0.22	0.36	2	6
G3	3.6	16	1.13	1.17	1.09	-0.28	4.47	19	35
G4	3.8	12	1.25	1.32	-0.86	0.15	3.04	18	30
G5	2.9	20	0.84	-0.14	-0.28	0.07	0.60	7	27
G6	4.6	3	0.76	0.4	0.39	0.85	1.12	12	15
G7	3.6	17	0.74	-0.03	0.21	0.50	0.96	10	27
G8	3.9	9	1.31	-0.26	0.18	-0.49	0.88	9	18
G9	3.7	13	1.03	0.09	0.63	0.02	1.85	17	29
G10	4.7	1	1.05	-0.23	-0.39	-0.16	0.97	11	12
G11	3.2	19	0.46	-0.33	0.21	0.69	1.32	14	32
G12	3.9	10	0.8	-0.38	-0.20	0.24	0.53	4	14
G13	4.0	6	1.21	-0.12	-0.09	-0.53	0.84	8	14
G14	3.9	8	1.34	-0.25	-0.23	-0.61	1.20	13	20
G15	3.7	14	1.06	0.42	0.62	-0.14	1.82	16	29
G16	3.6	15	0.99	-0.1	0.25	-0.10	0.55	5	20
G17	4.0	5	1.04	-0.28	0.01	-0.41	0.57	6	11
G18	3.8	11	1.08	-0.47	0.00	0.04	0.04	1	12
G19	4.5	2	1.3	-0.07	-0.35	-0.61	1.45	15	16
G20	3.3	18	1	1.44	-1.20	0.29	5.20	20	38

GGE Biplot Analysis

The AMMI model was used to analyzed biplot graph (Figure 1) using individual environments and mean grain yield performance of barley genotypes in XY plan. X- axis is designated for mean grain yield, while Y-axis for IPCA1 scores. A single arrowed line that passes through the biplot origin and pointes to higher mean yield across environments was drawn. The line is called the average environment coordination (AEC) abscissa. The arrow direct towards higher average yield and hence genotypes on the right side most of the line have the highest average yield. Single arrowed line that is perpendicular to AEC abscissa was also drown and this line is called the AEC ordinate and is labeled as perpendicular line (PL). This line points towards greater variability in either direction and hence genotype that has longer vector along this line is highly unstable (Ilker et al., 2011). Genotype and environment that fall on the right side of the vertical line of grain yield are rated as high-yielding genotypes above the grand mean (3.9 ton $ha-^{1}$) and potential ideal environments, Accordingly G10, G19, G8, G1, G6, G17, G13, G12, G14 and G2 were found in this category. Furthermore environment Bore 2019, Bore 2020 and Sinana 2020 which found at the right side of perpendicular line, were also gave mean grain yield above the ground mean (figure 1). The remaining falls on the left side of the line are low –yielding genotypes and low potential environment for barley production.

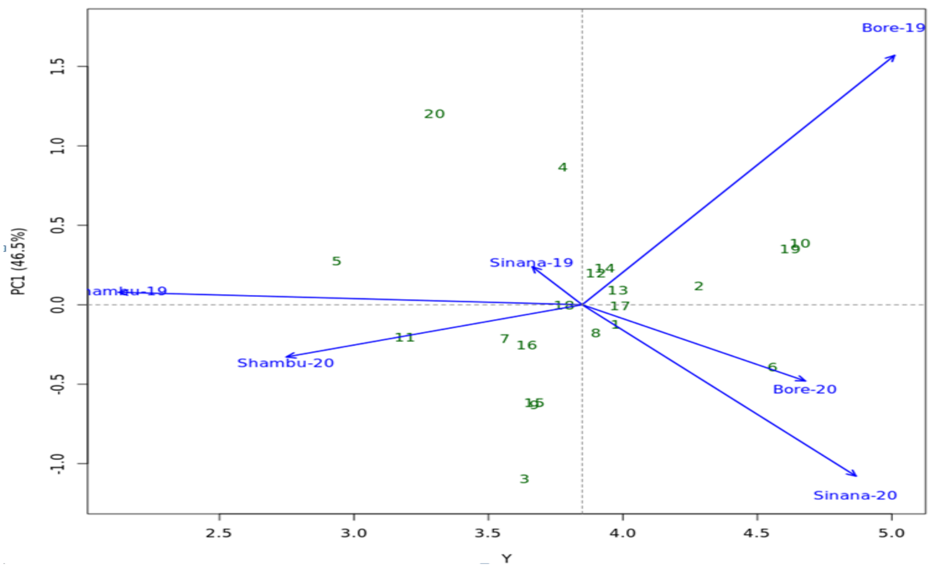


Figure 1.Biplot analysis of GEI based on AMMI model for the IPCA1 scores and grain yield
In AMMI2 biplot, the distance from the biplot origin are indicative of the amount of interaction exhibited by the genotypes over environment or environment over genotypes. Genotypes located near the biplot origin are less responsive than the vertex genotypes indicating general adaptability to all environments (Voltas et al,.2002). Environments with longer vectors are very interactive and discriminate the difference among genotypes more than environments with shorter vectors. Shorter vectors are less interactive and provide little or no information about the difference among genotypes performance (Yan, 2002). Accordingly, in figure 2, the barley genotypes (G6, G11, G4, G20, G3, G15, G8, G19, G14, G13, G17 and G7) placed furthest away from the biplot origin and expressed the highly interactive behavior whereas G18, G1, G2, G5, G12, G10 and G16 placed relatively closed to the biplot origin expressed less interaction and more adaptable to all location.

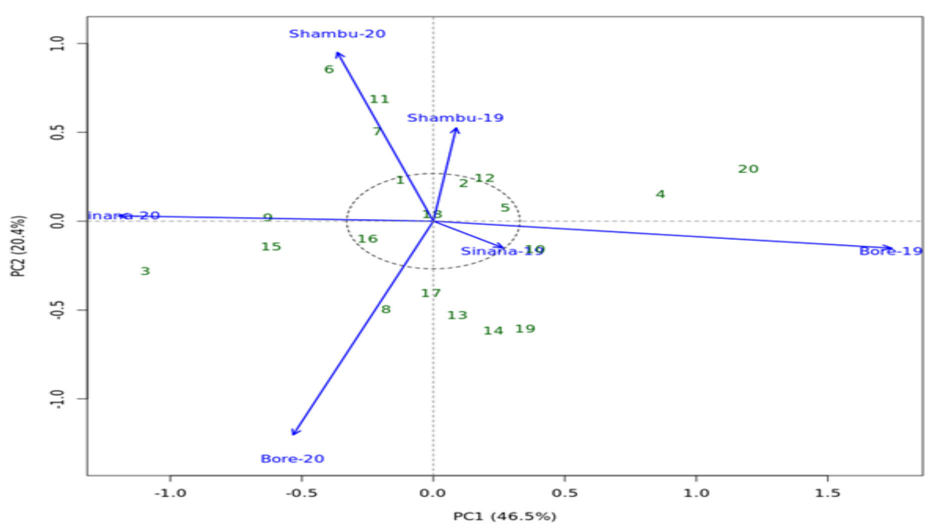


Figure 2. Interaction biplot of the AMMI 2

In AMMI 2 biplot, those environments having shorter length of arrow do not create strong interaction while those with long length of arrow have strong interaction and they are not favorable to all genotypes. In the present study, Sinana 2019 and Shambu 2019 having shorter spokes interact less with the genotypes whereas Bore 2019, Bore 2020,Shambu 2019 and Sinana 2020 having longer spokes or length of the arrow line exerts high interaction with the genotypes (figure 2).

Conclusions and Recommendations

Combine analysis of variance reveled highly significant variation for genotypes, environments and GXE interaction indicating as the genotypes react differently to the testing environment, and the influence of the environment were very high for the amount of variation existed. The AMMI stability values and the genotype selection index along with different stability parameters like slope, deviation from regression reveled that G6 and G10 were widely adapted and stable with high grain yield, and thus these two genotypes are recommended for possible released with wider environmental adaptability.

References

Abay, F. and Bjørnstad, A., 2009. Specific adaptation of barley varieties in different locations in Ethiopia. *Euphytica*, *167*(2), pp.181-195.

Annicchiarico, P. and Perenzin, M., 1994. Adaptation Patterns and Definition of Macro- environments for Selection and Recommendation of Common- wheat Genotypes in Italy. *Plant Breeding*, *113*(3), pp.197-205.

Bantayehu, M., 2009. Analysis and correlation of stability parameters in malting barley. *African Crop Science Journal*, *17*(3).

Bekele, B., Alemayehu, F. and Lakew, B., 2005. Food barley in Ethiopia. *Food Barley: Importance, Uses, and Local Knowledge*, pp.53-82.

Brar, K.S., Singh, P., Mittal, V.P., Singh, P., Jakhar, M.L., Yadav, Y., Sharma, M.M., Shekhawat, U.S. and Kumar, C., 2016. GGE biplot analysis for visualization of mean performance and stability for seed yield in taramira at diverse locations in India. *Journal of Oilseed Brassica*, *1*(2), pp.66-74.

Crossa, J., 1990. Statistical analyses of multilocation trials. In *Advances in agronomy* (Vol. 44, pp. 55-85). Academic Press.

Dixon, A. and Nukenine, E., 1997. Statistical analysis of cassava yield trials with the additive main effects and multiplicative interaction (AMMI) model.

Gauch Jr, H.G. and Zobel, R.W., 1997. Identifying mega- environments and targeting genotypes. *Crop science*, *37*(2), pp.311-326.

Kendal, E., 2016. GGE biplot analysis of multi-environment yield trials in barley (Hordeum vulgare L.) cultivars. *Ekin Journal of Crop Breeding and Genetics*, *2*(1), pp.90-99.

Letta, T., D Egidio, M.G. and Abinasa, M., 2008. Analysis of multi-environment yield trials in durum wheat based on GGE-biplot. *Journal of Food Agriculture and Environment*, *6*(2), p.217.

Pacheo, C.C., Dulikravich, G.S., Vesenjak, M., Borovinšek, M., Duarte, I.M.A., Jha, R., Reddy, S.R., Orlande, H.R.B. and Colaço, M.J., 2016. Inverse parameter identification in solid mechanics using Bayesian statistics, response surfaces and minimization. *Technische Mechanik-European Journal of Engineering Mechanics*, *36*(1-2), pp.120-131.

Purchase, J.L., Hatting, H. and Van Deventer, C.S., 2000. Genotype× environment interaction of winter wheat (Triticum aestivum L.) in South Africa: II. Stability analysis of yield performance. *South African Journal of Plant and Soil*, *17*(3), pp.101-107.

Sabaghnia, N., Mohammadi, M. and Karimizadeh, R., 2013. Yield stability of performance in multi-environment trials of barley (Hordeum vulgare L.) genotypes. *Acta Univ. Agric. Silvic. Mendelianae Brun*, *61*(3), pp.787-793.

Sebsibe, H., Endeshaw Tadesse, E.T. and Fana, G., 2020. Genotype by environment interaction and stability analysis of malt barley genotypes in highlands of south eastern Ethiopia. *Adaptation and Generation of Agricultural Technologies*, *23*, p.112.

Tonk, F.A., Ilker, E. and Tosun, M., 2011. Evaluation of genotype x environment interactions in maize hybrids using GGE biplot analysis. *Crop Breeding and Applied Biotechnology*, *11*, pp.01-09.

Voltas, J., van Eeuwijk, F., Igartua, E., Garcia del Moral, L.F., Molina-Cano, J.L. and Romagosa, I., 2002. Genotype by environment interaction and adaptation in barley breeding: basic concepts and methods of analysis. *Barley science: Recent advances from molecular biology to agronomy of yield and quality*, pp.205-241.

Von Bothmer R, Sato K, Komatsuda T, Yasuda S, Fischbeck G (2003) The domestication of cultivated barley. In: von Bothmer R, van Hintum T, Knu¨pffer H, Sato K (eds) Diversity in barley (Hordeum vulgare). Elsevier Science B. V., Amsterdam, pp 9–27. View publication

Yan, W., Hunt, L.A., Sheng, Q. and Szlavnics, Z., 2000. Cultivar evaluation and mega- environment investigation based on the GGE biplot. *Crop science*, *40*(3), pp.597-605.

Yan, W., 2001. GGEbiplot—A Windows application for graphical analysis of multienvironment trial data and other types of two- way data. *Agronomy journal*, *93*(5), pp.1111-1118.

Identification of Stable Lentil Genotypes Using AMMI Analysis for the highlands of Bale, Southeastern Ethiopia

Tadele Tadesse*, Amanuel Tekalign and Belay Asmare
Oromia Agriculture Research Institute, Sinana Agriculture Research Center, Bale-Robe, Ethiopia
Email address:
tadyeko20@gmail.com/tadeleta20@yahoo.com
* Corresponding author

Abstract

Genotype x environment interaction was evaluated under six environments during 2017 to 2019 cropping season in the highlands of bale, Southeastern Ethiopia for grain yield of fifteen promising lentil genotypes promoted from the previous trials. Randomized Complete Block Design with four replications was used. The ANOVA revealed significant variation of grain yield for genotypes, environments, and genotypes by environment interaction. The explained percentage of grain yield by the environment, genotype, and genotype-environment interaction was 47.64, 25.47, and 26.89 respectively. In Additive Main Effect and Multiplicative Interaction (AMMI) analysis, the first two Principal components revealed more than 73% of the variability for the yield which indicates that G and GE together accounted for more than 25 percent of the total variability. The results finally indicated that AMMI stability value, GSI, and AMMI biplot are informative methods to explore stability and their by in subsequent variety recommendations. Based on AMMI Stability Value (ASV), G13, G5, G12, G1, and G15 showed the least ASV and were found to be more stable whereas G10, G7 G9 G8, and G14 have the second lower ASV and showed moderate stability. Based on Genotypes Selection Index (GSI), G5, G13, and G15 showed the lowest GSI whereas G10, G1, G4, G11, and G15 showed the second-lowest GSI. However, G4 and G10 gave grain yield higher than the checks, with moderate stability. Therefore, these two genotypes were identified as candidate genotypes to be verified for possible releases for the highlands of Bale, Southeastern Ethiopia, and similar agro-ecologies

Keywwords: AMMI, Genotypes by Environment interaction, GSI, Lentil, stability,

Introduction

Lentil (*Lens culinaris* Medik.) is an annual legume better adapted to cool climates and is traditionally grown as a rain-fed crop is the fourth most important food legume crop after beans (*Phaseolus vulgaris* L.), Field pea (*Pisum sativum* L.), and chickpea (*Cicer arietinum* L.) in the world (FAO, 2006). Lentil is one of the most important food crops in developing countries, and its seed is a rich source of quality protein in human diets in the arid and semiarid areas in most parts of the world (Sabaghpour et al., 2004). Cultivating legumes in a rotation with cereals has been shown to be beneficial in many arid and semi-arid areas (Jones and Singh, 2000). Lentil is adapted to low rainfall and is predominantly grown in the winter in regions where the annual average rainfall is 300 to 400 mm (Sarker *et al*., 2003). Before any recommendation is made to a given area, new genotypes should be evaluated at many locations and for several years. Selection based on the yield performances are the two major phases of varietal development and the latter one is highly influenced by the locations and years of testing. The main environmental effect (E) and Genotype by Environment Interaction (GEI) has been reported as the most important source of variation for the measured yield of crops (Dehghani *et al.,* 2006). To achieve this goal, multiple environmental trials (MET) are conducted annually for all major crops throughout the world with the purpose of identifying superior genotypes for the target locations. In most cases, GE interaction is observed and needs to be modeled and interpreted (Naser et *al.*, 2008). Evaluating genotypes of a specific crop in diverse environments for overall stability and adaptability in the presence of the genotype × environment (G × E) interaction is essential for all stages of plant breeding (Yan & Hunt, 2010).

The additive main effects and multiplicative interaction (AMMI) and site regression (SREG) models and genotype plus G × E interaction (GGE) (Cornelius, Crossa, Seyedsadr, & Kang, 1996; Gauch, 2006; Yan, 2001) is the most popular parametric statistical model. These models effectively capture the additive (linear) and multiplicative (bilinear) components of G × E interaction and provide meaningful interpretation of multi-environment data to predict adaptability and genetic stability (Flores, Moreno, & Cubero, 1998; Zobel, Wright, & Gauch, 1988). The AMMI model uses ANOVA to analyze the main effects (additive part) and the principal component analysis (PCA) to analyze the non-additive residual effects of ANOVA (Gauch & Zobel, 1997) compared with the traditional ANOVA. The AMMI separates additive variance from the multiplicative variance and then applies PCA to the G × E interaction portion to a new set of coordinate axes that explain more detail of the G × E patterns (Gauch, 2006). The AMMI stability value (ASV) and yield stability index (YSI) generated in Core Idea · AMMI are commonly used to rank and describe the stability of genotypes (Purchase, Hatting, & van Deventer, 2000; Zobel et al., 1988). Although several studies have focused on the genetic variation for the grain yield of lentils (Khazaei et al., 2019), there is limited knowledge on genetic stability, variability, and G × E interactions for lentil. Thus this study aimed to identify high yielding and stable lentil genotypes to the highlands of bale, Southeastern Ethiopia.

Materials and Methods

In this study twelve lentil genotypes promoted from the previous yield trial were used to be evaluated along with two standard checks, Asano and Alemaya, and local check (Table 1) at two locations, Sinana and Agarfa, in the highlands of Bale zone Southeastern Ethiopia for three consecutive years, 2017 to 2019. Randomized Complete Block Design with four replications was used with a plot size of 3.2m2 (4rows at 0.2m spacing with 4m long). The combined ANOVA and LSD for mean separation were analyzed using Crop stat program.

AMMI analysis was also analyzed using the model suggested by (Cross *et a*l., 1990). The G × E interaction was partitioned into two principal component effects (IPCA1 and IPCA2). Stable genotypes across sites-years were identified by analyzing the contribution of the variation into total sums of squares. The ranking of genotypes was conducted using both ASV and GSI values..

The AMMI Stability Value (ASV): is the distance from zero in a two-dimensional scatter graph of IPCAI against IPCA2 scores, was calculated for each genotype according to the relative contributions of the principal component axis scores (IPCA1 and IPCA2) to the interaction sum of squares using the model suggested by (Purchase et al., 2000).

$$ASV=\sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1score)\right]^2+[IPCA2]^2}$$

Where, $\frac{SSIPCA1}{SSIPCA2}$ the weight given to the IPCA1 value by dividing the IPCA1 sum squares by the IPCA2 sum of squares. whereas GSI is calculated by ranking the mean grain yield of genotypes (RY) across environments and rank of AMMI stability (rASV) value GSIi= RYi +RASVi, where GSI = genotype selection index, RYi = rank of genotypes for mean grain yield across environment, RASV = rank of the genotypes based on the AMMI stability value.

Table 1. Lists of genotypes used in the trial and their source

Genotype code	Genotypes	Source
G1	PBA BLITZ	DZARC, Ethiopia
G2	07H212L-07HG1003-08HS2003	DZARC, Ethiopia
G3	CIPAL1304	DZARC, Ethiopia
G4	ILL 50075	DZARC, Ethiopia
G5	CIPAL 1306	DZARC, Ethiopia
G6	CIPAL 1204	DZARC, Ethiopia
G7	06H122L-07HS2003	DZARC, Ethiopia
G8	PBA BOLT	DZARC, Ethiopia
G9	07H071L-08HS2009	DZARC, Ethiopia
G10	06H13SL-07HS2001	DZARC, Ethiopia
G11	03-1 06LX1-07H4008	DZARC, Ethiopia
G12	07H029L-08HS2021	DZARC, Ethiopia
G13	Asano	Released from SARC
G14	Alemaya	Released from DZARC
G15	Local check	Local cultivar

DARC= Debrzeit Agricultural Research Center, SARC=Sinana Agricultural Research Center

Results and Discussions

The analysis of variance combined over locations and years revealed that highly significant variation for mean grain yield of lentil at ($p<0.01$) among genotypes, environments, genotype by environment interaction (Table 2). Such a similar significant result in their study of lentil was reported by (Dehghani *et al.,* 2008; Subedi *et al.,* 2020; and Darai *et al.*, 2017). The highly significant effects of the environment indicate high differential genotypic responses across the different environments. The variation in soil structure and moisture across the different environments was considered as a major underlying causal factor for the G×E interaction. Furthermore, the significant interaction of G X E indicates the differential response of genotypes across the tested environments (Khaldun *et al.*, 2012).

Table 2. Combined ANOVA for mean grain yield of 15 lentil genotypes tested across locations and yeasr

Source of Variation	Degree freedom	Sum Squares	Mean Squares
YEAR (Y)	2	30.45	15.22**
Location (L)	1	60.4	60.40**
Replication	3	0.14	0.048
Genotype (G)	14	49.46	3.53**
Y X L	2	1.65	0.82
G X L	14	14.51	1.04**
Y X L X G	56	37.71	0.67**

RESIDUAL	267	94.55	0.35
TOTAL	359	288.87	0.8

The highest mean grain yield of genotypes (Table 3) was obtained from G4 (2.32t/ha) followed by G10 (2.08t/ha), G6 (1.98t/ha), G3 (1.81t/ha), and G5 (1.81t/ha) whereas from the environments, the highest mean grain yield obtained from Sinana 2018 (2.26t/ha), followed by Sinana 2019 (1.92t/ha), Sinana 2017 (1.88t/ha) and Agarfa 2018 (1.68t/ha).

Table 3. Mean grain yield (t/ha) for 15 lentil genotypes tested across locations and years

Entry	Treat code	Sinana 2017=A	Agarfa 2017=B	Sinana 2018=C	Agarfa 2018=D	Sinana 2019=E	Agarfa 2019= F	TRT MEANS
PBA BLITZ	G1	1.37	1.95	2.34	1.46	1.75	1.16	1.67
07H212L-07HG1003-08HS2003	G2	1.52	0.47	1.96	0.58	1.77	1.22	1.25
CIPAL1304	G3	2.6	1.27	2.18	1.45	2.01	1.39	1.81
EC837891	G4	2.2	1.35	3.88	2.65	2.41	1.44	2.32
CIPAL 1306	G5	2.5	0.96	1.3	2.61	2	1.49	1.81
CIPAL 1204	G6	2.38	1.05	3.47	2.02	1.8	1.25	1.99
06H122L-07HS2003	G7	1.69	0.3	2.6	1.19	1.57	0.61	1.5
PBA BOLT	G8	1.97	0.45	1.95	0.83	2.15	0.96	1.38
07H071L-08HS2009	G9	2.16	1.1	1.98	0.97	2.31	0.87	1.56
EC837840	G10	2.35	1.48	3.19	1.73	2.41	1.35	2.08
03-1 06LX1-07H4008	G11	1.71	0.57	2.49	2.2	1.81	0.8	1.6
07H029L-08HS2021	G12	1.16	0.63	1.65	1.57	1.67	0.45	1.19
Asano (st. Check)	G13	1.68	1.31	2.3	1.57	1.94	1.18	1.66
Alemaya	G14	1.6	1.43	1.17	2.82	1.81	0.73	1.59
Local check	G15	1.29	0.48	1.41	1.5	1.48	1.15	1.6
MEANS		1.88	0.99	2.26	1.68	1.92	1.07	1.67
5% LSD		0.49	0.96	0.84	1.37	0.46	0.54	0.67
C.V.		19	21.4	24	24	16	22	21.3

AMMI Analysis

AMMI analysis in six environments (Table 4) shows that AMMI analysis partitioned main effects into genotypes, environments, and G×E with all the components showing highly significant effects ($P<0.001$). The environment had the greatest influence and showed for 47.64% of the total sum of squares; genotype shared for 25.47% of the total sum of squares and GEI had 26.89% which is the next highest contribution after the environment. The environment has a large sum square which indicates that the environments were dissimilar, with the large differences among environmental means causing larger variation in seed yield in lentil. The same significant variation results in their study in lentil has been reported by Muniyandi et *al.*, 2019; Darai *et al.*, 2017; Abebe *et al.*, 2020. The G × E interaction was partitioned into principal component effects. Highly significant variation was observed by the first two principal components. The first principal components (IPCA1) accounted for 43.98% of the GE interaction effect whereas the second principal component (IPCA2) explained 29.78% of the interaction sum of square. The two principal components were jointly responsible for 73.76% of the total GE interaction effect variation of grain yield with 34 degrees of freedom.

Table 4. Analysis of Variance for AMMI model for grain yield of 15 lentil genotypes

Sources of variation	DF.	SS	MS	TSS explained %
Genotypes	14	12.366	0.883	25.47
Environment	5	23.124	4.625	47.64
G X E	70	13.053	0.186	26.89
AMMI COMPONENT 1	18	5.74	0.319**	43.98
AMMI COMPONENT 2	16	3.887	0.243**	29.78
AMMI COMPONENT 3	14	2.114	0.151	16.2
AMMI COMPONENT 4	12	0.785	0.065	6.01
GXE RESIDUAL	10	0.527		
TOTAL	89	48.543		

Stability analysis

AMMI stability value (ASV) was proposed by Purchase *et al*. (2000) quantifies and ranks genotypes according to their yield stability. In the present study, AMMI stability value discriminated genotypes G13, G5, G12, G1, G4, and G15 as the stable accessions, whereas those with the second-lowest ASV, G10, G7, G9, G3, and G4 were considered moderate stable. Since the most stable genotypes are not necessarily the high yielder, the Genotype Selection Index (GSI) which incorporates both mean grain yield and stability helped to discriminate genotypes. Accordingly, G4 and G10 were found to be the best genotypes since they gave the highest mean seed yield and showed moderate stability (Table 5).

Table 5. Mean grain yield, and Stability parameters for 15 lentil genotypes

Code	Genotypes	Mean	Rank Yi	Slope (bi)	MS-DEV (S^2di)	IPCA1	IPCA2	ASV	Rank ASV	GSI
G1	PBA BLITZ	1.67	6	0.36	0.18	-0.11	0.4	0.43	4	10
G2	07H212L-07HG1003-08HS2003	1.25	14	0.79	0.24	0.41	0.46	0.76	14	28
G3	CIPAL1304	1.81	4	0.91	0.21	-0.43	-0.25	0.68	11	15
G4	EC837891	2.32	1	1.01	0.05	0.22	-0.62	0.7	12	13
G5	CIPAL 1306	1.81	5	1.47	0.05	0.07	-0.32	0.34	2	7
G6	CIPAL 1204	1.99	3	1.43	0.16	0.36	-0.47	0.71	13	16
G7	06H122L-07HS2003	1.5	12	1.43	0.05	0.39	-0.25	0.63	8	20
G8	PBA BOLT	1.38	13	1.05	0.23	0.35	0.41	0.66	10	23
G9	07H071L-08HS2009	1.56	8	0.88	0.24	0.22	0.57	0.65	9	17
G10	EC837840	2.08	2	0.99	0.08	0.35	0.04	0.51	7	9
G11	03-1 06LX1-07H4008	1.6	8	1.3	0.08	-0.13	-0.43	0.47	5	13
G12	07H029L-08HS2021	1.19	15	0.89	0.06	-0.27	0.04	0.41	3	18
G13	Asano (st. Check)	1.66	6	0.89	0.05	-0.02	0.13	0.13	1	7
G14	Alemaya	1.59	8	0.35	0.58	-1.11	0.08	1.64	15	23
G15	Local check	1.6	8	0.53	0.08	-0.28	0.22	0.47	5	13

AMMI Biplots

Biplots are graphs where aspects of both genotypes and environments are plotted on the same axes so that interrelationships can be visualized. There are two basic AMMI biplots, the AMMI 1 biplot, where the main effects of grain yield (genotype mean and environment mean) and IPCA1scores for both genotypes and environments are plotted against each other. On the other hand, the second is AMMI 2 where scores for IPCA1 and IPCA2 are plotted. In the AMMI 1 biplot, the usual interpretation of biplot is that the displacements along the abscissa indicate differences in main (additive) effects, whereas displacements along the ordinate indicate differences in interaction effects (Dari *et al.,* 2017). Genotypes that group together have similar adaptation while environments that group together influences the genotypes in the same way (Kempton *et al.,* 1984).

In AMMI 1 biplot genotypes and environments found at the right side of the perpendicular line gave mean grain yield higher than the grand mean. Accordingly, Genotypes, G3, G4, G5, G6, and G10 whereas environments SN 17, SN 18, AG 18, and SN 19 gave the highest mean grain yield above the grand mean (Figure 1). Genotypes and environment found in the same quadrants interact positively whereas those that found in different quadrants interact negatively.

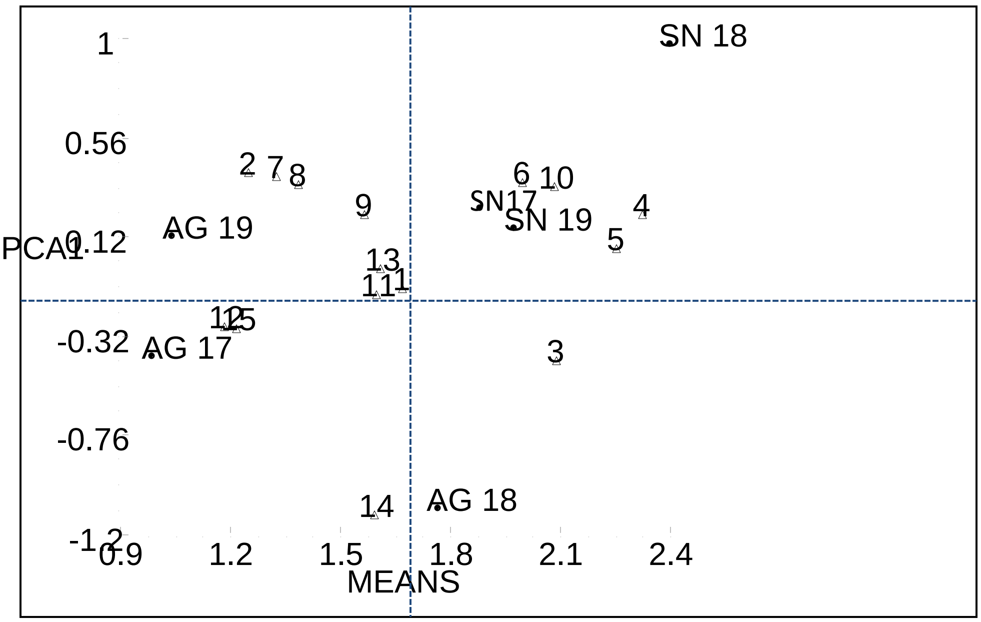


Figure 1. AMMI biplot for fifteen lentil genotypes plotted by Mean grain yield against PCA1 scores of genotypes and Environment

AMMI 2 biplot

This biplot is constructed by plotting the IPCA1scores against IPCA2 scores of the genotypes and environments. The environmental scores are joined to the origin by sidelines. Sites with short arrows do not exert strong interactive forces. Those with long arrows exert strong interaction. The genotypes close to ordinate expressed general adaptation, whereas the farthest genotypes depicted more specific adaptation to environments (Ebdon *et al.,* 2002; Guach *et al.,* 1996). In the present study genotypes found near the center of origin were G4, G10 and G13 showed stable performance across the testing sites whereas environments that have shorter distance from the origin were Sinana 2017, Sinana 2019 and Agarfa 2019 showed little deviation or showed stability, or have less deviation to most of the genotypes and gave higher mean yield (Figure 2).

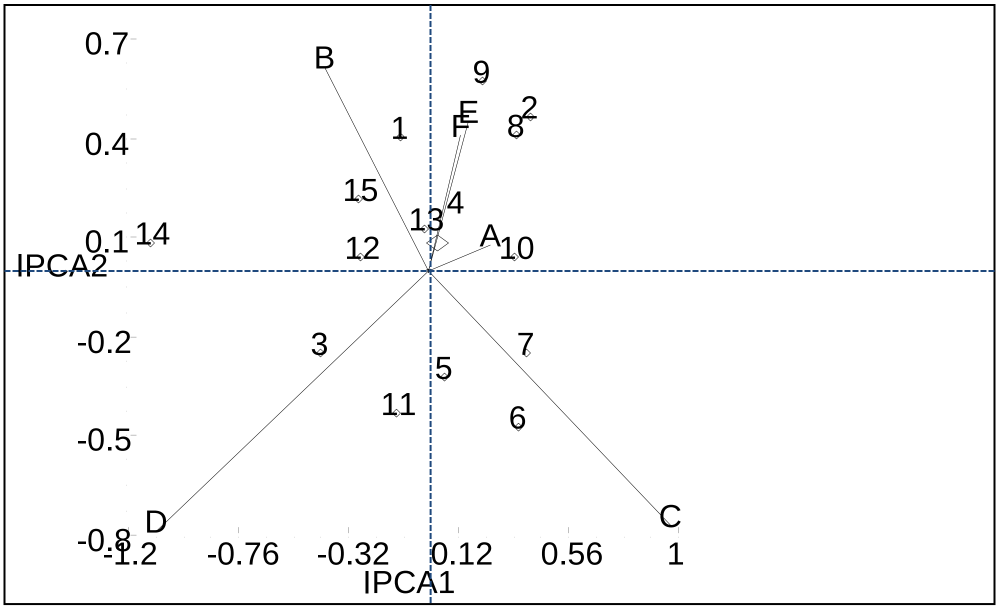


Figure 2 Interaction Biplot for the AMMI 2 constructed by plotting IPCA1 against IPCA2 for genotypes and environments

Conclusions and Recommendations

Yield is a quantitative trait that is strongly affected by the environment. Therefore, there is a need to have genotypes that can withstand the variable environmental factors so as to give better yield. Thus, from this study it has been concluded that two genotypes G4, and G10 were identified as candidate genotypes because of their high yielding ability as well as stable performance over the testing sites with tolerant types of reaction to major lentil diseases, to be verified for possible release for the highlands of Bale, Southeastern Ethiopian and similar agro-ecologies in the 2022/23 cropping season.

Acknowledgement

The authors would like to thank Oromia Agriculture Research Institute for financial support. The authors also thank Sinana Agriculture Research Center for providing the necessary support and Pulse and Oil Crops research case team staff for the entire trial management and data collection.

References

Abebe S., and Esayas T. (2020). Genotype x environment interaction and yield stability analysis of sugarcane (Saccharum officinarum L.) genotypes. *Int. J. Adv. Res. Biol. Sci*. (2020). 7(1): 14-26

Cornelius, P. L., Crossa, J., Seyedsadr, M. S., & Kang, M. (1996). Statistical tests and estimators for multiplicative models for cultivar trials. In M. Kang & J. Gaich (Eds.), Genotype-by-environment interaction (pp. 199–234). Boca Raton, FL: CRC Press

Crossa J. Statistical analyses of multi-location trials. Adv. Agron. 1990; 44: 55-85.

Darai R, Sarker A, Sah RP, Pokhrel K and Chaudhary R. (2017). AMMI Biplot Analysis for Genotype X Environment Interaction on Yield Trait of High Fe content Lentil Genotypes in Terai and Mid-Hill Environment of Nepal. Ann Agric Crop Sci. 2017; 2(1): 1026.

Dehghani H, Ebadi A, Yousefi A (2006). Biplot analysis of genotype by environment interaction for barley yield in Iran. Agron J.; 98: 388-393.

Dehghani H., Sabaghpour SH., and Sabaghnia N. (2008). Genotype × environment interaction for grain yield of some lentil genotypes and relationship among univariate stability statistics. *Spanish Journal of Agricultural Research:* 6(3), 385-394

Ebdon J, Gauch H. Additive main effect and multiplicative interaction analysis of national turfgrass performance trials: I. Interpretation of genotype X Environment Interaction. Crop Sci. 2002; 42: 489-496. FAO, 2006. Data stat year 2006. Food Agriculture Organization, Rome, Italy.

Flores, F., Moreno, M. T., & Cubero, J. I. (1998). A comparison of univariate and multivariate methods to analyze G×E interaction. Field Crops Research, 56, 271–286. https://doi.org/10.1016/S0378- 4290(97)00095-6

Gauch, H. (2006). Statistical analysis of yield trials by AMMI and GGE. Crop Science, 46, 1488–1500. https://doi.org/10.2135/ cropsci2005.07-0193

Gauch, H., & Zobel, R. (1997). Identifying mega-environments and targeting genotypes. Crop Science, 37, 311–326.

Gauch HG, Zobel RW, Kang MS & Gauch HG. (1996). AMMI analysis of yield trials. Genotype by-environment interaction, pp: 85-122. Gujarat Agric Uni Res J.; 22: 101-102.

Jones M.J., Singh M., 2000. Long-term yield patterns in barley-based cropping systems in northern Syria. 2. The role of feed legumes. J Agric Sci 135, 237-249.

Kempton RA. The use of biplots in interpreting variety by environment interactions. Journal of Agricultural Science. 1984; 103: 123-135.

Khazaei, H., Subedi, M., Nickerson, M., Martínez-Villaluenga, C., Frias, J., & Vandenberg, A. (2019). Seed protein of lentils: Current status, progress, and food applications. Foods, 8(9).

Khaldun A., Banik B., Mondal A. (2012). Genotype-by-environment Interaction Assessment Using Additive Main Effects and the Multiplicative Interaction Model (AMMI) in Maize. *Jordan Journal of Agricultural Sciences*, Volume 8, No.1 pp 22-32.

Muniyandi S., Kadanamari S., Shabir H., Amit K., and Sher A. (2019). Identification of stable lentil (Lens culinaris Medik) genotypes through GGE biplotand AMMI analysis for North Hill Zone of India. *Legume Research*, 42(4) 2019: 467-472

Naser Sabaghnia, Hamid Dehghani,* and Sayyed Hossain Sabaghpour (2008). Graphic Analysis of Genotype by Environment Interaction for Lentil Yield in Iran. *Agronomy Journal* Volume 100, Issue 3. pp 760-764.

Purchase, J. L., Hatting, H., & van Deventer, C. S. (2000). Genotype × environment interaction of winter wheat (Triticum aestivum L.) in South Africa: II. Stability analysis of yield performance. South African Journal of Plant and Soil, 17, 101–107

Sabaghpour, S.H., M. Safi khni, A. Sarker, A. Ghaff ri, and H. Ketata. 2004. Present status and future prospects of lentil cultivation in Iran. p. 23. In AED (ed.) 5th European Conf. on Grain Legumes, Dijon, France. 7–11 June. AEP Publ., Paris, France.

Sarker A., Erskine W., Singh M., 2003. Regression models for lentil seed and straw yields in Near East. Agr Forest Meteorol 116, 61-72.
Subedi M., Khazaei H., Arganosa G., Etukudo E., and Vandenberg A. (2020). Genetic stability and genotype × environment interaction analysis for seed protein content and protein yield of lentil. *Crop Science.* 2020;61:342–356
Yan, W. (2001). GGEbiplot: A windows application for graphical analysis of multi-environment trial data and other types of twoway data. Agronomy Journal, 93, 1111–1118.
Yan, W., & Hunt, L. (2010). Genotype by environment interaction and crop yield. In J. Jules (Ed.), Plant breeding reviews (Vol. 16, pp. 135– 178). Hoboken, NJ: John Wiley & Sons.
Zobel, R., Wright, M., & Gauch, H. (1988). Statistical analysis of a yield trial. Agronomy Journal, 80, 388–398.

The Release and Registration of "Weleshe" barley (*Hordeium vulgare L.)* variety

Hiwot Sebsibe*, Endeshaw Tadesse, Kasahun Tadesse,
Ermias Teshome and Girma Fana
Sinana Agricultural Research Center P O Box 208, Bale-Robe, Ethiopia
*Corresponding author email: hiwotsebsibe@yahoo.com

Abstract: *Weleshe* is a common name for this barley (*Hordeium vulgare* L.) variety with a pedigree designation of IBON HI 14/15 P#116. The variety has been developed and released by Sinana agricultural research center for commercial production in the highlands of Bale. It has been tested at Sinana, Goba, Adaba, Dodola and Gassera areas during 2018-2019 main cropping season. *Weleshe* showed high mean grain yield, tolerant to major barley disease and relatively stable across locations and years than the standard checks (*Robera, Abdane* and *EH1493). Weleshe* was tolerant to barley shoot fly than checks and exhibit compensatory growth after shoot fly damage.

Keywords: *Weleshe*; *Barley* (*Hordeium vulgare* L); *Yield Performance; Resistance*

Introduction

Barley is a cool season crop which grows at altitudes of about 3000 meter above sea level and commonly cultivated in stressed areas where soil erosion occasional drought or frost limits the growth of other crops (Bekele et al., 2005). Ethiopia is the second largest barley producer in Africa, next to Morocco, accounting for about 25 percent of the total barley production in the continent (FAO, 2014). Barley production and consumption has a longstanding tradition in Ethiopia where the country is considered the center of diversity or secondary origin of the crop with more than 15,000 accessions conserved in the gene bank.

Barley improvement in Ethiopia was started in the 1950s through the introduction of exotic germplasem and collections of local landraces with an objective of improving grain yield potential, grain quality and resistance/ tolerant to biotic as well as abiotic stresses (Hailu et al., 1996). Despite the breeding endeavors, in the last decades varieties released by the federal and regional research center were limited in quantity and standard quality attributes (Wondimu et al., 2013). Therefore, currently the barley research program carried out different breeding activities using landraces, foreign germplasems and genetic variability created locally through hybridization. The objective of this paper is to present the result of a variety trial conducted at five locations in 2018 and 2019 cropping seasons with subsequent identification and released of one outstanding food barley variety, namely Weleshe (IBON HI 14/15 P#116)

Varietal Origin and Evaluation

Weleshe (IBON HI 14/15 P#116) barley (*Hordeum vulgare* L.) is food barley variety released in 2021 under Oromia Agricultural Research Institute by Sinana Agricultural Research Center. It was originally developed from ICARDA barley improvement research program lines through pure line selection methods to develop stable high yielding and disease resistant. The material has been evaluated together with other genotypes in different breeding nurseries from 2018-2019 and then advanced to variety trial to see its varietal performance across locations and years in barley producing areas of Bale highland. The variety was evaluated by National Variety Release committee and officially released for wider production in the highlands of Bale and areas with similar agro-ecologies.

Morphological and Agronomical Characters

Weleshe is six-rowed variety, erect growth habit with average days to heading and maturity date of 70 and 115 days, respectively (Table 1). The variety has short plant height (76.3cm) and this character is preferred by the local community for its tolerance to lodging problem in major barley growing areas. On the other hand, seed color is white and has average thousand-kernel weight of 38 g. It is also characterized by better resistance/tolerance to main biological insect pest (shoot fly) than specially the standard variety (*Robera, Abdane* and *EH1493)* and showed rapid compensatory growth after damage by the insect.

Yield Performance

Weleshe (IBON HI 14/15 P#116) was tested together with 16 barley genotypes including checks in regional variety trial at 5 environments in major barley producing areas in Bale highlands during 2018- 2019 consecutive years. It was evaluated along with *Robera*, *Abdane* and *EH1493* as standard variety at altitudinal range of 2300-2600 meter above sea level at Sinana, Gasera, Goba, Adaba and Dodola locations in each year. During evaluation seasons, the overall location grain yield mean of this variety was better than all genotype means. Beside, *Weleshe* showed 14% and 18% yield advantage over the standard check *Robera* and *Abdane* as well as 15% over third standard check *EH1493*, respectively. On research field *Weleshe* gave yield ranging from 3.7 to 5.4 tonsha^{-1}, whereas 3.3 to 4.4 tons ha^{-1} on farmers' field.

Table 1. Agronomic and morphological characteristics of *Weleshe* (IBON HI 14/15 P#116)

Agronomic characters	
Altitude (m.a.s.l)	2100 -2500
Rain fall (mm)	650 -1600
Fertilizer rate (DAP in kg/ha)	100
Seed rate(kg/ha)	125
Planting date	Mid-June to early August
Days to heading	70
Days to maturity	115
Plant height(cm)	76.3
Growth habit	Erect
1000 seed weight(g)	38
Seed color	White
Row type	6 row
Hectoliter weight (Kg/L)	63.1
Crop pest reaction	Moderately Resistance
Grain yield(t/ha)Research field	3.7 -5.4
Grain yield (t/ha) Farmer's field	3.3 -4.4
Year of released	2021

Stability performance: Stability analysis was done on grain yield using 16 food barley genotypes including checks were studied for two years across five locations. According to joint regression model, a variety with high mean yield, regression coefficient (bi) of unity and with deviation from regression (S2di) =0 is stable (Eberhart and Russell, 1966). In this regard, *Weleshe* is stable variety with high mean grain yield, regression coefficient (bi) of 0.95 which is nearly unity and deviation from regression of 0.06 which is equivalent to zero. Therefore, it has shown stable yield performance across locations of evaluation as well as higher mean grain yield over check varieties *Robera*, *Abdane* and *EH1493*.

Table 2. Results of Stability parameters of 16 Food barley genotypes over environments

Genotype	Mean	IPCA 1	IPCA 2	ASV	rASV	YSI	bi	S2di
ICARDA-GP 45	2.3	-0.71	0.29	0.94	14	21	0.10	0.05
IBON HI 14/15 12	1.5	-0.18	-0.39	0.46	8	24	0.70	0.01
IBON HI 14/15 18	1.7	0.03	0.26	0.26	6	21	1.11	0.03
IBON HI 13/14 12	2.0	-0.54	0.01	0.69	12	13	1.04	-0.07
ICARDA-GP 86	2.3	0.03	-0.61	0.61	10	18	1.23	-0.06
ICARDA ND 218	2.1	0.00	-0.28	0.28	7	18	1.49	0.19
IBON HI 14/15 141	2.2	0.02	0.13	0.13	3	12	1.93	0.00
ICARDA GP 35	2.8	-0.15	0.02	0.19	5	10	1.87	0.08
IBON HI 14/15 29	1.8	-0.29	0.56	0.67	11	25	1.16	0.05
IBON HI 13/14 15	2.0	-0.21	-0.46	0.53	9	22	1.05	-0.05
SBYT 19	2.7	-0.04	-0.09	0.10	2	8	-0.03	-0.05
IBON HI 14/15116	3.6	-0.03	0.00	0.03	1	2	0.95	0.06
ICARDA-GP 109	2.1	0.08	0.11	0.15	4	14	0.70	0.02
Robera	2.6	0.57	0.70	1.00	16	18	1.08	-0.06
Abdane	2.4	0.67	-0.01	0.84	13	17	0.78	-0.06
EH1493	2.4	0.76	-0.24	0.99	15	18	0.53	0.04

ASV= AMMI Stability Value, rASV=Rank of ASV, YSI=Yield Stability Index, bi= linear regression coefficient (slope), S^2di= Deviation from the regression component of interaction

Disease Reaction: Data recording was done for all genotypes including this variety for major barley diseases such as net blotch (*Pyrenophora teres* Drechs.), scald (*Rhynchosporium secalis* Oud.), stem rust *(Puccinia graminis* f. sp. *Tritici)* and barley leaf rust (*Puccinia hordei* Otth) at across all environments. Data was taken at 51-69% plant growth stages (Zadoks *et al*., 1974) across locations. Both net blotch and scald were scored using 00-99 double digit scale (Saari and Prescot,1975) in such a way that the first digit indicates the spread of disease in a plot (% incidence) and the second digit indicate the percentage of leaf area infected (% severity). Whereas, barley leaf rust and stem rust data were collected based on Stubs *et al*. (1986) methodology. The net blotch response of the candidate variety (*Weleshe*) was comparable with checks variety (Table 1) and it appears that *Weleshe* was moderately resistant to these diseases. The variety *Weleshe* less susceptible for stem rust *(Puccinia graminis* f. sp. *Tritici)* and barley leaf rust (*Puccinia hordei* Otth) than checks.

Table 3. Summary of pooled mean of yield and other data on Weleshe and the checks across location and years

Variety	DH	DM	PH	ST	YLD	TKW	HLW	NB	SR	LR	BSF	
											Inf.	D.pla
Weleshe	70	115	76.3	69	3.6	37.8	63.1	86	5ms	5s	4.8	1.8
Robera	67	113	83	73.6	2.6	36.5	61.7	90	10s	20s	4.3	2
Abdane	67	114	89.1	76	2.4	35.9	62.5	85	15s	15s	5.5	1.8
EH1493	74	116	86.9	71.3	2.4	36.1	63.6	85	10s	10s	4.6	1

Key: **DH=days to heading, DM= days to maturity, PH= plant height, YLD= grain yield t ha-1, TKW= thousands kernel weight, HLW=hectoliter weight, NB= Net blotch, SR= stem rust, LR=leaf rust, SC= scald, BSF=barley shoot fly, Inf= infestation and D.pla=dead plant*

Adaptation

Weleshe variety is recommended for production in the highlands of Bale with annual rainfall of about 650 -1600mm and areas with similar agro-ecologies. On black soils, 100 kg DAP (diammonium phosphate) fertilizer is recommended to give good yield and with 125 kg seed rate. In addition, the variety can be planted early March for *Ganna* season and early August for *Bona* season.

Conclusions and Recommendations

Weleshe is a stable variety in grain yield performance, has good agronomic traits and tolerant to shoot fly infestation. It is resistance for major barley attacking disease in the area. *Weleshe* was released for major barley growing regions of Bale highlands and similar agroecology. The variety will be helpful for local farmers mainly due to its yield performance, productive tillers, resistance to lodging and relatively disease free than other varieties grown in the area. Therefore, smallholder farmers, privet and public seed enterprises and other barley producers in Bale highlands and similar agro ecology can produce Weleshe with its full management recommendation.

Reference

Bekele Hunde, Kiros melese, Fekede Abebe, Asnakech Tekalign, Melkamu Ayalew, Getaneh Woldeabe, Yonas Worku, Eshetu Belete and Birhanu Bekele.2011. Achievement in Barely scalds research in Ethiopia. In Bayeh Mulatu and Stefani Grando eds. Barley research and developments in Ethiopia. Preceding of the 2nd national barley research and development workshop, 28-30, November,2006 Holeta Ethiopia pp 245-255

Eberhart, S.A. and Russell, W.A. 1966. Stability parameters for comparing varieties. *Crop Science* 6:36-40.

Hailu Gebre, Brehane lakew, Fikadu Fufa, Brihanu Bekele, Alemayehu Assefa and Tesfaye Getache, 1996. Food barley breeding In: Hailu Gebre and Joob Van Luer (eds). Barley research in Ethiopia. Past work and feature prospective Proceeding of 1st barley research review workshop 16-19 October 1993, Addis Abeba IAR/ICARDA, Addis Abeba, Ethiopia pp;9-23

Wondemu Fikadu, Amsalu Ayana and Habtamu Zeleke.2013. Impruvement in grain yield and malting quality barley (*Hodurem vulgare L.)* in Ethiopioa. Ethiop.J.Appel .Sci. Techenol.4(2):37-62 (2013)

Zadoks, J.C., Chang, T.T. and Konzak, C.F. 1974. A decimal code for the growth stages of cereals. *Weed Research* 14:415-421.

Determination of Nitrogen Fertilizer Rate and Time of Application on Malt Barley Varieties In Bale Highlands, South Eastern Ethiopia

Jitu Alemi*, Mangistu Bogale, Girma Fana, Endashaw Taddese

Oromia Agricultural Research Institute,

Sinana Agricultural Research Center, P.O.Box, Bale-Robe, Ethiopia

*Corresponding author: jitualemi2009@gmail.com

Abstract: *A field experiment was conducted at two locations in Bale, south eastern Ethiopia (Goba and Dinsho) for two consecutive years (2019-2020) to study determination of Nitrogen rate and time of application on malt barley varieties(V1=Traveler And V2=Singitan) and assessing the economic feasibility. The treatments were four levels of N (0, 23, 46, 69, and 92 kg ha^{-1}) and two Varieties (V1=Traveler And V2=Singitan) and time of application (T1=1/2 at planting+1/2at tillering,T2=1/3 at planting+2/3 at tillering and T3=All at planting3),methods of application (Hand drilling) laid in split- plot randomized complete block design (RCBD) with three replications. (V1=Traveler and V2=Singitan) was used as a test crop. The analysis showed that almost all parameters studied were not significantly (P<0.05) affected by the main effect of N fertilizer and time of application at both locations over years. This could be due to relatively medium to high accumulation of studied nutrients in the soil and conducive environmental conditions in the specific area. Therefore, based on this findings future research should focus on prior soil test based fertilizers recommendations.*

Keywords*:* N, hand drilling, Non-significant, Nutrient status

Introduction

Barley (*Hordeum vulgare* L.) is one of the main cereal crops produced in the World. It ranks fourth in the world in production after wheat, maize and rice (FAO, 2013). Global barley production is estimated about 141.7 million tons (USDA, 2017). Globally European Union, Russia, Canada, USA and Argentina are the top five largest world barley producers where, European Union produces the greatest quantities of barley with an estimated production of 20.5 million tons followed by Russian federations with a production of about 8 million tons, whereas Canada, USA and Argentina barley production was estimated 7.3, 3.1 and 2.8 million tons respectively (USDA, 2017). Ethiopia is the second largest producer of barley in Africa next to Morocco, accounting for about 26 percent of the total barley production in the country (Shahidur *et al*., 2015). It is the fifth important cereal crop next to *tef*, maize, sorghum and wheat in the country's domestic production with total area coverage of 959,273.36 hectares and total annual production of about 2.03 million tons in main season, whereas the mean barley productivity was 2.1 tons ha-1 (CSA, 2017). In Ethiopia, barley production is highly concentrated in Oromia National Regional State with total area coverage of 454,662.78 hectares and total annual production of about 1.09 million tons, whereas the mean barley productivity was around 2.4 tons ha-1 in main cropping season (CSA, 2017).

In Ethiopia, barely is a dependable source of food in the highlands areas. Its grain is used for the preparation of different foodstuffs, such as *injera, kolo*, and local drinks, such as *tela*, *borde* and beer (Melle *et al*., 2015). Very recently it is being adopted for preparation of bread all alone or mixed with wheat. Malt barley is a high-opportunity crop, with great room for profitable expansion, particularly when connected with the country's commercial brewing and value-added industries (Berhane, 2011). Barley (*Hordeum vulgare* L.) is the modest grain which has a broad range of compatibility and transmittance among other crops. Following wheat, rice and maize barley is the fourth main grain in the globe (Khodabandeh, 2003). Originated and domesticated in mountainous areas of Ethiopia and Southwest Asia where (Harlan, 1976). Ethiopia is both center of origin and diversity, (Vavilov, 1951; Quasar, 1975, and Bonman et al., 2005). Second largest producer in Africa (25%) (FAO, 2014). The readily available sources, which provide essential nutrients and maintain a favorable balance, are chemical fertilizers. (Chen, 2006). Out of several nutrients provided to plants, nitrogen is the major and essential nutrient. However, barley production in Ethiopia is usually practiced with little or no external input (Getachew Alemu, 2001). Chemical fertilizer use by small scale farmer is insignificant and in adequate. Di-ammonium phosphate is the only fertilizer they use.

Proper dose and time of N application has important effect in terms of increasing crop yield, improve use efficiency and determining the grain protein content which is the major quality for malt barley ((Dhugga and Waines, 1989; Blankenau*et al*., 2002, Buskiene and Uselis 2008). Malting barley is emerging as a potential industrial crop and received global attention with drastically increase in the brewery companies. The yield and quality attributes are highly depends appropriate dose of applied N fertilizer. Among the factor affecting yield and quality of malt barley agro-ecological conditions and production technology primarily the natural soil fertility, Carbon to nitrogen (C/N) ratio (Acuna et al., 2005) the amount of applied nitrogen

(Abeledo.et. al., 2003b), Time and rate of N fertilizer application are the major one. About 50% of applied N fertilizer remains unavailable to a crop due to N losses (Zafar and Muhammad, 2007). Not more than 50 to 60% of applied N is usually recovered under average field conditions whereas efficient timing and placement of N could increase recovery of applied N up to 70 or to 80% (Legg and Meisinger (1982)). Growth stage of plants at the time of application determines uptake efficiency by crop. Split N application in the later stages was effective in attaining higher N uptake efficiency by crop (Kumariet al., 2000; Ashraf and Azam, 1998). It is the most important element to achieve stable high grain yields and improving grain quality (Delogu G, et al,1998, Shi Z, *et al*,1996, Pan J, *et al*,2006).

Objective: To evaluate the effect of N fertilizer application rate and timing on Yield component and some physico-chemical quality parameters of malt barley cultivars considered.

Materials and Methods

Description of the Study Area

The experiment was conducted on farmer's field at Goba and Dinsho districts of Bale highland. Goba is located 443km south east of Addis Ababa and 13 km from Robe (i.e. the capital city of the zone) in the southwest direction. It's found within a latitude of 7° 01'N and 39° 58' 59.99"E and an elevation of 2743m above sea level. Dinsho is located at 410km from Addis Ababa on southeast direction. The latitudinal and longitudinal location of Dinsho lies between 7°05' N and 39 45' E with an elevation of 3207m above sea level. These areas are characterized by bimodal rainfall with two cropping seasons; called *belg*whichextends from March to July and the meher/main season which extends from August to December. The average rainfall of *meher*ranges from 270-560 mm; that of *belg*ranges from 250-560 mm and average annual maximum and minimum temperatures are 21 and 9°C, respectively (Tafa, 2003). In general, the average monthly maximum and minimum temperatures and rainfall distribution are suitable for barley production. Furthermore, the dominant crops widely grown around the experimental area are bread wheat followed by barley.

Experimental Materials and Treatments

Two malt barley varieties differing in their time of flowering, morphological characteristics, plant height and yield potential was used for the study. The description of each variety was given in Table 1. One of the varieties selected was released from Sinana Agricultural Research Center (SARC) and the other one from Holeta Agricultural Research Center (HARC). Four levels of nitrogen (23, 46, 69, 92 kg N ha^{-1}), two malt barley varieties Traveler and Singitan and three time of nitrogen fertilizer application was used during the study time. The treatment combination consisted of Varieties as main plot, combined factors of N rate (23, 46, 69, 92 kg/ha) as sub-plot and application timing (1/2 at planting + ½ at tillering, 1/3 at planting + 2/3 at tillering, and all at planting)) as sub-sub plot. As a control, 0kg N ha^{-1} is systematically included for both varieties, bringing the total treatment combinations to twenty six. TSP at the rate of 100 kg ha-1 is applied as basal dose. All other input and agronomic practices will be carried out uniformly. The source of N fertilizer will be urea (46% N) and that of P is triple super phosphate, TSP (uniform rate of 46 kg P_2O_5 ha-1)(Tilahun*et al.*, 2008).

Experimental Design and Procedures

The field experiment was conducted in a 4x 2x3 factorial arrangement with two additional treatments of no N fertilizer (control) for the two varieties using a split-plot in Randomized Complete Block Design (RCBD) with 3 replications. Replications was folded into two blocks of thirteen plots each to reduce heterogeneity within replications. The experimental field was prepared following the conventional tillage practice before planting the barley varieties. In accordance with the specifications of the design, a field layout was prepared and each treatment was assigned randomly to experimental plots within a block. The plot size will be 2.4 x 3m (7.2 m^2) and each plot consisted of 12 rows and spaced 20 cm apart with a net plot size of 6.0 m^2.The adjacent blocks and plots was separated by 1m wide-open space and 0.5m blank rows, respectively.

Malt barley varieties, was sown at the recommended rate of 125kg seed ha-1, by hand drilling in the rows as uniformly as possible and covered with soil manually. The full dose of triple super phosphate (uniform rate of 46 kg P_2O_5 ha-1)was applied equally to all plots by surface broadcasting and mixing with the soil at planting. Similarly, all, half and one-third of fertilizer N (i.e., as per the treatment) and was applied uniformly within the rows at planting. The remaining half and two-thirds of each N fertilizer treatments was top dressed on the inter-row spaces by hand at the mid-tillering at specified Zadoks crop growth stages. The field was weeded twice by hand or sprayed with herbicide (at 25 and 45 days after planting) during the crop season to control weeds and weed-crop competition for growth factors. Moreover, all the necessary field management practices was carried out as per the recommended practices followed by the farming community around the areas. Finally, harvesting will be made manually using a sickle from the central tenrows at physiological maturity. All necessary data was collected from the central ten rows while the four rows will left as a border plant.

Table 1. Description of barley Varieties used in the experiment

SN	Varieties name	Origin	Pedigree	Releasing Center	Maturity	Altitude	year of release
1	Traveler	Heineken		Heineken/HARC	122	2200-2800	2013
2	Singitan	Ethiopia	IBON-MRA	SARC	119	2200-2600	2016

MOA (2014-2017)

Methods of Data Collection

Data was collected as yield/plot for yield then converted to yield/ha and for the quality parameters (Teshome *et al*., 2011) and grain samples from the harvested malt barley varieties was used to determine the characteristics. Protein content, were analyzed for malt grain quality parameters.

Statistical Analysis

Analysis of variance (ANOVA) for malt barley quality parameters of the varieties subjected to different nitrogen rates was analyzed using SAS (statistical analysis system) for two factors arranged in a factorial RCBD version 9.2, 1999 to 2000, SAS Institute inc., Cary, NC, USA. Means of each character for each variety was compared by LSD at a probability level of 5%.

Results and Discussions

Soil chemical properties

The results of soil analysis (Table 1) showed that the soil reaction of the experimental sites were moderately neutral at Diinshoo and Goba, where the pH was 6.92 and 6.88, respectively This indicates that the soil reaction of the experimental sites is suitable for optimum growth and yield of most crops. The CEC value of the soil was very high at Diinshoo and Moderate at Goba; this indicates that the soil has relatively high capacity to hold nutrient cation and supply to the crop. The experimental soil is medium in available P at Goba and very Low In Diinshoo where 10.5 and 3.5 respectively. Data also indicated that the soils of the experimental sites had Medium total N which means fertilizer addition may increase growth and yield.

Table 2. Chemical properties of the experimental soil before planting

Location	Sand (%)	Clay (%)	Silt (%)	Textural Class	% OC	%OM	TN (%)	CEC (meq/100g)	Av. P (mg/Kg)	pH-H_2O
Goba	11	71	18	Clay	1.52	2.62	0.231	24.5	10.5	6.88
Dinsho	23	47	30	Clay	1.68	2.89	0.273	46.2	3.15	6.92

The experiment was conducted for two years (2011 and 2012 cropping season). The statistical results revealed that most of the parameters considered were not significantly (P<0.5) affected by the main effect of Nitrogen rate and Timing of application conducted over two years at GOBA and DIINSHOO (Table 3 and 4). This might be due to relatively medium to high accumulation of studied nutrients in the soil. Under nutrient sufficient and conducive environmental conditions plants in the range of studied factor levels did not interact or compete.

Table 3. Determination of Nitrogen rate and time of application on malt barley varieties at Goba, 2011 and 2012 (combined)

Treatments	DM	PHT	SPP	SL	TPP	BM	GYD	HI	TKW	HLW	PRo
Variety											
V1	136.5a	81.1a	33.2a	10.73a	6.3b	8291b	3359.7b	40.8a	38.2a	60.7a	12a
V2	133	68.2b	28.5b	9.1b	7.5a	10733.6a	4391.7a	41.2b	30.7b	59.2b	11.1b
LSD (5%)	0.67	2.5	2.2	0.42	1.0	344.7	144.1	0.9	0.9	1.3	0.8
Nitrogen rates											
0kg ha-1	135.3	72.9	29.7	9.5	7.2	6541.5d	2801.4c	43.2a	34.5	58.7b	11.2b
23 kg ha-1	134.6	72.8	31.8	10	7.1	9166b	3534.7b	38.8b	35.5	58.3b	11.3b
46 kg ha-1	135	73.8	29.5	10	6.5	9416.7ba	3943ab	42a	34.3	61.3a	11.9ba
69 kg ha-1	135	75.9	30.8	10.2	6.8	1..96.4ba	4166a	41.3ba	34	60.9ba	13.7a
92 kg ha-1	134.5	76.9	31.7	9.7	7.3	10459.9a	4270.6a	41.3ba	34.2	59.3ba	13.5ba
LSD (%)	ns	Ns	Ns	Ns	ns	1037	433.6	2.7	ns	ns	2.2
Timing											
T1	128.4	76.9	28.7	8.7	6	6705.4	2824.7	36.4	36.3	60.6	11.9
T2	128.3	77.8	28.4	8.7	6.4	6537.7	3165.8	36	36.0	60.8	12.6
T3	128.2	77.1	28.8	8.6	6.2	6951.5	2800.0	36.4	36.4	61.5	12.3
LSD (5%)	ns	ns	Ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	12	7.5	15.5	9.5	30	8	8.2	5	6.3	4.8	14.8

Keys: DM=Days to maturity, PHT=Plant height, SPP=Seeds per spike, SL=Spike length, TPP=Total tillers per plant, BM=Biomass yield (kg ha^{-1}), GYD=Grain yield (kg ha^{-1}), HI=Harvest index (%), TKW=thousand kernel weight (gm), HLW=Hectoliter weight, Pro=Protein (%), T1= 1/2 at planting + tillering, T2= 1/3 at planting + 2/3 at tillering, T3= All at planting

Table 4. Determination of Nitrogen rate and time of application on malt barley varieties at Dinsho, 2011 and 2012 (combined)

Treatments	DM	PHT	SPP	SL	TPP	BM	GYD	HI	TKW	HLW	Pro
Variety											
V1	126b	70a	27	6.7	5.1	6342.5b	2523.8b	39.7	43.3a	59.3b	11.1a
V2	130.4a	56.2b	25	6.4	4.8	7747.2a	3049.3a	38.5	37.3b	60.8a	9.8b
LSD (5%)	2.4	1.8	Ns	Ns	Ns	1056	491.2	Ns	1.05	1.4	0.5
Nitrogen rates											
0 kg ha-1	127.8	60.4b	23.8	6.3	4.4	5395.4b	2283	41.8	39.2b	60.1	9.2c
23 kg ha-1	127.7	62.8ba	23.8	6.4	4.7	6883.4ba	2609.5	37.1	40.3ba	60.2	9.6c
46 kg ha-1	128.3	62.8ab	29.6	6.6	5.1	6877.9ba	2953.9	43.8	39.7ba	60	10.0bc
69 kg ha-1	128.8	63.4ab	24.7	6.6	5.1	7317.6ab	2804.6	37	40.2ba	59.5	10.7b
92 kg ha-1		64.2	24.4	6.5	5.1	7651.4a	2626.9	37.2	41.3a	60.5	11.8a
LSD (%)	ns	3.1	Ns	ns	ns	1840	ns	ns	1.8	Ns	0.8
Timing											
T1	128.6	63.2	24	6.5	4.9	7063.2	2768.8	35.6	40.5	60.1	10.4
T2	128.3	62.1	28	6.4	4.8	6923.5	2687.1	37.7	39.7	60.7	10.5
T3	128.3	64	25.1	6.8	5.3	7155.5	2921	41.4	40.8	59.5	10.4
LSD (5%)	ns	ns	Ns	ns	ns	ns	ns	ns	ns	ns	ns
CV (%)	6	9.1	12.3	19.5	29	27.8	28.5	29.4	18.3	18.7	14.2

Keys: DM=Days to maturity, PHT=Plant height, SPP=Seeds per spike, SL=Spike length, TPP=Total tillers per plant, BM=Biomass yield (kg ha^{-1}), GYD=Grain yield (kg ha^{-1}), HI=Harvest index (%), TKW=thousand kernel weight (gm), HLW=Hectoliter weight, Pro=Protein (%)(%), T1= 1/2 at planting + ½ at tillering, T2= 1/3 at planting + 2/3 at tillering, T3= All at planting

Grain Yield, Biomass, Harvest Index Protein

Grain Yield

Significant ($p < 0.001$) differences among nitrogen rate treatments, varieties and their interaction for grain yield of malt barley (Table 1). The varieties Singitan and Traveler showed better performance of grain yield at the 69,92 kg Nha-1 application which may be due to the highest response varieties to N and use efficiency. The Singitan variety obtained the maximum grain yield at the N rate application of 92kg ha-1. The Traveler variety obtained the maximum grain yield at the N rate application of 69 kg ha-1. While the lowest (2801kg ha-1) grain yields were obtained with combination of the control (0 N) and Singitan And Traveler variety. In general, in this study grain yield ranged between 2801kg ha-1 (SINGITAN) and4270.6 kg ha-1 (SINGITAN) (Table 1). This large grain yield variation among barley varieties under different nitrogen rate treatments could help in the selection of better varieties for different N supply environments. When the N fertilizer rates increased from 0 to 92 kg Nha-1 the mean grain yield was increased by 52.45% .This indicating increasing response with increasing N fertilizer rates. This result were in agreement with Amare (2015) reports who mentioned that significant increases in grain yields of malt barley crop with increasing levels of N fertilizer.

Biomass

Biomass was Significant ($p < 0.001$) differences among nitrogen rate treatments, varieties and their interaction for biomass of malt barley (Table 1 and 2). The varieties Singitan showed better performance of grain yield at the 92 kg Nha-1 application which may be due to the highest response varieties to N and use efficiency. The singitan variety obtained the maximum grain yield at the N rate application of 92 kg ha-1. The singitan variety obtained the maximum grain yield at the N rate application of 92 kg ha-1. While the lowest (5395 kg ha-1) grain yields were obtained with combination of the control (0 N) and traveler variety. In general, in this study grain yield ranged between 5395g ha-1 (Traveler) and 10459.9 kg ha-1 (SINGITAN) (Table 1 and 2). This large grain yield variation among barley varieties under different nitrogen rate treatments could help in the selection of better varieties for different N supply environments. When the N fertilizer rates increased from 0 to 92 kg Nha-1 the mean grain yield was increased by 21.24% and 36.71%, respectively, indicating increasing response with increasing N fertilizer rates. This result were in agreement with Amare (2015) reports who mentioned that significant increases in biomass of malt barley crop with increasing levels of N fertilizer.

Harvest Index

The ability of a variety to partition the dry matter into economic (grain) yield is indicated by its harvest index of malt barley which was significantly ($p \leq 0.05$) varied among varieties and N rate treatments (Table 1). The control treatment had resulted in the highest harvest index (43.2%), followed by N rates of 46 kg/ha with a harvest index value of 42%. This result indicated that as increased the applied N rate, harvest index of barley was decreased. In line with Munir (2002) and Demelash (2016) reported that applied N fertilizer rate were increased while the mean harvest index were decreased. There were also highly significant ($p \leq 0.05$) differences between the singitan and the rest of the varieties for harvest index across N rate treatments. This could be accounted for the enhanced above ground biomass yield in response to the incremental rates of N in contrast to grain yield during the growing season. In the case of Singitan and Traveler varieties, statistically all were at par for their HI ranging from 43.2- -42 % suggesting nearly an equal early assimilation and utilization of nitrogen nutrients of those varieties while lowest harvest index (38.8 %) was recorded for variety . There was variation in harvest index of different barley varieties due to barley inherent variability.

Grain Protein Content

Grain protein content of malt barley was significant ($p \leq 0.05$) difference to the main effect of N fertilizer levels and varieties. As N fertilizer increases grain protein content also increased. The highest (13.5%) grain protein content was recorded from the highest N fertilizer application (92 kg Nha-1), whereas the lowest (9.2%) grain protein obtained from control treatment. Similarly, Adane (2015) found that with low available nitrogen in the soil, malt barley responds well to applied fertilizer, showing increases in both grain yield and protein content. Increasing in protein may increase steep times, create undesirable qualities in the malt, excessive enzymatic activity and low extract yield (Johnston *et al*., 2007). It also slows down water uptake during steeping, potentially affecting final malt quality. The highest (13.5%) grain protein content was recorded from Singitan variety. The lowest grain protein content (9.2%) in the Traveler variety might be due to the low grain N uptake. The variation in grain protein content was due to genetic variation of malt barley varieties. According to the Ethiopian standard authority and Asella malt factory (AMF), the protein level of the raw barley quality standard for malt should be between 9-12% (EQSA, 2006). Both main effect of N fertilizer.

Table 5. *Partial budget analysis* of Nitrogen rate and time of application on malt barley varieties at Goba, 2011 and 2012 (combined) *conditions.*

TRT	YLD	TCV	AdY (kg ha-1)	GB (ETBha-1)	NB (ETBha-1)	MRR (%)	CR
V2N0T1	2237.11	218.475	2013.399	32214.38	31995.91		146.4511
V1N0T1	2495.05	285.75	2245.545	35928.72	35642.97	1413.91	124.7348
N1T1V2	2882.67	411.25	2594.403	41510.45	41099.2	4347	99.93726
N3T2V1	2601	411.25	2340.9	37454.4	37043.15	D	90.07453
N1T2V1	2801	570.5	2520.9	40334.4	39763.9	D	69.70009
N1T2V2	2830.28	590.75	2547.252	40756.03	40165.28	D	67.99032
N2T1V2	2678.82	602	2410.938	38575.01	37973.01	D	63.07809
N2T1V1	2732.11	651.5	2458.899	39342.38	38690.88	D	59.38739
N4T2V2	3177.67	653.75	2859.903	45758.45	45104.7	1651.75	68.9938
N1T2V1	3310.5	662.75	2979.45	47671.2	47008.45	21153	70.92939
N3T2V1	2663.1	665	2396.79	38348.64	37683.64	D	56.66713
N4T2V1	2742.06	667.25	2467.854	39485.66	38818.41	D	58.17672
N3T2V2	2969.12	685.25	2672.208	42755.33	42070.08	D	61.39377
N1T3V1	2352.53	759.675	2117.277	33876.43	33116.76	D	43.59332
N1T3V2	2796.98	763.5	2517.282	40276.51	39513.01	D	51.75247
N2T2V2	3291	788.25	2961.9	47390.4	46602.15	D	59.12103
N3T1V1	2842.2	844.5	2557.98	40927.68	40083.18	D	47.4638
N3T1V2	3310	943	2979	47664	46721	D	49.54507
N4T1V2	3791.06	1167.5	3411.954	54591.26	53423.76	1270.97	45.75911
N4T1V1	2674.03	1194.5	2406.627	38506.03	37311.53	D	31.23611
N2T3V2	2588.82	1302	2329.938	37279.01	35977.01	D	27.63211
N2T3V1	3208.45	1308.75	2887.605	46201.68	44892.93	D	34.30214
N3T3V2	2933.87	1369.5	2640.483	42247.73	40878.23	D	29.84902
N3T3V1	3140.58	1392	2826.522	45224.35	43832.35	D	31.48876
N4T3V2	2920.17	1829.25	2628.153	42050.45	40221.2	D	21.98781
N4T3V1	2665.38	1942.65	2398.842	38381.47	36438.82	D	18.75728

AGY (kg/ha) = Adjusted grain yield, GB (GY) = Gross benefit, TVC (EB/ha) = Total variable costs, NB (Birr/ha) = Net benefit and MRR (%) = Marginal rate of return, D = Dominated treatment and EB = Ethiopian Birr, CR=Cost Ratio, NO=.Control Treatment(0),N1=23,N2=46,N3=69,N4=92 V1=Traveler,V2=Singitan,T=Timing

Table 6. *Partial budget analysis* of Nitrogen rate and time of application on malt barley varieties at Diinshoo, 2011 and 2012 (combined) *conditions.*

Treatment combination	TVC (ETBha-1)	GY (kg ha-1)	AdY (kg ha-1)	GB (ETBha-1)	NB (ETBha-1)	MRR (%)	CR(EB)
V1N0T1	0	2041.13	1837.017	29392.27	29392.27		#DIV/0!
N1T1V2	555	2864.37	2577.933	41246.93	40691.93	2036	73.31879
N3T2V1	555	2541	2286.9	36590.4	36035.4	D	64.92865
N1T2V1	570	2458.77	2212.893	35406.29	34836.29	D	61.11629
N1T2V2	570	2580.45	2322.405	37158.48	36588.48	D	64.19032
N1T2V1	817.5	2517.86	2266.074	36257.18	35439.68	D	43.3513
N2T2V2	967.5	2857.3	2571.57	41145.12	40177.62	D	41.52726
N3T2V1	1087.5	2132.4	1919.16	30706.56	29619.06	D	27.23592
N2T1V1	1087.5	2618.14	2356.33	37701.22	36613.7	D	33.66777
N2T1V2	1087.5	3182.93	2864.637	45834.19	44746.69	761.45	41.14638
N3T2V2	1087.5	2916.42	2624.778	41996.45	40908.95	D	37.61742
N1T3V2	1260	3209.54	2888.586	46217.38	44957.38	122	35.68046
N1T3V1	1260	2220.18	1998.162	31970.59	30710.59	D	24.37349
N4T2V2	1357.5	3189	2870.1	45921.6	44564.1	D	32.82807
N4T2V1	1357.5	2695.5	2425.95	38815.2	37457.7	D	27.59315
N3T1V1	1642.5	2666.92	2400.228	38403.65	36761.15	D	22.38122
N3T1V2	1792.5	231.78	208.602	3337.632	1545.132	D	0.861998
N4T1V1	2325	2749.7	2474.73	39595.68	37270.68	D	16.0304
N4T1V2	2325	3445.8	3101.22	49619.52	47294.52	219.45	20.34173
N2T3V2	2475	2883.2	2594.88	41518.08	39043.08	D	15.77498
N2T3V1	2475	2750	2475	39600	37125	D	15
N3T3V2	3262.5	2918.3	2626.47	42023.52	38761.02	D	11.88077
N3T3V1	3262.5	2824.8	2542.32	40677.12	37414.62	D	11.46808
N4T3V2	4500	3152.33	2837.097	45393.55	40893.55	D	9.087456
N4T3V1	4500	2620.43	2358.387	37734.19	33234.19	D	7.385376

AGY (kg/ha) = Adjusted grain yield, GB (GY) = Gross benefit, TVC (EB/ha) = Total variable costs, NB (Birr/ha) = Net benefit and MRR (%) = Marginal rate of return, D = Dominated treatment and EB = Ethiopian Birr, CR=Cost Ratio, NO=.Control Treatment(0),N1=23,N2=46,N3=69,N4=92 V1=Traveler,V2=Singitan,T=Timing

Determination of Nitrogen rate and time of application on Economic Feasibility of malt barley varieties at Goba, 2011 and 2012 (combined)

Partial budget analysis of the combination of nitrogen levels with different varieties was presented in Table 1 and 2. The highest net benefit of ETB 53423.7 ha-1 and marginal rate return of 1270.97 % with value to cost ratio of ETB 45.76 per unit of investment was obtained from combination 92 kg Nha-1 and Singitan variety for malt barley production followed by net benefit of ETB 47294.52and marginal rate of return of 219.45 % with value to cost ratio of ETB 20.34 per unit of investment from combination 92kg Nha-1 and Singitan variety. The lowest net benefit of ETB 35642.97ha-1 and marginal rate of return of 1413.91 % with value to cost ratio of ETB 124.73 per unit of investment was obtained from combination 0 kg Nha-1 and Traveler variety. Increasing nitrogen fertilizer along with different varieties provided the lowest net return, whereas decreasing nitrogen fertilizer rates with different varieties was profitable. Therefore, the combination of 92kg Nha-1 fertilizer rate with Singitan variety was economically feasible for barley production in Goba and Dinsho area.

Conclusions and Recommendations

Crop production could be increased either by improving the inherent genetic potential of the Singitan variety crop or through application of better agronomic management, such as use of fertilizer. Study was conducted using different levels of Nitrogen rate and time of application on malt barley varieties at Goba woreda and Diinsho to determine on growth and yield of Malty Barley. The results of the present study showed that N fertilizer rates and time of application on malty barley variety (Singitan And Traveler) were all most not significant. This may be due to the fact that their nutrient relatively medium to high accumulation of studied nutrients in the soil. Under nutrient sufficient and conducive environmental conditions plants in the range of studied factor levels did not interact or compete. The fertilizer application by the farmers in the field without knowledge of soil fertility status and nutrient requirement of different crops usually leads to adverse effect on soil as well as crops by way of nutrient deficiency or toxicity due to over use or inadequate use of fertilizer. Therefore, based on this findings future research should focus on prior soil test based fertilizers recommendations.

References

AACC (American Association Cereal Chemists). 2000. Approved Methods of the American Association Cereal Chemists. American Association of Cereal Chemists, Inc., St. Paul, Minnesota.

Abdullatif, M., Asmat, U.M., sattar, A., Fiaz, H., Abbas, G. and Huss, J. 2010. Response of growth and yield of wheat to NPK fertilizer. *Science international* (lahore), 24 (2): 185-189.

Abebe Getu. 2012. Soil characterization and evaluation of slow release urea fertilizer rates on yield components and grain yields of wheat and *teff* on *Vertisols* of Jamma District of South Wollo Zone, Amhara Region. MSc Thesis, Haramaya University, Haramaya, Ethiopia.

Amare Aleminew and Adane Legas. 2015. Grain quality and yield response of malt barley varieties to nitrogen fertilizer on *Brown Soils* of Amhara Region, Ethiopia. *World Journal of Agricultural Sciences*, 11 (3): 135-143.

Amsal, T., Tanner, D., Taye, T. and Chanyalew, M. 2000. Agronomic and economic evaluation of the on farm N and P response of bread wheat grown on two contrasting soil types in Central Ethiopia. pp. 329. In: The 11th Regional wheat workshop for central, Eastern and Southern Africa. Addis Ababa, Ethiopia

Anonymous, 2012. Progress report of All India coordinated wheat and barley improvement project. 2011-12. Vol. VI. Barley network. *Directorate of Wheat Research*, Karnal, India.

Assefa Fenta, Maqsood, M., Akbar, M. and Yousaf, N. 2017. Effect of urea fertilizer on growth response of food barley. *International of Journal Agricultural Biology*, 1: 359-36.

Biadge Kefale, Ashagrie Zewdu and Berhane Lakew. 2017. Assessment of Malt Quality Attributes of Barley Genotypes grown in Bekoji, Holeta and Ankober, Ethiopia. *Academic Research Journal of Agricultural Science and Research*, 4(6): 255-263.

Berhane Lakew and Mulatu Bayeh. 2011. Barley research and development in Ethiopia. PP. 1-15. *Proceedings of the second national barley research and development review workshop*. 28-30 November 2006. Holetta, Ethiopia.

Biruk Gezahegn and Demelash Kefale. 2016. Effect of nitrogen fertilizer level on grain yield and quality of malt barley varieties in Malga Woreda, Southern Ethiopia. *Food Science* and *Quality Management*, 52: 2224-6088.

Bouyoucos, J. 1962. Hydrometer method improved for making particle size analysis of soil. *Agronomy Journal,* 54: 464-465.

Brady, N. C. and Weil, R.R. 2002. The nature and properties of soils (*13th Edition*). *Pearson Education* Ltd., USA.

Bray, R.H., and Kurz, L. T. 1945. Determination of total, organic and available forms of phosphorous in soil. *Soil science Journal*, 59: 39-45.

CIMMYT (International center for wheat and maize improvement). 1988. From agronomic data to farmer recommendations: An economics training manual. Completely revised edition. Mexico, D.F.

CSA (Central statistical agency) agricultural sample survey. 2017. Report on area and production of major crops (private peasant holdings, Meher season). Volume I, *Statistical bulletin*, Addis Ababa, Ethiopia,

Fageria, N. K. and Baligar, V. C. 2001. Enhancing nitrogen use efficiency in crop plants. *Advances in Agronomy,* 88: 97-185.

Fageria, N.K. and Baligar, V.C. 2005. Methodology for evaluation of lowland rice genotypes for nitrogen use efficiency. *Journal of Plant Nutrition*, 26: 1315-1333.

FAO (Food and Agriculture Organization of the United Nations). 2008. Fertilizer and plant nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis. *FAO*, Rome, Italy, 203 p.

FAO (Food and Agriculture Organization of the United Nations). 2013. Global production of barley. *Faostat* 2013.

Fox, G.P., Panozzo, J.F., Li, C.D., Lance, R.C., Inkerman, P.A. and Henry, R.J. 2003. Molecular basis of barley quality. *Australian Journal of Agricultural Research,* 54: 1081-1101

Getachew Agegnehu, Berhane Lakew and Paul Nelson. 2014. Cropping sequence and nitrogen fertilizer effects on the productivity and quality of malting barley and soil fertility in the Ethiopian Highlands. *Journal of Agronomoy and Soil Science,* 60 (9): 1261-1275.

Getachew Agegnehu, Paul Nelson and Michael Bird. 2016. The effects of biochar, compost and their mixture and nitrogen fertilizer on yield and nitrogen use efficiency of barley grown on a *Nitisols* in the Highlands of Ethiopia. *Science of the Total Environment,* 569-570, 869-879.

Girma Fana, Haile Deressa, Reta Dargie, Mengistu Bogale, Seyfudin Mehadi and Firehiwot Getachew. 2012. Grain hardiness, hectoliterweight, nitrogen and phosphorus concentrations of durum wheat (*Triticum turgidum* L) as influenced by nitrogen and phosphorus fertilization. *World Applied Sciences Journal*, 20 (10): 1322-1327.

Integrated Coffee Nutrient Management in West Hararghe

Sintayehu G., Alemisa G., AdisuW, Iyob A, and Mohamadsani A.

Oromia Agricultural Research Institute, Mechara Agricultural Research Center, P.O.Box.19, Mechara Ethiopia

Corresponding author: **girmasintayehu@gmail.com**

Abstract

The experiment was conductedat Mechara Agricultural research center on station for seven consecutive years from 2013/14 to 2020/21 to determine the effect of integrated nutrient management on growth, yield and yield components of coffee and investigate the role of integrated nutrient management on soil fertility. . It consisted of nine treatment combinations and laid out in Randomized Completely Block Design with three replications. Bultumcoffe variety was used as testing material. The analysis of variance revealed significant variation among the treatments for growth traits and clean coffee yield due to application of organic and inorganic fertilizers. The highest plant height, Length of primary branch and stem girth was recorded from noapplication of inorganic fertilizer+10 t/ha organic fertilizer. The highest clean coffee yield (11.73 Qtha^{-1}) was recorded from the application of 100% rate of recommended inorganic fertilizer+5 t/ha organic fertilizer followed by 0% rate of recommended inorganic fertilizer +10 t/ha organic fertilizer 11.41 Qtha^{-1}, while the lowest clean coffee yield (8.40 Qtha^{-1})was recorded from no application of inorganic and organic fertilizers. From the partial budget analysis, application of 25% rate recommended inorganic fertilizerwith 5 t/ha organic fertilizerresulted in the increment of net benefit and marginal rate of return.Therefore, application of 25% rate of recommended inorganic fertilizer with 5 t/ha organic fertilizer was recommended for coffee production at Mechara and similar agro ecology.

Keywords: *fertilizer, inorganic, integrated, nutrient, organic*

Introduction

Hararghe coffee is one of the specialty coffees with unique inherent quality thatfetches good foreign currency. In spite of the enormous genetic variability and importance of coffee to the national economy of the country, productivity and production of the crop is very low and hardly exceeds 600 kg per hectare (MoARD, 2010). The major factors contributing to low productivity of the crop are lack of high yielding, disease resistant and adaptable varieties for the diverse agro-ecologies, lack of improved management practices, and poor processing technologies (Antenehe*t al*., 2008).The nature and properties of soils are of vital concern in the production of coffee since it ranks among those tropical crops with high nutrient demand. Soil nutrient availability changes over time. A nutrient balance for a system consists of the sum of nutrient inputs minus the sum of nutrient outputs. This system always represents a particular spatial scale, and it can range from a small soil aggregate to the country level. Various studies on soil nutrient flows and balance have been conducted at diffident time and location in Ethiopia. Study conducted by Stoorvogel and Smaling (1990) revealed that annual nutrient mining in Ethiopia was -41 kg N, -6 kg P and -26 kg K $ha^{-1}yr$-^{1}. Nutrient balance studied by FAO (2003) based on specific land/water classes showed that the nutrient depletion rate of Ethiopia at national level was -47N, -7P and -32 K kg ha-1. These were about twice as much as the average depletion rates for Sub Saharan Africa -22 kg N, -2.5 kg P and -15 kg K ha^{-1} yr^{-1} (Stoorvogel and Smaling, 1990) and indicate the magnitude of soil nutrient depletion in Ethiopia.Soil fertility depletion occurs when conditions that support soil's health are not maintained and the components which contribute to fertility are removed and not replaced. In agriculture, soil fertility depletion can occur due to excessively intense cultivation with inadequate soil management (Ethiosis, 2015). The main causes of soil fertility decline include nutrient removal through entire crop harvests, uncontrolled soil erosion, low soil organic matter and inherent soil fertility, limited application of appropriate types of fertilizers and inappropriate land management practices (Getachew*et al.,* 2016).

Combining organic and mineral inputs has been advocated as a sound management principle for smallholder farming in the tropics because neither of the two inputs is usually available in sufficient quantities, because positive interactions between both inputs have often been observed (Vanlauwe*et al.,* 2001) and because both inputs are needed in the long term to sustain soil fertility and crop production. The integration of organic fertilizers like vermicompost and conventional compost with inorganic sources may improve and sustain crop yields without degrading soil fertility status. Integration of organic and inorganic fertilizers improved the crop yield compared to fertilizers applied separately (Getachew*et al.,* 2014). Organic fertilizers or combining organic fertilizers and inorganic fertilizers have been shown to have much potential in the production of coffee and solve those problems.

Farmers in Harerghe commonly use organic manure chiefly on coffee field on gardens and /or near their homestead. They cannot afford to purchase and use inorganic fertilizer. One of the major reasons behind the suboptimal use of inorganic fertilizers for grain crops is the costly price. Continuous production of crops against a backdrop of little fertilizer use over decades has aggravated the decline in soil fertility and crop yield (Gete*et al.,* 2010; Sanchez *et al.,* 1997; Getachew*et al.,* 2014). But it is clear that if it is enriched with mineral fertilizes, it could be used even for the intensive cultivation of coffee. Integrated plant nutrient management is the best approach to mitigate the inherent soil fertility problems for sustainable crop production. Therefore, the development of a comprehensive integrated nutrient management package particularly with regard to the reduction of inputs needed for coffee production is crucial and this experiment was initiated with the objectives to determine the effect of integrated nutrient management on growth, yield and yield components of coffee and to investigate the role of integrated nutrient management on soil fertility under coffee.

Materials and Methods

Description of the study area

The experiment was conducted at Mechara Agricultural Research Center (McARC) on stationfor seven consecutive years starting from 2013/14 to 2020/21. Mechara is located 434 km to the east of Addis Ababa in DaroLabu district of West Hararghe Zone in Oromia Regional State. It is 110 km from Ciro (Zonal Capital) to the south on a gravel road that connects to Arsi and Bale Zones. The center is geographically located at altitude of 1760 m.a.s.l and receives an average annual rainfall of about 900mm with monthly mean maximum and minimum temperatures of 26^{o} C and 14^{o} C, respectively.The major soil type of the center is sandy clay loam which is reddish in color.

Experimental Treatments and Design

The experimental materials consisted of nine treatments combinations and Bultum coffee variety was used astesting material. The experiment was laid out in Randomized Complete Block Design with three replications.The spacing between plants and between rows was 2m and 30 trees per plot were used. Pre and post soil physical & chemical characters were tested. Decomposed organic farm yard manure or compost was incorporated in to soil one month before seedling transplanting. DAP and UREA were used as inorganic fertilizers and applied at time of transplanting at the distance of 50cm from the base of coffee tree. In the remaining seasons, to facilitate efficient nutrient uptake by the roots fertilizer was applied in two splits starting from the commencement of rainy season.

Treatment combinations

S/N	Treatment Combination
1	100% rate RIF +0 OF (control)
2	100% rate RIF +5 t/ha OF
3	50% rate RIF +5 t/ha OF
4	25% rate RIF +5 t/ha OF
5	25% rate RIF +10 t/ ha OF
6	0% rate RIF +0 OF (absolute control)
7	0% rate RIF +5 t/ha OF
8	0% rate RIF +10 t/ha OF
9	0% rate RIF +15 t/ha OF

Conventional Compost Preparation procedure

Maize and sorghum straw were laid at the bottom of the heap in about 5 cm thickness. This is important for keeping good ventilation; immediately on the maize and sorghum straws, spread animal dung with a thickness of about 20cm. The next layer was farm yard manure and/or chicken manure in 15cm thickness. Then thin layer (5 cm) of kitchen (wood) ash was added.On top of the layer (5 cm) of garden soil was again added to introduce beneficial microorganisms for decomposition. After each layer, water sprinkled twice in a layer as required to make the layers moist but not wet or soggy. The above steps were repeated until pile reaches the height of 130cm. Finally the pit was covered by banana leaves and grasses. The materials were mixed and turned to next pit/bin every 21 days. After two times turning, i.e. after 63 days, the compost was ready for field application after air drying. Good decomposition can be detected by a pleasant odor, heat produced (this is even visible in the form of water vapor given off during the turning of the pile), growth of white fungi on the decomposing organic material, reduction of volume and by the change in color of the materials to dark brown.

Data Collected

The growth and yield data collected were; Plant height (cm), Number of internodes of the main stems (cm), Internode length of the main stems (cm), stem girth (cm), Number of primary branches, Length of the longest primary branch (cm), Internodes length of the longest primary branch (cm), Leaf length (cm), Leaf width (cm), Canopy diameter (cm) and clean coffee yield ($Qtha^{-1}$).

Soil Sampling

Prior to transplanting and treatment application, soil samples at a depth of 0-30 cm were collected and a composite soil sample was made. Similarly, at completion of the trial soil samples were collected from each plot receiving different treatments for analysis. Soil samples collected from the field was air dried, crushed and passed through a 2mm sieve after a careful removal of plant parts and other unwanted materials. Soil analysis was carried for physicochemical properties of soil.

Data Analysis

The collected data were analyzed using SAS software. All significant treatment mean differences were separated using the Least Significant Difference (LSD) test at 5% probability level. Partial

Budget Analysis

Economic analysis was conducted to identify the most economical treatment combination with optimum biological yield. For economic evaluation, cost and return, and benefit to cost ratio was calculated according to the procedure given by CIMMYT (1988). The average total clean coffee yield was obtained from each treatment at different levels of inorganic fertilizer rate and organic compost. The total clean coffee yield obtained from the control plot was taken as a reference and the clean coffee yield increment of treatments that received different inorganic and organic fertilizer (increase over the control) was considered for evaluation. The economic analysis formula developed by CIMMYT (1988) is as follows:

$$AJY = GAY - (GAY * 0.1)$$

Where;Gross average yield (GAY) ($Qtha^{-1}$): is an average yield of each treatment, Adjusted yield (AJY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmer's field.

$$GFB = AJY * \frac{Field}{farm\ gate\ price\ of\ a\ crop}$$

Where;Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale.

$$NB = GFB - TC$$

Where; Total cost (TC): is the cost of inputs that were used for the experiment as mean current prices of UREA, DAP, Organic compost, wage for compost preparation, application, and transport were considered per hectare. Net benefit (NB): was calculated by subtracting the total costs from the gross field benefit for each treatment.

$MRR\ (\%) = \left(\frac{MB}{MC}\right) * 100$ Where;

Marginal cost (MC) = change in costs between treatments.

Marginal benefit (MB) = change in net benefits between treatments.

Marginal rate of return: - was calculated as changes in net benefit (raised benefit) divided by changes in cost (raised cost).

Results and Discussions

Soil physicochemicalproperties

Pre planting and post harvesting soil analysis was conductedto determine some physicochemicalproperties of the soil (Table 2). The soil analysis indicated that there was significant difference between pre and post-harvest soil physicochemical properties such as total nitrogen, organic carbon, pH and available phosphorus. The textural class of the soil was changed as a result of these fertilizers application. Application of integrated fertilizer changed the soil textural class from clay (before planting) to loam (post- harvest). Application of organic and inorganic fertilizers increased total nitrogen from 0.12 to 0.18, available phosphorus from 9.51 to 13.72and organic carbon increased from 1.58 to 2.15. Soil pH was also significantly affected by addition of these fertilizers. The highest pH was recorded from control treatment (0% rate RIF +0 OF) followed by application of 0% rate RIF +5 t/haOF. The soil class was slightly acidic which preferable pH range for the production of coffee is.

Table 1: Pre planting and post harvesting soil sample analysis

Pre planting soil sample analysis								
	Parameters							
	pH-H20 (1-14)	Sand (%)	Clay (%)	Silt (%)	OC (%)	TN (%)	Avail. P (ppm)	Textural Class
	6.03	18.89	57.56	23.56	1.58	0.12	9.51	Clay
Treatment	Post harvesting soil sample analysis							
100% rate RIF +0 OF (control)	4.51	47.5	29	23.5	2.05	0.18	13.72	loam
100% rate RIF +5 t/ha OF	4.54	43.5	41	15.5	2.15	0.18	6.36	loam
50% rate RIF +5 t/ha OF	4.66	27.5	49	23.5	2.05	0.18	6.82	loam
25% rate RIF +5 t/ha OF	4.81	41.5	11	47.5	1.95	0.17	2.1	clay
25% rate RIF +10 t/ ha OF	5.68	45.5	37	17.5	1.95	0.17	1.24	loam
0% rate RIF +0 OF	6.13	49.5	27	23.5	1.95	0.17	1.74	sandy clay
0% rate RIF +5 t/ha OF	6.1	43.5	37	19.5	1.95	0.17	1.66	loam
0% rate RIF +10 t/ha OF	5.03	43.5	35	21.5	1.95	0.17	1.68	loam
0% rate RIF +15 t/ha OF	5.68	51.5	25	23.5	1.95	0.17	2.3	loam

Growth parameters

Application of integrated nutrients on coffee showed significant difference in growth parameters like; mean plant height, stem girth and length of first primary branch. However, non-significance difference was obtained for number of primary branches, node number and canopy diameter.

Plant Height (PH):Significant difference ($P<0.05$) for plant height was observed due to application of different rates of organic and inorganic fertilizers. The tallest mean value of plant height (199.08cm) was recorded from the application of 25% of recommended inorganic fertilizer (RIF) and 10 ton/ha of organic compost while the shortest mean plant height (175.5cm) was recorded from recommended inorganic fertilizer (RIF) and 5 ton/ha organic fertilizer (Table 3). The increased plant height of coffee over the control in response to the mixed application of the fertilizers might be attributed to the released major nutrients and improved soil physicochemical property in enhancing plant growth owing to their contribution to enhanced cell division, stem elongation, promotes leaf expansion and vegetative growth of plants (Muluneh, 2018).Chemura (2014) reported that combining inorganic and organic fertilizers performed better than just organic fertilizers alone in both the mean height and the final height of the coffee seedlings.

Canopy Diameter (CD): Statistically there was no significant differenceamong the treatmentsdue to application of the fertilizers. However, numerically application of 50% RIF +5 t/ha OF had highest (187) canopy diameter. The results were in agreement with Chemura (2014) that reported non-significant differences between the slopes of girth and number of primaries ($p < 0.05$) between organic, integrated and inorganic fertilizer options over time.

Length of primary branch(LLB):organic and inorganic nutrient application significantly affected length of primary branch (LLB). Analysis of variance revealed significant difference among the treatments on length of primary branch with the highest mean of 52.68cm recorded from 0% rate of recommended inorganic fertilizer (RIF) and10 ton/ha organic fertilizer.This difference may be due to high nitrogen content exist organic fertilizer and slow release of nitrogen rather than inorganic fertilizer. While the lowest (38.34cm) mean length of primary branch was recorded from the application of 50% rate of recommended inorganic fertilizer (RIF) and 5 ton/ha organic fertilizer (Table 3).

Stem Girth (GR): The stem girth of coffee showed significant ($p < 0.05$) difference among the treatment means as shown in the table 3 below. The maximum mean stem girth (18.33cm and 18cm) of coffee was recorded from application of 100% rate RIF +0 OF and 0% rate RIF +10 t/ha OF, respectively while, the lowest mean stem girth (12.7cm) of coffee plant was recorded from 0% rate RIF +15 t/ha OF. The maximum mean girth recorded from application of 100% rate RIF +0 OFmight be due to more nutrients gained from both organic compost and NP integrated fertilizers. The results were in line with, Bikila (2018) who reported that there was positive effect of application of combined amendments on stem diameter of coffee seedlings.

Table 3: Effect of application of INM on coffee growth parameters

Treatments	PH	GR	LLB	NB	NN	CD
0% rate RIF +15 t/ha OF	186.33a-c	12.17b	50.57ab	50.5	28.83	178.63
0% rate RIF +10 t/ha OF	191.00a-c	18.0a	52.68a	54.25	29.08	183.33
100% rate RIF +0 OF	179.16bc	18.33a	40.58bc	49.08	27.17	160.88
0% rate RIF +0 OF	194.33a-c	15.0ab	51.44ab	50.42	29.17	177.17
100% rate RIF +5 t/ha OF	175.50c	13.92ab	49.34a-c	48.58	27.08	162.8
25% rate RIF +10 t/ ha OF	199.08a	15.08ab	45.34a-c	48.83	30.08	169.46
0% rate RIF +5 t/ha OF	187.0a-c	14.42ab	44.97a-c	50.67	28	168.67

25% rate RIF +5 t/ha OF	194.33a-c	14.50ab	49.32a-c	49.58	28.75	171.67
50% rate RIF +5 t/ha OF	195.08-b	14.25ab	38.34c	53.25	28.17	187.13
Mean	189.09	15.07	46.95	50.57	28.48	173.3
LSD (5%)	19.03	5.61	11.87	NS	NS	NS
C V (%)	5.84	21.59	14.68	16.35	9.09	10.95

Clean coffee Yield (Qtha^{-1})

Application of organic and NP integrated nutrient fertilizer affected clean coffee yield (Table 4). There was significant difference between the treatment means($p < 0.05$) on cleancoffee yield. The highest mean value of clean coffee yield (11.73 Qt/ha) was recorded from plots receiving 100% rate of recommended inorganic fertilizer (RIF) and 5 ton/ha of organic fertilizer (OF) followed by 0% rate RIF +10 t/ha OF Qt/ha (11.41Qt/ha),while the lowest mean value of clean coffee yield (8.4 Qt/ha) was obtained from plots receiving 0% rate of recommended inorganic fertilizer (RIF) and 0 ton/ha of organic fertilizer(OF) respectively.This result is in agreement with, Obsaand Mohamed, (2020) reported the application of inorganic and organic increased clean coffee yield.

Table 4: Clean coffee yield on application of different INM on coffeeyield

Treatments	Clean coffee yield (Qtha^{-1})				
	2017	2018	2019	2020	Mean
100% rate RIF +5 t/ha OF	3.04	5.35^{ab}	12.16	26.36^{a}	11.73^{a}
0% rate RIF +10 t/ha OF	3.65	5.65^{ab}	12.56	23.81^{ab}	11.41^{a}
100% rate RIF +0 OF (control)	1.46	7.55^{a}	11.96	23.51^{ab}	11.12^{ab}
50% rate RIF +5 t/ha OF	2.54	4.67^{b}	12.59	24.12^{ab}	10.98^{ab}
25% rate RIF +5 t/ha OF	2.35	5.11^{b}	13.17	22.96^{ab}	10.89^{ab}
0% rate RIF +15 t/ha OF	4.22	5.90^{ab}	13.05	20.00^{a-c}	10.79^{ab}
25% rate RIF +10 t/ ha OF	2.63	5.52^{ab}	14.23	19.99^{a-c}	10.59^{ab}
0% rate RIF +5 t/ha OF	1.94	5.77^{ab}	13.15	16.80^{bc}	9.41^{ab}
0% rate RIF +0 OF	3.13	5.57^{ab}	12.58	12.31^{c}	8.40^{b}
Mean	2.77	5.68	12.83	21.09	10.6
LSD (5%)	NS	2.31	NS	8.79	2.96
CV %	75.65	23.65	13.83	24.18	16.2

Partial budget analysis

Based on dominant analysis, 0% rate RIF +15 t/ha OF was the dominated treatment because, it resulted in the highest total varying costs (29625.75ETB/ha) and the smallest net benefits(43206.75ETB/ha) that was less than those of treatments with lower costs that vary and it was eliminated from further consideration as shown in table 5 below.Application of 25% rate RIF +5 t/ha OF gave the maximum net benefit (59339.97 ETB/ha). The largest marginal rate of return (80%) was obtained from application of 0% rate RIF +5 t/ha OF followed by application of 25% rate RIF +5 t/ha OF(67%)that indicated for every 1birr invested on application of 0% rate RIF +5 t/ha OF;farmers can expect to recover 1 ETB and obtain additional 0.80 ETB.But recommendation is not necessarily the treatment with the highest marginal rate of return compared to neither that of next lowest cost, nor the treatment with the highest net benefit, nor the treatment with the highest yield (CIMMYT, 1988). Theidentification of a recommendation requires a careful marginal analysis using an appropriate minimum rate of return and if the technology simply represents an adjustment in current farmer practice (such as a different fertilizer rate for farmers that are already using fertilizer), then a minimum rate of return as low as 50% may be acceptable (CIMMYT. 1998). The marginal rate of return of the change from the application of 0% rate RIF +5 t/ha OF (80%) to the application of 25% rate RIF +5 t/ha OF (67%) obtained was above the minimum rate of return (50%).Therefore, the comparisons stopped at the marginal rate of return was far below the minimum rate of return and the slope of the net benefit curve continued to fall, then the analysis stopped at the treatment (25% rate RIF +5 t/ha OF) that had an acceptable rate of return compared to the treatment of next lowest cost (Table 5).

Table: 5 Partial budget analysesonapplication of different INM on coffee yield

Treatments	GAY (q/ha)	AJY (q/ha)	GFB (ETB/ha)	TC (ETB/ha)	NB (ETB/ha)	MRR (%)
0% rate RIF + 0 t/ha OF(Control)	8.4	7.56	56700	0	56700	35
0% rate RIF +5 t/ha OF	9.41	8.469	63517.5	9875.25	53642.25	80
25% rate RIF +5 t/ha OF	10.89	9.801	73507.5	14167.53	59339.97	67
100% rate RIF +0 OF	11.12	10.008	75060	17169.1	57890.9	28
50% rate RIF +5 t/ha OF	10.98	9.882	74115	18459.8	55655.2	47
0% rate RIF +10 t/ha OF	11.41	10.269	77017.5	19750.5	57267	44
100% rate RIF +5 t/ha OF	11.73	10.557	79177.5	21894.1	57283.4	1
25% rate RIF +10 t/ ha OF	10.59	9.31	69825	24042.78	45782.22	46
0% rate RIF +15 t/ha OF	10.79	9.711	72832.5	29625.75	43206.75D	

Summary and Recommendation

Combined application of inorganic fertilizer and organic fertilizer was found to increase the coffee growth parameters (plant height, length of primary branch, stem girth) and yield. The highest clean coffee yield was recorded from the application of100% RIF and 5 ton/ha organic fertilizer.However, from partial budget analysis integrated application of 25% rate RIF +5 t/ha OF resulted in the increment of net benefit and marginal rate of return that might help the farmers of the study area to practice coffee production at lower cost. Therefore, 25% rate RIF +5 t/ha OFis recommended for coffee production for Mechara and similar agro ecology.

References

AntenehNetsere and HelufGeberekidane. 2007. Response of Arabica coffee seedling to lime and phosphorus: II. Dry matter production and distribution. p. 1095-1100. *In* Int.Conf.Coffee Science, 21st, Montpellier, 11th– 15thSeptember 2007.ASIC, France.

Assis, G. A., Scalco, M.S., Guimaraes, R. J., Colombo, A., Dominghetti, A.W and Matos, N. (2014). Drip irrigation in coffee crop under different planting densities: Growth and yield in southeastern Brazil. Rev. Bras. De Engenharia Agric. Ambient. 8(11):116-11123.

BikilaTakala, 2018.Effects of Lime and Compost on acidic Soil Amelioration and Growth of Coffee (Coffea Arabica L.)Seedlings at Haru, West Wollega. M.Sc. Thesis Submitted to School of Graduate Studies of Jimma University College of Agriculture and Veterinary Medicine, Department of Natural Resource Management.

Chemura, Abel,2014. The growth response of coffee (Coffea Arabica L.) plants to organic manure, inorganic fertilizers and integrated soil fertility management under different irrigation water supply levels. International Journal Recycling Organic Waste Agriculture, 3, 1-9.

CIMMYT. 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico. D.F.

Esther, A.K and Adomako, B. (2010).Genetic and environmental correlations between bean yield and agronomic traits in Coffeacanephora. J. Plant Breed. Crop Sci. 2(4): 64-72.

Ethiopian Soil Information System (Ethiosis). 2015.http://www.ata.gov.et/highlighted-deliverables/ethiopiansoil-information-system-ethiosis. Accessed 15 March, 2015.

Etienne, H and Betrand, B (2001). True-to-type and agronomic characteristics of Coffea Arabica trees micro propagated by the embryogenic cell suspension technique. Tree Physiol. 21:1031-1038.

FAO (Food and Agricultural Organization of the United Nations). 2006.Plant Nutrition for Food Security a Guide for Integrated Nutrient Management. FAO fertilizer and Plant nutrition bulletin No.16. Rome

Getachew, A., Lakew B, Nelson P N. 2014. Cropping sequence and nitrogen fertilizer effects on the productivity and quality of malting barley and soil fertility in the ethiopian highlands. Archives of Agronomy and Soil Science 60, 1261-1275.

Getachew, A., Nelson P N, Bird M I. 2016. Crop yield, plant nutrient uptake and soil physicochemical properties under organic soil amendments and nitrogen fertilization on nitisols. Soil and Tillage Research 160, 1-13.

Gete, Z, Getachew, A., Dejene, A and Rashid, S. 2010. Fertilizer and Soil Fertility Potential in Ethiopia: Constraints and Opportunities for Enhancing the System. IFPRI, Washington DC, USA.

International Coffee Organization (ICO).(2011). World coffee trade conversions and statistics. [http://www.intracen.org/coffee guide/ world-coffee-trade/conversions-and-statistics] site visited on 20/7/2016.

MoARD (Ministry of Agricultural and Rural Development) five-year performancereport. 2010. Crop performance report for 2008/2009 cropping season Department of crop production Addis Abeba.105p.

MulunehSiraj, 2018. Effect of Blended NPSB fertilizer rates on Growth yield and yield related traits of Potato (Solanum tuberosum L.) Varieties under Irrigation in Degem.M.sc.thesis Submitted to School of Plant Sciences Haramaya University.

Obsa, A. and Mohamed, K. 2020. Response of Limu coffee variety to integrated organic and inorganic nutrients.

Sanchez, P.A., K.D. Shepherd, M.J. Soule, F.M. Place, R.J. Buresh, A.M.N. Izac, A. UzoMokwunye, F.R. Kwesiga, C.G. Ndiritu and P.L. Woomer, 1997. Soil fertility replenishment in Africa: an investment in natural resource capital. Replenishing soil fertility in Africa, 51, pp.1-46.

Stoorvogel, J.J., and E.M.A., Smaling. 1990. Assessment of soil nutrient depletion in sub-Saharan Africa, 19832000. Winand Staring Centre for Integrated Soil and Water Research (SC DLO), Wageningen, the Netherlands

Tefera, F., Alamerew, S and Wagery, D. (2016).Assessment of the growth and yield characters of some promising Arabica coffee hybrids under highland environments in Southwestern Ethiopia. J. American- Eurasian J. Agric. Environ. Sci. 16(5): 917-923.

Vanlauwe, B., Wendt, J., Diels, J. 2001. Combined application of organic matter and fertilizer.InTian G; Ishida, F; KeatingeJDH. (Eds.), Sustaining Soil Fertility in West Africa. SSSA, American Society of Agronomy, Madison, WI 58:247-279.

Zelleke, G., G. Agegnehu, D. Abera, and S. Rashid, 2010.Fertilizer and soil fertility potential in Ethiopia. International food policy institute: Working Paper

Status of major coffee pests in Arsi coffee growing areas, Oromia, Ethiopia

Sintayehu G., Ibrahim K., Adisu W., Iyob A.and Hika B.

Oromia Agricultural Research Institute, Mechara Agricultural ResearchCenter,

P.O.Box.19, Mechara Ethiopia

Corresponding author: **girmasintayehu@gmail.com**

Abstract

The average coffee yield is very low in Ethiopia due to different biotic factors such as insect pests, diseases and weeds. A field survey was conducted to assess major coffee pests and determine the occurrence, geographical distribution and status of major coffee pests in Arsi coffee growing areas. The assessment was conducted atShanan Kolu, Gololcha and Choledistricts during 2021 cropping season. Disease prevalence, severity and incidence were assessed by visual observation and random sampling techniques. Weed population density and diversity was taken using quadrate with 50cm × 50cm area. Thesurvey result showedlow to moderately high infections due tocoffee berry disease, coffee leaf rust and coffee wilt disease in all assessed districts. High CBD infected coffee farm was observed at the high land of Shanan Kolu followed by Gololcha and Choledistricts.CBD disease severity ranged from 5.9 to 23.05 % with the overall mean of 12.45 % and 9.26 standard deviation. Whereas the overall mean of CLR incidence and severity recorded across the surveyed districts was 27.46 and 30.04 % with standard deviation of 16.06 and 7.84, respectively. CWD prevalence and incidence mean was 60.27% and 9.83 %, respectively.The surveyed results indicated that disease incidence significantly varied among and within assessed districts.This difference might be due to the presence of diverse environmental condition, various agronomic practices under taken by coffee growers, coffee genetic diversity, and disease management measures that varied from area to area and virulence of the pathogen.Coffee leaf miner moderately affected the crop at Chole district.A total of 46 diversified weed floraspecies belonging to 24 familieswere identified. Out of 46 identified weed species 40 (86.96%) were broad leaves weeds, 3 (6.52%) grasses 2 (4.34%) sedge and 1 (2.17%) was parasite.About 54.35% were important and 45.65% were noxious weed species.Thus, this information is vital for setting research and development priorities for the

crop. Therefore, due to variability in pest distribution and status across the districts, management strategy should focus on the important/major pests of the particular area.
Keywords:*Abundance,Dominance, Frequency, Incidence, Severity, prevalence*

Introduction

Coffee is one the most important commodities in the world as well as in Ethiopia. It isthe backbone of the Ethiopian economy and Coffee is the most important foreign currency earner for Ethiopia and contributes about 30 % of the annual foreign currency (USDA, 2019).Ethiopia is the center of origin and diversity for Arabica coffee. The wide climatic and soil factors offer the country to grow diverse Arabica coffee which accounts for 80% of the world coffee trade. It is well known that the multiplying effect of coffee on the overall economy of the country is quit great. In spite of the enormous genetic variability and importance of coffee to the national economy, productivity and production of the crop is very low and hardly exceeds 500 kg per hectare, primarily because of poor and traditional management practices, disease and pests, shortage of improved and adaptable varieties(Mamadsani and Hika,2018).

There are many biotic and a biotic factors that affect coffee yield.Among the biotic factors, coffee diseases and insects cause significant losses. Diseases may cause yield losses varying between 10 to 40% (Silva et al., 2006) in different countries. Coffee Berry Disease(CBD) is one of the important diseases where its wide spread affected coffee cultivation, and decreased the annual coffee production by an average of 47 % on some of the individual small holder's fields (Biratu, 1998).The other disease is coffee leaf rust(CLR),that has been considered as minor disease of coffee in Ethiopia since it had never reached epidemic proportion as in other countries. Currently, CLR is widely distributed all over coffee growing regions of the country with varying intensities(Hika, 2018). The average national infected trees were estimated to be about 36.3% in 1990 (Meseret, 1991). Eshetu*et al.* (2000) reported as high as 27% CLR severity in Ethiopia. Therefore; as an essential prerequisite in the effective management of major coffee diseases, there was a need to ascertain the current incidence and spread of those diseases at Arsi coffee growing areas. Therefore, this survey was initiated with objective to assess major coffee pests and determine the occurrence, geographical distribution and status of major coffee pests in Arsi coffee growing areas.

Materials and Methods

Description of the study area

An assessment was conducted on coffee farms in selected districts of Arsi zone namely, Shanan Kolu, Gololcha and Chole during 2021 cropping season. The geographical locations of the districts are presented in table below.

Table 1. Agro-ecological features of the surveyed locations

District	Altitude (m.a.s.l)	Annual rain fall (mm)	Soil type	Geographical co-ordinates		Annual temperature
				Latitude	Longitude	
Shanan Kolu	1560-1961	1100	black, red, brown	08º29'211"	040º13'302"	$23^{\circ c}$
Gololcha	1537-2076	900	Sand and silt	08º06'427"	040º01'592"	$27^{\circ c}$
Chole	1537-1937	1000	black, red, brown	08º04'523"	039º59'423"	$25^{\circ c}$

Source: Respective districts office in Arsi Zonal Bureau of Agriculture

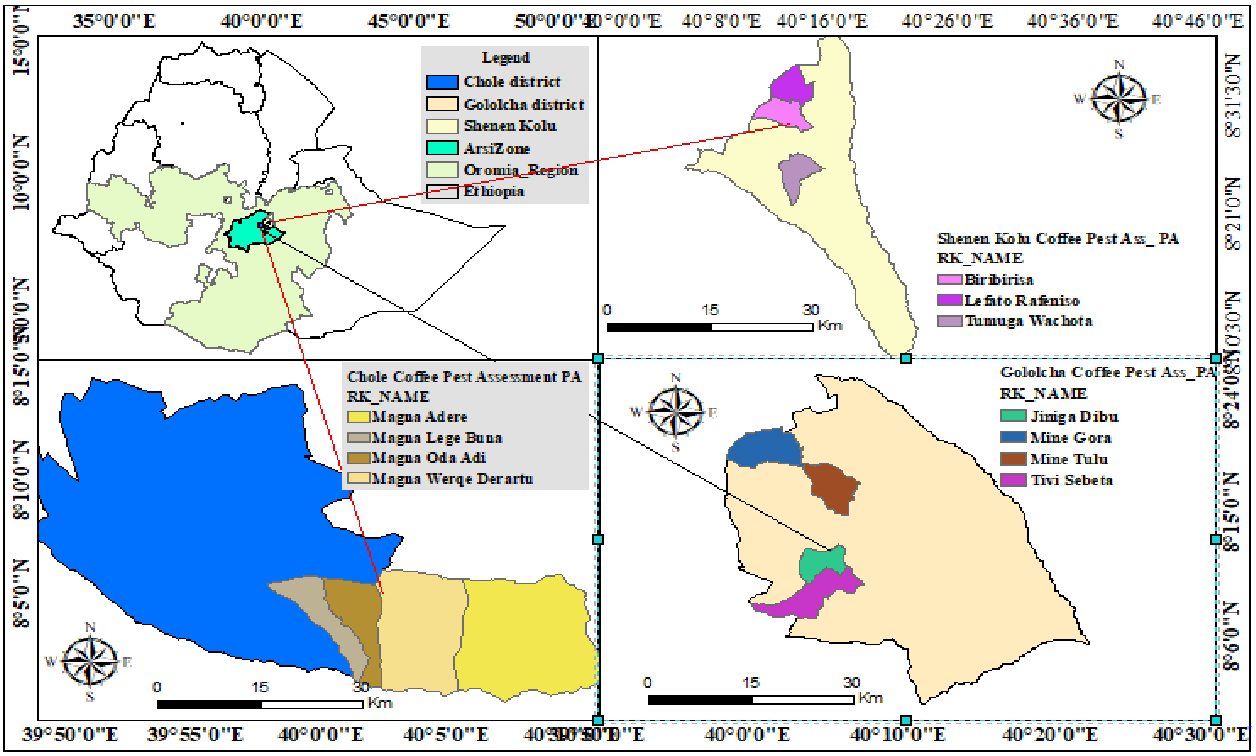


Figure: 1Map of study areas

Sample Size and Sampling Method

Assessment was conducted on coffee farms in Arsi Zone. Before making field survey secondary data on area of production, annual production, major diseases, insect pests and weeds of the coffee, pest's occurrence, intensity, distribution and seasonality were collected from Zonal and districts agricultural office.Farm owners (farmers) were interviewed with semi structured questionnaires about coffee production potential, marketing and the major types of crop diseases, part of crop attacked and damaged by the pests,their economic importance, their frequency, the time of occurrence , symptoms, severity, relation with weather condition, whether pests are new, how farmers are trying to control those coffee pests (type of control measures they are using), effectiveness of control measures, the growth stage of the plant at which the pests occur and other important data was collected. Five to seven coffee mother treesthat represent all coffee mother trees on the farm were selected randomly and diagnosed visually for incidence and severity for disease and insect pest's assessment.From each PA ten representative farms were selected. The number of sample per farm depended on the farm size. Similarly, weed population density and diversity were taken using quadrate with (50cm × 50cm area).Zigzag sampling method was used for weed data collection in selected farm. Each and every weed species were counted manually and recorded during weed assessment.

Pests Field Assessment

Disease and insect pest assessment

Prevalence assessment: the selected **farms were visually assessed for presence and absence of diseases and insects. Finally disease distribution was calculated as number of infected farm divided by total assessed farms and multiplied by 100.**

Incidence assessment: thirty trees per farm were randomly taken and diagnosed visually for presence and absence of the disease on each selected trees. Thereafter, disease incidence was calculated as number of diseased plants (trees) divided by total observed plants (trees)and multiplied by 100.

Severity assessment: Ten trees per farm were randomly taken and each tree was divided into three strata of branches (top, middle and bottom) and examined visually by counting infected tissue (s) per sample and then percentage of diseased tissue (s) over total counted tissues was calculated for computing disease severity.

Weed assessment

Weed Frequency (f %):it explains how often a particular weed species occurs in the survey area. Frequency was calculated for all weed species as follows;

$F = 100 * \frac{X}{N}$Where, F = frequency of particular weed species, X = number of samples in which a particular weed species occurs, N = total number of samples.

Weed Abundance: By quadrats method, samplings are made at random at several places and the number of individuals of each species was summed up for all the quadrats divided by the total number of quadrants in which the species occurred.It is represented by the equation:

$A = (\sum w) / N$Where; A = abundance, ∑w = sum of individuals of a particular weed species across all samples, N = total number of samples.

Weed Dominance (D %): Dominant weeds were those species which occurred in relatively greater number than the other species.D = A * 100/ (∑W), Where; D = dominance of a particular species, A = Abundance of the same species, ∑w = total abundance of all weed species.

Weed Density (D):It is calculated as; D=X/AWhere; D=density of particular weed species, X=number of individual target weed species, A=surface area of sampling unit.

Weed Field Uniformity (Fu %): Field uniformity, expressed asa percentage and in all fields was obtained by dividing the number of quadrates in which the species was observed by the total number of Field studied. FU= X/A, Where; FU= Field uniformity of individual weed species, x=number of quadrant to be studied,A= total number of field studied.

Data management and Analysis

All collected data entered into computer and arranged using Microsoft Excel spread sheets. Then the arranged data were analyzed using SPSS 20th edition.

Results and Discussions

Coffee production ecology in surveyed area

Coffee is widely grown in Shanan Kolu, Gololcha and Chole districts of Arsi zone, with low to highland agro-ecologies. The minimum and maximum altitudes of the surveyed areas were in Gololcha(1599m.a.s.l) and Chole (1715 m.a.s.l), respectively. About 65 % of the coffee farms surveyed were established on gentle slope land followed by23.7 % hilly, 9.3 % valley and 7 % flat sloped land.

Coffee production and agronomic practice in the area

From the assessed coffee fields, about 75% are d greater than 30 years old. Itis grown mostly as an intercrop with other crops and fruits; banana, maize and orange in Chole and Gololcha while coffee is intercropped with maize, chat,groundnut and sorghum in Shanan Kolu district. Farmers manage their coffee farms using digging, slashing and hoeing. Slashing is the most commonly used agronomic practice in the surveyed area. About 65% of coffee farms were fully shaded and 30 % of coffee farms were semi- shaded, whereas 5% of coffee farms remained without shade. From total of all surveyed field in all districts, 85% of farmers use cultural weed management. About 15 % use chemical method of weed management.

Coffee landrace grown in the area

In all the surveyed areas, all the farms grow local coffee landraces which are known for susceptibility to diseases and insect pests with low yield potential. Coffee farmers in the surveyed area still depend on the heterogeneous local coffee landrace. There are different local coffee landraces grown by Arsi coffee farmers, which farmers locally named as Shumbure, Abadir, Kubania, Buna Guracha, Telo and Buna ShekAman. There is no improved coffee variety in all districts except very few farmers growing improved Hararghe coffee varieties at Shanan Kolu and Gololcha districts. The presences of susceptible coffee landraces are favorable for the development of CBD epidemic which influence coffee production and reduce the income generation to farmers (Benti, 2017; Castiblanco*et al.*, 2018).

Occurrence of major coffee pests

Occurrence of Major Coffee Diseases

Major coffee diseases such as coffee berry disease, coffee leaf rust and coffee wilt disease were recorded during the survey. Coffee berry disease (CBD): coffee berry disease was observed in all assessed coffee growing districts. It was recorded in different intensity between and within surveyed districts. The disease prevalence, incidence and severity varied from district to district, even from smallest administration unit (Ganda) to another unit. The survey result shows that CBD was prevalent (100%) in all assessed districts (figure 2). High coffee berry disease (CBD)infected coffee farm was observed at the high land of Shanan Kolu followed by Gololcha district. CBD incidence mean ranged between 0 - 93.33 %, 0 - 43.33 % and 3.33 - 83.33 % in Shanan Kolu, Golocha and Chole, respectively with the overall mean of 31.61 %..CBD incidence significantly varied among and within districts. This difference might be due to the presence of diverse environmental condition, various agronomic practices under taken by coffee growers, coffee genetic diversity, and disease management measures that varied from area to area and virulence of the pathogen. CBD disease severity ranged from 5.9 to 23.05 % with the overall mean of 12.45 % (Table 2). Relatively high (23.05%) CBD severity was recorded at Shanan Kolu followed by Gololcha (8.39 %) and Chole (5.91 %)(Figure2). From the assessed coffee farms Shanankolu showed more CBD severity than the Gololcha and Chole districts. CBD severity ranged from 4.19 - 62.09 %, 0.95 - 51.18 % and 0 - 42.86 % in Shana Kolu, Gololcha and Chole districts, respectively.

Birhanu, (2014) reported CBD mean incidence was 51% at Darolebu and 75% at Bedeno. The highest percent of CBD infection was recorded at highland of Bedeno and the lowest was recorded at DaroLebu which is characterized by midland elevation. Similarly the highest CBD incidence was recorded from the high land of Shanan Kolu, while the lowest was recorded at Chole. Abdi and Abu (2015) also reported 49.3 and 14.8% CBD overall mean incidence and severity in Borena and Guji, respectively. According to Kumlachew*et al.* (2016) at national level sixty percent of the surveyed coffee producing districts had significantly higher levels of CBD incidence that ranged from 50 to 80 %.

Relatively high coffee berry disease infection was recorded from altitude ranges of 1534-1972m.a.s.l, while medium to low coffee berry disease infection was observed in altitudes of 1550-1924 to 1418-1920 m.a.s.l (Table 5). Wayesa*et al.* (2017) reported that high rain fall, high humidity or wetness and relatively low temperatures that persist for long periods favor CBD development and the disease is invariably severe at higher altitudes where these conditions generally exist.

Survey result indicated that coffee berry disease severity had ranged from 5.91% for Chole to 23.05% for Shanan Kolu whereas diseases incidence ranged from 17.14% for Gololcha to -34.81% for Shanan Kolu.

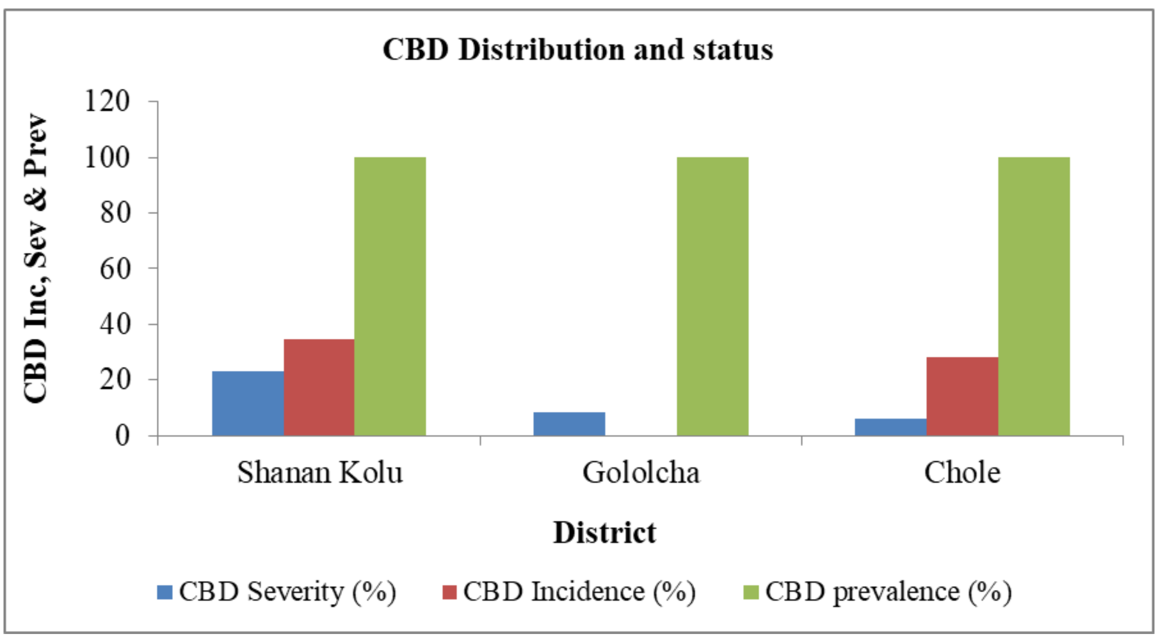


Figure2:Coffee berry disease prevalence, incidence and severity across the surveyed districts

Coffee leaf rust (CLR):Coffee leaf rust severity ranged from 24.87% to 39.06 % at Chole and Shanan Kolu, respectively (figure 3). The magnitude of coffee leaf rust incidence was relatively high (39.06%) at Shanan Kolu followed by Gololcha (26.19%) and Chole (24.87%) districts. The overall mean of incidence and severity of coffee leaf rust recorded across the surveyed districts was 27.46 and 30.04 %, respectively. Relatively high to medium coffee leaf rust infection was observed at altitude of1534-1972 m.a.s.l (Table 5).

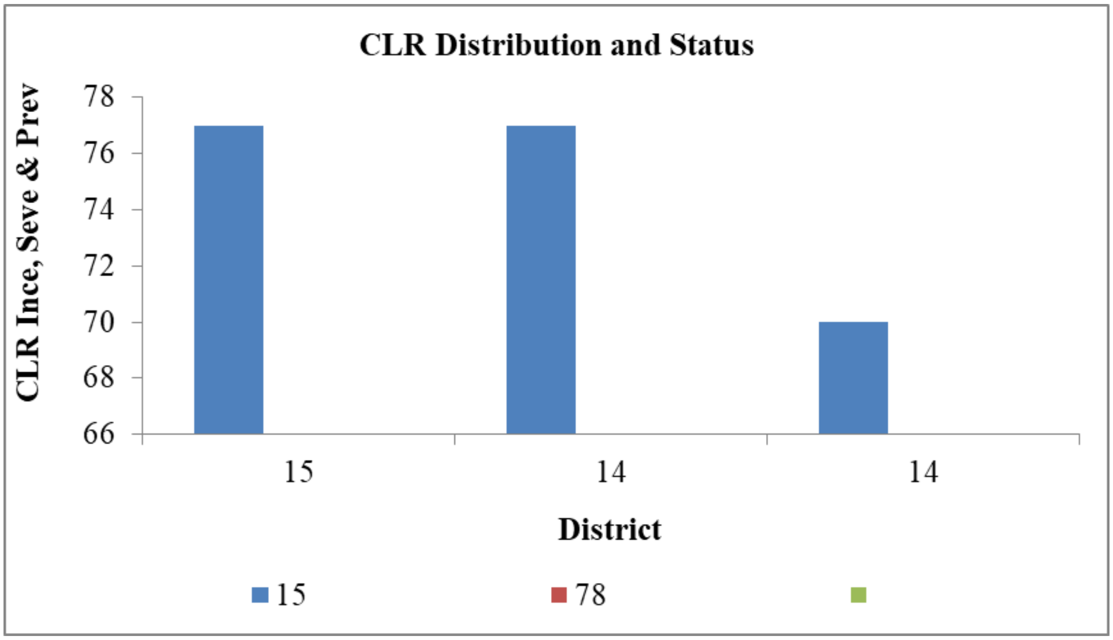


Figure 3: Coffee leaf rust prevalence, incidence and severity across the surveyed districts

Coffee Wilt Disease (CWD): Coffee wilt disease was not commonly found almost in all assessed coffee farms. However, there was low to medium infection in coffee farms across all the assessed districts. Among them Shanan Kolu district showed more coffee wilt disease than Chole and Gololcha districts. The disease prevalence and incidence mean was 60.27% and 9.83 %, respectively (figure 4).

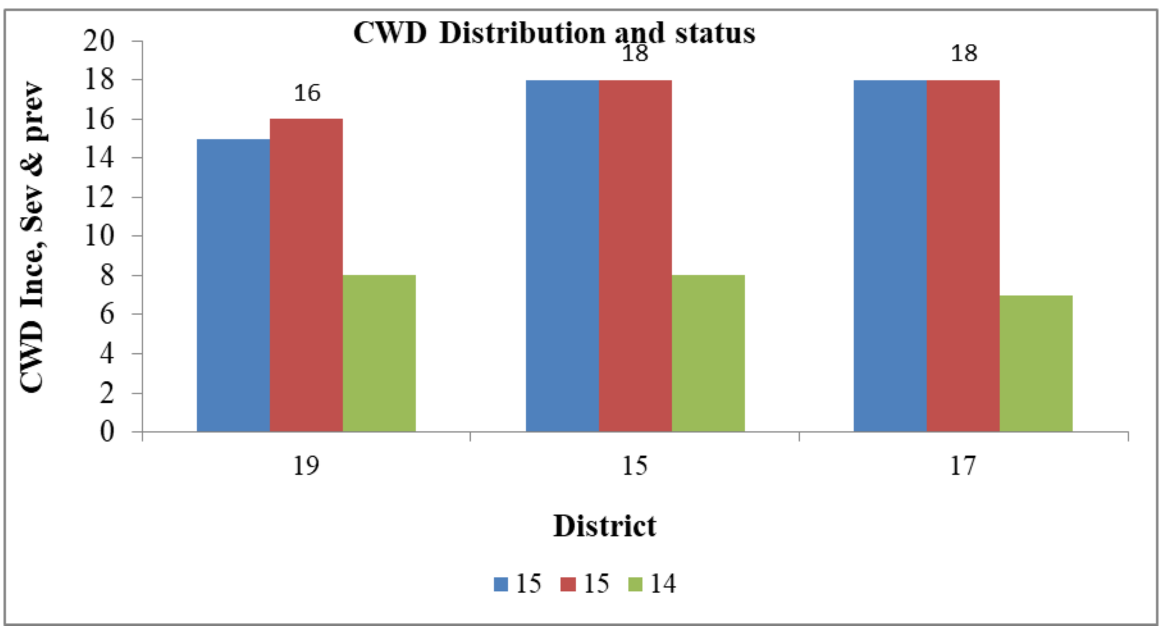


Figure 4: Coffee wilt disease prevalence, incidence and severity across the surveyed districts

Table 2: Occurrence of the disease by altitude

Altitude range	CBDsev%	CBDinc%	CLR sev%	CLR inc%	CWDinc%
1550-1924	8.5	28.5	24.7	24.5	9.3
1534-1972	23.3	35.6	39.9	30.5	13.9
1418-1920	5.7	17	26	27	6.2

Status of Major Coffee Insect Pests

Infestation of Blotch leaf miner was observed between and within the assessed districts. Blotch leaf minor infestation ranged from 15.87 to 25.07%. High infestation (10.27%) was recorded in Shanan Kolu followed by Chole (9.28%) and the lowest was 8.33% recorded in Gololcha district.

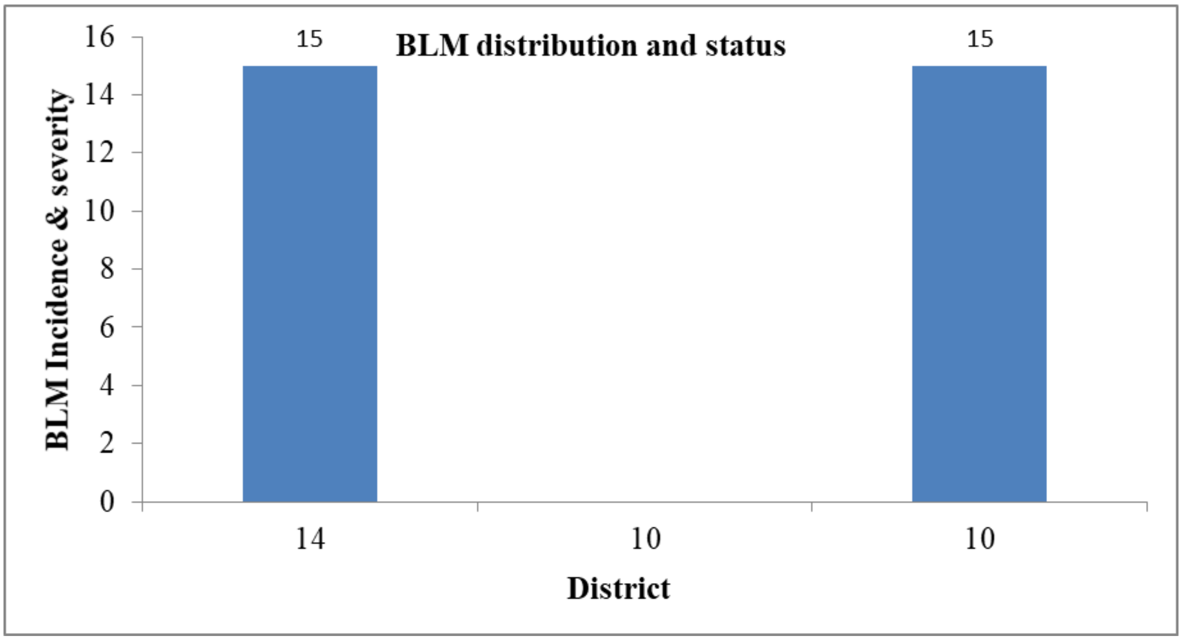


Figure 5: Blotch leaf minor infestationacross the surveyed districts

Weed species Composition and occurrence

A totalof 46 weed species were identifiedof which 24 are annuals and 22 are perennials. 40 (86.96%) are broad leave weeds, 3 (6.52%) grasses 2 (4.34%) sedge and 1 (2.17%) is parasite. About 54.35% were important and 45.65% were noxious weed species. The annual weed species were greater in number than perennial weed species and overall annual broadleaved species were more prevalent than perennial broadleaved species, grassesand sedges.The weed species represented 24 families in where Asteraceae family had the highest number of species (8), followed by Poaceae(5), Solanaceae(3), Malvaceae(3),Amaranthaceae(2), Lamiaceae(2),Papavaraceae(2), Convolvulaceae (2), Polygonaceae (2), Cyperaceae (2), Euphorbiaceae(2). The remaining of the 13 familiesare represented by one species each.

Table 3. Coffee weed species taxonomy

Family	Common name	Scientific name	Lifecycle	Morpho.	Econ.Impr
Amaranthaceae	Slender amaranth	*AmaranthusviridisHook.*	Annual	Broad leaf	Important
Amaranthaceae	Devil's hose whip	*Achyranthesaspera*	Perennial	Broad leaf	Important
Asteraceae	Wild lettuce	*LactucacapensisThunb*	Annual	Broad leaf	Important
Asteraceae	Gallant soldier	*Galinsoqaparviflora*	Annual	Broad leaf	Important
Asteraceae	Sun flecks	*Guizotiascabra*	Annual	Broad leaf	Noxious
Asteraceae	Congress weed	*Partheniumhysterophorus*	Annual	Broad leaf	Noxious
Asteraceae	Black jack	*Bidenspilosa*L.	Annual	Broad leaf	Noxious
Commelinaceae	Wandering jaw	*Commelinabenghalensis*	Perennial	Broad leaf	Noxious
Lamiaceae	Tilifolia	*Salvia tiliifoliaVahl*	Annual	Broad leaf	Noxious
Leguminosae	Clover	*Trifoliumrueppellianum*	Annual	Broad leaf	Important
Papavaraceae	Mexican poppy	*Argemonemexicana* L.	Perennial	Broad leaf	Noxious
Asteraceae	Mexic. marigold	*Tagetesminuta*L	Annual	Broad leaf	Noxious
Plantaginaceae	English plantain	*Plantagolanceolata*	Perennial	Broad leaf	Important
Lamiaceae	Bobbin weed	*leucasmartinicensis.L*	Annual	Broad leaf	Important
Euphorbiaceae	Wild poinsettia	*Euphor. geniculataOrteg.*	Annual	Broad leaf	Noxious
Solanaceae	Black nightshade	*Solanum nigrum* L.	Perennial	Broad leaf	Important
Solanaceae	Thorn apple	*Daturametel L.*	Perennial	Broad leaf	Noxious
Solanaceae	Chinese lantern	*Nicandraphysalodes*	Perennial	Broad leaf	Noxious
Verbenaceae	Wild sage	*Lantana camara* L.	Perennial	Broad leaf	Noxious
Asteraceae	Cocklebur	*Xanthium strumarium.L*	Perennial	Broad leaf	Noxious
Convolvulaceae	Bindweed	*Convolvulus arvensis.L*	Perennial	Broad leaf	Noxious
Portulacaceae	Dodder	*cuscutacampestris*	Annual	Broad leaf	Noxious
Convolvulaceae	ivy-ea.morn.glory	*Ipomeacordofana*	Annual	Broad leaf	Important
Euphorbiaceae	Acalypha	*Acalyphacrenata*	Annual	Broad leaf	Important
Poaceae	Wild finger millet	*Eleusineindica*	Annual	Broad leaf	Important
Gramineae	Basket grass	*Oplismenushirtellus*	Perennial	Broad leaf	Noxious
Poacaea	Wild sorghum	*Sorghum arundianaceum*	Annual	Broad leaf	Important
Oxalidaceae	Creeping wood	*Oxalis corniculata* L.	Perennial	Broad leaf	Important
Polygonaceae	Nepal persicaria	*Polygonumnepalense*	Annual	Broad leaf	Important
Papavaraceae	Pimpernil	*Anaqallisarvensis.l*	Annual	Broad leaf	Important
Urticaceae	Nettle leaf	*Urticadioica*	Annual	Broad leaf	Noxious
Chenopodiacea	white goosefoot	*Chenopodiummurale*	Annual	Broad leaf	Noxious
Boraginaceae	Lance leaf	*Cynoglossumlanceolatum*	Annual	Broad leaf	Important
Compositae	Rich weed	*Spilanthesmauritiana*	Annual	Broad leaf	Noxious
Brassicaceae	Wild gomenzer	*Brassica carinata*	Annual	Broad leaf	Important
Malvaceae	Diamond bur bark	*Triumfettarhomboidea.l*	Perennial	Broad leaf	Noxious
Poacaea	Hairy finger-grass	*Digitariasanguinalis*	Perennial	Grass	Important
Poacaea	Thompson grass	*Paspalumdistichum*	Perennial	Grass	Important
Asteraceae	Meskel flower	*Bidenspachyouma*	Annual	Broad leaf	Important
Malvaceae	Congo jute	*Urenalobata*	Perennial	Broad leaf	Noxious
Caryophyllacea	Com.chickweed	*Stellaria media*	Annual	Broad leaf	Important
Polygonaceae	Bitter dock	*Rumexobtusifolius*	Perennial	Broad leaf	Important
Malvaceae	Velvet Leaf	*Abutilon theophrasti*	Perennial	Broad leaf	Noxious
Poacaea	E.crowfoot grass	*Dactylocteniumaegypticu*	Perennial	Grass	Important

Cyperaceae	Cyperusesculentu	*Purple nutsedge*	Perennial	Sedge	Important
Cyperaceae	Cyprus Assimilis	*yellow nutsedge*	Perennial	Sedge	Important

Occurrence and Distribution of Coffee Weed Species

Among identified species, 71.73% were found at three districts while 15.21% were found at one district and 13.04% of them were found at two districts. Some weed species occurred at all agro-ecology lowland to highlandshowing wider adaptability than other species.

Table 4: Weed species with their belongs to family observed and recorded in coffee farm in Arsi coffee growing districts

Family	Weed species	Shanankolu	Golelcha	Chole
Amaranthaceae	Slender amaranth	*	*	*
Amaranthaceae	Devil's hose whip	*	*	*
Asteraceae	Wild lettuce			*
Asteraceae	Gallant soldier	*	*	*
Asteraceae	Meskel flower	*	*	*
Asteraceae	Guizotiascabra		*	*
Asteraceae	Congress weed	*	*	*
Asteraceae	Black jack	*	*	*
Commelinaceae	Wandering jaw	*	*	*
Lamiaceae	Tilifolia	*	*	*
Leguminosae	Clover			*
Papavaraceae	Mexican poppy			*
Asteraceae	Mexican marigold	*	*	*
Plantaginaceae	English plantain	*	*	*
Lamiaceae	Bobbin weed	*	*	*
Euphorbiaceae	Wild poinsettia	*	*	*
Solanaceae	Black nightshade	*	*	
Solanaceae	Thorn apple		*	*
Solanaceae	Chinese lantern	*	*	*
Verbenaceae	Wild sage	*	*	*
Asteraceae	Cocklebur	*	*	*
Convolvulaceae	Bindweed	*	*	*
Portulacaceae	Dodder		*	*
Poaceae	Wild finger millet	*	*	*
Gramineae	basket grass	*	*	*
Poacaea	Wild sorghum		*	
Oxalidaceae	Creeping wood	*	*	*
Polygonaceae	Nepal persicaria	*	*	*
Papavaraceae	Pimpefnil	*		*
Brassicaceae	Wild gomnzer	*	*	
Urticaceae	Nettle leaf	*	*	*
Malvaceae	diamond bur bark	*	*	*
Poacaea	Thompson grass	*	*	*
Caryophyllaceae	Common chickweed			*
Poacaea	hairy finger-grass	*	*	*
Malvaceae	Congo jute	*	*	*
Polygonaceae	bitter dock	*		
Convolvulaceae	ivy-leaved morning glory	*	*	*
Malvaceae	Velvet Leaf	*	*	*

Cyperaceae	Cyprus assimilis	*	*	*
Chenopodiaceae	white goosefoot	*	*	*
Compositae	Rich Weed	*	*	*
Poacaea	Egyptian crowfoot grass	*	*	*
Euphorbiaceae	Acalypha	*	*	*
Boraginaceae	Lance leaf		*	
Urticaceae	Nettle leaf	*	*	*

Where; * Occurred in one location, * Occurred in two location, * Occurred in three location.

Table 5: number of field, Kebele, Sample, farm number, species type and amount per across surveyed area

District	Number of farm assessed per kebele	List of kebele per proposed district	Total no of quadrant assessed	Number of farm studied	Species type to be assessed	Total number of species
Shanan Kolu	6	Dumugabala	84	18	Annual, perennial, broad leaf, grassy and sedge	37(80.43%)
	7	Laftorifenso				
	5	Birbirsakune				
Gololcha	7	Mine gora	100	21	Annual, perennial, broad leaf, grassy, sedge and parasite	40(87%)
	8	Tibisenbeta				
	6	Mine tulu				
Chole	7	Workederartu	94	20	Annual, perennial, broad leaf, grassy, sedge and parasite	41(89.13%)
	7	Magna lagabuna				
	6	Magna Adare				

Weed Species Frequency (F)

Weed species frequency value in average recorded ranges between 71.10% and 1.19% which was recorded withblack jack and wild sorghum, respectively. The ten superior weed frequencies across surveyed area wereblack jack (71.10%), Bobbin weed (62.22%), hairy finger-grass(61%), wandering jaw (46.65%),*Nepalpersicaria*(44.35%), gallant solder creeping wood (34.94%), Thompson grass (30.33%), Slender amaranth (30%), Congo jute (24.86%). Among top ten weed species 30% and 70% were perennial and annuals, respectively, while 20% of them were grasses and remaining 80% were broad leaved weed species.

Unless the weeds are controlled timely they cause poor coffee production and productivity parallel to increasing year. Begum *et al.* (2008) and Begum (2006) reported different frequencies of different weed species including broad leaves, grasses and sedges in their study.

Table 6. Weed Species Frequency across surveyed areas

Weed species	Weed frequency (F, in %)			Mean
	Shanankolu	Golelcha	Chole	
Black jack	60.71	84.52	68.08	71.1
Devil's hose whip	42.85	59.53	47.48	67.44
Hairy finger-grass	73.81	46.43	62.76	61
Wandering jaw	48.81	45.23	45.91	46.65
Nepal persicaria	32.14	11.91	12.77	44.35
Gallant solder	44.05	45.23	30.95	40.07
Creeping wood	35.71	59.52	9.58	34.94

Thompson grass	29.76	35.71	25.53	30.33
Slender amaranth	19.05	36	34.04	30
Congo jute	28.57	2.38	43.62	24.86
Meskel flower	2.38	3.57	4.25	3.4
Congress weed	9.52	17.85	3.19	10.19
Tiliifolia	11.9	7.14	6.38	8.47
Mexican marigold	4.76	3.57	22.34	10.22
English plantain	8.33	25	2.13	11.82
Wild poinsettia	5.95	16.67	13.83	12.15
Wild sage	17	8.33	1.07	8.8
Bindweed	23.81	27.38	19.14	23.44
Dodder	-	5.95	2.13	8.08
Wild finger millet	7.14	2.38	10.64	6.72
Basket grass	17.85	20.23	35.11	24.4
Nettle leaf	10.71	7.14	-	8.925
Wild gomnzer	0.023	14.29	-	7.16
Diamond bur bark	4.76	150	14.89	9.825
Egyptian crowfoot grass	17.86	5.95	8.52	10.78
Cyprus esculents’	13.09	2.38	14.89	10.12
Bitter dock	1.19	-		1.19
Ivy-leaved morning glory	5.95	2.38	11.71	6.68
Velvet Leaf	9.52	-	18.05	13.785
Cyprus assimilis	22.61	19.05	9.57	17.08
White goosefoot	19.05	8.33	3.19	10.19
Rich Weed	3.57	5.95	-	4.76
Acalypha	7.14	2.38	5.31	7.415
Lance leaf	-	1.19	-	1.19
Sun flecks	-	5.95	12.77	9.36
Chinese lantern	4.76	2.38	5.31	4.15
Black nightshade	5.95	2	-	3.975
Pimpefnil	2.38	-	5.25	3.82
Common chickweed	-	-	7.45	3.74
Cocklebur	2.38	1.19	6.38	3.32
Clover	-	-	3.19	3.19
Thorn apple	-	2.38	2.13	2.255
Mexican poppy	-	-	2.13	2.13
Wild lettuce	-	-	2.13	2.13
Wild sorghum	-	1.19	-	1.19

Density (D) of the Weed Species

Bobbin weed was recorded with high field density value (4945 plants/m^2) while low field density value (8plants/m^2) was recorded in Mexican poppy. The superior ten species with higher field densities were Bobbin weed (4945), Black jack (3521), Basket grass (2473), Creeping wood (2403), Thompson grass (2036), Devil's hose whip (1705), Gallant soldier (1563), Bindweed (1401), Cyprus assimilis (939) and Hairy finger-grass (936plants/m^2). The field densitiesvary from district to districtand even from kebele to kebele, and farm to farm.

Table7. Density (D) of weed species insurvey districts

Weed species	Density (D)			Mean
	Shanankolu	Gololcha	Chole	
Bobbin weed	2456	7124	5256	4945
Black jack	1852	5464	3248	3521
Basket grass	2236	960	4224	2473
Creeping wood	3500	3424	284	2403
Thompson grass	3340	852	1916	2036
Devil's hose whip	1068	1860	2188	1705
Gallant soldier	1100	2708	880	1563
Bindweed	1168	1816	1220	1401
Cyprus assimilis	1180	1632	4	939
Hairy finger-grass	504	1488	816	936
English plantain	12	948	6	322
Wandering jaw	604	752	672	676
Slender amaranth	264	772	604	546.7
White goosefoot	928	164	84	392
Thorn apple	-	44	24	68
Chinese lantern	16	8	32	28
Wild sage	72	32	112	72
Cocklebur	12	8	40	20
Bindweed	1168	1816	1220	1401
Mexican poppy	-	-	8	8
Wild lettuce	-	-	24	24
Wild finger millet	48	124	168	113
Wild sorghum	-	16	-	16
Dodder	-	20	28	14
Pimpefnil	100	-	8	54
Nettle leaf	60	88	16	55
Wild gomnzer	72	132	-	102
Diamond bur bark	16	24	8	16
Egyptian crowfoot grass	28	92	180	100
Cyprus esculents	1160	712	476	783
Black night shade	48	36	-	42
Common chickweed	-	-	24	24
Congo jute	236	312	792	447
Bitter dock	12	-	-	12

Ivy-leaved morning glory	28	28	52	36
Velvet Leaf	136	36	168	113
Cyprus assimilis	1180	1632	4	939
White goosefoot	928	164	84	392
Rich Weed	36	188	16	80
Acalypha	84	12	32	43
Lance leaf	-	8	-	8
Sun flecks	-	24	100	62
Meskel flower	16	20	56	31
Congress weed	176	616	36	276
Tiliifolia	280	392	132	268
Clover	-	-	180	180

Abundance (RA)

Basket grass was significantly outstanding in abundance among the 46 weed species followed by Bobbin weed (23.54), Cyprus assimilis (19.32), Bindweed (18.76), Creeping wood (17.84), Cyprus esculents (15.21), Black jack (14.41), Congo jute (11.47), Thompson grass (11.21). It topped both as a broadleaf weed species as well as in the overall top eleven weeds species that were established to have abundance (A).Among ten most abundant species 7(70%) of them were broad leave while 1(10%) is grass and remain 2(20%) were sedge.

Table8. Relative abundance (RA) of weed species survey districts

Weed species	Abundance			Mean
	Shanankolu	Gololcha	Chole	
Basket grass	35.94	15.67	30.44	27.35
Bobbin weed	15.35	26.65	28.62	23.54
Cyprus assimilis	3.78	30.17	24	19.32
Bindweed	4.95	29.17	22.17	18.76
Creeping wood	29.8	18.88	4.83	17.84
Cyprus esculents	4.81	31.31	9.5	15.21
Black jack	10.22	19.49	13.53	14.41
Congo jute	3.312	25.67	5.44	11.47
Thompson grass	15.85	7.58	10.21	11.21
English plantain	1	30.71	1.5	11.07
Mexican poppy	-	-	1	1
Mexican marigold	1	1.67	2.64	1.77
Tilifolia	7.89	7.18	7.8	7.62
Wandering jaw	2.85	4.18	4.85	3.96
Meskel flower	1.5	1.75	4.67	2.64
Slender amaranth	4.4	6.05	5.81	5.42
Devil's hose whip	7.57	3.96	15.97	9.17
Wild lettuce	-	-	2.5	2.5

Wild poinsettia	2.5	3.8	2.67	2.99
Black nightshade	1.67	2	-	1.835
Thorn apple	-	3	2	2.5
Chinese lantern	1.25	1.5	2	1.58
Wild sage	2.46	1.6	2.29	2.12
Cocklebur	2.5	1	4	2.5
Dodder	-	4.33	3	3.66
Wild finger millet	2.4	6.25	3.71	4.12
Wild sorghum	-	5	-	5
Sun flecks	-	2.5	2.78	2.64
Nepal persicaria	12.48	5.62	14.8	10.97
Pimpefnil	8	-	2	5
Nettle leaf	2.4	9	1.67	4.36
Wild gomnzer	5.67	5.75	-	5.71
Diamond bur bark	2.29	3	2	2.43
Egyptian crowfoot grass	4.75	2.4	2.44	3.2
Congress weed	5.5	19.25	4	9.58
Common chickweed	-	-	20	20
Hairy finger-grass	6.94	10.33	9.69	8.99
Bitter dock	1.5	-	-	1.5
Ivy-leaved morning glory	1.67	3	1.63	2.1
Velvet Leaf	4.85	2	2.6	3.15
Nettle leaf	2.4	9	1.67	4.36
White goosefoot	17.84	7.5	4.67	10
Rich Weed	3	9.2	1.33	4.51
Acalypha	7	2	3.5	4.17
Lance leaf	-	2	-	2
Sun flecks	-	2.5	2.78	2.64

Dominance (D) of Weed Species in Surveyed Areas

Among 46 identified weed species, Basket grass over dominant across surveyed areas with the value of (9.04%)whereas the least dominant was lance leaf (0.53%). Following Basket grassthe dominance values and in a descending order the top ten weed species were Bobbin weed (7.14), Creeping wood (6.03), Bindweed (5.38), Black jack (4.37), Cyprus esculents (4.31), Common Thompson grass (3.74),white goosefoot (3.45), Cyprus assimilis (3.39) and Congo jute (3.23).

Table9. Dominance (D) of Weed Species in Survey Area

Weed species	Dominance (D)			Mean
	Shanankolu	Gololcha	Chole	
Basket grass	14.09	4.15	8.87	9.04
Bobbin weed	6.02	7.07	8.34	7.14
Creeping wood	11.68	5.01	1.41	6.03
Bindweed	1.94	7.74	6.46	5.38

Black jack	4.01	5.17	3.94	4.37
Cyprus esculents	1.88	8.3	2.76	4.31
Thompson grass	6.22	2.01	2.98	3.74
Congo jute	1.3	6.81	1.58	3.23
White goosefoot	6.99	2	1.36	3.45
Cyprus assimilis	1.48	8	0.69	3.39
Slender amaranth	1.72	1.6	1.69	5.01
Wild lettuce	0	0	0.73	0.73
Gallant soldier	3.08	1.204	2.97	2.42
Meskel flower	0.58	0.46	1.36	0.8
Congress weed	2.2	5.1	1.16	2.82
Wandering jaw	1.12	1.11	1.42	1.22
Tiliifolia	3.09	1.9	2.27	2.42
Clover	0	0	1.31	1.31
Mexican poppy	0	0	0.29	0.29
Mexican marigold	0.39	0.44	0.77	0.53
English plantain	0.39	8.15	0.43	2.99
Wild poinsettia	0.98	1.01	0.77	0.92
Black nightshade	0.65	0.53	0	0.59
Thorn apple	0	0.8	0.58	0.69
Chinese lantern	0.49	0.4	0.87	0.59
Wild sage	0.96	0.42	0.67	0.68
Cocklebur	0.98	0.26	1.16	0.8
Dodder	0	1.15	0.87	1.01
Wild finger millet	0.94	1.66	1.08	1.23
Wild sorghum	0	1.32	0	1.32
Nepal persicaria	4.89	1.49	0.43	2.27
Pimpefnil	3.13	0	0.58	1.86
Nettle leaf	0.94	2.38	0.48	1.27
Wild gomnzer	2.22	1.52	0	1.87
Diamond bur bark	0.89	0.8	0.58	0.76
Egyptian crowfoot grass	1.86	0.64	0.71	1.07
Common chickweed	0	0	1.46	1.46
Hairy finger-grass	2.72	2.74	2.82	2.76
Bitter dock	0.58	0	0	0.58
Ivy-leaved morning glory	0.65	1	0.47	0.71
Velvet Leaf	1.9	0.53	0.75	1.06
Rich Weed	1.17	2.44	0.38	1.33
Acalypha	2.74	0.53	1.02	1.635
Lance leaf	0	0.53	0	0.53

Sun flecks	0	0.66	0.81	0.735

Field uniformity (FU) of Weed Species

Out of 46 identified weed species Bobbin weed showed the highest value of field uniformity (90%), while the lowest value of field uniformity was recorded in Clover (5%). The top ten weed species with first-class field uniformity were Bobbin weed (90%), Black jack (88.12%), Thompson grass (84.76%), Devil's hose whip (78.15%), Creeping wood (68.94%), Gallant soldier (68.25%), Slender amaranth (67.14%), Wandering jaw (65.93), Hairy finger-grass (58%) and Cyprus esculents (54.31%). Species field uniformity was varying from district to districts, even from Kebele to Kebele. This dissimilar field uniformity due to edaphic (including soil pH, soil moisture, etc.) and biological (dominated by another weed species, seed dormancy, eaten by insects and micro-organisms and etc.) factors (Hakim, *et al.*, 2010).

Table 10. Field uniformity (FU) of Weed Species in Survey Districts

Weed species	Field Uniformity (FU %)			Mean
	Shanan Kolu	Gololcha	Chole	
Bobbin weed	88.88	95.23	90	91.37
Black jack	88.88	90.47	85	88.12
Thompson grass	83.33	80.95	90	84.76
Devil's hose whip	77.77	66.67	90	78.15
Creeping wood	61.11	85.71	60	68.94
Gallant soldier	83.33	71.43	50	68.25
Slender amaranth	50	71.43	80	67.14
Wandering jaw	61.11	66.67	70	65.93
Hairy finger-grass	55.55	57.15	60	58
Cyprus esculents	55.55	52.38	55	54.31
Wild lettuce	0	0	15	15
Meskel flower	11.11	9.52	15	12
Congress weed	33.33	28.57	10	24
Tiliifolia	27.77	9.52	15	17.43
Clover	0	0	5	5
Mexican poppy	0	0	10	10
Mexican marigold	11.11	14.29	35	20.13
English plantain	5.55	38.09	0	9.92
Wild poinsettia	22.22	28.57	45	31.93
Black nightshade	16.66	4.76	0	10.71
Thorn apple	0	9.52	5	7.26
Chinese lantern	16.66	14.28	25	10.71
Wild sage	55.55	23.81	50	43.12
Cocklebur	5.55	9.52	20	12
Bindweed	50	47.61	50	49.2
Dodder	0	14.29	15	14.64
Wild finger millet	22.22	19.04	30	23.75

Basket grass	33.33	23.81	65	40.71
Wild sorghum	0	14.29	0	14.29
Nepal persicaria	44.44	19.05	20	27.83
Pimpefnil	5.55	0	5	5.27
Nettle leaf	16.66	52.38	35	34.68
Wild gomnzer	16.66	33.33	0	25
Diamond bur bark	22.22	28.57	5	19
Egyptian crowfoot grass	27.77	42.86	45	38.54
Common chickweed	0	0	30	30
Congo jute	61.11	4.76	85	50.29
Bitter dock	11.11	0	25	18.05
Ivy-leaved morning glory	27.77	0	50	39
Velvet Leaf	22.22	9.52	40	23.91
Cyprus assimilis	16.66	28.57	30	25.08
White goosefoot	83.33	9.52	15	36
Rich Weed	11.11	14.28	10	12
Acalypha	11.11	9.52	15	12
Lance leaf	0	4.76	-	4.76
Sun flecks	0	14.28	30	22.14

Summary and Conclusion

Major coffee diseases such as coffee berry disease (CBD), coffee leaf rust (CLR), coffee wilt disease (CWD), bacterial blight of coffee (BBC), insect pest such as blotch leaf miner (BLM) and different weedspeciess were recorded in Cholle, Shanan Kolu and Gololcha districts of Arsi zone. Coffee disease severity and incidence and insect pest infestations were lower to moderately high in the districts. Diversified weed flora comprising of 46 species belonging to 24 families were identified and recorded in coffee fields of the three districts. Weed species composition, growth, occurrence, dominance, frequency and density varied from place to place, district to district even from farm to farm. Thus, this information is vital for setting research and developmental work priorities concerning coffee production, disease, insect and weeds management. Therefore, to increase production and productivity of Arsi coffee, it is important to develop and high yielding, disease resistant coffee variety with appropriate improved agronomic practices for the area.

References

Abdi Mohammed and Abu Jambo. 2015. Importance and Characterization of Coffee Berry Disease (Colletotrichumkahawae) in Borena and Guji Zones, Southern Ethiopia. Journal of Plant Pathology and Microbiology, 6: pp302. doi:10.4172/2157- 7471.1000302.

BerhanuTamiru. 2014. Coffee berry disease (Colletotrichumkahawae): Status, pathogenic variability and reactions of coffee landraces in Hararghe, Eastern Ethiopia. International Journal of Plant Breeding and Crop Science, 2(1): 038-042

Alemayehu T., Esayas K. and Kassu K., 2008. Coffee development and marketing improvement plan in Ethiopia. In: Coffee diversity and knowledge; Girma, A., Bayetta, B., Tesfaye. S., Endale, T. and Taye, K. (eds). EIAR, Addis Ababa, Ethiopia.Pp 375-381.

CABI. 2003. Survey of assess the extent of coffee wilt disease in East and Central Africa. Final Technical Report.CABI Regional Center, Nairobi, Kenya, 49 pp.

Cook, R.T.A. 1975. Screening coffee plants for resistance to CBD.Coffee Research Foundation Kenya.Annual Report 1973/4.

Eshetu D., Teame G. and Girma A., 2000.Significance of minor coffee diseases of Coffee arabica L. in Ethiopia; a review. In: Proceedings of the workshop on control of coffee berry disease in Ethiopia, 13-15 August 1999, Addis Ababa,Ethiopia. Pp 58-64.

GirmaAdugna, MangistuHulluka and Hindorf,h. 2001. Incidence of *trecheomycosis, giberellaxyilariodes (Fusariumxylariodides*), on Arabica Coffee in Ethiopia. J. Plant Dis. And Pro.108 (2): 136-142

KumlachewAlemu, GirmaAdugna, FikreLemessa and DiribaMuleta. 2016. Current status of coffee berry disease (Colletotrichumkahawae, Waller & Bridge) in Ethiopia. Archives of Phytopathology and Plant Protection, 49:

Meseret W.1991. Epidemiology and resistance of coffee leaf rust in Ethiopia. Ministry of Coffee and Tea Development. Addis Ababa, Ethiopia.

Mohemmedsani A., and Hika B., 2018.Assessment of major coffee diseases status in eastern oromia.oromia agricultural institute, Mechara agricultural research center

Silva M.C., Varzea V., Guerra-Guimaraes L., AzinheiraH.G., Fernandez D, PetitotA.S., Bertrand B., Lashermes P. and Nicole M. 2006. Coffee resistance to main diseases: leaf rust and coffee berry disease. Brazilian journal of plant physiology, 18 (1) 119-147.

EAFCA (East Africa Fine Coffee Association). 2010. East Africa Fine Coffee Association. Coffee Outlook. 2010.

Graff, J. 1986. The economics of coffee.Wageningen, The Netherlands: PudocWageningen.

ICO (International Coffee Organization). 2017. Annual Review 2016/2017, International Coffee Organization Available on: http://Dev.Ico.Org/Documents/Review8e.pdf.

Senbeta, F., W/Mariam, T. and Denich, M. 2008. Species diversity and integration of their use values in coffee forests of southwestern and southeastern Ethiopia. pp. 121-129. *In*: GirmaAdugna, BayettaBellachew, TesfayeShimbir, T., Taye, E. and Kufa, T. (eds.). Coffee diversity and knowledge, EIAR, Addis Ababa, Ethiopia.

Tolera, FG. andGebermedin, GA. 2015. Opportunities and constraints of coffee production in West Hararghe Zone, Ethiopia.*Journal of Agricultural Economics and Rural Development*, 2(4): 054 - 059.

WayessaGaredow, GirmaAduga and FikireLamessa. 2017. Coffee yield lose caused by CBD and none CBD factors at Southwestern Ethiopia. Archives of Phytopathology and Plant Protection, 49: 421-433W/Tsedik, W. and Kebede, K. (2000). Coffee production systems in Ethiopia. pp. 99-107. Proceedings of the workshop on control of coffee berry disease in Ethiopia, 13-15 August 1999, Addis Ababa.