Regional Review Workshop on Completed Research Activities

Proceedings of Review Workshop on Completed Research Activities of Crop Research Directorate held at Adami Tulu Agricultural Research Center, Adami-Tulu, Ethiopia, 23-27 December 2020.

Editors

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Correct citation: Tesfaye Letta, Girma Mengistu, Dagnachew Lule, Gashaw Sefera, Fikadu Taddese and Bodena Gudisa (eds.). Proceedings of Review Workshop on Completed Research Activities of Crop Research Directorate held at Adami Tulu Agricultural Research Center, Adami Tulu, Oromia, Ethiopia 2020.

Table of Contents

Breeding and Genetics

Performance Evaluation of Garlic (*Allium sativum* L.) Varieties in the High Land of Eastern Hararghe Zone, Oromia, Ethiopia

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ABSTRACT
Garlic (Allium sativum L.) belongs to the family Alliaceae and is the second most widely used Allium next to onion. Eastern Hararghe has a considerable potential agroecologies which is suitable for garlic production. However, lack of improved and adaptable varieties are the major production constraints to study area. Accordingly,this study was initiated to identify adaptable, high yielding and diseases tolerant garlic varieties for study area and similar agro ecologies.A field experiment was conducted for during the 2019 and 2020cropping season on farmers' land at Kombolcha and Gursum districts. The treatments were consisted of five garlic varieties (Chelenko I, Kuriftu, Tsedey 92, HL and Chefe) and one local check. The treatments arranged in randomized complete block design with three replications. The result of the study showed significant differences among varieties for all the recorded traits except days to maturity. Among the varieties, Tsedey 92 provided about 54.3% and 13.3% yield advantages over the local and standard check, respectively. Besides,Tsedey 92 was tolerant to rust disease than allvarieties evaluated in the present study. Therefore, Tsedey 92 was recommended for demonstrated and large scale production in study areas and similar agro-ecologies.
Keywords: Adaptation, Bulb Yield, Diseases, Garlic, Varieties

INTRODUCTION

Garlic (*Allium sativum* L.) belongs to the family *Alliaceae* and is the second most widely used *Allium* next to onion (Yadav*et al*., 2017). Garlic is among the most important bulb vegetable crops used as a seasoning or condiment of foods because of its pungent flavor. Garlic adds a taste to foods as well as helps to make them more palatable and digestible (Higdon, 2005). Garlic has higher nutritive value than other bulb crops in addition to containing antibiotics like garlicin and allistatin(Maly, *et al*., 1998).Garlic requires growing period of 4.5-6 months and the amount of rainfall ranges between 600mm to 700mm during its production system. The optimum temperature for garlic growing lies between 12^0c and 24^0c (Lemma and Hearth, 1994). In Ethiopia, the area coverage of garlic during the 2017/18 main cropping season was 19,412.49 ha, and total production was about 178, 22.19 tonneswith an average productivity of 9.1 t ha^{-1}(CSA, 2018). This is far below the world average yield of 16.71 t ha^{-1} (FAOSTAT, 2013) and neighboring country like Egypt produced 309,155 tonnes with productivity of 24.34 tha^{-1}(FAO, 2015). The low yield of this crop due to many biotic and abiotic factors such as lack of high yielding varieties, non-availability of quality seeds, imbalanced fertilizer use, lack of irrigation facilities, lack of proper disease and insect pest management and other agronomic practices, low storability, and lack of proper marketing facilities (Getachew and Asfaw, 2010;Mohammed *et al*., 2014). Eastern Hararghe has a great potential to produce garlic under rain fed and irrigation. However, due to lack of improved and adaptable garlic varieties with their improved agronomic practices the farmers use only the local cultivar with their own traditional production. Even if the area is very suitable and the crop is very important commercially, farmer's income generation from garlic and productivity is still unsatisfactory. There are no any research efforts made in relation to adaptability of garlic varieties in the study area. Therefore, objective of this study was to identify adaptable, high yielding and diseases tolerant garlic varieties for study area and similar agro ecologies.

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Source:Ministry of Agriculture and Natural Resources, 2018

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The treatments were consisted of five garlic varieties and one local check (Table 1). The trial was carried out in randomized complete block design (RCBD) having three replicates in a gross plot size of 3.6m^2 (1.8m and 2m) with a spacing of 1m between replicates and 0.5m between plots. All treatments were assigned randomly to the experimental plots. The experimental field was prepared following the conventional tillage practice using oxen plow. Cloves of medium sized (2 -3 g) were planted by hand in rows 30 cm apart and with 10 cm between plants with in rows. N was split applied in the form of Urea half at planting and the other half at 30 days after planting while all the NPS was applied at time of planting.

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Data were recorded on plant height, leaves length, bulb diameter, number of cloves per bulb and bulb weight from a sample of 10 representative plants while days to maturity and bulb yield ware collected on plot base. Also disease data were collected using 1-5 scoringscale.

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Analysis of variance was carried out using GenStatdiscovery 15th edition software for the parameters studied following the standard procedures (Gomez and Gomez, 1984). Means that showed significant difference were compared using Least Significant Difference (LSD) test at 5% significant level.

RESULTS AND DISCUSSION

Combined analysis of variance showed the presence of highly significant (P≤0.01) differences among the varieties for the plant height, number of cloves per plant, bulb diameter and yield; significant difference(P≤0.05) for leave length and bulb weight. The presence of significant differences among varieties indicates the presence of genetic variability for each of the characters among the tested varieties. There was also highly significant (P≤0.01) differences among treatments for maturity date; significant difference (P≤0.05) for plant height due to the environmental variation. The genetype by environment interaction showed significant (P≤0.05) differences only for bulb weight.

Table 2.The mean squares for different sources of variation and the corresponding CV (%) for parameter studied.

S V	DF	PH	DM	LL	NCPB	BD	BW	BY
Rep	2	14.73	0.26	32.62	0.306	0.53	35.97	81.79
Variety	5	244.44**	4.88	68.84*	26.8**	202.8**	120.54*	2939.78**
Environment	1	206.72*	2900.7**	53.13	0.038	94.35	117.86	172.33
V * E	5	37.69	9.41	4.41	2.095	12.71	39.8*	133.45
Error	58	50.96	66.1	21.47	4.102	15	49.99	90.08
Total	71							
CV (5%)		14.7	5.8	13.8	19.6	15.4	33.9	15

Keys: *, **: significant at 5% and 1% respectively, S.V=source of variation, E=environment, V * E=variety verses environment, CV=coefficient of variation, DF=degree of freedom DM=days to maturity, PH=plant height, LL=leaf length, NCPB= number of clove per bulb, BD=bulb diameter, BW=bulb weight, BY=bulb yield

Table 3.Combined mean of yield and yield parameters of garlic varieties over years and locations.

Varieties	DM	PH(cm)	LL(cm)	BD(mm)	NCPB	BW(g)	BY(t/ha)	RDS
Tsedey 92	140.4	48.98b	35.44ab	31.20a	10.08b	26.18a	8.45a	1
Chelenko I	139.9	55.29a	36.51a	27.46b	10.17b	22.50ab	7.46b	2
Kuriftu	140	46.9bc	31.54b	26.72b	11.11b	20.98ab	7.00b	2
Chafe	139.6	46.02bc	31.32b	25.16bc	9.47bc	18.96b	5.17c	3
Local	140.1	51.52ab	35.28ab	22.98c	12.75a	19.54b	5.47c	3
HL	138.6	42.37c	31.47b	23.37c	8.36c	17.14b	4.34d	4
LSD (5%)	NS	5.90	3.70	2.71	1.61	5.78	0.79	
CV (%)	7.4	14.9	13.5	12.7	19.1	33.9	15.4	

Keys:NS= Not significant, CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05). DM=days to maturity, PH=plant height, LL=leaf length, NCPB= number of clove per bulb, BD=bulb diameter, BW=bulb weight, BY= bulb yield, RDS= Rust disease score (1-5)

Maturity Date

The current result showed that there was no significance difference among varieties, but HL variety matured relatively early (138.6 day), while Tsedey 92 variety was late maturing (140.4 days) compared to other varieties and local.

Plant Height and Leaf Length

The current study revealed that the type of variety affected the plant height and leaf length. The highest plant height (55.29cm) was recorded from Chelenko-I followed by local (51.52cm) and Tsedey(48.98cm), while the lowest plant height (42.37cm) was recorded from HL. On the other hand, the highest leaf length (36.51cm) was recorded from Chelenko-I followed by Tsedey(35.44cm) and local check (35.28a), while the lowest leaf length was recorded from Chefe variety (31.32cm). In contrast to the current finding,Ayalew (2015)reported that the highest pseudo stem length was recorded from local cultivar (28.80 cm) followed by Kuriftu (24.53 cm). This might be variation between the two environments.

Bulb Diameter and Number of Cloves per Bulb

The highest bulb diameter was recorded from Tsedey 92 (31.2mm) followed by Chelenko-I (27.46mm), while the lowest bulb diameter (22.98mm) was recorded from local check. On the other hand the highest number of clove per bulb was recorded from local check (12.75) while the lowest from HL variety (8.36). This result is in line with Ayalew (2015)who reported that the highest number of cloves per bulb was recorded from local among tasted garlic varieties.

Bulb Weight and Yield

The current result showed that the bulb weight and yield were affected by the variety. Significantly the highest bulb weight (26.18g) and yield (8.45tha^{-1}) were recorded from Tsedey 92 variety while the lowest bulb weight (17.14g) and yield (4.34tha^{-1}) from HL variety. The current result showed the possibility of bulb yield increment by 54.3% and 13.3% via use of Tsedey- 92 variety over local and standard check (Chelenko-I), respectively. However, overall yield was lower compared to the national average yield. Similarly, Tadese (2009)reported that the maximum bulb weight (26.07g) and yield (8.067tha^{-1}) was recorded from Tsadey-92 as compared to five garlic varieties. However, this result varies from the study conducted by Ayalew(2015)reported that the highest tuber yield were recorded 16.16, 11.78 and 5.57$tha^{-1}$from local, Kuriftu and Tsadey 92 varieties, respectively. This might be variation between the two environments.

CONCLUSION AND RECOMMENDATION

As indicated in the result there was significant differences among the varieties for all parametersexceptfor days to maturity. Among the varieties, Tsedey-92 provided about 54.3% and 13.3% yield advantages over the local and standard check, respectively. Also Tsedey 92 was tolerant to rust disease than other varieties and local cultivar. Therefore, for sustainable garlic production and productivity in study area,Tsedey- 92 was recommended and need to be demonstrated.

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REFERENCES

Ayalew, A., Tadesse, D., Medhin, Z.G. and Fantaw, S. (2015) Evaluation of Garlic (*Allium sativum* L.)Varieties for Bulb Yield and Growth at Dabat, Northwestern Ethiopia. Open Access Library Journal, 2: e1216.

CSA (Central Statistical Agency). The Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey,2017/18 Volume I Report on area and production of major crops Addis Ababa,April, 2018

FAOSTAT (Food and Agriculture Organization of the United Nations Statistics).(2011)http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor; 21/12/2013.

FAO 2015.Major Food and Agricultural Commodities and Producers Countries by Commodity. http://faostat.fao.org/site/567.

Getachew, T., Asfaw, Z. 2010.Achievements in shallot and garlic research. Report No.36. Ethiopian Agricultural Research Organization, Addis Ababa Ethiopia

Gomez KA, Gomez AA. Statistical procedures for agricultural research, 2nd edition, John Wiley and Sons, New York.1984, 680.

Higdon, J. (2005). Garlic and organosulfur compounds. Linus Pauling Institute, Macronutrient Information Center, Oregon State University. Retrieved from http://lpi. oregonstate.edu/mic/food-beverages/garlic

Kibebew, 2014 characterization of Agricultural soils in cascape intervention woredas in

Eastern region.
Lemma, D., &Herath, E. (1994).Agronomic Studies on Allium. Pp.139-145. In: Horticultural Research and Development in Ethiopia. 1-3 December 1992. Institute of Agricultural research and food and Agricultural Organization. Addis Ababa, Ethiopia.
Maly, I., Bartos, J., Hlusek, J., Kopec, K., Peteikova, K., Rod, J., Spitz, P. (1998). Polnizelina_stvi.AgrospojPraha, 175-185
Ministry of Agriculture and Natural Resources, Plant Variety Release, protection and seed qual1ty control directorate crop variety register issue No. 19 June, 2016 Addis Ababa, Ethiopia
Mohammed Amin, ShiberuTadele and ThangavelSelvaraj. 2014. White rot (ScelerotiumcipivorumBerk)-an aggressive pest of onion and garlic in Ethiopia: an overview. Journal of Agricultural Biotechnology & Sustainable Development 6(1): 6 - 15.
TadeseTeweldebrhan,2009 Participatory varietal evaluation and faremer based seed production: A sustainable approach to garlic seed delivery in AtsbiWombertaWereda, Eastern Tigray.
TakeleTesgera, FikruRegassa, BultoGiro and Abdinur Mohammed (2017) Study on prevalence and identification of ixodid ticks in cattle in Gursum district, East Hararghe Zone of Oromia Regional State, Ethiopia.Journal of Parasitology and Vector Biology
Yadav RN, Bairwa HL, Gurjar MK (2017). Response of garlic (*Allium sativum* L.) to organic manures and fertilizers. International Journal of Current Microbiology and Applied Sciences 6(10):4860-4867

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Kibebew, 2014 characterization of Agricultural soils in cascape intervention woredas in Eastern region.

Lemma, D., &Herath, E. (1994).Agronomic Studies on Allium. Pp.139-145. In: Horticultural Research and Development in Ethiopia. 1-3 December 1992. Institute of Agricultural research and food and Agricultural Organization. Addis Ababa, Ethiopia.

Maly, I., Bartos, J., Hlusek, J., Kopec, K., Peteikova, K., Rod, J., Spitz, P. (1998). Polnizelina_stvi.AgrospojPraha, 175-185

Ministry of Agriculture and Natural Resources, Plant Variety Release, protection and seed qual1ty control directorate crop variety register issue No. 19 June, 2016 Addis Ababa, Ethiopia

Mohammed Amin, ShiberuTadele and ThangavelSelvaraj. 2014. White rot (ScelerotiumcipivorumBerk)-an aggressive pest of onion and garlic in Ethiopia: an overview. Journal of Agricultural Biotechnology & Sustainable Development 6(1): 6 - 15.

TadeseTeweldebrhan,2009 Participatory varietal evaluation and faremer based seed production: A sustainable approach to garlic seed delivery in AtsbiWombertaWereda, Eastern Tigray.

TakeleTesgera, FikruRegassa, BultoGiro and Abdinur Mohammed (2017) Study on prevalence and identification of ixodid ticks in cattle in Gursum district, East Hararghe Zone of Oromia Regional State, Ethiopia.Journal of Parasitology and Vector Biology

Yadav RN, Bairwa HL, Gurjar MK (2017). Response of garlic (*Allium sativum* L.) to organic manures and fertilizers. International Journal of Current Microbiology and Applied Sciences 6(10):4860-4867

Evaluation of small pod hot pepper varieties at Fedis and Babile districtsof Eastern Hararghe Zone, Oromia

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ABSTRACT

Field experiment was conducted at Fedis (on station) and Babile (Erer on Farm) during the rainy season from June to early November, 2017, to identify high yielding and disease tolerant small pod hot pepper variety. Three released small pod hot pepper varieties (Kume,Dinsire and Dame) and one local check arranged in Randomized Complete Block Design (RCBD) with three replications. The analysis of variance showed significance difference ($P \leq 0.05$) for days to maturity, average fruit length, average fruit width and fruit yield, while there was no significance difference for above ground biomass and average fruit weight. The result indicated that the earlier days to first fruit set (104.7 days) was attained by Dinsire variety, longest fruit Length (4.375 cm) was recorded for Local and highest fruit Diameter was recorded from Dinsire (3.372 cm). The highest (6996kgha^{-1}) fruit yield was obtained from local; though there was no significant differences with Dinsire variety which recorded (6797kgha^{-1}) and the smallest (5975kgha^{-1}) fruit yield was obtained from Kume variety. Therefore,locally available small pod hot pepper was recommended for further breeding works and Dinsire variety for furtherdemostrationand large scale production for the study area and similar agro-ecologies.

Keywords: Fruit yield, hot pepper, small pod.

INTRODUCTION

Pepper *(Capsicum annuum)* is the world's most important vegetable after tomato and used as fresh, dried or processed products, as vegetables and as spices or condiments (Acquaah, 2004). The total area devoted to pepper worldwide is estimated at 4 million hectare with an average annual increase of 5% (Weiss, 2002). Vegetables took up about 0.98 % of the area under crops at national level. In Ethiopia, the total area under hot pepper for dry pod (Berbere) and for green pepper (Karia) in 2015was estimated to be 92,455.73ha and 5,889.02ha and total production was 367,926.32qt and 1,707,656.64qt, respectively. In Eastern Hararghe, the total area covered with Red pepper in 2015 was 42.59 ha and total production was 1,754.43qt (CSA, 2015). This production was low as compared to other zones. This is due to lack of improved varieties that are not adaptable to different agro-ecologies, poor quality seeds, disease and insect pests, high post-harvest loss and also due to lack of awareness of existing improved technology.Due to this and other reasons, some parts of Fedis and Babile ecology are unable to produce enough Small pod hot pepper for local consumption. The available local variety has low fruit yield, poor quality fruits, short shelf life and high susceptibility to insect pest and diseases. Hence, small pod hot pepper is transported from neighboring rural areas at unreasonable prices to augment the supply deficit. However, the knowledge of the types of variety that will yield best in a given environment is important for good crop variety selectionand other management decisions.

Currently, there are limited Capsicum species and varieties including both improved and the local ones. As a result, varietal information for the improvement of the crop for high fruit yield and quality in the existing agro-ecology is insufficient. Little was done on evaluation of hot pepper which enables the growers to select the best performing varieties in the study area. Performaceevaluation of varieties areimportant to ease the existing problems of obtaining the desired varieties for which the output of this study was likely to assist small pod hot pepper growers.Therefore, the objective of this experiment wasto identify high yielding and disease tolerant variety of small pod hot pepper adaptale to the study area and similar agro-ecologies.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Fedis (on station) and Babile (Erer on Farm) during the rainy season from June to early November, 2017, Eastern Hararghe zone, Oromia region state, Ethiopia. Fedis is located at 24 km far away from Harar town in the southdirection and at the altitude of 1702meters above sea level. The mean rainfall is about 860.4 mm for the last five years. The mean maximum and minimum annual temperature are 28.2 °C and 10.2 °C, respectively, for the last five years (Fedis Agriculture Research Center Metrological Station). Babile is located at 34 km from Harartown. The altitude of the area ranges between 950 - 2000 masland, latitude of 09°10'41.5" and 042°15'27.3", respectively. The area receives an average annual rainfall of about 400 - 600mm.

Experimental material and Design

The treatments were consisted of three small pod varieties **(**Kume,Dinsire and Dame) and one local check. Planting materials were collected from Bako Agricultural Research Center, while the local cultivar was collected from the respective districts. The experiment was laid out in RCBD with three replications. The size of each experimental plot was $10m^2$ (2m wide and 5m long). Treatments were randomly assigned to the experimental plots. The spacing between rows and plants was 40 and 10 cm, respectively. There were 4 rows per plot and 10 plants per row with a total of 40 plants per plot.

Experimental procedure

Seeds of the three varieties of small pod hot pepper were sown on nursery beds at the rate of 600 gm/ha on rows separated by 15 cm and at the depth of 1.5 cm, keeping 4 cm distance between seeds then seedlings with 10-12 cm height, 4-5 true leaves and with no disease and pest sign was transplanted one seedling/hill. Nitrogen fertilizer was applied by split application method in the form of urea the first three weeks after transplanting and the second at first fruiting. Phosphorus was applied in the form of NPS at the time of transplanting. Recommended cultural practices such as weeding, pest and disease control was carried out uniformly in all plots. Plots were irrigated when there was insufficient rainfall as supplementary irrigation.

Data collected

Days to maturity, average fruit length, average fruit width, above ground biomass, average fruit weight and fruit yield.

Data analysis

Analysis of variance was carried out using GenStat18th edition software for the parameters studied following the standard procedures outlined by Gomez and Gomez (1984). The means were separated using the Least Significant Difference (LSD) test at 5% level of probability.

RESULTS AND DISCUSSIONS

Combined analysis of variance showed significance difference ($P\leq 0.05$) for days to maturity, average fruit length, average fruit width and fruit yield, while there was no significance difference for above ground biomass and average fruit weight (Table1).

Days to Maturity

Days to Maturity was significantly ($P < 0.05$) affected by variety Dinsire and Local. The result indicated that relatively the earlier days to first fruit set (104.7 days) was attained by Dinsire variety and (104.8) by local check, whereas Dame (108.8 days) variety and Kume (109.2) required relatively longer time (Table 1). This result might be due to the effect of inherited characters of the hot pepper.

Fruit Length

Analysis of variance revealed that fruit length was significantly ($P < 0.05$) affected by varieties (Table 1). The longest fruit Length (4.375cm) was recorded from local while the shortest fruit length (3.722) was recorded from Dinsire.In this study, the local small pod hot pepper variety showed longest plant height.

Fruit Diameter

There was significant difference ($P < 0.05$) on fruit diameter (Table 1) which might be due to differences among verities. The highest fruit diameter was recorded from Dinsire (3.372 cm) and lowest fruit diameter was observed forlocal variety (2.58 cm).This result was in agreement with the finding of Haileslassie*et al*, (2015) found that fruit diameter was significantly affected due to varietal effect. In addition fruit diameter has importance in markets. According to Beyene and David (2007), larger and wider hot pepper pods are considered to be the best in quality and have better demand for fresh as well as dry pod use in Ethiopian markets.

Above ground biomass and average fruit weight

The result of current study revealed that there was no significant difference ($P < 0.05$) forabove ground biomass and average fruit weight amongvarieties (Table 1). The highest above ground biomass (4811kgha^{-1}) was recorded from local while the smallest (4376kgha^{-1})was recorded from Dame Variety. Likewise, Dame variety recorded the highest average fruit weight(19.62 gm), but the smallest fruit weight (15 gm) was recorded from Kumevariety.

Fruit Yield

Significant differences ($p<0.05$) were observed between varieties testedfor fruit yield. The highest fruit yield (6996kgha^{-1})was obtained from local; though there was no significant differences with Dinsire variety which recorded (6797kgha^{-1}) and the smallest fruit yield(5975kgha^{-1}) was obtained from Kume variety.Among the treatment, local check provided about 17% and 13.8% yield advantages over Kume and Dame Varieties,respectively. This result indicated that the local cultivar is superior to the released small pod hot pepper varieties.The variation of fruit yield of these varieties could be due to difference in genetic characteristics and agro ecological adaptability nature (Fekadu*et al*., 2008).

Table 1: Mean of yield and yield parameters of combined small pod hot paper over year at Fedis andErer

Variety	DM	AFL(cm)	AFD(cm)	AGBM(kg/ha)	AFWt(g)	FY(kgha^{-1})
Kume	109.2^{b}	4.041^{ab}	3.202^{a}	4662	16.04	5975^{c}
Dame	108.8^{b}	4.114^{ab}	3.255^{a}	4376	19.62	6145^{bc}
Local	104.8^{a}	4.375^{a}	2.589^{b}	4811	15	6996^{a}
Dinsire	104.7^{a}	3.722^{b}	3.372^{a}	4511	16.78	6797^{ab}
LSD (5%)	5.462	1.0459	0.4501	NS	NS	1379.121
CV (%)	3.1	15.4	8.7	23.2	32	12.8

Key: LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance. DM (Days to Maturity), AFL (Average Fruit Length), AFD (Average Fruit diameter), AGBM (Above Ground Biomass), AFWt (Average Fruit Weight), FY (Fruit Yield)

CONCLUSION AND RECOMMENDATION

The experiment conducted on adaptability of small pod hot pepper showed significant differences on days to maturity, average fruit length, average fruit width and fruit yield.Locally produced small pod hot pepper gavethe highest fruit yield; though there was no significant difference with Dinsirevariety.The smallest fruit yield was obtained from Kume variety. Therefore,further research should be conducted on locally collected landraces, larger number of varieties should be tested to widen the chance of gettingadaptable variety. For the time being, the llocally available small pod hot pepper should be maintained and produced in the study area.

REFERENCES

Acquaah, G. (2004). Horticulture: Principles and Practices. 2nd edition.Prentice Hall of India Private Ltd. New Delhi, India. Pp.787.

Beyene T. and David Phillips, 2007.Ensuring Small Scale Producers in Ethiopia to Achieve Sustainable and Fair Access to Pepper Market. Uganda Journal of Agriculture, 3(2): 113-119

Bosland, P.W., Votava, E.J. (2000). Peppers: Vegetable and Spice Capsicums. Crop Production Science in Horticulture.CABI Publishers.Pp.304.

CSA (Central Statistical Authority). 2015. Report on the preliminary results of area, production and yield of crops.AddisAbaba, Ethiopia.

Fekadu Marame, Lemma Desalegne, Harjit-Singh, Chemeda,Fininsa and Roland Sigvald, 2008. Genetic Components and Heritability of Yield and Yield Related Traits in

Hot Pepper. Research Journal of Agriculture and Biological Sciences, 4(6): 803-809.
Haileslassie, G., Haile, A., Wakuma,B.andKedir, 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.
Lemma, D., Shimeli, A. (2008). Achievement and research experience on capsicum crop Melkasa Agricultural Research center. EIAR.

Performance Evaluation of Garlic (Allium sativum L.) Varieties in the High Land of Eastern Hararghe Zone, Oromia, Ethiopia

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ABSTRACT
Garlic (Allium sativum L.) belongs to the family Alliaceae and is the second most widely used Allium next to onion. Eastern Hararghe has a considerable potential agroecologies which is suitable for garlic production. However, lack of improved and adaptable varieties are the major production constraints to study area. Accordingly, this study was initiated to identify adaptable, high yielding and diseases tolerant garlic varieties for study area and similar agro ecologies. A field experiment was conducted for during the 2019 and 2020 cropping season on farmers' land at Kombolcha and Gursum districts. The treatments were consisted of five garlic varieties (Chelenko I, Kuriftu, Tsedey 92, HL and Chefe) and one local check. The treatments arranged in randomized complete block design with three replications. The result of the study showed significant differences among varieties for all the recorded traits except days to maturity. Among the varieties, Tsedey 92 provided about 54.3% and 13.3% yield advantages over the local and standard check, respectively. Besides, Tsedey 92 was tolerant to rust disease than all varieties evaluated in the present study. Therefore, Tsedey 92 was recommended for demonstrated and large scale production in study areas and similar agro-ecologies.
Keywords: Adaptation, Bulb Yield, Diseases, Garlic, Varieties

INTRODUCTION

Garlic (*Allium sativum* L.) belongs to the family *Alliaceae* and is the second most widely used *Allium* next to onion (Yadav *et al*., 2017). Garlic is among the most important bulb vegetable crops used as a seasoning or condiment of foods because of its pungent flavor. Garlic adds a taste to foods as well as helps to make them more palatable and digestible (Higdon, 2005). Garlic has higher nutritive value than other bulb crops in addition to containing antibiotics like garlicin and allistatin (Maly, *et al*., 1998). Garlic requires growing period of 4.5-6 months and the amount of rainfall ranges between 600mm to 700mm during its production system. The optimum temperature for garlic growing lies between 12^{0}c and 24^{0}c (Lemma and Hearth, 1994). In Ethiopia, the area coverage of garlic during the 2017/18 main cropping season was 19,412.49 ha, and total production was about 178, 22.19 tonnes with an average productivity of 9.1 t ha^{-1} (CSA, 2018). This is far below the world average yield of 16.71 t ha^{-1} (FAOSTAT, 2013) and neighboring country like Egypt produced 309,155 tons annually with productivity of 24.34 t ha^{-1}(FAO, 2015). The low yield of this crop due to many biotic and abiotic factors such as lack of high yielding varieties, non-availability of quality seeds, imbalanced fertilizer use, lack of irrigation facilities, lack of proper disease and insect pest management and other agronomic practices, low storability, and lack of proper marketing facilities (Getachew and Asfaw, 2010; Mohammed *et al*., 2014). Eastern Hararghe has a great potential to produce garlic under rain fed and irrigation. However, due to lack of improved and adaptable garlic varieties with their improved agronomic practices the farmers use only the local cultivar with their own traditional production. Even if the area is very suitable and the crop is very important commercially, farmer's income generation from garlic and productivity is still unsatisfactory. There are no any research efforts made in relation to adaptability of garlic varieties in the study area. Therefore, objective of this study was to identify adaptable, high yielding and diseases tolerant garlic varieties for study area and similar agro ecologies.

MATERIALS AND METHODS

Description of Experimental Site

The experiment was conducted under rain fed for two consecutive years (2019 and 2020) on farmers' field at Kombolcha and Gursum districts, Eastern Hararghe zone, Oromia region state, Ethiopia. Kombolcha is located at 17 km far away from Harar town. The altitude of district ranges from 1200 to 2460 meters above sea level. The district receives a mean annual rainfall of 600-900 mm, which is bimodal and erratic in distribution. The small rainy season starts in February/March and extends to mid-May, while the main rainy season stretches between July and August. The mean annual minimum and maximum temperatures are 13.8 and 24.4°C, respectively (Kibebew, 2014). Gursum is located at 75km far away from Harar town. The altitude of the district ranges from 1200 to 2938 m above sea level with the annual rain fall of 650 to 750 mm and the mean annual minimum and maximum temperature of 18 and 25°C, respectively. The area has short rainy season from March to April and long rainy season from June to August (Takele *et al*., 2017)

Experimental Materials

Table 1. Description of five garlic varieties and one local check selected for the trial.

No	Varieties	Year of released	Breeder/Maintainer
1	Chefe	2015	Debre Zeit Agricultural Research Center
2	Kuriftu	2010	Debre Zeit Agricultural Research Center
3	Tsedey 92	1999	Debre Zeit Agricultural Research Center
4	Holeta	2015	Debre Zeit Agricultural Research Center
5	Chelenko I(Standard check)	2014	Haramaya University
6	Local	-	Farmers of study area

Source: Ministry of Agriculture and Natural Resources, 2018

Treatments and Experimental Design
The treatments were consisted of five garlic varieties and one local check (Table 1). The trial was carried out in randomized complete block design (RCBD) having three replicates in a gross plot size of 3.6m^2 (1.8m and 2m) with a spacing of 1m between replicates and 0.5m between plots. All treatments were assigned randomly to the experimental plots. The experimental field was prepared following the conventional tillage practice using oxen plow. Cloves of medium sized (2 -3 g) were planted by hand in rows 30 cm apart and with 10 cm between plants with in rows. N was split applied in the form of Urea half at planting and the other half at 30 days after planting while all the NPS was applied at time of planting.

Data Collection
Data were recorded on plant height, leaves length, bulb diameter, number of cloves per bulb and bulb weight from a sample of 10 representative plants while days to maturity and bulb yield ware collected on plot base. Also disease data were collected using 1-5 scoring scale.

Data Analysis
Analysis of variance was carried out using GenStat discovery 15th edition software for the parameters studied following the standard procedures (Gomez and Gomez, 1984). Means that showed significant difference were compared using Least Significant Difference (LSD) test at 5% significant level.

RESULTS AND DISCUSSIONS
Combined analysis of variance showed the presence of highly significant ($P \leq 0.01$) differences among the varieties for the plant height, number of cloves per plant, bulb diameter and yield; significant difference ($P \leq 0.05$) for leave length and bulb weight. The presence of significant differences among varieties indicates the presence of genetic variability for each of the characters among the tested varieties. There was also highly significant ($P \leq 0.01$) differences among treatments for maturity date; significant difference ($P \leq 0.05$) for plant height due to the environmental variation. The genetype by environment interaction showed significant ($P \leq 0.05$) differences only for bulb weight.
Table 2. The mean squares for different sources of variation and the corresponding CV (%) for parameter studied.

S V	DF	PH	DM	LL	NCPB	BD	BW	BY
Rep	2	14.73	0.26	32.62	0.306	0.53	35.97	81.79
Variety	5	244.4**	4.88	68.8*	26.8**	202.8**	120.5*	2939.78**
Environment	1	206.7*	2900.7**	53.13	0.038	94.35	117.86	172.33
V * E	5	37.69	9.41	4.41	2.095	12.71	39.8*	133.45
Error	58	50.96	66.1	21.47	4.102	15	49.99	90.08
Total	71							
CV (5%)		14.7	5.8	13.8	19.6	15.4	33.9	15

Keys: *, **: significant at 5% and 1% respectively, S.V=source of variation, E=environment, V * E=variety verses environment, CV=coefficient of variation, DF=degree of freedom DM=days to maturity, PH=plant height, LL=leaf length, NCPB= number of clove per bulb, BD=bulb diameter, BW=bulb weight, BY=bulb yield

Table 3. Combined mean of yield and yield parameters of garlic varieties over years and locations.

Varieties	DM	PH(cm)	LL(cm)	BD(mm)	NCPB	BW(g)	BY(t/ha)	RDS
Tsedey 92	140.4	48.98b	35.44ab	31.20a	10.08b	26.18a	8.45a	1
Chelenko I	139.9	55.29a	36.51a	27.46b	10.17b	22.50ab	7.46b	2
Kuriftu	140	46.9bc	31.54b	26.72b	11.11b	20.98ab	7.00b	2
Chafe	139.6	46.02bc	31.32b	25.16bc	9.47bc	18.96b	5.17c	3
Local	140.1	51.52ab	35.28ab	22.98c	12.75a	19.54b	5.47c	3
HL	138.6	42.37c	31.47b	23.37c	8.36c	17.14b	4.34d	4
LSD (5%)	NS	5.90	3.70	2.71	1.61	5.78	0.79	
CV (%)	7.4	14.9	13.5	12.7	19.1	33.9	15.4	

Keys: NS= Not significant, CV=Coefficient of Variation, LSD= Least Significant Difference. Means followed by different letters within columns are significantly different by Duncan's new multiple range test (P = 0.05). DM=days to maturity, PH=plant height, LL=leaf length, NCPB= number of clove per bulb, BD=bulb diameter, BW=bulb weight, BY= bulb yield, RDS= Rust disease score (1-5)

Maturity Date

The current result showed that there was no significance difference among varieties, but HL variety matured relatively early (138.6 day), while Tsedey 92 variety was late maturing (140.4 days) compared to other varieties and local.

Plant Height and Leaf Length

The current study revealed that the type of variety affected the plant height and leaf length. The highest plant height (55.29 cm) was recorded from Chelenko-I followed by local (51.52cm) and Tsedey (48.98cm), while the lowest plant height (42.37cm) was recorded from HL. On the other hand, the highest leaf length (36.51cm) was recorded from Chelenko-I followed by Tsedey (35.44cm) and local check (35.28a), while the lowest leaf length was recorded from Chefe variety (31.32 cm). In contrast to the current finding, Ayalew (2015) reported that the highest pseudo stem length was recorded from local cultivar (28.80 cm) followed by Kuriftu (24.53 cm). This might be variation between the two environments.

Bulb Diameter and Number of Cloves per Bulb

The highest bulb diameter was recorded from Tsedey 92 (31.2mm) followed by Chelenko-I (27.46mm), while the lowest bulb diameter (22.98mm) was recorded from local check. On the other hand the highest number of clove per bulb was recorded from local check (12.75) while the lowest from HL variety (8.36). This result is in line with Ayalew (2015) who reported that the highest number of cloves per bulb was recorded from local among tasted garlic varieties.

Bulb Weight and Yield

The current result showed that the bulb weight and yield were affected by the variety. Significantly the highest bulb weight (26.18g) and yield (8.45 t ha^{-1}) were recorded from Tsedey 92 variety while the lowest bulb weight (17.14g) and yield (4.34 t ha^{-1}) from HL variety. The current result showed the possibility of bulb yield increment by 54.3% and 13.3% via use of Tsedey- 92 variety over local and standard check (Chelenko-I), respectively. However, overall yield was lower compared to the national average yield. Similarly, Tadese (2009) reported that the maximum bulb weight (26.07g) and yield (8.067 t ha^{-1}) was recorded from Tsadey-92 as compared to five garlic varieties. However, this result varies from the study conducted by Ayalew (2015) reported that the highest tuber yield were recorded 16.16, 11.78 and 5.57 t $ha^{-1}$from local, Kuriftu and Tsadey 92 varieties, respectively. This might be variation between the two environments.

CONCLUSION AND RECOMMENDATION

As indicated in the result there was significant differences among the varieties for all parametersexcept for days to maturity. Among the varieties, Tsedey-92 provided about 54.3% and 13.3% yield advantages over the local and standard check, respectively. Also Tsedey 92 was tolerant to rust disease than other varieties and local cultivar. Therefore, for sustainable garlic production and productivity in study area, Tsedey- 92 was recommended and need to be demonstrated.

ACKNOWLEDGEMENTS

The authors greatly indebted to acknowledge the Oromia Agricultural Research Institute for financing this research and Fedis Agricultural Research Centre to facilities and operate the research. We warmly acknowledge Murtesa Yusuf for his involvement in field data collection.

REFERENCES

Ayalew, A., Tadesse, D., Medhin, Z. G. and Fantaw, S. (2015) Evaluation of Garlic (*Allium sativum* L.) Varieties for Bulb Yield and Growth at Dabat, Northwestern Ethiopia. Open Access Library Journal, 2: e1216.

CSA (Central Statistical Agency). The Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey,2017/18 Volume I Report on area and production of major crops Addis Ababa, April, 2018

FAOSTAT (Food and Agriculture Organization of the United Nations Statistics).(2011)http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor; 21/12/2013.

FAO 2015. Major Food and Agricultural Commodities and Producers Countries by Commodity. http://faostat.fao.org/site/567.

Getachew, T., Asfaw, Z. 2010. Achievements in shallot and garlic research. Report No.36. Ethiopian Agricultural Research Organization, Addis Ababa Ethiopia
Gomez KA, Gomez AA. Statistical procedures for agricultural research, 2nd edition, John Wiley and Sons, New York. 1984, 680.
Higdon, J. (2005). Garlic and organosulfur compounds. Linus Pauling Institute, Macronutrient Information Center, Oregon State University. Retrieved from http://lpi.oregonstate.edu/mic/food-beverages/garlic
Kibebew, 2014 characterization of Agricultural soils in cascape intervention woredas in Eastern region.
Lemma, D., & Herath, E. (1994). Agronomic Studies on Allium. Pp.139-145. In: Horticultural Research and Development in Ethiopia. 1-3 December 1992. Institute of Agricultural research and food and Agricultural Organization. Addis Ababa, Ethiopia.
Maly, I., Bartos, J., Hlusek, J., Kopec, K., Peteikova, K., Rod, J., Spitz, P. (1998). Polni zelina_stvi. Agrospoj Praha, 175-185
Ministry of Agriculture and Natural Resources, Plant Variety Release, protection and seed qual1ty control directorate crop variety register issue No. 19 June, 2016 Addis Ababa, Ethiopia
Mohammed Amin, Shiberu Tadele and Thangavel Selvaraj. 2014. White rot (Scelerotium cipivorum Berk)-an aggressive pest of onion and garlic in Ethiopia: an overview. Journal of Agricultural Biotechnology & Sustainable Development 6 (1): 6 - 15.
Tadese Teweldebrhan, 2009 Participatory varietal evaluation and faremer based seed production: A sustainable approach to garlic seed delivery in Atsbi Womberta Wereda, Eastern Tigray.
Takele Tesgera, Fikru Regassa, Bulto Giro and Abdinur Mohammed (2017) Study on prevalence and identification of ixodid ticks in cattle in Gursum district, East Hararghe Zone of Oromia Regional State, Ethiopia. Journal of Parasitology and Vector Biology
Yadav RN, Bairwa HL, Gurjar MK (2017). Response of garlic (*Allium sativum* L.) to organic manures and fertilizers. International Journal of Current Microbiology and Applied Sciences 6 (10): 4860-4867

Evaluation of small pod hot pepper varieties at Fedis and Babile districts of Eastern Hararghe Zone, Oromia

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ABSTRACT

Field experiment was conducted at Fedis (on station) and Babile (Erer on Farm) during the rainy season from June to early November, 2017, to identify high yielding and disease tolerant small pod hot pepper variety. Three released small pod hot pepper varieties (Kume, Dinsire and Dame) and one local check arranged in Randomized Complete Block Design

(RCBD) with three replications. The analysis of variance showed significance difference (P≤ 0.05) for days to maturity, average fruit length, average fruit width and fruit yield, while there was no significance difference for above ground biomass and average fruit weight. The result indicated that the earlier days to first fruit set (104.7 days) was attained by Dinsire variety, longest fruit Length (4.375 cm) was recorded for Local and highest fruit Diameter was recorded from Dinsire (3.372 cm). The highest (6996 kg ha^{-1}) fruit yield was obtained from local; though there was no significant differences with Dinsire variety which recorded (6797 kg ha^{-1}) and the smallest (5975 kg ha^{-1}) fruit yield was obtained from Kume variety. Therefore, locally available small pod hot pepper was recommended for further breeding works and Dinsire variety for further demostration and large scale production for the study area and similar agro-ecologies.
Keywords: Fruit yield, hot pepper, small pod

INTRODUCTION

Pepper *(Capsicum annuum)* is the world's most important vegetable after tomato and used as fresh, dried or processed products, as vegetables and as spices or condiments (Acquaah, 2004). The total area devoted to pepper worldwide is estimated at 4 million hectare with an average annual increase of 5% (Weiss, 2002). Vegetables took up about 0.98 % of the area under crops at national level. In Ethiopia, the total area under hot pepper for dry pod (Berbere) and for green pepper (Karia) in 2015 was estimated to be 92,455.73ha and 5,889.02 ha and total production was 367,926.32 qt and 1,707,656.64 qt, respectively. In Eastern Hararghe, the total area covered with Red pepper in 2015 was 42.59 ha and total production was 1,754.43 qt (CSA, 2015).

This production was low as compared to other zones. This is due to lack of improved varieties that are not adaptable to different agro-ecologies, poor quality seeds, disease and insect pests, high post-harvest loss and also due to lack of awareness of existing improved technology. Due to this and other reasons, some parts of Fedis and Babile ecology are unable to produce enough Small pod hot pepper for local consumption. The available local variety has low fruit yield, poor quality fruits, short shelf life and high susceptibility to insect pest and diseases. Hence, small pod hot pepper is transported from neighboring rural areas at unreasonable prices to augment the supply deficit. However, the knowledge of the types of variety that will yield best in a given environment is important for good crop variety selection and other management decisions.

Currently, there are limited Capsicum species and varieties including both improved and the local ones. As a result, varietal information for the improvement of the crop for high fruit yield and quality in the existing agro-ecology is insufficient. Little was done on evaluation of hot pepper which enables the growers to select the best performing varieties in the study area. Performace evaluation of varieties are important to ease the existing problems of obtaining the desired varieties for which the output of this study was likely to assist small pod hot pepper growers. Therefore, the objective of this experiment was to identify high yielding and disease tolerant variety of small pod hot pepper adaptable to the study area and similar agro-ecologies.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted at Fedis (on station) and Babile (Erer on Farm) during the rainy season from June to early November, 2017, Eastern Hararghe zone, Oromia region state, Ethiopia. Fedis is located at 24 km far away from Harar town in the south direction and at the altitude of 1702 meters above sea level. The mean rainfall is about 860.4 mm for the last five years. The mean maximum and minimum annual temperature are 28.2 °C and 10.2 °C, respectively, for the last five years (Fedis Agriculture Research Center Metrological Station). Babile is located at 34 km from Harar town. The altitude of the area ranges between 950 - 2000 masl and, latitude of 09°10'41.5" and 042°15'27.3", respectively. The area receives an average annual rainfall of about 400 - 600mm.

Experimental material and Design

The treatments were consisted of three small pod varieties **(**Kume, Dinsire and Dame) and one local check. Planting materials were collected from Bako Agricultural Research Center, while the local cultivar was collected from the respective districts. The experiment was laid out in RCBD with three replications. The size of each experimental plot was $10m^2$ (2m wide and 5m long). Treatments were randomly assigned to the experimental plots. The spacing between rows and plants was 40 and 10 cm, respectively. There were 4 rows per plot and 10 plants per row with a total of 40 plants per plot.

Experimental procedure

Seeds of the three varieties of small pod hot pepper were sown on nursery beds at the rate of 600 gm/ha on rows separated by 15 cm and at the depth of 1.5 cm, keeping 4 cm distance between seeds then seedlings with 10-12 cm height, 4-5 true leaves and with no disease and pest sign was transplanted one seedling/hill. Nitrogen fertilizer was applied by split application method in the form of urea the first three weeks after transplanting and the second at first fruiting. Phosphorus was applied in the form of NPS at the time of transplanting. Recommended cultural practices such as weeding, pest and disease control was carried out uniformly in all plots. Plots were irrigated when there was insufficient rainfall as supplementary irrigation.

Data collected

Days to maturity, average fruit length, average fruit width, above ground biomass, average fruit weight and fruit yield.

Data analysis

Analysis of variance was carried out using GenStat 18^{th} edition software for the parameters studied following the standard procedures outlined by Gomez and Gomez (1984). The means were separated using the Least Significant Difference (LSD) test at 5% level of probability.

RESULT AND DISCUSSION

Combined analysis of variance showed significance difference ($P \leq 0.05$) for days to maturity, average fruit length, average fruit width and fruit yield, while there was no significance difference for above ground biomass and average fruit weight (Table1).

Days to Maturity

Days to Maturity was significantly ($P < 0.05$) affected by variety Dinsire and Local. The result indicated that relatively the earlier days to first fruit set (104.7 days) was attained by Dinsire variety and (104.8) by local check, whereas Dame (108.8 days) variety and Kume (109.2) required relatively longer time (Table 1). This result might be due to the effect of inherited characters of the hot pepper.

Fruit Length

Analysis of variance revealed that fruit length was significantly ($P < 0.05$) affected by varieties (Table 1). The longest fruit Length (4.375 cm) was recorded from local while the shortest fruit length (3.722) was recorded from Dinsire. In this study, the local small pod hot pepper variety showed longest plant height.

Fruit Diameter

There was significant difference ($P < 0.05$) on fruit diameter (Table 1) which might be due to differences among verities. The highest fruit diameter was recorded from Dinsire (3.372 cm) and lowest fruit diameter was observed forlocal variety (2.58 cm). This result was in agreement with the finding of Haileslassie *et al*, (2015) found that fruit diameter was significantly affected due to varietal effect. In addition fruit diameter has importance in markets. According to Beyene and David (2007), larger and wider hot pepper pods are considered to be the best in quality and have better demand for fresh as well as dry pod use in Ethiopian markets.

Above ground biomass and average fruit weight

The result of current study revealed that there was no significant difference ($P < 0.05$) for above ground biomass and average fruit weight among varieties (Table 1). The highest above ground biomass (4811 kg ha^{-1}) was recorded from local while the smallest (4376 kg ha^{-1}) was recorded from Dame Variety. Likewise, Dame variety recorded the highest average fruit weight (19.62 gm), but the smallest fruit weight (15 gm) was recorded from Kume variety.

Fruit Yield

Significant differences ($p<0.05$) were observed between varieties tested for fruit yield. The highest fruit yield (6996 kg ha^{-1}) was obtained from local; though there was no significant differences with Dinsire variety which recorded (6797 kg ha^{-1}) and the smallest fruit yield (5975 kg ha^{-1}) was obtained from Kume variety. Among the treatment, local check provided about 17% and 13.8% yield advantages over Kume and Dame Varieties, respectively. This result indicated that the local cultivar is superior to the released small pod hot pepper varieties. The variation of fruit yield of these varieties could be due to difference in genetic characteristics and agro ecological adaptability nature (Fekadu *et al*., 2008).

Table 1: Mean of yield and yield parameters of combined small pod hot paper over year at Fedis and Erer

Variety	DM	AFL(cm)	AFD(cm)	AGBM(kg/ha)	AFWt(g)	FY(kg ha^{-1})
Kume	109.2^{b}	4.041^{ab}	3.202^{a}	4662	16.04	5975^{c}
Dame	108.8^{b}	4.114^{ab}	3.255^{a}	4376	19.62	6145^{bc}
Local	104.8^{a}	4.375^{a}	2.589^{b}	4811	15	6996^{a}
Dinsire	104.7^{a}	3.722^{b}	3.372^{a}	4511	16.78	6797^{ab}
LSD (5%)	5.462	1.0459	0.4501	NS	NS	1379.121
CV (%)	3.1	15.4	8.7	23.2	32	12.8

Key: LSD (0.05) = Least Significant Difference at 5% level; CV (%) = Coefficient of variation. Means in the table followed by the same letter are not significantly different at 5% level of significance. DM (Days to Maturity), AFL (Average Fruit Length), AFD (Average Fruit diameter), AGBM (Above Ground Biomass), AFWt (Average Fruit Weight), FY (Fruit Yield)

CONCLUSION AND RECOMMENDATION

The experiment conducted on adaptability of small pod hot pepper showed significant differences on days to maturity, average fruit length, average fruit width and fruit yield. Locally produced small pod hot pepper gave the highest fruit yield; though there was no significant difference with Dinsire variety.The smallest fruit yield was obtained from Kume variety. Therefore, further research should be conducted on locally collected landraces; larger number of varieties should be tested to widen the chance of getting adaptable variety. For the time being, the llocally available small pod hot pepper should be maintained and produced in the study area.

REFERENCES

Acquaah, G. (2004). Horticulture: Principles and Practices. 2nd edition. Prentice Hall of India Private Ltd. New Delhi, India. Pp.787.

Beyene T. and David Phillips, 2007.Ensuring Small Scale Producers in Ethiopia to Achieve Sustainable and Fair Access to Pepper Market. Uganda Journal of Agriculture, 3(2): 113-119

Bosland, P.W., Votava, E.J. (2000). Peppers: Vegetable and Spice Capsicums. Crop Production Science in Horticulture. CABI Publishers. Pp.304.

CSA (Central Statistical Authority). 2015. Report on the preliminary results of area, production and yield of crops.AddisAbaba, Ethiopia.

Fekadu Marame, Lemma Desalegne, Harjit-Singh, Chemeda,Fininsa and Roland Sigvald, 2008. Genetic Components and Heritability of Yield and Yield Related Traits in Hot Pepper. Research Journal of Agriculture and Biological Sciences, 4(6): 803-809.

Haileslassie, G., Haile, A., Wakuma,B.andKedir, 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.

Lemma, D., Shimeli, A. (2008). Achievement and research experience on capsicum crop Melkasa Agricultural Research center. EIAR.

Registration of "Gadisa" Newly Released Coriander Variety

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ABSTRACTS

Gadisa (Acc.MAB-030) is coriander variety developed and released by Oromia Agricultural Research institute, Sinana Agricultural Research Center. Originally it was obtained from landrace collections followed by pure line selection method. The trial was done at Sinana Agricultural Research Center from observation nursery to preliminary yield trial. But, it was conducted at Sinana, Goro and Gindhir on farmers' fields for three years (2015 to 2017) during multi-location or regional variety trial stage. . Mean seed yield of Gadisa ranged from 15 to 33 Qt ha^{-1} on research field, and 12 to 21 Qt ha^{-1} on farmers field with 21.36% oleoresin content. Finally '*Gadisa'* released as superior coriander variety for Bale mid altitude and similar agro ecologies in 2019.

***Key Words**: Coriander, Gadisa, Oleoresin content, Variety verification.*

INTRODUCTION

Coriander (*Coriandrum sativum* L, 2n=2x=22) is a diploid annual plant, belonging to the Apiaceae/Umbliferae family (Hedburg, 2013). Due to wide range of climatic, ecological and topographic conditions, Ethiopia has long been known as a center of origin and diversity for several plants among which, coriander is the one in which Ethiopia is known as a center of primary diversity (Jansen, 1981). The existence of sufficient variability for agronomic and chemical traits for Ethiopian coriander accessions was also reported by Beemnet and Getinet (2010). Coriander is used as a spice in food, beverage, and pharmaceuticals industries. It is also a good melliferous plant and studies indicated that one hectare of coriander allows honey bees to collect about 500 kg of honey (Romanenko *et al*., 1991). In Ethiopia, mature fruits, which is commonly named as seeds are commonly used as spice and the fresh green herb also used as a green salad. Coriander seed is widely used as a spice in diversified societies of the country and its seed is found in every market. In addition, the leaves and the immature fruits are used as an ingredient for the preparation of ''data'', a traditional spice eaten as a "wot" together with meat (Beemnet et al., 2010).

Plant breeders usually maintain their own active collections consisting of carefully selected genotypes, but there is a continuous need for new, specific trait and combinations of trait in introductions, selection, domestication and improvement programme, allowing new problems to be solved and new demands to be met. Coriander is the major seed spices produced in Bale mid altitude, however, its production and productivity is low. Lack of improved varieties that are high yielding and resistance/tolerant to disease 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 coriander genotypes that are stable, high yielding and adaptable for Bale mid altitude and similar agro ecologies.

Varietal Origin and Evaluation

Gadisa (*Acc. MAB-030*) coriander variety developed and released by Oromia Agricultural Research institute, Sinana Agricultural Research Center for Bale and similar Agro ecologies. Originally it was obtained from landrace collections through pure line development. A total of .75 genotypes were evaluated at sinana Agricultural research Centre from observation nursery to preliminary yield trial. About 16 genotypes were selected for further multi-location trial based on seed yield and reaction to diseases. These genotypes were evaluated against standard check Walta'i across locations for three years (2015-2017).. Promising genotype and standard checks were planted on 10x10m^2 at nine locations for variety verification trial in 2018 for evaluation. Finally 'Gadisa' approved as superior coriander variety for Bale mid altitude and similar agro ecologies in 2019.

Morphological Characteristics of Gadisa

The released variety *Gadisa* exhibited similar morphological and agronomic characteristics compared to the standard check walta'i. *Gadisa* has vigor's and Erect growth habit, white flower color, brown seed color with medium day to flowering, days to maturity and plant height (68, 123 and 62 cm), respectively.

Yield Performance

Gadisa (*Acc. MAB-030*) showed superior yielding ability, producing a mean tuber yield of 15 – 33 t ha^{-1} at research field and 12 – 21 t ha^{-1} on farmers' field. In fact, the seed yield of the new variety exceeded that of the standard check walta'i about 14.56%.

Adaptation and Agronomic recommendation

Gadisa is Coriander variety released for Bale high lands, south eastern Ethiopia. It is well adapted in similar agro ecologies with altitude of 1650 -2400 m.a.s.l with annual rainfall 650 – 800 mm. Recommended fertilizer rate for coriander is 100 kg ha^{-1} NPS which is applied at planting while the spacing between rows is 30cm, respectively for planting

Table 1. Agronomic and Morphological descriptors for newly released Coriander variety

Variety Name	***Gadisa* (Acc. MAB-030)**
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 -12 Broadcasting - 15
Planting date	End of August to late September
Fertilizer rate(kg/ha)	NPS = 100
Days to flowering	68
Days to Maturity	123
Plant Height(cm)	62
Growth habit	erect
Seed Color	Brown
Flower Color	White

Yield (Qt/ha)		
	Research field	15 - 33
	Farmers field	12 - 21
Oleoresin content (%)		21.36
Year of Release		2019
Breeder/Maintainer		Sinana ARC/IQQO

CONCLUSION AND RECOMMENDATION

'*Gadisa'* was found to be superior to the standard check walta'i variety in terms of both seed yield and oleoresin content. Therefore, '*Gadisa'* Coriander variety could be cultivated sustainably and profitably by smallholder farmers and investors in Bale and similar agro ecologies in the country.

ACKNOWLEDGEMENTS

The financial assistance of Oromia Agricultural Research Institute is sincerely acknowledged and all staffs of horticulture and seed spice case team of Sinana Agricultural Research center is also acknowledged for field management and data collection

REFERENCES

Beemnet Mengesha, Getinet Alemaw and Bizuayhu Tesfaye. 2010. Performance of Ethiopian Coriander (Coriandrum sativum L.) Accessions in Vegetative, Phenological, Generative and Chemical Characters. Improving Quality Production of Horticultural Crops for Sustainable Development Proceedings, Februay 04-05, 2010. Jimma University College of Agriculture and Veterinary Medicine, Jimma, Ethiopia.

Hedburg, 2013. Flora of Ethiopia and Eritrea Apiaceae to Dipsacaceae. Hedeger, I., S. Edwards and Sileshi Nemomsa (Eds.). Volume 4, Part 1. Uppsala, Sweden. 352pp.

Jansen, P.C.M. 1981. Spices, condiments and medicinal plants in Ethiopia; their taxonomy and agricultural significance. Center for Agricultural Publishing and Documentation, Wageningen, Netherlands. 294pp. Parthasarathy V, Chempakam B, Zachariah TJ. Chemistry of spices. CAB International. 2008;455.

Romanenko, L.G., Nevkrytaja, N.V. and Kuznecova, E.J.U. 1991. Features of pollination in coriander. Moscow, Russia.pp. 16-17. In: Diederichsen, A. 1996. Coriander (*Corianderum sativum* L). Promoting the conservation and use of underutilized and neglected crops. 3. Institute of Plant Genetics and Crop Plant Research, Gaterslbebn/ International Plant Genetic Resources Institute, Rome, Italy. 83pp.

The Release and Registration of 'Wabi' Potato (Solanum tuberosom L.) Variety

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ABSTRACTS

Wabi with the accession name CIP-84866-5 is a potato variety released by Sinana Agricultural Research center. The trial was conducted at Sinana Agricultural research centre from observation nursery to preliminary yield trial and promising potato genotypes were selected from yield trial based on tuber yield and reaction to late blight. These promising genotypes were evaluated against standard check Moti and Belete across three locations for three years (2016 to 2018). *Wabi* showed superior yielding ability, producing a mean tuber yield of 44 - 47.52 t ha^{-1} at research field and 31- 45.85 t ha^{-1} on farmers' field. In fact, the tuber yield of the new variety exceeded that of the standard check Belete and Moti varieties by about 11.39% and 14.56% respectively. Finally *Wabi* was released as variety for Bale high lands and similar agro ecologies

***Key Words**: Potato (*Solanum tuberosum*), Variety verification,Wabi*

INTRODUCTION

Potato (*Solanum tuberosum*) is a valuable crop for smallholder farmers in Ethiopia, serving as both cash and food security crop. It is a nutritionally balanced food crop, which provides a high calorie intake and a substantial amount of vitamins. Due to its nutritional value, potato is considered by the Government of Ethiopia as one of the strategic commodities for ensuring food security (FAO, 2018). Also, potato is one of the most productive food crops in terms of nutrition (edible energy and good quality protein) and in terms of yield per hectare, approximately doubles that of grains (Asefa *et al.*, 2016; FAO, 2018).

In Ethiopia, especially in Bale high lands, potato is produced for local consumption. Addis Ababa is the main market for potatoes produced in South-Eastern Oromia, while other important markets centres including Adama, Bishoftu, Hawassa, Shashamene and Harer were the majors. Ethiopia exports mainly fresh and chilled potato, followed by a relative small portion of potato seed. The exports of potato grew substantially in recent years, both in terms of quantity and value. According to FAO(2018) In 2015, Ethiopia exported approximately 71 thousand tonnes of potato to regional markets. Djibouti is by far the largest market outlet, absorbing approximately 80 to 90 percent of Ethiopian's potato export while Somalia is the second largest market, receiving 8 to 15 Percent of the total. Other regional markets such as Sudan, Yemen and Saudi Arabia import small quantities of potatoes from Ethiopia.

Bale Zone is known by its suitable environmental condition for potato production and different agro ecologies. But, the production of this crop is not as much as the potential of the Zone. The most bottlenecks for potato production are lack of improved varieties and late blight diseases. Although improved potato varieties resistant to late blight are being developed, some varieties with major gene resistance are quickly overcome by

Phythophtora infestans. Therefore, varieties with better resistance to late blight are needed every time. Accordingly, this activity was developed to evaluate and release high yielder, stable and resistance to late blight diseases to bridge this technological gap.

Varietal Origin/Pedigree and Evaluation

'*Wabi'* with the accession name of CIP-84866-5 is CIP material which introduced from Holleta agricultural research center and developed through selection. About 12 promising potato genotypes were evaluated against standard check Moti which was released from Sinana Agricultural Research Center and Belete which was released nationally from Holleta agricultural research center across three locations for three years (2016 to 2018). Promising genotypes and standard checks were further evaluated under verification trial & planted on $10x10m^2$ at nine environments in 2019 and evaluated by national Variety Releasing Committee. Finally, *Wabi* was officially released for further demonstration and dissemination for wider production in the highlands of Bale and similar agro-ecologies.

Morphological Characteristics of *Wabi*

The released variety *Wabi* exhibited good-natured morphological and agronomic characteristics compared to the standard check Moti and Belete. It has deep green foliage, oval tuber shape with very shallow eye depth and medium of days to flowering (64), days to maturity (112) and plant height (53.96 cm)(Table 1).

Yield Performance

*Wabi (*CIP-84866-5) showed superior yielding ability, producing a mean tuber yield of 44 - 47.52 t ha^{-1} at research field and 31- 45.85 t ha^{-1} on farmers' field. In fact, the tuber yield of the new variety exceeded that of the standard check Belete and Moti variety by about 11.39% and 14.56%, respectively.

Adaptation and Agronomic recommendation

Wabi is potato variety released for Bale highlands and similar agro-ecologies. It is well adapted in the altitude range of 2350 -3650 m.a.s.l with annual rainfall 600 -1000 mm. Recommended fertilizer rate for *Wabi* is 165 kg of nitrogen which is split applied at planting and at flower initiation and 195 kg ha^{-1} of NPS while the spacing between plants and rows is 30x75cm, respectively for planting

Table 1:- Agronomic and Morphological Characteristic of *Wabi*, thenewly released potato Variety for Bale high lands and similar agro-ecologies

Variety Name	***Wabi* (CIP-84866-5)**
Agronomic and Morphological Characteristics	
Adaptation Area	Sinana, Goba, Dinsho and similar agro ecology
Altitude(masl)	2350 -3650
Rain fall(mm)	600 -1000
Soil type	Clay Loam
Seed Rate(Tuber/ha)	Row planting -10 15/Qt/he(44,440tuber/ha)
Fertilizer rate(kg/ha)	N=165 and NPS =195

Days to flowering	63.78
Days to Maturity	112.48
Plant Height(cm)	53.96
Growth habit	Erect
Tuber shape	Oval
Eye depth	Very shallow
Flower color	White
Tuber color	White
Disease reaction	Tolerant to late blight
Yield (t/ha)	Research field = 44 - 47.52
	Farmers field = 31- 45.85
Year of Release	2020
Breeder/Maintainer	SARC/IQQO

CONCLUSION

The newly released Potato variety 'Wabi' was found to be superior to the commercial variety Moti and Belete which were used as a standard check, in terms of both tuber yield and reaction to late blight. The variety was also found to be stable over seasons and locations. It is, thus, concluded that, 'Wabi' potato variety could be cultivated sustainably and profitably by smallholder farmers and investors in highlands of Bale and similar agro ecologies in the country

ACKNOWLEDGEMENTS

The authors are acknowledged Oromia Agricultural Research Institute, Sinana Agricultural Research Center and AGP-II program for financing and facilitate this research work.

REFERENCES

Brasesco, F., Asgedom, D., Casari, G. 2019. *Strategic analysis and intervention plan for potatoes and potato products in the Agro-Commodities Procurement Zone of the pilot Integrated Agro-Industrial Park in Central-Eastern Oromia, Ethiopia*. Addis Ababa, FAO. 80 pp. Licence: CC BY-NC-SA 3.0 IGO.

Getachew Asefa, Wassu Mohammed and Tesfaye Abebe 2016: Genetic variability for yield, related traits and reaction to late blight in potato (*Solanum tuberosum L.*) genotypes at Sinana, South Eastern Ethiopia. *Journal of Crop and Weed, 12(2):60-64(2016)*

Evaluation of Potato genotypes for yield and yield related parameters in Bale Highlands, Southeastern Ethiopia

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ABSTRACT
Bale Zone is known for potato production, but the productivity of the crop is low due to many factors among which lack high yielding variety tolerant of potato disease is major ones. A study was conducted to evaluate potato genotypes for stable high yielding and resistance to late blight. The experiment was laid out in randomized complete block design with three replications at three locations (Sinana, Goro and Gindhir districts) for three years (2017-2019) during 'Gena' cropping season. The highest total tuber yield was recorded from genotypes CIP-392640-524 (45.75 t ha^{-1}) followed by CIP-395114.5 (40.01 t ha^{-1}) while the lowest total tuber yield was obtained from local checks (25.27 t ha^{-1}). The yield performance of genotypes (CIP-392640-524) across environments and yield advantage of genotype over standard checks(Moti) 11.45% with less disease (late blight reaction). This suggested that, the genotypes will be promoted to variety verification trial stage for Bale highlands and similar agro ecologies
Key Words: *Late blight, Potato (Solanum tuberosum), stable performance*

INTRODUCTION
Potato considered as a food security crop that helps to meet the rising of food demands in the tropical highlands of Sub-Saharan Africa (Kolech, 2019). Like many other countries in the world, potato is a very important food and cash crop especially on the highland and mid altitude areas of Ethiopia. In highlands of Ethiopia, the potato holds great promise for improving the livelihoods of millions of smallholder farmers. The potential for high yield, early maturity and excellent food value give potato great potential for improving food security, increasing household income and reducing poverty. In Ethiopia, potato ranks first in the category of root and tuber crops in terms of area coverage and total production (Abebe, 2019). Its contribution to the food security and food self-sufficiency strategy of the country, income generation and export is also great. It is one of the most productive food crops in terms of nutrition (edible energy and good quality protein) and in terms of yield per hectare (approximately double that of grains) (FAO, 2019). It is grown in Ethiopia in almost all the regional states. It is possible to see the crop in field round the year in one part of the country or the other both under irrigation and rainfed.

In Ethiopia, potato breeding programs depend entirely on CIP materials. These introduced potato materials served as base population for developing promising cultivars. The variety development which involves evaluation, selection, release and registration procedures pass through several stages. It is mandatory to introduce potato genotypes every time from the source if creating variation through crossing is not implemented. The introduced genotypes need to be evaluated for target area or for wide adaptability across regions in the country.

In Bale highlands, potato production is mainly depends on rain fed and also irrigation in some areas. However, its average yield is not as much as the potential of the Zone. The low yield is attributed to many factors such as shortage of good quality seeds of improved potato varieties and diseases (mainly late bight) have prevented growers from achieving full yield. Although improved potato varieties resistant to late blight were developed, some varieties with major gene resistance are quickly overcome by Phythophtora infestans. Hence, it is necessary to introduce potato genotypes from the source. The introduced genotypes need to be evaluated for target area. Therefore, varieties with better resistance to late blight are needed every time. Accordingly, this activity was initiated to evaluate potato genotypes for stable high yielding and tolerant to late blight disease adaptable to the highlands of Bale and similar agro ecologies.

MATERIAL AND METHODS

A total of eight potato genotypes which consisted of 6 advanced clones, one standard check (Moti) variety and one farmers cultivar ‘kellecho’ as a local check were evaluated at Sinana Agricultural Research Centre on station, Goba and Dinsho on-farm for three years (2017-2019) during ‘Gena’ cropping season. The experiment was arranged in randomized complete block design (RCBD) with three replications. The spacing between rows and plants were 0.75 m and 0.30 m, respectively. The spacing between plots and adjacent replications were 1 m and 1.5 m, respectively. Fertilizer application was made as per the recommendation for the crop which is 165 and 195 kg ha^{-1} urea and NPS, respectively. Nitrogen fertilizer was applied at the rate of 75 kg ha^{-1} in the form of Urea in two splits, half after full emergence (two weeks after planting) and half at tubers initiation (at the start of flowering). Moreover, other management practices were uniformly applied to all experimental plots.

Data collection and Statistical Analysis

The two middle rows were used for data collection. Data were collected on Phenological, growth parameters, tuber yield and yield components. Collected data was subjected to analysis of variance (ANOVA) for RCBD using Genstat 16th edition software. Means that are significantly different were compared using Least Significant Difference (LSD) at 5% level of significance.

Table 1. Combined Summary of Mean tuber Yield, Other agronomic traits and Disease measured on promising potato genotypes Selected as candidate for release and checks in regional variety trial across nine environments

No	genotypes	DE	DF	DM	PH	NSH	UTNH	MTY	TTY	UMTY	MTNH	DI
1	CIP 396039-1	18.11	65.7	114.89	54.22	3.81	9.06	23.10	27.4	4.53	11.76	2.67
2	CIP 396029-2	18.33	61.70	107.33	43.15	2.02	10.07	32.31	37.35	5.03	12.12	4.04
3	CIP-395112-1	17.22	64.56	110.44	45.50	2.12	7.13	28.14	30.2	2.07	8.03	4.37
4	CIP-395114.5	16.89	59.26	108.07	56.22	3.15	8.30	38.41	41.01	3.65	12.34	4.33
5	CIP-392640-524	16.89	64.96	113.37	54.79	3.89	5.53	44.96	45.75	1.79	14.69	2.30
6	Moti	18.89	63.26	110.89	46.46	3.08	7.79	37.62	40.51	3.89	6.73	3.59
7	CIP-36240.23	16.59	63.78	112.48	53.96	3.36	7.52	37.69	39.95	3.26	13.29	2.22
8	Local	16.30	62.22	104.93	48.53	4.42	20.49	15.02	25.27	10.24	7.13	4.83
Mean		17.53	63.14	110.3	50.35	3.12	9.48	33.4	35.93	4.3	10.71	
CV		25.00	17.90	15.20	34.10	47.70	19.50	22.60	16.50	19.50	53.00	
LSD		2.38	6.04	9.02	9.07	0.79	2.93	11.63	11.90	1.46	3.09	

NB: DE= days of emergence, DF=days to flower, DM=days to Maturity, PH=plant height, NSH=number of stem per hill, UTNH = unmarketable tuber number per hill, MTY =marketable tuber yield t/ha, TTYT=total tuber yield t/ha, UMTY= unmarketable tuber yield t/ha MTNH =marketable tuber number per hill, ,DI = late bligtht.

Table 2: Means of tuber yield (t ha^{-1}) of eight potato genotypes across location and years

	Sinana			Goba			Disho			
Genotype	**2009**	**2010**	**2011**	**2009**	**2010**	**2011**	**2009**	**2010**	**2011**	**GrandMeans**
CIP 396039-1	37.6	35.49	37.5	35.49	35.49	36.07	33.66	36.83	36.07	27.4
CIP 396029-2	51.0	39.06	34.0	39.06	39.06	34.00	35.39	12.28	24.13	37.35
CIP-395112-1	57.5	28.63	45.9	28.63	28.63	28.63	14.03	17.35	16.20	30.2
CIP-395114.5	39.5	43.50	39.5	49.25	43.50	42.25	54.87	49.48	56.87	41.01
CIP-392640-524	46.0	49.70	49.9	51.77	49.70	50.74	36.44	49.74	56.27	45.75
Moti	40.4	40.01	40.4	40.10	40.01	42.01	43.72	44.25	42.43	40.51
CIP-36240.23	24.6	47.97	42.0	36.00	47.97	32.00	38.93	22.57	37.09	39.95
Local	53.9	29.28	15.7	29.28	29.28	29.28	12.27	29.08	12.70	25.27
Mean	42.1	37.37907	40.2	38.05	37.37907	38.17	1.022414	32.1728	31.73	
CV	13.1	40.90	20.1	29.70	40.90	26.00	35.00	21.80	25.10	
LSD	16.3	13.73	16.0	21.06	13.73	14.00	20.53	10.21	9.70	

The mean total tuber yield of genotypes across environment ranged from 45.75 to 25.27 t ha^{-1}. The highest total tuber yield was recorded from genotypes CIP-392640-524 (45.75 t ha^{-1}) followed by CIP-395114.5(40.01 t ha^{-1}) while the lowest total tuber yield was obtained from local checks (25.27 t ha^{-1}). The genotypes have total tuber yield advantage of 11.45% over standard check Moti. Addisu *et al.* (2013) and Baye (2002) also reported some of the newly introduced potato genotypes had higher tuber yield than the existing commercial potato varieties and mean total tuber yield of released varieties (*Belete*, *Gudanie* and *Ararsa)* was within the range of 15.9 to 41 t ha^{-1}. This indicated the presence of variation in genotypes under study for total tuber yield that can be exploited in improving the crop. The highest means of marketable tuber yield and marketable tuber number per hill and the lowest unmarketable tuber yield and unmarketable tuber number per hill was recorded from the same genotypes. It has 22% of marketable tuber yield advantage over standard check Moti. Asefa *et al.* (2016) reported positive and significant genotypic correlations in the range was observed between total tuber yield per hectare and marketable tuber yield, Hence, improvement of total tuber yield in Potato is possible through selection of best performing genotypes than other genotypes for those strongly correlated traits. This showed that total tuber yield per hectare is the end product of components of several yield contributing characters. Days to maturity and days to flowering were ranged from 114.89 to 104.93 and 65.7 to 59.26, respectively. CIP-392640-524 recorded similar days to emergence, flowering and maturity with standard check moti while it recorded higher days to maturity than local check. The highest mean of total tuber yield was recorded from Dinsho (56.27 t ha^{-1}) followed by Goba (51.77 t ha^{-1}) location.

CONCLUSION AND RECOMMENDATION

The yield performance of genotype (CIP-392640-524) were across environments and showed yield advantages of 11.45% over standard checks (Moti) with less disease reaction mainly late blight potato. This implied that the genotypes should be promoted to variety verification trial stage for further evaluation at on-farm and on-station in the highlands Bale.

ACKNOWLEDGMENTS

The Authors would like to thank all Horticulture and Seed Spice case team staff of Sinana Agricultural Research Centre. Oromia Agricultural Research Institute is also dully acknowledged for financial support

REFERENCES

Abebe 2019, Review of Potato Research and Development in Ethiopia: Achievements and Future Prospects Journal of Biology, Agriculture and Healthcare Vol.9, No.19, 2019 www.iiste.org

Addisu F. Yohannes P. and Habtamu Z. 2013**.** Genetic variability and association between agronomic characters in some potato (*Solanum tuberosum* L.) genotypes in SNNPRS Ethiopia. *Int. Biodiversity Con*. **5:** pp :523-28

Asefa, G. and W. Mohammed. 2016. Correlation coefficients, path analysis and disease reaction between yield and yield components in Potato (*Solanum tuberosum* L.) genotypes in Bale, South Eastern Ethiopia. *Plant Science Today* 3(3): 293-297. http://dx.doi.org/10.14719/pst.2016.3.3.201

Baye, B., Ravishankar, R. and Singh, H. 2005. Variability and association of tuber yield and related traits in potato (*Solanum tubersum* L.). *Ethiopian Agric. Sci.* **18:** 103-21.

Brasesco, F., Asgedom, D., Casari, G. 2019. *Strategic analysis and intervention plan for potatoes and potato products in the Agro-Commodities Procurement Zone of the pilot Integrated Agro-Industrial Park in Central-Eastern Oromia, Ethiopia*. Addis Ababa, FAO. 80 pp. Licence: CC BY-NC-SA 3.0 IGO.

Kolech, Semagn Asredie, Walter De Jong, Donald Halseth and Steffen Schulz. 2019. Understanding farmer needs and unlocking local genetic resources for potato improvement: a case study in Ethiopia. *Afr. J. Food Agric. Nutr. Dev*.; 19(1):13883-13905 DOI: 10.18697/ajfand.84.BLFB1012

Registration of "*Gadisa*" Newly Released Coriander Variety

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ABSTRACTS

Gadisa (Acc.MAB-030) is coriander variety developed and released by Oromia Agricultural Research institute, Sinana Agricultural Research Center. Originally it was obtained from landrace collections followed by pure line selection method. The trial was done at Sinana Agricultural Research Center from observation nursery to preliminary yield trial. But, it was conducted at Sinana, Goro and Gindhir on farmers' fields for three years (2015 to 2017) during multi-location or regional variety trial stage. . Mean seed yield of Gadisa ranged from 15 to 33 Qt ha^{-1} on research field, and 12 to 21 Qt ha^{-1} on farmers field with 21.36% oleoresin content. Finally '*Gadisa'* released as superior coriander variety for Bale mid altitude and similar agro ecologies in 2019.

***Key Words**: Coriander, Gadisa, Oleoresin content, Variety verification.*

INTRODUCTION

Coriander (*Coriandrum sativum* L, 2n=2x=22) is a diploid annual plant, belonging to the Apiaceae/Umbliferae family (Hedburg, 2013). Due to wide range of climatic, ecological and topographic conditions, Ethiopia has long been known as a center of origin and diversity for several plants among which, coriander is the one in which Ethiopia is known as a center of primary diversity (Jansen, 1981). The existence of sufficient variability for agronomic and chemical traits for Ethiopian coriander accessions was also reported by Beemnet and Getinet (2010). Coriander is used as a spice in food, beverage, and pharmaceuticals industries. It is also a good melliferous plant and studies indicated that one hectare of coriander allows honey bees to collect about 500 kg of honey (Romanenko *et al*., 1991). In Ethiopia, mature fruits, which is commonly named as seeds are commonly used as spice and the fresh green herb also used as a green salad. Coriander seed is widely used as a spice in diversified societies of the country and its seed is found in every market. In addition, the leaves and the immature fruits are used as an ingredient for the preparation of ‘‘data’’, a traditional spice eaten as a “wot” together with meat (Beemnet et al., 2010).

Plant breeders usually maintain their own active collections consisting of carefully selected genotypes, but there is a continuous need for new, specific trait and combinations of trait in introductions, selection, domestication and improvement programme, allowing new problems to be solved and new demands to be met. Coriander is the major seed spices produced in Bale mid altitude, however, its production and productivity is low. Lack of improved varieties that are high yielding and resistance/tolerant to disease 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 coriander genotypes that are stable, high yielding and adaptable for Bale mid altitude and similar agro ecologies.

Varietal Origin and Evaluation

Gadisa (*Acc. MAB-030*) coriander variety developed and released by Oromia Agricultural Research institute, Sinana Agricultural Research Center for Bale and similar Agro ecologies. Originally it was obtained from landrace collections through pure line development. A total of .75 genotypes were evaluated at sinana Agricultural research Centre from observation nursery to preliminary yield trial. About 16 genotypes were selected for further multi-location trial based on seed yield and reaction to diseases. These genotypes were evaluated against standard check Walta’i across locations for three years (2015-2017).. Promising genotype and standard checks were planted on $10x10m^2$ at nine locations for variety verification trial in 2018 for evaluation. Finally ‘Gadisa’ approved as superior coriander variety for Bale mid altitude and similar agro ecologies in 2019.

Morphological Characteristics of Gadisa

The released variety *Gadisa* exhibited similar morphological and agronomic characteristics compared to the standard check walta’i. *Gadisa* has vigor's and Erect growth habit, white flower color, brown seed color with medium day to flowering, days to maturity and plant height (68, 123 and 62 cm), respectively.

Yield Performance

Gadisa (*Acc. MAB-030*) showed superior yielding ability, producing a mean tuber yield of 15 – 33 t ha^{-1} at research field and 12 – 21 t ha^{-1} on farmers’ field. In fact, the seed yield of the new variety exceeded that of the standard check walta’i about 14.56%.

Adaptation and Agronomic recommendation

Gadisa is Coriander variety released for Bale high lands, south eastern Ethiopia. It is well adapted in similar agro ecologies with altitude of 1650 -2400 m.a.s.l with annual rainfall 650 – 800 mm. Recommended fertilizer rate for coriander is 100 kg ha^{-1} NPS which is applied at planting while the spacing between rows is 30cm, respectively for planting

Table 1. Agronomic and Morphological descriptors for newly released Coriander variety

Variety Name	***Gadisa* (Acc. MAB-030)**
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 -12 Broadcasting - 15
Planting date	End of August to late September
Fertilizer rate(kg/ha)	NPS = 100
Days to flowering	68
Days to Maturity	123
Plant Height(cm)	62
Growth habit	Erect
Seed Color	Brown
Flower Color	White
Yield (Qt/ha)	
Research field	15 – 33
Farmers field	12 – 21
Oleoresin content (%)	21.36
Year of Release	2019
Breeder/Maintainer	Sinana ARC/IQQO

CONCLUSION AND RECOMMENDATION

'*Gadisa'* was found to be superior to the standard check walta'i variety in terms of both seed yield and oleoresin content. Therefore, '*Gadisa'* Coriander variety could be cultivated sustainably and profitably by smallholder farmers and investors in Bale and similar agro ecologies in the country.

ACKNOWLEDGEMENTS

The financial assistance of Oromia Agricultural Research Institute is sincerely acknowledged and all staffs of horticulture and seed spice case team of Sinana Agricultural Research center is also acknowledged for field management and data collection

REFERENCES

Beemnet Mengesha, Getinet Alemaw and Bizuayhu Tesfaye. 2010. Performance of Ethiopian Coriander (Coriandrum sativum L.) Accessions in Vegetative, Phenological, Generative and Chemical Characters. Improving Quality Production of Horticultural Crops for Sustainable Development Proceedings, Februay 04-05, 2010. Jimma University College of Agriculture and Veterinary Medicine, Jimma, Ethiopia.

Hedburg, 2013. Flora of Ethiopia and Eritrea Apiaceae to Dipsacaceae. Hedeger, I., S. Edwards and Sileshi Nemomsa (Eds.). Volume 4, Part 1. Uppsala, Sweden. 352pp.

Jansen, P.C.M. 1981. Spices, condiments and medicinal plants in Ethiopia; their taxonomy and agricultural significance. Center for Agricultural Publishing and Documentation, Wageningen, Netherlands. 294pp. Parthasarathy V, Chempakam B, Zachariah TJ. Chemistry of spices. CAB International. 2008;455.

Romanenko, L.G., Nevkrytaja, N.V. and Kuznecova, E.J.U. 1991. Features of pollination in coriander. Moscow, Russia.pp. 16-17. In: Diederichsen, A. 1996. Coriander (*Corianderum sativum* L). Promoting the conservation and use of underutilized and neglected crops. 3. Institute of Plant Genetics and Crop Plant Research, Gaterslbebn/ International Plant Genetic Resources Institute, Rome, Italy. 83pp.

The Release and Registration of 'Wabi' Potato (Solanum tuberosom L.) Variety

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ABSTRACTS

Wabi with the accession name CIP-84866-5 is a potato variety released by Sinana Agricultural Research center. The trial was conducted at Sinana Agricultural research centre from observation nursery to preliminary yield trial and promising potato genotypes were selected from yield trial based on tuber yield and reaction to late blight. These promising genotypes were evaluated against standard check Moti and Belete across three locations for three years (2016 to 2018). *Wabi* showed superior yielding ability, producing a mean tuber yield of 44 - 47.52 t ha^{-1} at research field and 31- 45.85 t ha^{-1} on farmers' field. In fact, the tuber yield of the new variety exceeded that of the standard check Belete and Moti varieties by about 11.39% and 14.56% respectively. Finally *Wabi* was released as variety for Bale high lands and similar agro ecologies

***Key Words**:* Potato (*Solanum tuberosum*), *Variety verification,Wabi*

INTRODUCTION

Potato (*Solanum tuberosum*) is a valuable crop for smallholder farmers in Ethiopia, serving as both cash and food security crop. It is a nutritionally balanced food crop, which provides a high calorie intake and a substantial amount of vitamins. Due to its nutritional value, potato is considered by the Government of Ethiopia as one of the strategic commodities for ensuring food security (FAO, 2018). Also, potato is one of the most productive food crops in terms of nutrition (edible energy and good quality protein) and in terms of yield per hectare, approximately doubles that of grains (Asefa *et al.*, 2016; FAO, 2018)

In Ethiopia, especially in Bale high lands, potato is produced for local consumption. Addis Ababa is the main market for potatoes produced in South-Eastern Oromia, while other important markets centres including Adama, Bishoftu, Hawassa, Shashamene and Harer were the majors. Ethiopia exports mainly fresh and chilled potato, followed by a relative small portion of potato seed. The exports of potato grew substantially in recent years, both in terms of quantity and value. According to FAO(2018) In 2015, Ethiopia exported approximately 71 thousand tonnes of potato to regional markets. Djibouti is by far the largest market outlet, absorbing approximately 80 to 90 percent of Ethiopian's potato export while Somalia is the second largest market, receiving 8 to 15 Percent of the total. Other regional markets such as Sudan, Yemen and Saudi Arabia import small quantities of potatoes from Ethiopia.

Bale Zone is known by its suitable environmental condition for potato production and different agro ecologies. But, the production of this crop is not as much as the potential of the Zone. The most bottlenecks for potato production are lack of improved varieties and late blight diseases. Although improved potato varieties resistant to late blight are being developed, some varieties with major gene resistance are quickly overcome by Phythophtora infestans. Therefore, varieties with better resistance to late blight are needed every time. Accordingly, this activity was developed to evaluate and release high yielder, stable and resistance to late blight diseases to bridge this technological gap.

Varietal Origin/Pedigree and Evaluation

'*Wabi'* with the accession name of CIP-84866-5 is CIP material which introduced from Holleta agricultural research center and developed through selection. About 12 promising potato genotypes were evaluated against standard check Moti which was released from Sinana Agricultural Research Center and Belete which was released nationally from Holleta agricultural research center across three locations for three years (2016 to 2018). Promising genotypes and standard checks were further evaluated under verification trial & planted on $10x10m^2$ at nine environments in 2019 and evaluated by national Variety Releasing Committee. Finally, *Wabi* was officially released for further demonstration and dissemination for wider production in the highlands of Bale and similar agro-ecologies.

Morphological Characteristics of *Wabi*

The released variety *Wabi* exhibited good-natured morphological and agronomic characteristics compared to the standard check Moti and Belete. It has deep green foliage, oval tuber shape with very shallow eye depth and medium of days to flowering (64), days to maturity (112) and plant height (53.96 cm)(Table 1).

Yield Performance

*Wabi (*CIP-84866-5) showed superior yielding ability, producing a mean tuber yield of 44 - 47.52 t ha^{-1} at research field and 31- 45.85 t ha^{-1} on farmers' field. In fact, the tuber yield of the new variety exceeded that of the standard check Belete and Moti variety by about 11.39% and 14.56%, respectively.

Adaptation and Agronomic recommendation

Wabi is potato variety released for Bale highlands and similar agro-ecologies. It is well adapted in the altitude range of 2350 -3650 m.a.s.l with annual rainfall 600 -1000 mm.

Recommended fertilizer rate for *Wabi* is 165 kg of nitrogen which is split applied at planting and at flower initiation and 195 kg ha^{-1} of NPS while the spacing between plants and rows is 30x75cm, respectively for planting

Table 1:- Agronomic and Morphological Characteristic of *Wabi,* thenewly released potato Variety for Bale high lands and similar agro-ecologies

Variety Name	***Wabi* (CIP-84866-5)**
Agronomic and Morphological Characteristics	
Adaptation Area	Sinana, Goba, Dinsho and similar agro ecology
Altitude(masl)	2350 -3650
Rain fall(mm)	600 -1000
Soil type	Clay Loam
Seed Rate(Tuber/ha)	Row planting -10 15/Qt/he(44,440tuber/ha)
Fertilizer rate(kg/ha)	N=165 and NPS =195
Days to flowering	63.78
Days to Maturity	112.48
Plant Height(cm)	53.96
Growth habit	Erect
Tuber shape	Oval
Eye depth	Very shallow
Flower color	White
Tuber color	White
Disease reaction	Tolerant to late blight
Yield (t/ha)	Research field = 44 - 47.52 Farmers field = 31- 45.85
Year of Release	2020
Breeder/Maintainer	SARC/IQQO

CONCLUSION

The newly released Potato variety ‘Wabi’ was found to be superior to the commercial variety Moti and Belete which were used as a standard check, in terms of both tuber yield and reaction to late blight. The variety was also found to be stable over seasons and locations. It is, thus, concluded that, ‘Wabi’ potato variety could be cultivated sustainably and profitably by smallholder farmers and investors in highlands of Bale and similar agro ecologies in the country

ACKNOWLEDGEMENTS

The authors are acknowledged Oromia Agricultural Research Institute, Sinana Agricultural Research Center and AGP-II program for financing and facilitate this research work.

REFERENCES

Brasesco, F., Asgedom, D., Casari, G. 2019. *Strategic analysis and intervention plan for potatoes and potato products in the Agro-Commodities Procurement Zone of the pilot Integrated Agro-Industrial Park in Central-Eastern Oromia, Ethiopia*. Addis Ababa, FAO. 80 pp. Licence: CC BY-NC-SA 3.0 IGO.

Getachew Asefa, Wassu Mohammed and Tesfaye Abebe 2016: Genetic variability for yield, related traits and reaction to late blight in potato (*Solanum tuberosum L.*) genotypes at Sinana, South Eastern Ethiopia. *Journal of Crop and Weed, 12(2):60-64(2016).*

Evaluation of Potato genotypes for yield and yield related parameters in Bale Highlands, Southeastern Ethiopia

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ABSTRACT

Bale Zone is known for potato production, but the productivity of the crop is low due to many factors among which lack high yielding variety tolerant of potato disease is major ones. A study was conducted to evaluate potato genotypes for stable high yielding and resistance to late blight. The experiment was laid out in randomized complete block design with three replications at three locations (Sinana, Goro and Gindhir districts) for three years (2017-2019) during 'Gena' cropping season. The highest total tuber yield was recorded from genotypes CIP-392640-524 (45.75 t ha^{-1}) followed by CIP-395114.5 (40.01 t ha^{-1}) while the lowest total tuber yield was obtained from local checks (25.27 t ha^{-1}). The yield performance of genotypes (CIP-392640-524) across environments and yield advantage of genotype over standard checks(Moti) 11.45% with less disease (late blight reaction). This suggested that, the genotypes will be promoted to variety verification trial stage for Bale highlands and similar agro ecologies

***Key Words**: Late blight, Potato (Solanum tuberosum), stable performance*

INTRODUCTION

Potato considered as a food security crop that helps to meet the rising of food demands in the tropical highlands of Sub-Saharan Africa (Kolech, 2019). Like many other countries in the world, potato is a very important food and cash crop especially on the highland and mid altitude areas of Ethiopia. In highlands of Ethiopia, the potato holds great promise for improving the livelihoods of millions of smallholder farmers. The potential for high yield, early maturity and excellent food value give potato great potential for improving food security, increasing household income and reducing poverty. In Ethiopia, potato ranks first in the category of root and tuber crops in terms of area coverage and total production (Abebe, 2019). Its contribution to the food security and food self-sufficiency strategy of the country, income generation and export is also great. It is one of the most productive food crops in terms of nutrition (edible energy and good quality protein) and in terms of yield per hectare (approximately double that of grains) (FAO, 2019). It is grown in Ethiopia in almost all the regional states. It is possible to see the crop in field round the year in one part of the country or the other both under irrigation and rainfed.

In Ethiopia, potato breeding programs depend entirely on CIP materials. These introduced potato materials served as base population for developing promising cultivars. The variety development which involves evaluation, selection, release and registration procedures pass through several stages. It is mandatory to introduce potato genotypes every time from the source if creating variation through crossing is not implemented. The introduced genotypes need to be evaluated for target area or for wide adaptability across regions in the country.
In Bale highlands, potato production is mainly depends on rain fed and also irrigation in some areas. However, its average yield is not as much as the potential of the Zone. The low yield is attributed to many factors such as shortage of good quality seeds of improved potato varieties and diseases (mainly late bight) have prevented growers from achieving full yield. Although improved potato varieties resistant to late blight were developed, some varieties with major gene resistance are quickly overcome by Phythophtora infestans. Hence, it is necessary to introduce potato genotypes from the source. The introduced genotypes need to be evaluated for target area. Therefore, varieties with better resistance to late blight are needed every time. Accordingly, this activity was initiated to evaluate potato genotypes for stable high yielding and tolerant to late blight disease adaptable to the highlands of Bale and similar agro ecologies.

MATERIAL AND METHODS

A total of eight potato genotypes which consisted of 6 advanced clones, one standard check (Moti) variety and one farmers cultivar 'kellecho' as a local check were evaluated at Sinana Agricultural Research Centre on station, Goba and Dinsho on-farm for three years (2017-2019) during 'Gena' cropping season. The experiment was arranged in randomized complete block design (RCBD) with three replications. The spacing between rows and plants were 0.75 m and 0.30 m, respectively. The spacing between plots and adjacent replications were 1 m and 1.5 m, respectively. Fertilizer application was made as per the recommendation for the crop which is 165 and 195 kg ha^{-1} urea and NPS, respectively. Nitrogen fertilizer was applied at the rate of 75 kg ha^{-1} in the form of Urea in two splits, half after full emergence (two weeks after planting) and half at tubers initiation (at the start of flowering). Moreover, other management practices were uniformly applied to all experimental plots.

Data collection and Statistical Analysis

The two middle rows were used for data collection. Data were collected on Phenological, growth parameters, tuber yield and yield components. Collected data was subjected to analysis of variance (ANOVA) for RCBD using Genstat 16th edition software. Means that are significantly different were compared using Least Significant Difference (LSD) at 5% level of significance.

Table 1. Combined Summary of Mean tuber Yield, Other agronomic traits and Disease measured on promising potato genotypes Selected as candidate for release and checks in regional variety trial across nine environments

No	genotypes	DE	DF	DM	PH	NSH	UTNH	MTY	TTY	UMTY	MTNH	DI
1	CIP 396039-1	18.11	65.7	114.89	54.22	3.81	9.06	23.10	27.4	4.53	11.76	2.67
2	CIP 396029-2	18.33	61.70	107.33	43.15	2.02	10.07	32.31	37.35	5.03	12.12	4.04
3	CIP-395112-1	17.22	64.56	110.44	45.50	2.12	7.13	28.14	30.2	2.07	8.03	4.37
4	CIP-395114.5	16.89	59.26	108.07	56.22	3.15	8.30	38.41	41.01	3.65	12.34	4.33
5	CIP-392640-524	16.89	64.96	113.37	54.79	3.89	5.53	44.96	45.75	1.79	14.69	2.30
6	Moti	18.89	63.26	110.89	46.46	3.08	7.79	37.62	40.51	3.89	6.73	3.59
7	CIP-36240.23	16.59	63.78	112.48	53.96	3.36	7.52	37.69	39.95	3.26	13.29	2.22
8	Local	16.30	62.22	104.93	48.53	4.42	20.49	15.02	25.27	10.24	7.13	4.83
Mean		17.53	63.14	110.3	50.35	3.12	9.48	33.4	35.93	4.3	10.71	
CV		25.00	17.90	15.20	34.10	47.70	19.50	22.60	16.50	19.50	53.00	
LSD		2.38	6.04	9.02	9.07	0.79	2.93	11.63	11.90	1.46	3.09	

NB: DE= days of emergence, DF=days to flower, DM=days to Maturity, PH=plant height, NSH=number of stem per hill, UTNH = unmarketable tuber number per hill, MTY =marketable tuber yield t/ha, TTYT=total tuber yield t/ha, UMTY= unmarketable tuber yield t/ha MTNH =marketable tuber number per hill, ,DI = late bligtht.

Table 2: Means of tuber yield (t ha^{-1}) of eight potato genotypes across location and years

	Sinana			Goba			Disho			
Genotype	**2009**	**2010**	**2011**	**2009**	**2010**	**2011**	**2009**	**2010**	**2011**	**Grand Means**
CIP 396039-1	37.6	35.49	37.5	35.49	35.49	36.07	33.66	36.83	36.07	27.4
CIP 396029-2	51.0	39.06	34.0	39.06	39.06	34.00	35.39	12.28	24.13	37.35
CIP-395112-1	57.5	28.63	45.9	28.63	28.63	28.63	14.03	17.35	16.20	30.2
CIP-395114.5	39.5	43.50	39.5	49.25	43.50	42.25	54.87	49.48	56.87	41.01
CIP-392640-524	46.0	49.70	49.9	51.77	49.70	50.74	36.44	49.74	56.27	45.75
Moti	40.4	40.01	40.4	40.10	40.01	42.01	43.72	44.25	42.43	40.51
CIP-36240.23	24.6	47.97	42.0	36.00	47.97	32.00	38.93	22.57	37.09	39.95
Local	53.9	29.28	15.7	29.28	29.28	29.28	12.27	29.08	12.70	25.27
Mean	42.1	37.37907	40.2	38.05	37.37907	38.17	1.022414	32.1728	31.73	
CV	13.1	40.90	20.1	29.70	40.90	26.00	35.00	21.80	25.10	
LSD	16.3	13.73	16.0	21.06	13.73	14.00	20.53	10.21	9.70	

The mean total tuber yield of genotypes across environment ranged from 45.75 to 25.27 t ha^{-1}. The highest total tuber yield was recorded from genotypes CIP-392640-524 (45.75 t ha^{-1}) followed by CIP-395114.5(40.01 t ha^{-1}) while the lowest total tuber yield was obtained from local checks (25.27 t ha^{-1}). The genotypes have total tuber yield advantage of 11.45% over standard check Moti. Addisu *et al.* (2013) and Baye (2002) also reported some of the newly introduced potato genotypes had higher tuber yield than the existing commercial potato varieties and mean total tuber yield of released varieties (*Belete*, *Gudanie* and *Ararsa)* was within the range of 15.9 to 41 t ha^{-1}. This indicated the presence of variation in genotypes under study for total tuber yield that can be exploited in improving the crop. The highest means of marketable tuber yield and marketable tuber number per hill and the lowest unmarketable tuber yield and unmarketable tuber number per hill was recorded from the same genotypes. It has 22% of marketable tuber yield advantage over standard check Moti. Asefa *et al.* (2016) reported positive and significant genotypic correlations in the range was observed between total tuber yield per hectare and marketable tuber yield, Hence, improvement of total tuber yield in Potato is possible through selection of best performing genotypes than other genotypes for those strongly correlated traits. This showed that total tuber yield per hectare is the end product of components of several yield contributing characters. Days to maturity and days to flowering were ranged from 114.89 to 104.93 and

65.7 to 59.26, respectively. CIP-392640-524 recorded similar days to emergence, flowering and maturity with standard check moti while it recorded higher days to maturity than local check. The highest mean of total tuber yield was recorded from Dinsho (56.27 t ha^{-1}) followed by Goba (51.77 t ha^{-1}) location.

CONCLUSION AND RECOMMENDATION

The yield performance of genotype (CIP-392640-524) were across environments and showed yield advantages of 11.45% over standard checks (Moti) with less disease reaction mainly late blight potato. This implied that the genotypes should be promoted to variety verification trial stage for further evaluation at on-farm and on-station in the highlands Bale.

ACKNOWLEDGMENTS

The Authors would like to thank all Horticulture and Seed Spice case team staff of Sinana Agricultural Research Centre. Oromia Agricultural Research Institute is also dully acknowledged for financial support

REFERENCES

Abebe 2019, Review of Potato Research and Development in Ethiopia: Achievements and Future Prospects Journal of Biology, Agriculture and Healthcare Vol.9, No.19, 2019 www.iiste.org

Addisu F. Yohannes P. and Habtamu Z. 2013**.** Genetic variability and association between agronomic characters in some potato (*Solanum tuberosum* L.) genotypes in SNNPRS Ethiopia. *Int. Biodiversity Con*. **5:** pp :523-28

Asefa, G. and W. Mohammed. 2016. Correlation coefficients, path analysis and disease reaction between yield and yield components in Potato (*Solanum tuberosum* L.) genotypes in Bale, South Eastern Ethiopia. *Plant Science Today* 3(3): 293-297. http://dx.doi.org/10.14719/pst.2016.3.3.201

Baye, B., Ravishankar, R. and Singh, H. 2005. Variability and association of tuber yield and related traits in potato (*Solanum tubersum* L.). *Ethiopian Agric. Sci.* **18:** 103-21.

Brasesco, F., Asgedom, D., Casari, G. 2019. *Strategic analysis and intervention plan for potatoes and potato products in the Agro-Commodities Procurement Zone of the pilot Integrated Agro-Industrial Park in Central-Eastern Oromia, Ethiopia*. Addis Ababa, FAO. 80 pp. Licence: CC BY-NC-SA 3.0 IGO.

Kolech, Semagn Asredie, Walter De Jong, Donald Halseth and Steffen Schulz. 2019. Understanding farmer needs and unlocking local genetic resources for potato improvement: a case study in Ethiopia. *Afr. J. Food Agric. Nutr. Dev*.; 19(1):13883-13905 DOI: 10.18697/ajfand.84.BLFB1012

Genotype by Environment Interaction and Yield Stability of Bread Wheat Genotypes in western Ethiopia

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Abstract

Studying genotype-by-environment interaction and determining representative testing environments are important for releasing new varieties. Sixteen bread wheat genotypes were evaluated to study their adaptability and stability in six environments of western Oromia. The experiment was laid in a randomized complete block design with three replications. The result of AMMI analysis of variance for genotype, environment and genotype-by-environment interaction, and interaction principal component analysis (IPCA-I and IPCA-II) showed 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 36.9% and 35.5%, of the total sum of squares of genotypes, respectively. Analysis using Eberhart and Russell model showed that genotypes G14 and G15 have regression coefficients closer to unity both (bi= 0.95) and nearly acceptable deviation from regression near to zero (s2di = 0.0.184 and 0.075), 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, G9, G10 and G15 attain IPCA values both (from positive and negative) relatively close to zero and hence are better stable and widely adaptable genotypes across location. However, G16, G14 and G12 were attained IPCA values far away from zero in both sides (either positive or negative, it indicates those genotypes specific location based adaptable. Therefore, both G15 and G10 genotypes are proposed for further research because of wider adaptability; the uppermost yielding genotype G9 is proposed and recommended for release in western Oromia.

Keywords: Bread wheat, AMMI model, G x E, genotype, stability

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal food crops in Ethiopia, from the total grain area coverage and production, wheat accounts about 13.49 and 15.63%, respectively, feeding population of the country and providing 15 % of total food calories and protein in human nutrition (CSA,2017, FAO,2014). 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 (CSA, 2019; Demeke and Marcantonio, 2013). The crop can be grown over wider agro-ecologies of Ethiopia mainly at mid and highland areas, commonly known as the east African wheat-belt (Dawit et al., 2017). Oromia is one of the largest region 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 tha^{-1}) is very low compared with other major wheat producing countries in the world like Germany (7.64 tha^{-1}), Denmark (7.2 tha^{-1}), Egypt (6.58 tha^{-1}), China (5.4 tha^{-1}), France (5.3 tha^{-1}), India (3.09 tha^{-1})(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. However, it is difficult to estimate all together the interaction effects of these all factors over years. Developing high yielder verities with stable in wide agro ecologies and rust diseases resistance genotypes are important in wheat variety development breeding strategy. Selection of bread wheat genotypes with wide adaptability across various environments is important before recommending for commercial production. Genotype-by-environment interaction and determining representative testing environments are important for releasing 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) resulting in 6 environments. Sixteen genotypes consisting of 15 advanced genotypes and one released variety were evaluated (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 m length and the spacing was 0.2m between rows and 0.50 m 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.

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 9.0 (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) analysis and was performed using PBSTAT-GE software version.

Table 1. Bread wheat genotypes evaluated in the six environments

Genotypes	Code	Source
ETBW8590	G1	CIMMYT
ETBW8610	G2	CIMMYT
ETBW8609	G3	CIMMYT
ETBW8579	G4	CIMMYT
ETBW8629	G5	CIMMYT
ETBW8638	G6	CIMMYT
ETBW8577	G7	CIMMYT
ETBW8647	G8	CIMMYT
ETBW9042	G9	CIMMYT
ETBW9019	G10	CIMMYT
ETBW8070	G11	CIMMYT
ETBW8427	G12	CIMMYT
ETBW8459	G13	CIMMYT
ETBW9037	G14	CIMMYT
ETBW9045	G15	CIMMYT
Liben	G16	CIMMYT

AMMI analysis

The Additive Main effect and Multiplicative Interaction (AMMI) model analysis was performed for grain yield. The AMMI model equation is given as:

$$yij = \mu + Gi + Ej + (\sum KnVniSnj) + Qij + eij$$

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.

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 ($kgha^{-1}$) of 16 bread wheat genotypes tested in six environments showed highly significant differences ($p<0.01$) for environments (E), genotypes (G) and IPCA4, and significant variation($p<0.05$) was obtained for environments by genotypes interaction (GEI), IPCA1, IPCA2, IPCA3 and IPCA4 (Table 2). These results were in agreement with the works of Assefa et al. (2020) who reported the significant difference of wheat genotypes, environments and their interactions were attributed to variations in different climatic and edaphic conditions across locations. This showed that the genotypes responded differently over environments, 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, 98.4% of the interaction sum of squares were cumulatively explained, of which 36.9%, 35.5%, 14.6%, 8.0% and 3.4% 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 G x E interaction (>50) was explained by the first two IPCA score (Gadisa et al.,2019 and Assefa et al.2020, on wheat; Dangachewet 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 square	Mean square	F value	Pr (>F)	G x E explained (%)
ENV	5	97249091.3	19449818.3	20.1	0.003	
REP(ENV)	12	11596003.2	966333.6	1.4	0.16	
GEN	15	372120458.3	24808030.6	41.8	0.001	
ENV:GEN	75	44473900.9	592985.3	0.9	0.025	
IPCA1	19	16402413.8	863284.9	1.3	0.021	36.9
IPCA2	17	15803645.3	929626.2	1.4	0.013	35.5
IPCA3	15	6505284.4	433685.6	0.6	0.084	14.6
IPCA4	13	3536053.7	272004.1	0.4	0.97	8.0
IPCA5	11	1498794.4	136254.0	0.2	0.01	3.4
Residuals	180	122838565.5	682436.5			

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 deviation from regression low or near to zero and high mean. The coefficient of regression (bi) values for sixteen genotypes used in this study ranged from 0.20 (G5) to 1.65 (G2) (Table3). Regression values of unity are interpreted as average stability. The variations in bi values proposed that the response of 16 genotypes is differed to the various environments. Variability among environments is a prominent factor and mostly determines the usefulness of bi values (Mohammadi et al., 2012). There was no genotype with bi-values equal to unity, while the regression coefficient values for some of genotypes including G14, G15 and G4 were close to 1. Genotype 2 had the highest (1.65) regression coefficient, followed by Genotype 1 (1.36)(Table3). The yields of these genotypes were lower than the other genotypes and significantly influenced by varying environmental conditions. However, genotypes 14(0.96) and 15(0.95) showed regression coefficient close to unity and with low deviation from regression value (0.075 and 0.009). 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 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 (Table 3), genotypes G9, G4, G10 and G15 were selected as the most stable varieties combining high grain yield performance with stability, hence these can be selected to the advanced yield trials for wide adaptable variety development. Although genotypes G9, G4 and G10 were high yielding genotypes had high ASV scores resulting in high YSI scores, however, they can be recommended for specific environments where they performed well. This method has been successfully used in wheat (Farshadfar et al., 2011).

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	Wi2	Di	YSi
G1	2574.58	34.01	1.36**	0.007	407865.1	1467.09	11
G10	4902.77	4.15	0.21***	0.000	1368742	1455.37	3
G11	1906.84	43.08	1.17ns	0.191	698323.5	1624.77	16
G12	4528.68	22.71	1.19ns	0.150	2544988	2115.23	8.5
G13	2374.8	32.48	1.20ns	0.131	192037.9	1454.01	14
G14	4431.67	17.3	0.96ns	0.184	1080506	1754.1	7
G15	4536.23	15.16	0.95ns	0.075	580801.5	1604.31	5
G16	4452.04	12.43	0.66**	0.009	910855.6	1634.58	6
G2	2553.84	41.21	1.65***	0.000	957768.1	1457.32	12
G3	2242.37	34.78	1.15ns	0.244	439526.5	1546.94	15
G4	4917.1	13.69	0.87ns	0.304	798887.6	1662.07	2
G5	4887.43	4.86	0.20***	0.000	1477154	1483.31	4
G6	3928.2	19.89	1.18ns	0.165	334085.3	1506.07	8.5
G7	3276.3	26.71	1.32*	0.016	564594.7	1537.29	10
G8	2481.88	37.44	1.28*	0.032	1197049	1743.18	13

G9	5277.36	11.14	0.68*	0.014	1028880	1678.38	1

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, G15, G13, G3, G11 and G9 attain IPCA values both (frompositive and negative) relatively close to zero and hence are better stable and widely adaptable genotypes across location (Figure 1). However, G16, G14 and G12 were attained IPCA values far away from zero in both sides (either positive or negative) (Figure 1).

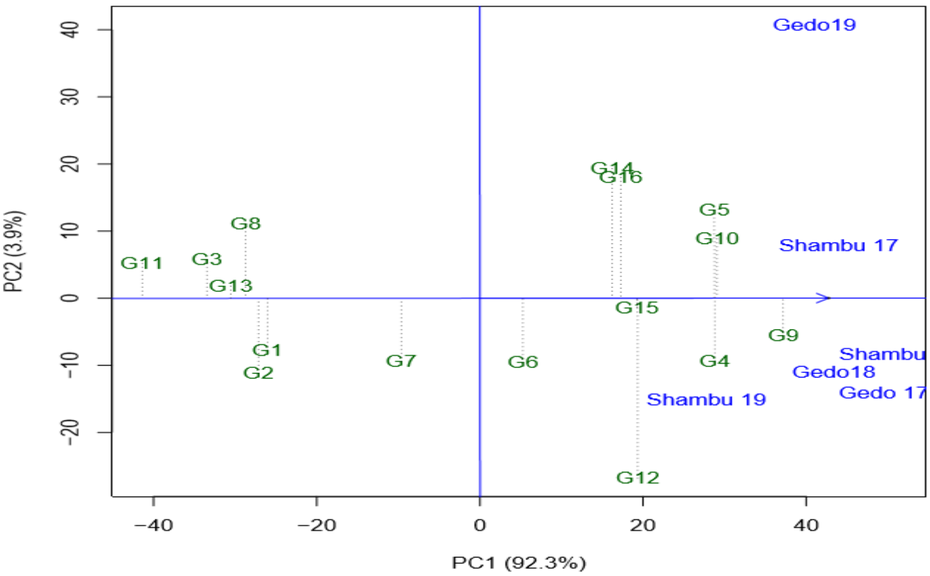

Figure 1."Mean vs Stability" GGE biplot for the wheat trials yield data (kg/ha) with 16 genotypes (G) and 6 environments (E)

Conclusion

The genotype and environment main effects (genotype and environment) and genotype x environment interaction effect were significant for bread wheat genotypes studied in western oromia, Ethiopia. Both AMMI and Eberhart and Russell models revealed that genotypes G15 was widely adaptable and stable high yielding, and thus are recommended for further research with wider environmental adaptability. Genotype G9 gave the highest mean grain yield, with a regression coefficient (bi) significantly less than unity and hence is recommended for high yielding environments.

Reference

Assefa Amare, FirewMekbib, Wuletaw Tadesse3 &Kindie Tesfaye (2020). Genotype x Environment Interaction and Stability of Drought Tolerant Bread Wheat (*Triticumaestivum* L.) Genotypes in Ethiopia. International Journal of Research Studies inAgricultural Sciences (IJRSAS). 6: PP 26-35

CSA (Central Statistical Authority). (2019). Agricultural sample survey 2018/19. Report on areaand 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 areaand production of major crops for private peasant holdings, main cropping season. Statistical 586 (1), Central statistical agency, Addis Ababa, Ethiopia

Crossa,J., HG Gauch, and RWZobel. (1990). Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. Crop Sci. 30:493–500

DagnachewLule, Kassahun Tesfaye, and Girma Mengistu. (2014). Genotype by environmentinteraction and grain yield stability analysis for advanced triticale (*x. triticosecale*wittmack) genotypes in western Oromia. Ethiopian Journal of Science. 37(1):63–68.

Dawit Asnake, Zerihun Tadesse, HabtemariamZegeye and Alemayehu Assefa. (2017). Seasonal variablity and genetic response of elite bread wheat lines in drought prone environments of Ethiopia. Journal of Plant Breeding and Genetics. 5(1):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- 40.

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 2008. 7(2):154-162.

FAO. (2016). FAOSTAT data. Food and Agriculture Organization of the United Nations. http://faostat.fao.org/site/339/default.aspxFAO.2014a. Rome:FAO. Accessed at http://faostat. fao.org/site/368/DesktopDefault.aspx?PageID=368#ancor

FarshadfarE .(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. Ethiop. J. Crop Sci. Vol 8 No.1,2020

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.

Mkumbira N M., Mahungu and U. Gullberg.2000. “Grouping locations for efficient cassavaevaluation in Malawi,” *Experimental Agriculture.* 39(2): 167–179, 200

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 blackseeded finger millet genotypes. African Crop Science Journal. 27(2): 281-294.
Purchase JL. (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.
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. Agron J.80:388–393

Adaptation Trial of Drought Tolerant Maize Varieties (*Zea Mays* L.) for Low Land of Guji Zone, Southern Oromia

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Abstract
Lack of improved maize variety is highly affecting its production in different parts of Ethiopia due to inaccessibility. Lowlands of Guji Zone is one of such areas where the technologies are not widely addressed and adopted so far. This study was conducted by Bore agricultural research center with the objective of selecting and recommending adaptable high yielding and early maturing maize varieties for low land agro-ecologies of Guji zone. The experiment was done at lowland parts of three districts Adola, Wadera and Liben. Seven released maize varieties with one local check were evaluated in RCBD design with three replications with plot size of 3m x 3.75m. All phonological and yield data were collected subjected to analysis using GenStat software. Data analysis was used to test the performance of the varieties across the testing locations. The result of the study shows that, all varieties revealed significant difference for the selected characters across the locations. Based on the obtained result, two Maize varieties (Melkassa 07 and Melkassa 03) were early maturing and gave higher yield. Therefore, these varieties are recommended for demonstration and popularization in the study area and similar agro-ecologies of the zone.
Key words: Variety, effect, significant

Introduction

Maize (*Zea mays* L.) is one of the most important cereal adapted in different part world (Christian *et al*, 2012). It was introduced in Ethiopia before three centuries (Hafnagel, 1961) and is grown mainly for human consumption. It is largely produced in Western, Central, Southern and Eastern parts of Ethiopia. In Ethiopia, maize grown in the lowlands, the mid-altitudes and the highland areas. It is an important field crop in terms of area coverage, production and utilization for food and the stover for feed purposes in Ethiopia.

According to the Central Statistical Authority (CSA, 2018/19), maize is grown on 2.13 million hectares of land, which is about 16.98% of the cultivated area in Ethiopia. Maize cultivars that are used in the low land regions of Ethiopia are well adapted, but low yielding open-pollinated varieties used by farmers. However, Maize is one of the most important cereal crops in Ethiopia, ranking second in area coverage and first in total production. About 40% of the total maize growing area is also located in moisture stress areas, where it contributes less than 20% to the total annual production. Availability of the limited number of drought tolerant maize varieties that reached few smallholders is the main factor for instability and low production in moisture stress areas of the country (Worku,M.,*et al* , 2012).

Maize is one of the most important cereal crops in Southern Oromia region in general and lowlands of Gujizone in particular. Its productivity (26.55 $qtha^{-1}$) very low when compared with potential maize productivity reach (39.9 qt ha^{-1}) (CSA, 20118/19). Most of the low land farmer of Guji zone mainly earn their livelihood from livestock and practice crop production. Maize is the major crop cultivated in the zone. However, information is lacking on performance and variability of drought tolerant maize variety. The low yield in this area is mainly attributed to recurrent drought, low levels of fertilizer use and low adoption of improved varieties. Hence, it is paramount important to introduce improved drought tolerant maize varieties to the target area for improved maize production and productivity. Thus, this study was proposed with the objective of selecting the best performing drought tolerant maize varieties to the target area.

Materials and Methods

Experimental Materials and Design

The experiment was conducted in lowland parts of Guji zone by using eight released lowland maize varieties which was obtained from Bako and Melkasa Agricultural research centers including local check. Randomized complete block design with three replications was used to conduct the experiments. The Seeds was planted in rows with two seeds per hill at a rate of 25 $kgha^{-1}$ in a plot consisting of six rows each of 3.75m long and 3m wide and seedlings will be thinned into one plant per hill four weeks after emergence to obtain 144 plants per plot. The inter row spacing was 0.75m, while the intra row spacing was 0.25m, giving population density of 53,333 plants per hectare. Fertilizers was applied at the rate of 100/100 $kgha^{-1}$ NPS/Urea. Urea was applied in split (half at planting and the other half at knee height). First weed control was carried out after three weeks of planting and next weeding as needed.

Data Collected

The middle four rows were used for data collection and harvested at maturity. Data was collected on individual plant basis from five randomly selected plants such as: plant height (cm), Ear length (cm), ears per plant, tassel length (cm) and cob weight (g) while data on plot basis included grain yield ($qtha^{-1}$).

Results and Discussion

Phenological and agronomic parameters

The analysis of variance revealed that the main effect of variety was significant (P < 0.05) effect on days to tasseling and days to silking (Table 1). The highest prolonged duration to tassel (77.83 days) and silking (76.17days) were observed in the local check as it was not statistically different from the Gambela composite variety. However, the minimum duration (71.5 days) to tasseling and silking (76.17days) were recorded at variety Melkassa 07 (Table 2). This may be due to genetic variations among different maize varieties. In line with this result, Abduselam*et al. (2017*) reported significant difference among maize varieties. Similarly, Hussain *et al*. (2011) reported differential pattern of maize varieties for days to tassel and silking. Other researchers also reported genetic variations among different maize hybrids (Ihsan *et al*., 2005; Haq*et al*., 2005).

Table 1:Mean squares of ANOVA for growth parameters of maize at lowland of Guji

Source of variation	DF	Mean squares DTT	DS	DM	PH (cm)	E/P	EL(cm)
Rep	2	0.0007	23.62	73.5	327	0.05	0.80
Variety	7	0.003*	154.21*	200.71*	7593**	0.15NS	7.43*
Error	62	0.0006	1.87	26.91	1483	0.09	2.10
CV (%)	-	19.1	1.7	3.2	20.6	27.1	9.70

Key: DTT-days to tassel, DS-days to silk, DM- days to mature, PH-plant height, E/P-ear/plant, EL-ear length

The analysis of variance revealed that the main effect of variety was highly significantly (P<0.05) for days to maturity. The highest prolonged duration to mature (170 days) was observed in the local check as it was not statistically different from the Gibe 02 variety while the minimum duration to maturity (155.8 days) was recorded with variety Melkassa 07 (Table 2). Similar to the current study, Hailegabriel*et al.* (2016) also reported different days to maturity for different maize varieties. This variation may be due to difference in experimental locations.

The analysis of variance revealed that the main effect of variety was significantly (P < 0.01) affect plant height of maize. The highest plant height was observed for local (246.6cm) while the minimum plant height (151.2cm) was recorded at variety Melkassa 01 (Table 2). This might be due to the reason that genetic variation among maize varieties. Similarly, Hailegabriel*et al.* (2016) and Abduselam*et al. (2017*) reported different plant height for different maize varieties.

Table 2. Combined mean of phenological and morphological traits of maize at Lowland of Guji

variety	DTT	DS	DM	PH(cm)	E/P	EL(cm)
Melkassa02	73.83^{cd}	78.5^{c}	160.7^{bc}	192.6^{bc}	1.141	15.21^{bc}
Melkassa01	73.83^{cd}	77.83^{c}	158.5^{bc}	151.2^{d}	1.033	13.83^{d}
Melkassa03	72.83^{d}	77.5^{c}	158.3^{bc}	173.9^{bcd}	1.085	15.36^{ab}
Melkassa07	71.5^{e}	76.17^{d}	155.8^{c}	162.5^{cd}	1.259	14.47^{bcd}

Gibe02	74.17 c	80.83 b	160.3 bc	176.6 bcd	0.993	15.08 bcd
Gibe03	75.5 b	81.17 b	167 a	199.6 b	1.022	16.67 a
Local	77.83 a	89.5 a	170 a	246.6 a	0.896	14.78 bcd
Gambela comp.	76.83 a	80.5 b	160.8 b	190 bc	1.263	13.92 cd
Mean	74.54	80.25	161.44	186.	1.09	14.92
CV(%)	1.4	1.7	3.2	20.6	27.1	9.7
LSD(5%)	1.014	1.26	4.88	36.28	ns	1.36

Key: DTT-days to tassel, DS-days to silk, DM- days to mature, PH-plant height, E/P-ear/plant, EL-ear length

Yield and yield component parameters

The analysis of variance revealed that the main effect of variety significantly ($P < 0.05$) for ear length of maize. The longest ear length (16.67cm) was recorded from Gibe 03 whereas the shortest ear (13.83cm) obtained from Melkassa 01.

The analysis of variance revealed that the main effect of variety was significantly ($P < 0.01$) affect cob weight of maize. The highest cob weight was (0.154 kg) observed in the variety Melkassa 07 which was statistically not different from Gibe 03 while the minimum cob weight (0.092 kg) was recorded at variety Melkassa 01 (Table 4). This may be due to genetic and environmental variability among maize varieties.

The analysis of variance revealed that the main effect of non-significant variations for number of ear per plant of maize (Table 1). This finding in line with that of Kandil *et al (2017*) who reported no significant difference among maize varieties. The analysis of variance revealed that not significantly effect for number of row per cob in maize.

Table 3: Mean squares of ANOVA for yield and yield components of maize at lowland of Guji

Source of variation	df	Mean squares					
		CW	R/C	S/R	S/C	TKW(g)	GY(kg/ha)
Rep	2	0.0007	0.38	27.74	2344	1103	760365
Variety	7	0.003**	3.28ns	32.52*	13504**	10032**	3356367**
Error	62	0.0006	1.56	8.12	1886	1202	714182
CV (%)		19.1	9.7	10.3	11.1	14.3	21.2

Key: df-degree of freedom, Cw-cob weight, R/C-row/cob, S/R-seed/row, S/C-seed/cob, TKW-thousand kernels weight, GY-grain yield

The analysis of variance revealed that the effect of variety was highly significantly ($P < 0.01$) affect thousand kernel weight of maize. The highest thousand kernel weight (277.5g) was observed in the variety Melkassa 07 while the minimum thousand kernel weight (23.1g) was recorded at variety Gibe 02 (Table 4). In agreement with Taye *et al*. (2016) and Hailegabriel *et al. (2016*) who evaluated and reported different thousand kernels weight of maize varieties among different tested varieties.

The analysis of variance revealed that the main effect of variety was highly significant ($P < 0.01$) on number of seed per cob of maize. The highest number of seed per cob (441.8) was observed in the variety Melkassa 07 while the minimum number of seed per cob (329.4)

(Table 4). Similar to this result, Inamullah *et al* (2011) reported different seed per cob for hybrid maize varieties.

The analysis of variance revealed that the effect of variety was significantly (P < 0.01) affect grain yield of maize. The highest grain yield (4663 kgha^{-1}) was obtained in the variety Melkassa 07 which was not statistically different from Melkassa 03 variety while the minimum (2870 kgha^{-1}) grain yield was recorded at variety local check (Table 4). This might be due to genetic variability among maize varieties. Similar with this result, Hailegabriel *et al.* (2016) reported effects of variety on yield of maize. Similar result was reported by Taye *et al*. (2016) and Abduselam*et al.* (2017) who evaluated and identified high yielding maize varieties among different genotypes tested.

Table 4. Combined mean of yield and yield related trait of Maize

variety	CW	R/C	S/R	S/C	TKW(g)	GY(kg/ha)
Melkassa02	0.1307 ^{abc}	14.14	28.81 ^{ab}	411 ^{abc}	273.8 ^{ab}	4262 ^{ab}
Melkassa01	0.0915 ^{d}	13.56	24.19 ^{c}	329.4 ^{f}	274.5 ^{a}	3430 ^{cd}
Melkassa03	0.1297 ^{bc}	13.83	27.92 ^{ab}	432.9 ^{ab}	239.5 ^{c}	4593 ^{a}
Melkassa07	0.1516 ^{ab}	13.54	26.12 ^{bc}	354.7 ^{ef}	231 ^{c}	4663 ^{a}
Gibe02	0.1437 ^{abc}	13.82	29.63 ^{a}	397 ^{bcd}	223.1 ^{c}	4225 ^{abc}
Gibe03	0.1541 ^{a}	13	29.75 ^{a}	441.8 ^{a}	277.5 ^{a}	4102 ^{abc}
Local	0.1283 ^{bc}	12.94	26.56 ^{bc}	366 ^{def}	241.7 ^{bc}	2870^{d}
Gambela comp.	0.1271 ^{c}	14.81	27.94 ^{ab}	390.3 ^{cde}	178.8 ^{d}	3700 ^{bc}
Mean	0.13	13.71	27.62	390.38	242.7	3980.62
CV(%)	19.1	9.7	10.3	11.1	14.3	21.2
LSD(5%)	0.024	Ns	2.686	40.927	32.67	796.35

Key: Cw-cob weight, R/C-row/cob, S/R-seed/row, S/C-seed/cob, TKW-thousand kernels weight, GY-grain yield

Conclusion and Recommendation

Significant differences between varieties were observed for grain yield and yield components. Based on the combined mean performance almost all varieties showed above mean performance of the local check in the studied locations. Based on the combined mean performance two varieties (Melkassa 07 and Melkassa 03) were showed better yield performance compared with the local check and other varieties. Therefore, these two varieties recommended for demonstration and popularization in the study area and similar agro-ecology of the zone.

Reference

Christian R, Angelika C, Christoph GJ, Frank T, Albrecht EM. Genomic and metabolic prediction of complex heterotic traits in hybrid maize. *Nat Genet*, 2012, 44: 217-220.

CSA (Ethiopian Central Statistical Agency). 2018/19. Agricultural sample survey Report on area and production for major crops.

Fuad Abduselam, ZalaqeLagese, Samuel Tegene, Fikadu Tadesse Alemayehu Biri and Nasir Siraj (2017). Performance Evaluation and Adaptability of Improved Released Maize (*Zea mays* L.) Varieties in the Midlands of Fedis District of Eastern Hararghe. *Asian Journal of Plant Science and Research*. 2017, 7(5):10-14

Hailegebrial Kinfe, Yiergalem T., Alem R., Redae W., Desalegn Y. Welegerima G., KifleG.,Husien S.2016. Evaluating Hybrid Maize Genotypes for Grain Yield and Yield Related Traits in north western Tigray, Ethiopia.*International Journal of Research in Agriculture and Forestry 3(12): 17-21*

Haq NM, Saad IM, Mozamil H, Sajjad URC, Habib IJ (2005). Genetic correlation among various quantitative characters in maize (*Zea mays L.*) hybrids. J. Agric. Soc. Sci. 3:262-265.

Hufnagel, C. A., Conrad, P. W., Schanno, J., and Pifarre, R.: Profound Cardiac Hypothermia, Ann. Surg. 153: 790, 1961.

Hussain M, Khan MY, Baloch MS (2011). Screening of Maize Varieties For Grain Yield At Dera Ismail Khan. J. Anim. Plant Sci. 21(3):626-628.

Ihsan H, Khalil IH, Rehman H, Iqbal M (2005). Genotypic Variability for morphological traits among exotic maize hybrids. Sarhad J. Agric. 21(4):599-602.

Inamullah, N. Rehman, N.H. Shah, M. Arif, M. Siddiq and I. Mian. 2011. Correlations among grain yield and yield attributes in maize hybrids in various nitrogen levels. Sarhad J. Agric. 27(4): 531-538

Kandil A. A, Sharief A. E. Abozied A. M. A.2017. Maize Hybrids Yield as Affected by Inter and Intra Row Spacing. International Journal of Environment, Agriculture and Biotechnology 4(4):643-652

Tolessa Taye, Natol Bekele and Yonas Shimalis.2016.Evaluation of highland maize at Bule hora District of Southern Oromia, Southern Ethiopia. *African Journal of Agricultural Research,* 11(34):3178-3181

Multi-location Based Evaluation of tef Genotypes for Grain Yield Stability and Agronomic Performance in Western Ethiopian high lands.

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Abstract

Tef [*Eragrostis tef* (Zucc.) Trotter] is extensively cultivated and most important cereal crop in Ethiopia in terms of production, consumption and cash crop value and grown on about 3 million hectares annually. Because of its gluten-free proteins and slow-release carbohydrate constituents, tef is recently being advocated and promoted as health crop at the global level. However, the productivity of tef is very low compared to other cereals mainly due to lack of high yielding and lodging tolerant cultivars. For this purpose, several genotypes were evaluated under different breeding stages in multi-locations so as to screen and reach at stable, high yielding and stress tolerant varieties. Accordingly, the year 2017/18 twenty five recombinant inbred-lines were tested in preliminary variety trial out of which sixteen genotypes advanced to regional variety trial and tested in 2018/19 and 2019/20 in multi-locations. Finally, the combined analysis of variance across the three locations revealed

highly significant (p<0.01) difference among genotypes for grain yield, days to mature, plant height, panicle length, lodging %, effective tiller, and crop stand. Among tested genotypes three, RIL 76B, RIL 46 and RIL 43A found to be stable, high yielder and lodging tolerant across the tasted locations with grain yield advantage of 26.62%, 19.77% and 12.72% over the standard check, respectively. Therefore, based on their high yield and stable performance, genotypes RIL 76B, RIL 46 and RIL 43A were promoted to variety verification trial (VVT) evaluation and for possible release.
Keywords: *Eragrostis tef*, stability, genotypes

Introduction

Tef [*Eragrostis tef* (Zucc.) Trotter]is a self-pollinated warm season annual grass with the advantage of C_4 photosynthetic pathway (Miller, 2010). Tef is among the major Ethiopian cereal crops grown on over 3 million hectares annually (CSA, 2018), and serving as staple food grain for over 70 million people. Tef grain is primarily used for human consumption after baking the grain flour into popular cottage bread called "injera". Tef has an attractive nutritional profile, being high in dietary fiber, iron, calcium and carbohydrate and also has high level of phosphorus copper, aluminum, barium, thiamine and excellent composition of amino acids essential for humans (Hager et al.,2012; Abebe et al.,2007; USDA 2015). The straw 'chid' is an important source of feed for animals. Generally, the area devoted to tef cultivation is increased because both the grain and straw fetch high domestic market prices. 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). Nevertheless, until recently, tef was considered as "orphan" crop: one receiving no international attention regarding research on breeding, agronomic practices or other technologies applicable to smallholder farmers.

The continued cultivation of tef in Ethiopia is accentuated by the following relative merits: 1) as the predominant crop, tef is grown in a wide array of agro-ecologies, cropping systems, soil types and moisture regimes; 2) with harvests of 4.75 million tons of grain per year from about 3 million ha. Tef constitutes about 23.85% of the total acreage and has about 17.26% contribution in grain production of cereals in Ethiopia followed by maize which accounts for about 21% of the acreage and 31% of the overall cereal grain production (CSA, 2018). 3) The values of the grain and straw contribute about four billion Birr to the national GDP; 4) it has a good export market, 5) tef grain has got relatively good nutritive value especially since it contains relatively high amounts of iron, calcium and copper compared to other cereals. Because of its gluten-free proteins and slow-release carbohydrate constituents, tef is recently being advocated and promoted as health crop at the global level (Ketema S. 1993; Spaenij-Dekking et al., 2005; kebebewAsefa et., al 2013; Assefa et al., 2017).

The most important bottlenecks constraining the productivity and production of tef in Ethiopia are: i) low yield potential of farmers' varieties under widespread cultivation; ii) susceptibility to lodging particularly under growth and yield promoting conducive growing conditions; iii) biotic stresses such as diseases, weeds and insect pests; iv) abiotic stresses such as drought, soil acidity, and low and high temperatures; v) the culture and labor intensive nature of the tef husbandry; vi) inadequate research investment to the improvement of the crop as it lacks global attention due to localized importance of the crop coupled with limited national attention; and vii) weak seed and extension system (kebebewAsefa et., al 2013; Assefa et al., 2017). Therefore, the objective of this activity was to develop and release high yielding, high market value, lodging and diseases tolerant tef varieties for potential growing areas of western parts of the country.

Objective:
To develop and release high yielding with high market value, lodging, pest and acidic soils tolerant tef varieties for Western parts of tef growing areas of Ethiopia.

Materials and Methods
The experimental materials were 89 recombinant tef inbred lines received from Debre Zeit Agricultural Research Center. The materials were initially 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. The material were tested in Nursery during 2016/17 at Shambu sub-site and reduced to twenty five genotypes and evaluated in preliminary variety trial for one year during 2017/18. Eighteen genotypes including the checks were evaluated in multi-location so as to see their adaptability, stability, yield, and resistance/tolerance to major tef diseases in the main cropping season during 2018/2019 and 2019/2020 in regional variety trial. The experiment was conducted at Shambu, Gedo and Arjo sub site using Randomized Complete Block design with three replications on a plot size (experimental unit) of 2m x 2m ($4m^2$) each with 0.2m of row spacing. The distance between block was 1.5m and between plots was 1.0m. Fertilizer rate of 100/50 $kgha^{-1}$ DAP/UREA at planting and 10 $kgha^{-1}$ of seed rate was used. Other agronomic practices were applied uniformly as required. Data on days to emergence, days to heading, days to maturity, panicle length, plant height, panicle length, shoot biomass, lodging %, effective tiller, stand %, grain yield per plot and disease score (1-9 scale) was collected and subjected to statistical analysis using SAS statistical software.

Result and Discussion
The combined analysis of variance across the three locations revealed highly significant ($p<0.01$) difference among genotypes for plant height, panicle length, shoot biomass, lodging % and grain yield $kgha^{-1}$ (Table 2). Genotype RIL 76B, RIL 46 and RIL 43A gave the highest grain yield (2278.97$kgha^{-1)}$ followed by genotype RIL 46 (2155.71 $kgha^{-1}$) and RIL 43A (2028.68Kg/ha). The standard check variety Dursi gave 1799.81.24 Kg/ha. The three candidate genotypes had yield advantage of 26.62%, 19.77%, and 12.72% over the standard check respectively (Table 1). In agreement with this finding; previous studies of genotype x environment 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-Hail et al., 1965).
The combined analysis of variance for biomass depicted non significant ($P<0.05$) difference among the tested genotypes. The analysis of variance for lodging percent revealed that low percent for genotype RIL 76B (2.51%) followed by RIL 43A (2.70%) and RIL 46 (2.91%),

respectively. The stability study indicated that RIL 76B, RIL46 and RIL 43A found to be stable and high yielders across the tasted locations with grain yield advantage of 26.62%, 19.77% and 12.72% respectively over the check (Table 1). In addition, the candidate varieties are very white and can fetch high market value.The GGE bi-plot analysis revealed that three candidate genotypes showed stable adaptability across the tested locations (Fig 1). They were also high yielders than the best check and fall farthest from the origin on the environment axis, suggesting their potential for wider adaptability with better grain yield performance.

Table 1. Mean grain yield across years and Locations

Genotype	**Shambu**		**Gedo**		**Arjo**		**mean GY**	**%yield**	
	2018	**2019**	**2018**	**2019**	**2018**	**2019**	**Kg/ha**	**advantage**	**Rank**
RIL76B	2422.667	2365.42	2305.83	2287.83	2111.67	2180.42	2278.97	26.62	1
RIL46	2203.167	2234	2160	2232.75	2051.67	2052.67	2155.71	19.77	2
RIL43A	2112.5	2105.67	2045.83	2046.25	1884.17	1977.67	2028.68	12.72	3
RIL66	1955.833	1976.42	1977.5	2068.08	1849.17	1958.75	1964.29	9.14	4
Dursi (check)	1865.833	1864.75	1812.17	1761.58	1746	1748.5	1799.81		5
RIL65	1540.833	1568.67	1874.17	1529.42	1675.83	1623.67	1635.43		6
(RIL80)	1813.167	1316.8	1985.17	1373.08	1697.5	1328.08	1585.62		7
RIL44	1726.667	1490.33	1575.83	1423.25	1718.33	1520.42	1575.80		8
RIL53	1637.777	1389.67	1784.17	1336.25	1628.33	1416.92	1532.19		9
RIL74	1462.5	1520.83	1693.33	1418	1605.83	1428.17	1521.44		10
RIL72	1525.833	1321.92	1724.17	1379.83	1685	1387.08	1503.97		11
RIL52	1698.333	1141.58	2079.17	1115.5	1802.5	1111.17	1491.38		12
Local Check	1607.5	1250.5	1759.5	1322.83	1720	1256.58	1486.15		13
RIL61	1576.667	1367	1775	1352.75	1630	1202.5	1483.99		14
RIL49	1575.833	1231.33	1864.17	1292.17	1663.33	1263.75	1481.76		15
RIL85	1585	1355.33	1726.67	1331.5	1583.33	1275.83	1476.28		16
RIL 91A Check	1693.333	1224	1700	1255.92	1520	1300.75	1449.00		17
RIL NO.7	1525.833	1154.42	1908.33	1179.17	1388.33	1122.08	1379.69		18
Mean	1751.63	1548.81	1875.06	1539.23	1720.06	1508.61			
LSD	143.54	359.18	162.73	360.89	237.88	377.36			
CV	4.94	13.98	5.23	14.13	8.33	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	**Trt No.**	**DH**	**DM**	**PH**	**ET**	**PL**	**LD**	**ST**	**LR**	**SBM**
RIL NO 76B	14	71.11	134.22	94.28	4.22	36.31	2.51	2.22	1.93	12.74
RIL NO.46	4	71.11	136.06	94.81	3.97	35.36	2.91	2.67	1.93	7.86
RIL NO.43A	2	71	135.17	93.24	4.67	34.64	2.7	3.78	1.87	7.76

RIL NO.66	10	72.5	136.72	99.32	3.9	37.98	3.24	2.67	3.03	7.24
Dursi (check)	17	72.11	135	102.23	4.49	39.31	2.31	1.67	1.69	7.64
RIL NO.65	9	70.17	136.56	99.13	4.13	37.44	2.95	2.22	2.67	6.69
RIL NO.80	15	70.17	135.94	97.87	3.96	35.68	3.03	3	2.53	5.79
RIL NO.44	3	73.28	134.39	97.98	4.35	36.72	2.83	2.78	2	7.54
RIL NO.53	6	71.06	136.67	96.57	3.86	35.98	3.17	2	3.37	6.71
RIL NO.74	13	68.44	137.28	94.9	4.21	35.63	3.67	2.89	2.29	6.29
RIL NO.72	11	71.28	136.61	98.13	3.66	37.49	3.61	2.67	2.85	6.82
RIL NO.52	5	71.11	135.17	99.54	3.97	38.11	3.27	2.44	2.43	6.38
Local check	18	71	134.5	97.48	4.12	37.2	3.52	2.78	2.5	6.82
RIL NO.61	8	68.11	132.11	87.64	3.89	30.79	2.94	2.67	1.98	6.07
RIL NO.49	7	71.22	137.5	99.44	3.62	38.58	3.24	2.56	2.29	7.25
RIL NO.85	16	72.5	134	95.57	4.03	36.79	3	2.89	2.23	6.36
Dagim(check)	1	69.5	133.22	90.78	4.16	33.67	2.58	3	2.3	6.39
RIL NO.73	12	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, RIL= 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

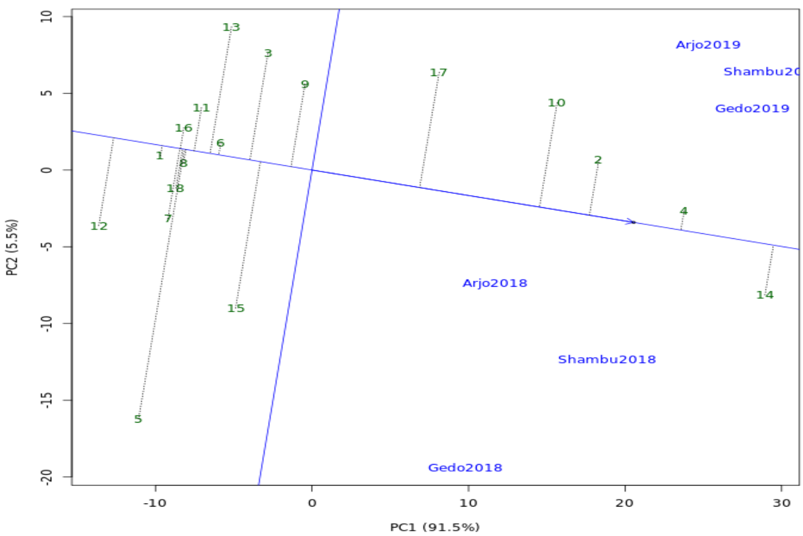

Figure1. GGE bi-plot: mean vs. stability

Conclusion and Recommendation

Combined analysis of variance for the genotypes portrayed highly significant differences for days to maturity, effective tillers, plant height, panicle length, lodging %, crop stand, leaf rust and grain yield kg/ha. Genotype RIL 76B, RIL 46 and RIL 43A were found stable, high yielders and lodging tolerant across the tasted locations with grain yield advantage of 26.62%, 19.77% and 12.72% over the standard check respectively. As a result of these all merits, these three genotypes were identified as candidate varieties to be verified at three locations the coming cropping season.

Acknowledgment

The author acknowledges Oromia Agricultural Research Institute funding the experiment and Bako Agricultural Research Center for fulfilling all the necessary inputs to undertake this activity. We are also grateful to all cereal research team staffs of Bako Agricultural research Center for technical support.

References

Abebe Y, Bogale A, Hamgidge, KM, Stoecker BJ, Bailey K, Gibson RS, (2007) Phytate, zinc, iron, and calcium content of selected raw and prepared foods consumed in rural Sudama, Southern Ethiopia and implication of bioavailability. J food Compo Anal.20:161-168.

Ashamo M, Belay G (2012) Genotype x Environment Interaction Analysis of Tef Grown in Southern Ethiopia Using Additive Main Effects and Multiplicative Interaction Model. Journal of Biology Agriculture and Healthcare 2: 66-72.

Balsamo R A, Willigen C V,Boyko W, Farrent L (2005) Retention of mobile water during dehydration in the desiccation-tolerant grass *Eragrostisnindeensis*'. Physiol Planetarium.134:336-342.

Central Statistical Agency (CSA).2018. The federal Democratic Republic of Ethiopia. Central Statistical Agency Agricultural Sample Survey 2018: Report on Area and Production of Major Crops (Private peasant Holdings, Maher Season), Volume III. Addis Ababa, Ethiopia.

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.

Kebebew Assefa, Solomon Chanyalew and GizawMetaferia (2013). Conventional and Molecular Tef Breeding, Proceedings of the Second International Workshop, November 7-9, 2011, Debre Zeit, Ethiopia.

Melak-Hail Mengesha, Picket R. C., Davis R. L. (1965). Genetic variability and interrelationship of characters in teff, *Eragrsotis tef* (Zucc.) Trotter, Crop Sci. 5: 155-157. Miller, D (2010) Teff guide 3rd edition, viewed on 24 September 2012, http://www.calwestseeds.com.product/teff

Spaenij-Dekking L, Kooy-Winkelaar Y and Koning F. (2005). The Ethiopian cereal tef in celiac disease. N. Engl. J. Med. 353: 16.

Assefa K, Chanyalew S, Tadele Z (2017) Tef, *Eragrostis tef* (Zucc.) Trotter. In: Patil JV (ed) Millets and sorghum, biology and genetic improvement. Wiley, Hoboken, pp 226–266

Ketema S (1993) Tef, *Eragrostis tef* (Zucc.) Trotter breeding, Genetic Resources, Agronomy, Utilization and Role in Ethiopian Agriculture.
USDA (2015) National Nutrient Database for Standard Reference Release 27, United States Department of Agriculture, USA.

Adaptation Trial of Improved Tef (*Eragrostis tef (Zucc.)* Varieties

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Abstract
Tef (*Eragrostis tef* (Zucc.) Trotter) is an annual grass crop and important indigenous cereal crop grown in Ethiopia. Twenty-six improved tef varieties were tested across three environments against local check in western Oromia, Ethiopia during 2018 and 2019 main cropping seasons to evaluate, select and recommend adaptable, high yielding, insect and pest resistant improved tef varieties for the study area. The varieties were arranged in a randomized complete block design (RCBD) with three replications. Pooled analysis of variance (ANOVA) indicated significant differences among tested varieties ($P \leq 0.01$). The combined mean of tested varieties indicated that Quncho and Dukem were top yielders compared with local check and other varieties evaluated. Therefore, the two varieties will be demonstrated at the farmers' level for larger scale production.

Key words: Adaptation, Yield, Tef, Dukem, Quncho

Introduction

Population growth which was 6 billion in 1999 is expected to surpass 9.7 billion in 2050 (United Nations Department of Economic and Social Affairs, 2015) whereas grain crops projected to increase by nearly 48% from 2000 – 2025 and by 70% up to 2050. The concerning issue for scientific community is nearly all of this growth forecast is to take place in the developing countries of which sub-Saharan Africa's population would grow the fastest. In addition, our growing population is becoming increasingly urban. The World Health Organization (WHO) estimates that 7 out of 10 people will live in a city by 2050. With the rapid increase in the global population and the impact of climate change on agriculture, there is a need for crops with higher yields and greater tolerance to abiotic stress. Keeping all these concerns in mind giving emphasis to vulnerable crops become a necessary effort the way forward. Tef (*Eragrostis tef (Zucc.) Trotter*) is a warm season annual C_4 plant (Kebede *et al.*, 1989), which is grown in Australia, India, and South Africa

as forage (Costanza *et al.,* 1979). It was domesticated in Ethiopia around 4000- 1000 BC and Ethiopia is considered as center of origin of tef. The great diversity within the species is evident in existence of different seed color. There are reports of purple, white, brown and red seeded types (Mengesha 1966; Costanza, 1979). The importance of tef is based primarily on consumer preference for Injera (Ethiopian fermented flatbread thin bread). Other forms of uses tef include local alcoholic beverages called "tela" and "katikala", and porridge. Additionally, tef plant residues could be used as fodder for livestock, and often incorporated as construction materials.
Tef's agronomic versatility and reliability even under adverse conditions suit it well to a country of contrasting and unpredictable environments where water logging, drought, pest and disease are common, makes this crop very important. It is grown in different climatic and edaphic zones at elevation ranging between 1000-2500m above sea level, (Westphal, 1975). Owing to it is hardy nature, this species has a considerable potential for agriculture in areas unsuitable for other cereals. However, a lot of manual labor is needed to grow the crop because there's not enough mechanization for planting or sowing, weeding, harvesting and threshing. Additionally, tef has also a good balance of essential amino acids, except lysine (Ebba, 1969). Among the cereals, tef straw is the best and comparable to a good natural pasture (Stallknech, 1997). Even though tef is one of the dominant cereal crops in Ethiopia in terms of area coverage and yet the yield per hectare is low nationally 15.60 quintals (CSA, 2015/16). Besides, national yield gave very low compared to other major cereals mainly due to the limited use of improved varieties seeds, inefficient farming practices and fragmented farm plots. Similarly, the yields of tef in Wollega areas are low due to different production problems of which lack of improved varieties. In contrast, tef production was expanding at the expense of other, higher-yield crops such as maize, wheat, barley and sorghum mainly due to food preference and this would pose significant challenges to achieve food security. Thus, to maintain the balance of farmers preference of this commodity and yield, increasing tef yield may be the most viable solution to pull Ethiopian farmers out of poverty and ensure food security but, that involves overcoming a number of obstacles. The increase in production of tef depends on the optimization of crop management and genetic improvement. Unlike other crops of international importance such as rice and wheat, where basic and applied research contributed significantly to their improvement, tef has received little attention. Lack of improved tef technology was evident in Western part of the country, especially in West and KellemWollega Zones. Therefore, the objectives of the study were to evaluate, select and recommend adaptable and high yielding improved tef varieties for West and KellemWollega Zones of Western Oromia thereby making communities of the area beneficiary of the tef technology

Materials and methods

Description of study sites

The experiment was conducted at three different locations of Kellem and West Wollega zones viz, Bellam research site (altitude 1759 masl, 09° 02' N, 035° 104'E), Mata FTC (altitude 2016 masl, 08° 34' N, 034° 44'E) and Aroji FTC (altitude 2054 masl, 08° 40' N, 034°47'E) in Western Oromia, Ethiopia, during 2018-2019 main cropping seasons.

Experimental materials

Twenty-six improved tef varieties collected from Debre Zeit and Bako agricultural research centers were evaluated with farmer's variety on three locations for two consecutive years.

Table 1. List of varieties evaluated during 2018-2019 main cropping seasons

No	Varieties	Hosting Center/Source
1	Simada	Debre Zeit
2	Boset	Debre Zeit
3	Megna	Debre Zeit
4	Tseday	Debre Zeit
5	Amarech	Debre Zeit
6	Quncho	Debre Zeit
7	Geredo	Debre Zeit
8	Key Tana	Debre Zeit
9	Menagesha	Debre Zeit
10	Welenkomi	Debre Zeit
11	Dukem	Debre Zeit
12	Ziquala	Debre Zeit
13	Gimbichu	Debre Zeit
14	Koye	Debre Zeit
15	Flagot	Debre Zeit
16	Enatit	Debre Zeit
17	Dagem	Debre Zeit
18	Gibe	Debre Zeit
19	Nigus	Debre Zeit
20	Asgori	Debre Zeit
21	Melko	Debre Zeit
22	Kora	Debre Zeit
23	Tesfa	Debre Zeit
24	Dega-Tef	Debre Zeit
25	Guduru	Bako
26	Kena	Bako
27	Farmer's variety	Local farmer

Experimental design and management

Randomized completed block design (RCBD) with three replications was used in all locations. Each experimental plot had six rows of 2.5 m long spaced and 20 cm apart with a plot area of 1.2 m x 2.5 m. Drill planting by hand was used with the same rate for all locations. Fertilizer was applied at a rate of 41 and 46 kg ha^{-1} of N and P_2O_5, respectively, in the form of Urea and NPS. All NPS and half of N were applied during planting, while the half splits were applied at tillering stages. A seeding rate of 10 kg ha^{-1} was used. First weeding was carried out 35 days after emergence and the second one at 30 days after the first weeding for all locations.

Data collection and statistical analysis

Days to heading, days to maturity, grain filling duration, plant height, head height, lodging percentage, biological yield and grain yield data were collected based on multi-crop descriptors (FAO/IPGRI, 2001) and were subjected to analysis using statistical analysis software (SAS, 2003). The data considered for analysis was from four central harvestable rows. The harvested varieties were sundried before being tested for moisture content and yield adjusted to 12% moisture content.

Results and Discussion

Analysis of variance

Pooled analysis of variance indicated highly significant differences for genotypes, environments and genotype × environment interaction (G×E). This indicated that environmental factors played a leading role for the variability observed among tef varieties tested in western Ethiopia ($P \leq 0.01$). In addition to the environmental factors, the contribution of G×E was also appreciable. The significant G×E suggests that grain yield of tef varieties varied across environmental conditions.

Table 2. Analysis of variance of major agronomic and yield components of tef Varieties tested at western Oromia,2018-2019

Source of variation	DF	Mean Squares								
		DH	DM	GFP	PT	PH	HH	LDG	BM(qt ha^{-1})	GY(qt ha^{-1})
Varieties	26	1287.03**	3602.22**	755.2**	30.42**	1491.7**	488.96**	3.41**	2235.27**	70.78**
Replication	2	54.59**	309.59**	624.04**	0.78	386.47**	67.08**	0.96	172.1**	3.12
Environment	3	1360.63**	2206.8**	5223.9**	145.93**	1712.6**	1165.80**	3.08	60432.6**	2487.53**
Var*env	26	1287.03**	61.29**	86.70**	2.42	24.85	19.99*	2.07	373.1**	8.83**

Where DH, DM, GFP, PT, PH, HH, LDG, BM. GY are days to heading, days to maturity, grain filling period, plant height, productive tiller, head height, lodging, biomass and Grain yield, respectively.

Yield and agronomic performance

The mean grain yield (qt ha^{-1}) of the twenty-seven tef varieties tested at Western Oromia indicated statistically significant difference among the varieties. The combined mean of tested varieties indicated Quncho and Dukem as better performers followed by Wolenkomi, Boset and Tseday while Dega tef was the least performer in a level that it cannot bear any yield. Besides, Ziquala, Menagasha, Gimbichu and Geredo were also the poorest in terms of yield they bear (Table 3).

Differences among the genotypes were significant for agronomic characters (Table 3). A local variety included in this investigation was the intermediate to days to heading (53 days). However, this local landrace was earliest for maturity relative to other varieties. This indicates that local landraces had relatively a shorter grain filling period. Geredo was the earliest to days to maturity whereas Menagasha and Melko were the late maturing varieties; though Geredo was late to flower (56); it pays its late to heading by filling the grain as short as possible (26). In contrast to this, Flagot, Melko, Simada and Menagasha acquired a long grain filling time. On the other hand, in terms of plant height Asgori, Enatit, and Gimbichu were the shorter whereas Kora and Geredo were comparatively the taller varieties. There is a small difference display among tested varieties for lodging; except Simada which is suspectable to lodging. Besides, Boset, Tseday and Kuncho gave high biomass yield which were possibly accounted from their respective higher productive tiller.

Table 3 Combined Mean performance of tef varieties tested at West and KellemWollega Zones Western Oromia 2018-2019

Varieties	DH	DM	GFP	PT	PH (cm)	HH (cm)	LDG	BM(qt ha^{-1})	GY(qt ha^{-1})
Simada	44.94o	89.08e-h	44.14a	7.96ab	49.72i-k	28.97d-h	3.565a	60.63jk	10.37h-l
Boset	49.94lm	89.25e-g	39.30b-f	7.11b-d	54.60d-g	31.10b-d	1.261b	79.27a	12.23a-d
Megna	52.60g	88.16f-i	35.55i-l	6.55c-e	52.88gh	29.24d-g	1.36b	68.72c	10.35h-l
Tseday	47.94n	87.66hi	39.72b-e	7.30a-c	53.08f-h	27.77f-h	1.24b	74.05b	12.13a-e
Amarech	54.85c	90.08c-e	35.22j-l	4.92h-j	58.19bc	24.25j	1.14b	63.50g-j	10.01j-m
Quncho	55.10bc	89.5d-f	34.39kl	8.17a	58.15bc	29.92c-f	1.24b	73.90b	13.35a
Geredo	56.15a	82.16j	26.00n	3.92j	60.10ab	24.91ij	1.14b	54.22l	9.97k-m
Keytana	51.27jk	91.08bc	39.83b-d	6.53c-e	49.14jk	28.43e-h	1.16b	64.41f-i	10.35h-l
Menagesha	55.82ab	96.75a	40.92b	4.25ij	57.77bc	24.75ij	1.14b	61.44i-k	8.29n
Welenkomi	53.44ef	90.41c-e	36.97g-j	6.11d-f	50.70h-j	27.36gh	1.16b	68.30c-e	12.28a-d
Dukem	54.52cd	89.83c-e	35.30j-l	4.54ij	55.97c-f	31.19b-d	1.16b	67.98c-f	13.11ab
Ziquala	55.82ab	87.5i	31.67m	3.92j	53.77e-g	21.75k	1.14b	53.78l	8.99mn
Local	52.60g	87.75g-i	35.14kl	5.67e-h	55.61c-g	31.92bc	1.37b	66.00c-g	12.41abc
Gimbichu	52.69fg	89.91c-e	37.22g-i	6.59c-e	46.86h-j	28.64e-h	1.20b	64.77d-i	9.56mn
Koye	51.44ij	90.58c-e	39.14b-f	6.34c-e	50.65h-j	31.95bc	1.20b	65.69c-h	10.66g-l
Flagot	47.44n	88.08f-i	40.64bc	7.30a-c	54.04e-g	32.31b	1.45b	62.07h-k	11.54c-f
Enatit	52.35gh	88.08f-i	35.72i-l	5.01g-i	47.80jk	28.38e-h	1.06b	61.18i-k	10.87e-l
Dagem	53.85de	87.91g-i	34.05l	5.07f-i	57.43b-d	32.63b	1bc	62.95g-j	11.96b-f
Gibe	49.44m	88.08f-i	38.64d-j	5.98e-g	49.01jk	29.73c-f	1.08b	64.58f-i	10.17i-m
Kenna	52.02g-j	88.08f-i	36.05h-k	6.01e-g	56.60c-e	28.32e-h	1bc	58.69k	11.09d-k
Nigus	50.02lm	87.83g-i	37.80f-h	6.51c-e	55.40c-g	31.07b-d	1bc	67.57c-f	11.83d-g
Asgori	50.60kl	89.91c-e	39.30b-f	6.63c-e	47.83jk	27.94f-h	1bc	60.32jk	10.81g-l
Melko	52.10g-i	92.16b	40.05b-d	5.73e-h	52.70g-i	26.65hi	1.18b	58.40k	10.39h-l
Kora	51.77h-j	90.83b-d	39.05c-f	6.38c-e	61.50a	31.72bc	1.18b	64.93d-i	11.33d-i
Tesfa	51.77h-j	87.91g-i	36.14h-l	5.07f-i	57.22b-d	30.36b-e	1.18b	60.60jk	11.28d-j
Dega-tef	0p	0k	0o	0.1567k	0l	0l	0c	0m	0o
Guduru	52.025g-j	90c-e	37.97e-g	6.34c-e	58.365bc	36.374a	1.3658b	68.382cd	11.425d-k
Mean	50.10	85.88	35.78	5.78	52.04	28.06	1.22	62.09	10.61
CV	2.06	2.23	6.33	22.60	7.32	10.39	10.85	7.51	15.23
LSD	0.83	1.55	1.82	1.05	3.07	2.35	1.04	3.76	1.30
F-test	**	**	**	**	**	**	**	**	**

Key:DH=Days to heading, DM=Days to maturity, GFP=Grain filling period, PT=Productive tiller, PH=Plant height, HH=Head height, LDG=Lodging, BM=Biomass, GY=Grain yield,

Conclusion and Recommendations

This study revealed that tef varieties differ in adaptation potential when subjected to different growing environments. From the current study some varieties exhibited an outstanding performance in terms of grain yield and yield related traits. The combined mean of tested varieties indicates that Quncho and Dukem were top yielders compared with local check and other varieties evaluated. Therefore, the two varieties need to be demonstrated at the farmers level for larger scale production till other recommendation provided for the area. In addition, other agronomic recommendations need to be done for the crop since still the yield gained is below to the National yield.

References

Costanza, S.H, J.M.J. DeWet, and J.R. Harlan, (1979). Literature review and numerical taxonomy of *Eragrostis tef*. Eco. Bot. 33: 413-424.

CSA (Central Statistical Agency) (2015/16). The Federal Democratic Republic of Ethiopia Agricultural Sample Survey2016/2017: Area and production of major crops, (private peasant holdings, Meher season). Vol. I. Addis Ababa, Ethiopia

Ebba, T. (1969). Teff (*Eragrostis tef)*. The cultivation, usage, and some of the known diseases and insect pests. Haile Sellassie Univ. College of Agr., Dire Dawa, Ethiopia. Expt. Sta.Bul.60. part 1.

Ebba, T. (1975). Tef (*Eragrostis tef*) Cultivars: Morphology and Classification. Addis Ababa Univ. College Agric., Dire Dawa, Ethiopia, Exp. Sta. Bul. 69. Part 2.

Eckoff, J.L.A., D.M. Wichman, J. Scheetz, M. Majerus, L.E. Welty, G.F. Stallknecht, R.L. Ditterline, R.L. Dunn, (1993). Tef: a potential forage and grain crop for Montana. Montana Agric. Research 10: 38 41.

Kebede, H., R.C. Johnson, and D. M. Ferris, (1989). Photosynthetic response of *Eragrostis tef* to temperature. Physiol. Plant 77: 262- 266.

Mengesha, M. H. (1966). Chemical composition of teff (*Eragrostis tef)* compared with that of wheat, barley and grainsorghum. Eco. Bot. 20: 268- 273.

Stallknecht, G.F., K.M. Gillbertson, and J.L. Eckhoff, (1993). Tef Food Crop for humans and animals. In: J.Janick and J.E. Simon (eds.) New Crop. Wiley, New York. pp. 231- 234.

Stallknecht, G.f. (1997). New Crop Fact Sheet. Teff, Purdue University. Centre for New crops and Plant Productions.

Westephal, E., (1975): Agricultural System in Ethiopia, 278. Centre for Agric. Publ. and Document (PUDOC), Wageningen.

Genotype by environment interaction of hulless barley (*Hordeum vulgare L.)* genotypes in western Oromia

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Abstract
AMMI biplot is an effective method based on principal component analysis to fully explore mult-location trials data. The study conducted to identify the best performing, high yielding stable hulless barley genotype for different environments and analysis of the ideal genotype. Twenty-five hulless barley genotypes were evaluated using lattice square design with three replications at six locations in western Oromia. The combined analysis of variance for grain yield of twenty five hulless barley genotypes indicated that genotype, environment and GEI were significant (P<0.05). The factors explained that the genotypes grain yield was affected by environment (21.2%), genotype (12.1%) and GEI (34.3%). The first two IPCAs are the most accurate model that could be predicted the stability of the genotype and explained by IPCA-I (34.7%) and IPCA-II (31.5%) of GEI. Similarly, analysis using Eberhart and Russell model revealed that genotypes, G19, G20, G21 and G22 were acceptable range of regression coefficients (bi), approaching to one (1.05, 1.05, 1.01 and 0.97), and deviation from regression closer to zero (s2di) (0.0834, 0.0823, 0.0952 and 0.0895), respectively. Genotype and genotype by environment (GGE bi-plot) analysis also revealed that genotypes G20 and G22 were stable across tested location while genotypes G3 and G24 high yielder and moderate stable. According, to stability parameters (bi, S2d2, biplot) and yield average results revealed that G20 and G22 genotypes are the most stable genotypes across test location, and G3 showed high yield and moderate stability with general adaptability. Therefore, these G3 was selected as potential candidates for possible release in western Oromia and similar agro-ecologies of the country
Key words: Hulless Barley, Genotype by Environment Interaction, Stability, AMMI, Biplot

Introduction
Barley (*Hordeum vulgare* L.) is one of the founder crops of the old world agriculture and one of the first domesticated cereal from its wild relative, *Hordeum vulgare*ssp, in the area of the middle east known as the Fertile Crescent (Zohary and Hopf, 1993; Badr et al., 2000; Gebremedhin, 2014). Ethiopia was at the beginning considered as the center of origin for cultivated barley, although gradually it was considered as a secondary center of diversity because of the absence of the wild relative (Vavilov, 1951). Barley is ranked fourth in the world after wheat, maize and rice in volume production (FAO, 2016), while in Ethiopia, it is fifth after tef, maize, sorghum and wheat with productivity of 2.16 ton ha^{-1} (CSA, 2018). Barley is a main food grain, in the highlands of Ethiopia. It is used for food (bread, injera, Kolo, Baso) beverages (local beer), livestock feed, and the straw are used for thatched roofing in the countryside of Ethiopia (USDA, 2015). Barley is grown twice a year from August to December (main season) and from March to July (belg season) in altitudes from

1800 to 3400 m. a. s. l. (Berhane et al., 1996; Muluken, 2013). Among cultivated cereal in Ethiopia, barley has a large number of accessions preserved in the Ethiopian gene bank, with over 15,300 samples. This is approximately 23% of the total landraces in the gene bank (Abebe, 2006). The large diversity of Ethiopian barley landraces could be due to the diversity in soils, climate, altitude and topography together with social and geographical isolation for long periods (Harlan, 1968). Cultivated barleys can be classified according to caryopsis form in hulled (syn. covered) and hull-less (syn. naked) types (Firdissa et al., 2010; Siebenhandl-Ehn et al. 2011). In Ethiopia, the cultivation of hulless barley is old like hulled barley but it is less common compared with hulled barley because of lower yield and less breeding activities. The most Ethiopian barley varieties are hulled, however, hulless barley (hulless barley) is gaining preference due to the ease with which it can be processed, prepared and presented for food (Zohary&Hopf, 2000).The national average yield of the barley is estimated at 22 kgha^{-1} (CSA, 2018), which is very low compared to the world's average yield of 30.9 kgha^{-1} (FAO, 2012). This yield gap between achieved and potential yield of barley in Ethiopia might be due to varietal and environmental variability.Evaluating genotypes of annual crops for grain yield on a multi-locational or multi-year basis frequently shows G x E interaction that complicates the selection or recommendation of materials. According to Annicchiarico (1997), it is possible to cope with genotype x year or genotype x location x year interaction effects only through selection for yield stability across environments defined as location x year combinations. G x E interactions are of major importance, because they provide information about the effect of different environments on cultivar performance and have a key role for assessment of performance stability of the breeding materials (Moldovan et al. 2000).The objectives of the study were to estimate the effect of genotype x environment interaction on the grain yield and stability of hulless barley genotypes and to estimate magnitude of genotype x environment interaction of hulless barley genotypes in Ethiopia.

Materials and Methods

Experimental Design, Management and season

Twenty five hulless barley genotypes were planted at each location in lattice square design (5 x 5) with three replications in the 2018-2020 cropping seasons. There were 5 blocks in each replication and each block had 5 genotypes. Each plot was consisted of 6 rows with spacing of 0.20m, 2.5m length and 1.2m width. The spacing between plots and replications was 0.5m and 1.5m, respectively. Seed rate of 125 kgha^{-1} and fertilizer rate of NPS 100 kgh^{-1} and urea 50 kgh^{-1} were utilized. The experiment was conducted in the main season under rain fed condition. All the agronomic managements and practices were adopted as per recommendation for each location. Yield data was taken per plot basis and converted to kgha^{-1} for each plot.

Statistical analysis

Analysis of Variance

The data collected to analysis of variance (ANOVA) using SAS version 9.3 and PBSTAT, and least significant difference (LSD) was used to separate the means that showed significant difference at five percent probability levels. The data to combined analysis of variance to obtain estimates of environmental, genotype, genotype x environment interaction.

Stability Analysis

Additive main effects and multiplicative interaction (AMMI) Model Analysis

Additive main effects and multiplicative interaction (AMMI) model analysis was performed for grain yield using SAS and PBSTAT software. AMMI model first applies the additive analysis of variance model to the multiplicative principal component analysis (PCA) model to residual from the additive model, that is, to the interaction. The AMMI analysis was performed according to the model suggested by crossa et al. (1995). In this model the first component were the main effect and the additive part of the model. The AMMI Model is

$$yij = \mu + Gi + Ej + (\sum Kn\, Vni\, Sj) + Qij + eij)$$

yij = observed yield of genotype i in environment j = grand mean, Gi= additive effect of the ith genotype (genotype means minus the grand mean), Ej= additive effect of the jth environment (environment mean deviation), Kn= eigen values of the PCA axis n, Vni and Snj = 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

Result and Discussion

AMMI analysis for grain yield.

The AMMI analysis of variance of grain yield showed that genotype and genotype by environment interaction were significant ($P<0.05$), and for the testing location was highly significant ($P<0.01$) (Table 2). The factors explained showed that hulless barley genotype grain yield was affected by environment (21.2%), genotype (12.1%) and GEI (34.3%). The results revealed that there were significant differences among the tested genotypes for grain yield, which suggested that the genotypes differed considerably with respect to yield performance. Muez et al., (2014) and Shahram et al., (2008) reported that food barley grain yield was significantly affected by the environment. Abdel-Raouf et al., (2020) also reported that a significant ($p<0.05$) mean squares due to genotypes (G) and GEI were detected for grain yield, which indicated that the hulless barley genotypes performed differently at different environments.

The AMMI analysis of variance (multiplicative effect) was further exploited by decomposition principal components analysis. The multiplicative variance of the genotypes sum of squares due to GEI was partitioned into five IPCAs. Among these IPCA axes the first four have statistically significant variance of GEI. IPCA-I score explained 34.7% and IPCA-II 31.5% of the variability, with the IPCA-III was also significant for hulless barley genotypes it contributed 18 % of the genotype by environment interaction (GEI) sum of squares (Table 2). Therefore, as indicated by the F-test, inclusion of the first two interactions PCA axes (IPCA- I & IPCA- II) that captured 66.2 % of total portion of GEI variance was recommended in the model. Stability analysis for genotypes. According to Purchase, 1997 the interaction principal component axis (IPCA) scores of a genotype provide indicators of the stability of a genotype across environments.

Table 1. Hulless barley genotypes evaluated in the six environments

Genotypes	Code	Source	Genotypes	Code	Source
BARC/JED/001/14	G1	Collection/Jaldu	INBYT13-3	G14	ICARDA
BARC/JED/002/14	G2		INBYT13-4	G15	
BARC/JED/003/14	G3		INBYT13-5	G16	
BARC/JED/004/14	G4		INBYT13-11	G17	
BARC/JED/006/14	G5		INBYT13-12	G18	
BARC/JED/008/14	G6		INBYT13-14	G19	
BARC/JED/009/14	G7		INBYT13-19	G20	
BARC/JED/004-2/14	G8		INBYT13-20	G21	
BARC/JED/005-2/14	G9		INBYT13-25	G22	
BARC/JED/007-1/14	G10		FCJelduSPS-10	G23	Collection/Jaldu
BARC/JED/008-1/14	G11		FCAmbo-16	G24	Collection/Ambo
BARC/JED/009-1/14	G12		**Qaxe(check)**	G25	Shambu

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 (%)
Total	449	369045650.3	8219			
Env	5	78154631.8	15630926.4	14.513	0.00009	21.2
Rep(Env)	12	12924102.8	1077008.6	2.903	0.0008	3.5
Gen	24	44679332.4	1861638.8	1.767	0.01419	12.1
Env:Gen	120	126450601.2	1053755.0	2.841	0.0505	34.3
PC1	28	43882056.9	1567216.3	4.22	0.00003	34.7
PC2	26	39788823.2	1530339.4	4.13	0.00007	31.5
PC3	24	22800446.9	950018.6	2.56	0.0001	18.0
PC4	22	12115646.8	550711.2	1.48	0.00791	9.6
PC5	20	7863627.5	393181.4	1.06	0.392	6.2
Residuals	288	106836982.1	370961.7			

Regression analysis based on Eberhart and Russell Model

According to Eberhart and Russell (1966), a stable genotype should have high yield, unit regression coefficient (bi) and deviation from regression (Sdi2) close to zero. The coefficient of regression (bi) values for twenty five genotypes used in this study ranged from G3 (0.16) to G13 (2) (Table 3). There was no genotype with b-values equal to unity, while the regression coefficient values for some of genotypes including G19, G20, G21 and G22 were close to 1, deviation from regression closer to zero (s2di) (0.0834, 0.0823, 0.0952 and 0.0895), respectively (Table 3). These genotypes had regression coefficient closer to unity, deviation from regression very close to zero with and mean grain yield greater than the average and hence could be considered as stable. Genotypes G3 and G24 had regression coefficients less than one and higher yielder, implying their specific adaptability to test locations.

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	s2di	P_s2di	Wi2	StabVar
G1	2765.76	22.66	0.39*	0.011	3.27**	0.006	2191786	1383610
G10	2876.13	18.52	0.52*	0.043	1.61ns	0.058	1385630	857856.3
G11	2270.63	26.78	1.15ns	0.539	0.03ns	0.425	501656.2	281351.6
G12	2816.22	31.65	1.94***	0.000	1.10ns	0.981	972315.7	588303.5
G13	3120.44	32.35	2.00***	0.000	1.03ns	0.122	1959415	1232064
G14	3237.68	23.23	0.73ns	0.264	4.42**	0.001	2339771	1480122
G15	2702.49	27.67	0.70ns	0.204	4.49**	0.001	2386316	1510478
G16	2166.71	31.6	0.90ns	0.688	2.49*	0.018	1501344	933321.7
G17	2796.01	30.32	1.60*	0.012	1.05ns	0.119	1294482	798412
G18	2802.45	22.65	0.85ns	0.531	1.91*	0.040	1283171	791035.4
G19	**2705.53**	**23.98**	**1.05ns**	**0.0834**	**1.15ns**	**0.105**	**959637.9**	**580035.4**
G2	2838.75	33.62	1.80***	0.001	1.70ns	0.052	1844493	1157114
G20	**2690.45**	**29.42**	**1.05ns**	**0.0823**	**3.70****	**0.004**	**1980408**	**1245755**
G21	**2735.01**	**28.04**	**1.01ns**	**0.0952**	**3.43*8**	**0.005**	**1869088**	**1173155**
G22	**2643.47**	**21.51**	**0.97ns**	**0.0895**	**0.36ns**	**0.273**	**640250.1**	**371739**
G23	2507.56	17.05	0.45*	0.022	0.51ns	0.228	1015489	616459.7
G24	2673.07	19.19	0.74ns	0.275	0.62ns	0.201	814712	485518.5
G25	2861.96	24.81	0.89ns	0.636	3.01**	0.009	1713697	1071813
G3	3751.99	23.87	0.16***	0.001	8.72***	0.000	4716688	3030285
G4	2764.05	29.23	1.56*	0.021	0.61ns	0.203	1063017	647456.6
G5	2778.78	17.07	0.78ns	0.357	0.01ns	0.413	539716.2	306173.4
G6	3145.89	29.16	0.49*	0.032	8.6***	0.000	4234508	2715820
G7	2742.44	41.17	1.87***	0.000	5.60***	0.000	3522716	2251608
G8	2692.1	15.44	0.56ns	0.064	0.11ns	0.360	744848.7	439955.4
G9	2244.5	23.41	0.84ns	0.497	0.38ns	0.266	675044.5	394431

AMMI biplot analysis

The interaction principal component (IPCA-I) was plotted in the x-axis whereas the interaction principal component two (IPCA-II) plotted in the y-axis (Figure 1). The AMMI analysis for the first interaction principal component (IPC-I) captured 34.7% and the second interaction principal(IPC-II) component explained 31.5%, the two interaction principal components cumulatively captured 66.2% of the sum of square the genotypes by environment interaction of hulless barley genotypes, 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. G8, G20 and G22 was located near to the origin implying that it was stable hulless barley genotypes. Genotypes with interaction principal component (IPCA1) values higher than zero classified as high yield while those with IPCA1 values lower than zero are classified as low yield and low adaptability (kaya et al., 2006). Genotypes G3 and G6 were genotypes with IPCA1 greater than zero implying that had higher in yield, it implies these genotypes high grain yield and moderate stable.

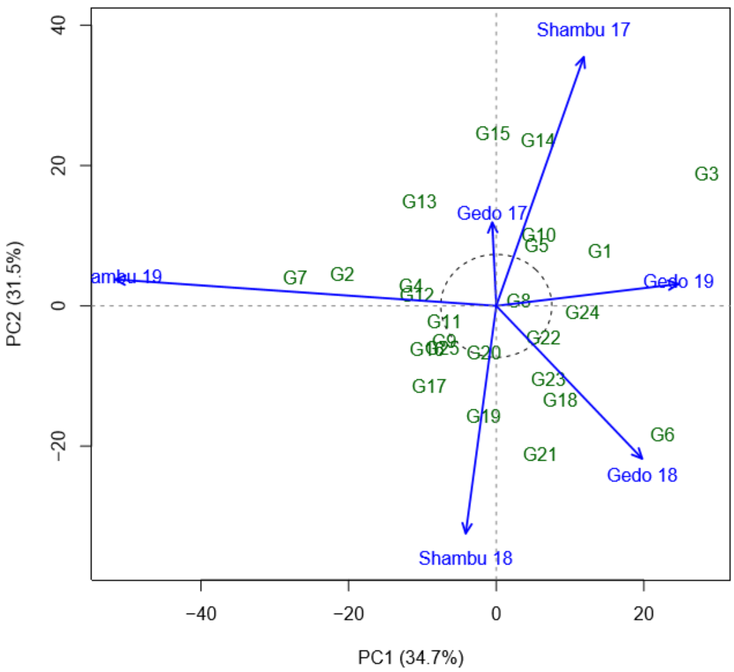

Figure 1. AMMI biplot: PC1 vs PC2

Conclusion

In conclusion, AMMI analysis, regression coefficient, deviation from regression and GG biplot results revealed that G20 and G22 were relatively stable genotypes with optimum grain yield and therefore recommended for further research. Besides, G3 and G5 genotypes were optimum stable across tested location and high grain yield, therefore, they are recommended for possible release for specific adaptability around western Oromia areas with similar agro-ecology in the country.

Reference

Abebe D. (2006). Regional strategy for the ex-situ conservation of plant genetic resources: Eastern Africa. Eastern Africa Plant Genetic Resources Network (EAPGRN

Abdel-Raouf, MS, AA Kandil1, AA El-Sayed and AM Attya. (2020). Stability of Hull-less Barley Genotypes Grown at Different Environments in Egypt. Alex. J. Agric. Sci. V 62:45-54.

Annicchiarico P. (1997). Additive main effects and multiplicative interaction (AMMI) analysis of genotype-location interaction in variety trials repeated over years. Theor Appl Genet. 94:072–1077.

Badr A, Müller KJ, Schäfer-Pregl R, El Rabey H, Effgen S, Ibrahim HH, Pozzi C, Rohde W, Salamini F. (2000). On the origin and domestication history of barley (*Hordeum vulgare*). Mol Biol Evol .17:499–510

Berhane L, Hailu G, Fekadu A. (1996). Barley production and research. In G. Hailu and J. van Leur (eds.). Barley Research in Ethiopia. Past work and future prospects. Proceedings of the First Barley Review workshop, 16- 19 October 1993, Addis Ababa: IAR/ICARDA

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

Crossa,J., HG Gauch, and RWZobel. (1990). Additive main eff ects and multiplicative interaction analysis of two international maize cultivar trials. Crop Sci. 30:493–500

Gebremedhin W., Firew M., Tesfye B. (2014). Stability analysis of food barley genotypes in northern Ethiopia. African Crop Science Journal .22:145–153

Berhane L, Hailu G, Fekadu A. (1996). Barley production and research. In G. Hailu and J. van Leur (eds.). Barley Research in Ethiopia. Past work and future prospects. Proceedings of the First Barley Review workshop, 16- 19 October 1993, Addis Ababa: IAR/ICARDA.

Firdissa E, Sinebo W, Heinrich G. (2010). On-farm diversity and characterization of barley (*Hordeum vulgare* L.) landraces in the highlands of West Shewa, Ethiopia. J. Plants People Appl. Res. 8:25- 34

Moldovan V, Moldovan M, Kadar R. (2000). Item from Romania. S:C:A Agricultural Research Station.

Muluken B. (2013). Study on malting barley genotypes under diverse agro ecologies of north western Ethiopia: Adet Agricultural Research Centre, p. O. Box 08, Bahirdar, Ethiopia

Muez M, Sentayehu A, Berhane L, Haddis Y, Mizan T. 2014. Parametric stability analysis of malt barley genotypes for grain yield in Tigray, Ethiopia. World J. Agric. Sci. 10: 210-215.

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.

Samarah NH. (2005). Effects of drought stress on growth and yield of barley. Agron sustain dev. 25:145-149.

Siebenhandl-Ehn S, Kinner M, Leopold LF, PoppernitschMB,Pru¨M, Wurbs P et al. (2011). Hulless Barley-are discovered source for functional foods phytochemical profile and soluble dietary fiber content in naked barley varieties and their antioxidant properties.http://cdn.intechopen.com/pdfs-wm/25502.pd.

Shiferaw T, Abate B, Lakew B. (2020). Genetic variability and association of traits in Ethiopian barley (*Hordeum vulgare* L.) genotypes at Holetta, Central Ethiopia. J. Agric. Crop Res. 8(1):11-19.

USDA (United State Department of Agriculture) .(2015). Global Agricultural information Network. Grain and Feed annual Report.

Vavilov, N. I. (1951). Phytogeographic basis of plant breeding. In The origin, variation, immunity and breeding of cultivated plants.13:1-366.

Zohary D, Hopf M. (1993). Domestication of plants in the Old World. 2nd edn. Oxford University Press.
Zobel RW, Wright MJ and GauchHG .(1988). Statistical analysis of a yield trial. Agron J 80:388– 393

Genotype by Environment Interaction and Grain Yield Stability Analysis for Ethiopian Sorghum [*Sorghum bicolor* (L.) Moench] Genotypes

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Abstract
Genotype performance depends on genetic makeup of the genotype and environment where it is grown. Twenty sorghum genotypes and a standard check (Bonsa) were evaluated at Bako, Gute and Bilo for three years (2017-2019) with the objective to identify stable and high yielding genotypes. The experiment was laid out in randomized complete block design with three replications and each plot comprised three rows of 5m long and 0.75 m spacing between rows and 0.15 m 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. Result of the study based on AMMI, GGE biplot and Eberhart and Russell models indicated that ETSL 101259 (G19) was the best variety followed by 8 line 2A (G18), ETSL 100618 (G10) and ETSL 101691 (G8) for their high mean grain yield and stability across test environments. These genotypes are also resistant to anthracnose and grain mold. Hence, these genotypes could be recommended for possible release for Bako, Gute and Bilo and areas with similar agroecology.

Introduction
Sorghum [Sorghum bicolor (L.) Moench] is an important food grain crop of Ethiopia which contributes about 19.3% of the total cereal production (CSA, 2018). High genetic diversity is vital for the development of stress resistant and climate resilient crop genotypes to mitigate the impact of climate change. Ethiopia has a wealth of genetic resources for sorghum (Birhane, 1973) and has contributed for the global germplasm pools and sources of genes for important traits (Doggett, 1988). As a center of origin and diversity for sorghum, extensive genetic variation of Ethiopian sorghum was reported by different authors (EBI, 2007; Dillon et al., 2007). Genotype by environment (G x E) interactions are considered to be one of the key factors limiting response to selection and the efficiency of breeding programs. Environment change can affect the performance of genotypes, and breeders should give due attention to the impact of G x E in genetic exploitation to be efficient in selection. Ghaderi et al. (1980) observed that analysis of variance procedure helps to estimate the magnitude of G x E interaction; but is unable to provide information on the contribution of each genotype and environment to G x E interactions. On the other hand, analyses 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 GGE 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). This experiment was conducted with the objective to identify stable and high yielding genotype(s).

Materials and Methods

Twenty Sorghum genotypes originally selected from Sorghum and Millets Innovate Lab (SMIL) core collections were used for this study (Table 1). The study was conducted for three years (2017-2019) at Billo- Boshe; and for two seasons (2018 and 2019) at Bako and Gute research stations. The experiment was laid out in randomized complete block design with three replications and each plot comprised three rows of 5m long and 0.75m spacing between rows and 0.15m intra rows spacing. Seed rate of 12 $kgha^{-1}$ and fertilizer rate of 100 kg ha^{-1} NPS and 100 $kgha^{-1}$ Urea were used. Urea was applied in split form; half at planting and the rest half at 35 days after emergence.

Data analysis

AMMI analysis of variance was carried out using AMMI model, regression (Eberhart and Russell, 1966) 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:

$Yij=\mu + gi + ej + \Sigma\lambda k + \alpha ikyjk + Rij$

Where, $Y_{ij}$is the yield of i^{th} -genotypes in j^{th} environment; μ is the overall mean; g_i is the effect of the i^{th} genotype; $e_j$is the effect of the j^{th} environment; λk is the Eigen value of the PCA for axis k. Then α_{ik} and y_{jk} are the genotype and environment principal component scores for axis k, respectively, and R_{ij} is the residual term. Environment and genotype PCA scores are expressed as unit vector times the square root of λk.

Table 1: Genotypes and the test environments with their sorghum codes used in a study in Ethiopia

No.	Genotype	Genotype code	No.	Environment	Environmental code
1	10 line 2A	A	1	Bako 18	A
2	16 line 1A	B	2	Bako 19	B
3	8 line 2A	C	3	Bilo 17	C
4	8 line 2C	D	4	Bilo 18	D
5	Bonsa	E	5	Bilo 19	E
6	ETSL 100124	F	6	Gute 18	F
7	ETSL 100406	G	7	Gute 19	G
8	ETSL 100548	H			
9	ETSL 100587	I			
10	ETSL 100618	J			
11	ETSL 100621	K			
12	ETSL 100657	L			
13	ETSL 101066	M			

14	ETSL 101168	N
15	ETSL 101259	O
16	ETSL 101327	P
17	ETSL 101343	Q
18	ETSL 101581	R
19	ETSL 101691	S
20	ETSL 101757	T

Eberhart and Russell Regression Model.

The Eberhart and Russel model was used and is represented by: Yij = μi +biIj +S2dij; 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 environments; 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.

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.

Result and Discussion

AMMI Analysis

The AMMI analysis of variance indicated that grain yield was highly significant (P<0.01) influenced by genotypes (G), environments (E) and genotype by environment interactions (Table 2). The grain yield performance of the genotypes is affected by the response of the genotypes to the different environments or the existence of genotype by environment interactions (GEI). Various authors also reported similar results for sorghum genotypes valuated across different locations and years (Admas and Tesfaye, 2018; Worede et al., 2020; Al-Naggar et al., 2018). The AMMI analysis partitioned the sum of squares of GEI into four interaction principal component axes (IPCA), of which the first three IPCA were significant (Table 2). 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 (46.02%) was explained by IPCA-I; followed by 20.42%, 11.76% and 9.60% for IPCA-II, IPCA-III and IPCA-IV, respectively (Table 2). The GEI components' values in this experiment using AMMI model are comparable with the reports from Mohammed (2020) in maize and Admas and Tesfaye (2017) in sorghum from their Genotype-by-environment interaction and yield stability analysis.

Table 2. Analysis of variance for Additive Main Effects and Multiple Interaction (AMMI) for yield stability of sorghum genotypes in Ethiopia

Source	Df	SS	MS	% GXE	% cumulative interaction explained
Genotypes (GEN)	19	124.9	6.574**		
Environments (ENV)	6	459	76.503**		
GEN* ENV	114	158.2	1.388**		
IPCA I	24	72.8	3.033**	46.02	46.02
IPCA II	22	32.3	1.468**	20.42	66.43

IPCA III	20	18.6	0.928*	11.76	78.19
PCA IV	18	15.20	0.844^{ns}	9.60	87.80
Residuals	266	140	0.526		

Grand mean = 3.0; R2= 0.8574; Coefficient of variation (CV, %) = 15.2%; *, ** = significant at P < 0.05 and P < 0.01 levels, respectively, ns=non-significant

The AMMI analysis result revealed that ETSL 101259(G19), 8 line 2A (G18), ETSL100618 (G10) and ETSL 101691(G8) attained IPCA values (0.007, -0.432, -0.804 and -0.161, respectively) which is relatively close to zero, and gave relatively high yield. The recorded data indicated that these genotypes are resistant to two important diseases v.z., anthracnose and grain mold (Table 4). These genotypes are better stable and widely adaptable genotypes across location, than the standard check and other tested genotypes (Table 2). On other hand, genotypes ETSL 100548, ETSL 101757, 16 line 1A and ETSL 101581 scored IPCA values closer to zero (-0.170, -0.178, -0.291, -0.375), but gave lower mean grain yield than the above genotypes. Hence, genotypes ETSL 101259, 8 line 2A, ETSL 100618 and ETSL 101691 are selected relatively as stable and high yielder candidates to be released as new variety in Ethiopia.

Table 3. Grain yield (GY) (t ha^{-1}) and IPCA1 scores of sorghum genotypes assessed for stability in Ethiopia

Genotype name	IPCA1 score	Mean grain yield (t ha^{-1})	Yield rank
10 line 2A	-0.910	2.4	
16 line 1A	-0.291	2.4	
8 line 2A	-0.432	3.8	2
8 line 2C	0.473	1.9	
Bonsa	0.859	2.7	
ETSL 100124	0.653	3.4	
ETSL 100406	0.432	2.9	
ETSL 100548	-0.170	2.5	
ETSL 100587	1.144	2.7	
ETSL 100618	-0.804	3.7	3
ETSL 100621	0.078	3.0	
ETSL 100657	-0.107	3.5	
ETSL 101066	0.061	3.2	
ETSL 101168	0.026	3.5	
ETSL 101259	0.007	3.9	1
ETSL 101327	-0.170	2.9	
ETSL 101343	-0.138	3.0	
ETSL 101581	-0.375	2.9	
ETSL 101691	-0.161	3.7	
ETSL 101757	-0.178	2.7	

Genotypes such as ETSL100587, Bonsa, ETSL100124 and ETSL100406 scored IPCA values deviating from zero (1.144, 0.859, 0.653, 0.432) and average mean grain yield; indicated unstable genotypes and their response were varied across locations. Among tested genotypes, 8 line 2C showed IPCA score deviating from zero and lower mean grain yield than other genotypes indicating environmental sensitivity of the genotype. The report of research result by Worede et al. (2020) from sorghum field experiments corroborated the present finding that genotypes with low grain yield and IPCA value deviated from zero are not stable and are highly environmental sensitive.

Table 4. Grain yield (tha^{-1}) for the tested genotypes over location and years in Ethiopia

Genotype	Bako		Bilo			Gute		Mean	Disease reaction (1-5)	
	2018	2019	2017	2018	2019	2018	2019		TH	GM
ETSL 101168(G1)	5.9	3.4	1.4	3.4	2.6	5.0	2.7	3.5	3.7	1.0
ETSL 101757(G2)	4.6	1.6	1.7	2.0	1.7	4.5	2.7	2.7	3.2	1.0
10 line 2A(G3)	3.8	1.0	1.5	2.0	0.2	5.5	3.1	2.4	3.3	1.8
ETSL 101343(G4)	5.0	2.0	3.1	2.2	1.5	4.7	2.4	3.0	3.2	1.0
8 line 2C(G5)	4.2	1.3	1.8	0.9	0.4	2.3	2.6	1.9	3.3	1.8
ETSL 101066(G6)	4.0	2.6	2.9	2.4	2.5	4.5	3.4	3.2	2.8	1.0
ETSL 101327(G7)	3.9	2.4	2.4	2.7	1.9	4.7	2.1	2.9	3.0	1.0
ETSL 101691(G8)	5.1	3.1	2.9	3.8	2.5	5.4	3.0	3.7	2.4	1.2
ETSL 100548(G9)	4.9	1.1	2.2	2.1	1.1	4.2	1.6	2.5	3.3	1.2
ETSL 100618(G10)	4.8	2.6	3.7	2.6	2.6	5.7	4.0	3.7	2.4	1.5
ETSL 100657(G11)	4.9	2.3	3.2	3.4	2.2	5.0	3.4	3.5	3.0	1.3
ETSL 100621(G12)	4.7	2.7	2.6	2.2	1.3	4.2	3.1	3.0	3.7	1.3
ETSL 100406(G13)	4.7	2.9	1.7	2.2	1.9	3.5	3.1	2.9	3.3	1.2
ETSL 101581(G15)	4.4	2.7	3.4	1.5	1.2	5.2	2.1	2.9	2.7	1.0
ETSL 100124(G16)	4.7	3.1	4.3	2.6	2.8	3.6	3.0	3.4	3.0	1.0
16 line 1A(G17)	4.0	1.2	2.7	2.2	0.4	4.2	1.9	2.4	2.0	2.7
8 line 2A(G18)	5.8	2.9	2.8	3.9	1.9	6.0	3.4	3.8	2.3	1.0
ETSL 101259(G19)	6.7	3.0	3.3	2.4	2.9	5.6	3.6	3.9	2.2	1.0
ETSL 100587(G20)	5.4	2.7	2.4	2.5	1.8	1.8	2.2	2.7	3.7	1.0
Bonsa (G14)	4.2	1.7	2.7	2.0	2.6	2.4	3.6	2.7	3.5	1.8
Mean	4.8	2.3	2.6	2.5	1.8	4.4	2.8	3.0	3.0	1.3
LSD	1.3	0.6	0.6	0.5	0.4	0.9	0.8	0.3	0.8	0.8
CV	16.1	15.0	14.5	12.8	14.1	11.7	16.4	14.4	15.2	23.4
F-test at 5%	**	**	**	**	**	**	**	**	**	**

ANTH=Anthracnosis, GM= Grain mold, 1-5 scale was used for disease record,1=highly resistant, 2=resistant, 3=moderately resistant, 4=susceptible and 5=highly susceptible)

Regression analysis

Analysis of variance for grain yield for sorghum genotype using the Eberhart and Russell Regression Model revealed, the presence of highly significant ($p<0.01$) difference among the genotypes for grain yield performance (Table 5). On the other hand, non-significant effect showed by genotypes by environment.

According to Eberhart and Russell (1966) 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. Genotypes that fitted to Eberhart and Russell Model can be proposed for possible release in breeding program. The result of this study showed

that ETSL101259 gave the highest grain yield followed by 8 lines 2A, ETSL101691 and ETSL100618 with mean 3.9, 3.8, 3.7, 3.7 t ha^{-1}, respectively.
These genotypes showed regression coefficients (bi) approaching to one (1.34, 1.30, 0.93, 1.21) and acceptable deviation from regression approaching to zero (0.09, 0.08,0.06, 0.69), respectively; indicating they are stable, widely adaptable and high yielding than other genotypes (Table 6). Supportive findings were reported by Amare et.al. (2019), in their genotype by environment interaction and grain yield stability on twenty-two sorghum genotypes.

Table 5. Analysis of variance for grain yield for sorghum genotypes using the Eberhart and Russell Regression Model

Source	Df	SS	MS
Total	139	247.39	1.78
Genotypes	19	41.638	2.191**
Env + (Gen x Env)	120	205.752	1.715
Env (linear)	1	153.007	153.007
Gen x Env (linear)	19	11.885	0.626^{ns}
Pooled deviations	100	40.86	0.409

Grand mean = 3.0; R2 = 0.8574; Coefficient of variation (CV) = 15.2 %,*, ** = Significant at P < 0.05 and P < 0.01 levels, respectively.

Table 6. Regression coefficient (bi) and squared deviation from linearity of regression (s2di) by the test sorghum genotypes using Eberhart and Russell model

Genotypes	Regression coefficient (bi)	squared deviation from regression (S^2di)	Grain yield (ton ha^{-1})
10 line 2A	1.46	0.50	2.38
16 line 1A	1.15	0.13	2.38
8 line 2A	1.30	0.08	3.81
8 line 2C	0.95	0.30	1.93
Bonsa	0.44	0.48	2.74
ETSL 100124	0.48	0.22	3.44
ETSL 100406	0.78	0.16	2.87
ETSL 100548	1.27	-0.01	2.46
ETSL 100587	0.62	1.07	2.68
ETSL 100618	1.21	0.69	3.70
ETSL 100621	1.01	-0.07	2.98
ETSL 100657	0.94	-0.07	3.46
ETSL 101066	0.69	-0.07	3.18
ETSL 101168	1.14	0.74	3.48
ETSL 101259	1.34	0.09	3.92
ETSL 101327	0.83	0.03	2.90
ETSL 101343	1.16	-0.06	2.98
ETSL 101581	1.17	0.43	2.94
ETSL 101691	0.93	0.06	3.70
ETSL 101757	1.13	-0.04	2.68

This result indicates that genotypes are less stable and not adaptable over testing environments. Genotypes, 8 line 2C and 10 line 2A showed better stability and, also were widely adaptable over the environment; but recorded lower grain yield. 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 Kebede et al. (2019) that significant differences between genotypes for grain yield of eight finger millet genotypes across six environments.

GGE biplot analysis

Stability analysis using biplot for grain yield explained 69.68 % of total variation (46.52, 23.16 % by PC1 and PC2, respectively) (Figure 1). The biplot showed that genotype ETSL 101259(G19) was in the first concentric circle, closer to IPCA stability horizontal line; followed by ETSL10691 (G8), 8 line 2A (G18), ETSL100618(G10) and ETSL101168(G1) and away from the mean vertical line which indicates these genotypes were stable and high yielders among tested genotypes.

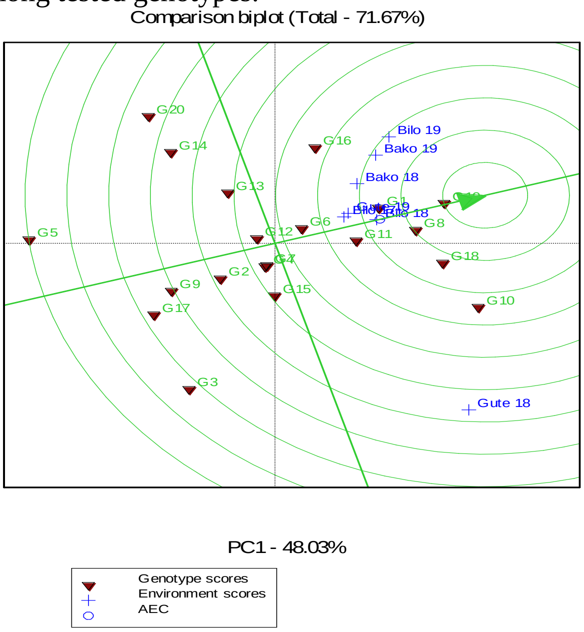

Figure 1. GGE Biplot analysis showing grain yield stability of sorghum genotypes and environments in Ethiopia.

On other hand, genotypes 8 line 2C (G5), 10 line 2A (G3) and 16 line 1A (G17) were stable genotypes, but showed inferior in grain yield which gave less than average (1.9, 2.4, and 2.4, respectively). Genotype ETSL100124 (G16) gave high grain yield (3.4 t ha^{-1}), however; it deviate from the mean horizontal line, which implies the genotype is not stable (Figure 1).

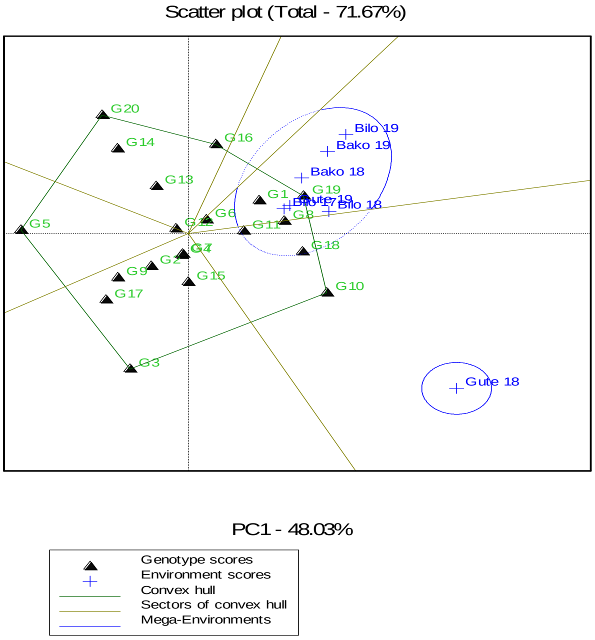

Figure 2. Polygon view of the GGE biplot based on grain yield for the environments

This result is in agreement with the AMMI and Eberhart and Russell models discussed above. Kebede et al. (2019); Kebede et al. (2018) for finger millet and, Worede et al. (2020); Hamidou et al. (2019) for sorghum also identified stable genotypes in their earlier research findings. The GGE biplot analysis (Figure 2 and 3) indicates the best performing genotype(s) for specific environment and the group of environments. Biplot divided the plot into seven sections and the environments categorized in two mega environments.

In GGE- 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 (Yan et al., 2007).

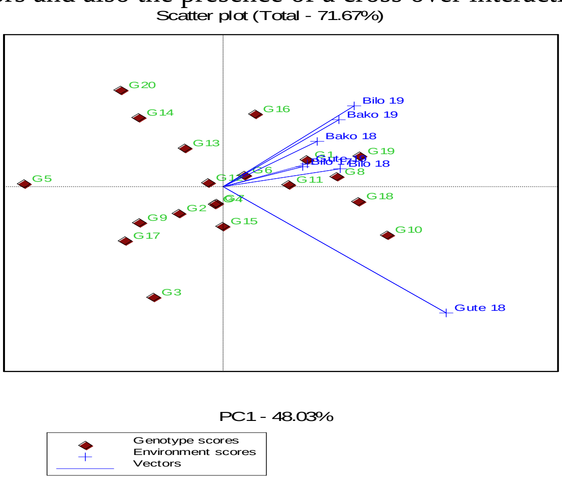

Figure 3. GGE biplot based on grain yield for the 20 genotypes showing the relationship among environments.

Moreover, according to Yan (2002) and Yan and Tinker (2006), genotype at the vertex of the polygon performs best in the environment falling within the sectors. In the present study, ETSL101259, ETSL10691 and ETSL101168 performs best at Gute 2019, Bako 2018, Bilo 2018 and Bilo 2017.
On other hand, presence of wide obtuse angles between environment vectors (Figure 3) indicates strong negative correlations among the test environments, suggesting existence of strong crossover GE across some locations for grain yield. Moreover, this result indicates genotypes responded differently over environments that genotypes performing better in one environment might be poorly performed in another environment. Oppositely, the closer relationship among other locations is an indication of there is no cross over G x E which implies ranking of genotype does not change from location to location.

Conclusion

Additive main effect and multiplicative interaction (AMMI) model analysis revealed highly significant ($P<0.01$) variations among environments, genotypes, G x E interaction for grain yield AMMI analysis showed that genotype ETSL101259 (G19) was highly stable among the tested genotypes followed ETSL10691(G8) and 8 line 2A (G18) and they were high yielder.
Analysis of 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). GGE bi-plot analysis also confirmed that these genotypes were stable and high yielder. The scored disease data showed that ETSL 101259(G19), 8 line 2A (G18), ETSL100618(G10) and ETSL101691(G8) were resistant to the two major sorghum diseases viz., anthracnose and grain mold. On the other hand, depending on stability, disease reaction and moderate plant height ETSL101259 (G19) and 8 line 2A (G18), genotypes could be selected as potential genotypes.

Acknowledgment

The authors acknowledge Agricultural Growth Plan (AGP) 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., & Tesfaye, K. 2018. Genotype-by-environment interaction and yield stability analysis in sorghum (*Sorghum bicolor* (L.) Moench) genotypesin North Shewa, Ethiopia. Acta Universitatis Sapientiae, Agriculture and Environment, 9:82–94.
Al-Naggar, A., El-Salam, R., Hovny, M., & Yaseen, W. 2018. Genotype Environment Interaction and Stability of Sorghum bicolor Lines for Some Agronomic and Yield Traits in Egypt. Asian Journal of Agricultural and Horticultural Research, 1: 114.
BirhaneGebrekidan 1973. The importance of the Ethiopian sorghum germplasm in the world sorghum collection. Economic Botany 27:442 - 445
CSA (Ethiopian Central Statistical Agency). 2017. Agricultural survey report on area and production of major crops

Dillon, S. L., Shapter, F. M., Henry, R. J., Cordeiro, G., Izquierdo, L. and Lee, S. 2007. Domestication to crop Improvement: genetic resources for sorghum and saccharum (Andropogoneae). Annals of Botany, 100: 975 – 989.

Doggett, H. 1988. Sorghum 2nd edition London: Longman; published by Wiley, New York.

EBI (Ethiopian Biodiversity Institute) 2007. Ethiopia: Second Country Report on the State of PGRFA to FAO. Addis Ababa, Ethiopia

Eberhart, S.A. and Russell, W.A. 1966. Stability parameters for comparing genotypes. Crop Science 6:36– 40

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, New York

Ghaderi, A., Cress, C.E. and Everson, E.H 1980. Classification of environments and genotypesin wheat. American Journal of Crop Science 20:707-710

Hamidou, M., Souleymane, O., Ba, M. N., Danquah, E. Y., Kapran, I., Gracen, V., & Ofori, K. (2019). Identification of stable genotypesand genotype by environment interaction for grain yield in sorghum (Sorghum bicolor L. Moench). Plant Genetic Resources: Characterisation and Utilisation, 17, 81–86.

Amare Seyoum*, AdaneGebreyohannes, Amare Nega, Habte Nida, Taye Tadesse, Alemu Tirfessa and TamiratBejiga (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 Tech 7: 423.

Kebede, D., Dagnachew, Lule., Girma, M., Kassa, Mamo., Chemeda, B, Girma, C. and Gudeta, B. Genotype by Environment Interaction and Grain Yield Stability Analysis for Finger Millet (Eleusine coracana (L.) Gaertn) Genotypesfrom Western Oromia, Ethiop. J. Crop Sci., 6:119-133

Kebede, D., Daganchew, L., Megersa, D., Chemeda, B., Girma, M., Geleta, G., &Gudeta, B. (2019). Genotype by Environment Interaction and Adaptation. Crop Science, 27:29–71.

Mohammed, A. 2020. Genotype by environment interaction and yield stability analysis of open pollinated maize genotypes using AMMI model in Afar Regional State, Ethiopia. Journal of Plant Breeding and Crop Science, 12: 8-15

Worede, F., Mamo, M., Assefa, S., Gebremariam, T., &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

Yan, W. 2002. Singular value partitioning for biplot analysis of multi-environment trial data. Agronomy Journal 4:990–996

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., 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.

Yuksel Kaya, Palta, C. and Taner, S. 2002. Additive main effects and multiplicative interactions analysis of yield performances in bread wheat genotypes across environments. Turk Journal of Agriculture and Forestry 26:275–279.

Registration of "*MARARA*" Sorghum [S*orghum bicolor*(L.)MOENCH] Variety

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Abstract

Sorghum is an important food grain crop of Ethiopia widely grown in diverse agro-ecologies which contributes about 19.3% of the total cereal production. The national average yield is far below the potential yield of the crop. Limited availability of stable, high yielding and disease resistant improved sorghum varieties is one of the major production constraints in the country. This study was conducted with the objective to develop widely adapted, stable and high yielding, disease tolerant sorghum varieties for western Oromia and similar areas in the country. Twenty one pipeline sorghum genotypes including standard checks (Gemedi and Chemeda) were evaluated under a regional variety trial at Bako, BilloBoshe, Uke and Gute research stations from 2017 to 2018 main cropping seasons using randomized complete block design. *Marara* variety with the pedigree of ETSL101371(Acc. 212642) has been collected from Amhara Regional State by Ethiopian Institute of Biodiversity (EIB). The analysis results from Additive Main effect and Multiplicative Interaction (AMMI) and Genotype and Genotype by Environment interaction (GGE) biplot analysis revealed that *Marara* variety was stable and highly yielding (5.35 t h^{-1}) among the tested genotypes. The new variety had a yield advantage of 40% over the best standard check Gemedi. Among the tested genotypes, Marara sorghum variety was selected and officially released in 2018 for its high grain yield potential, stability and resistant against major leaf disease (anthracnose) and grain disease (grain mold).

Keywords: AMMI, Marara, Sorghum, Stability, Variety

Introduction

Sorghum (*Sorghum bicolor* (L.) Moench), $2n=2x=20$ chromosome refers to cultivated sorghum a member of the grass family Poaceae (Paterson et al., 2009). It is the world most important cereal crop (Ejeta&Grenier, 2005; ICRISAT, 2015) and grown throughout the arid and semi-arid tropics (Smith CW, F. R., 2000). It is the dietary staple food of more than 500 million people across the globe and ranked the fourth food grains of the world (El Naim et al., 2012). It is produced mainly for food and feed purposes, and used for sweeteners for the food industry and bio fuel in developed nations (Berenji et al., 2011). In Ethiopia, sorghum is an important food grain crop which contributes about 19.3% of the total cereal production. Sorghum productivity is far below the potential in the country, estimated national mean yielding of 2.72 tha-1 due to different constraints (CSA, 2018). Limited availability of stable high yielding and disease tolerant variety is among the major constraints of sorghum production in the country. As the result, Bako Agricultural Research Center conducting field experiments for varietal improvement of sorghum for the last 2 decades.Therefore, the aim of this study was to identify a widely adapted, high yielder and diseases resistance/tolerant sorghum variety for sorghum growing areas of western Oromia and similar agro-ecologies of the country.

Varietal Origin and Evaluation

Marara (*ETSL 101371*),sorghum variety was sourced from Ethiopian Institute of Bio-diversity (EBI) collected from Amhara regional State. This variety and other 21 sorghum pipelines were evaluated against the standard checks Gemedi and Chemeda, for two consecutive years (2017-2018) at Bako, Bilo Boshe, Gute and Uke research stations.

Agronomic and Morphological characteristics

*Marara (ETSL 101371),*the newly released sorghum variety is characterized by red seeded compact panicle and average 1000 seeds weight of 26.5 grams; has an average plant height of 366.5 cm, 105 days to flower and 156 days to maturity. The detailed agronomic characteristics of the variety are indicated in (Table 3) below.

Yield Performance

The released sorghumvariety *Marara (ETSL 101371)***,** showed higher mean grain yield (5.35 th^{-1}), and stable with yield advantage of (40 %) over the best standard check Gemedi (Table 1).

Stability and Adaptability Performance

The IPCA scores of genotypes in AMMI analysis are an indication of the adaptability over environments and association between genotypes and environments (Gauch& Zobel, 1996). The IPCA scores of genotypes (Table 2) showed that the first interaction principal component axis (IPCA1), explained 49.06% and the second interaction principal component axis (IPCA2) explained 25.76%. The AMMI model analysis result revealed that, Marara (ETSL101371) attained IPCA value with relatively closer to zero and gave high yield. Hence, this genotype was stable and high yielder across location than the best standard check (Gemedi) and other tested genotypes. AMMI biplot showed, genotypes scattered close to the horizontal origin stability line and away from vertical mean line to the right corner of the biplot is an indication of minimal interactions of genotypes by environments and more stable (Misira et al., 2009). The GGE biplot analysis showed that the variety fell in the second concentric circle away from vertical mean line and closer to the stability line crossing the origin (Figure 2), indicating its high yield potential and relative stability compared to the other genotypes (Yan, 2001). Accordingly, the two stability models result revealed the released variety ***"Marara"*** is stable and high yielder.

Table 1: Mean Grain yield (tha^{-1}) of genotypes over the tested location and across years

Genotype	Mean Grain Yield tha^{-1}					Mean	GM (1-5)	Anth (1-5)	GY advantage (%)
	Bako		B. Boshe	Gute	Uke				
	2017	2018	2017	2018	2018	2017			
1. Chemeda	2.37	1.23	2.38	1.10	2.97	2.18	2.3	1.5	2
2. ETSL 100126	1.88	4.72	3.01	3.89	4.26	3.58	3. 6	1.5	2

3. ETSL 100560	2.39	5.71	2.16	2.52	4.81	2.18	3.3	1.5	4	
4. ETSL 100569	4.61	4.65	2.49	2.64	4.89	3.14	3.7	1.0	2	
5. ETSL 100601	3.75	5.28	3.25	4.53	5.35	2.08	4.1	1.0	1.5	6.5
6. ETSL 100622	3.28	1.24	2.74	1.62	3.23	3.67	2.6	1.0	2	
7. ETSL 100652	4.23	3.81	4.69	2.48	4.53	3.94	3.9	1.5	1.5	
8. ETSL 100691	3.69	4.43	4.10	3.13	4.56	3.43	3. 9	1.0	2	
9. ETSL 101371	4.79	6.41	4.53	5.96	6.16	4.24	5. 5	1.0	1	40
10.ETSL 100743	3.49	5.39	2.36	1.86	3.42	3.41	3.3	2.5	3	
11.ETSL 100810	3.25	5.24	3.61	3.43	4.89	2.34	3.8	1.0	2	
12.ETSL 100845	2.64	1.72	2.83	4.12	6.22	3.63	3.5	1.0	1	
13.ETSL 100914	4.37	6.56	3.69	3.19	4.42	3.25	4.3	1.0	2	
14.ETSL 100705	2.80	6.20	1.14	3.28	5.38	2.31	3.5	1.5	3	
15.ETSL 101519	3.69	4.76	3.46	4.24	3.61	3.03	3.8	1.0	3.5	
16.ETSL 101651	1.45	3.11	2.03	3.07	4.97	2.20	2.8	1.5	3	
17.ETSL 101849	3.47	5.42	4.05	3.00	5.77	3.10	4.1	1.0	3	
18. Gemedi	3.45	4.31	3.18	2.88	5.82	3.14	3.8	1.0	2	
19. IS 25531	4.86	6.21	4.22	3.77	5.27	4.67	4.8	1.5	1.5	
20. IS 25542	4.25	3.93	4.46	2.62	4.58	3.76	3.9	2.0	2.5	
21. IS 38279	1.54	4.38	0.68	2.62	4.49	2.44	2.7	2.0	1.5	
G. Mean	3.35	4.51	3.10	3.14	4.74	3.13	3. 7			
LSD	0.41	1.63	0.93	1.10	0.82	0.71				
CV	14.7	22.1	18.1	21	10.5	13.8				
F-value	**	**	**	**	**	**				
Pooled ANOVA						F. Pr				
Environment						**				
Genotype						**				
G x E						**				

LSD= Least significant difference, CV= Coefficient of variation, GXE= Genotype by Environment interaction, GM S = Grain mold Severity (1-5), Anth Se = Anthracnose Severity (1-5)

Table 2: Analysis of variance for grain yield using AMMI model

Source	df	ss	ms	% Explained Total	Gxx E	Cumulative interaction
Environments	5	237.6	47.529**	49.28		
Genotypes	20	169.9	8.495**	21.99		
G x E Interactions	100	247	2.470**	28.73		
IPCA 1	24	121.2	5.049**		49.06	49.06
IPCA 2	22	63.6	2.892**		25.76	74.82
Residuals	240	177.8	0.741			
Total	377	850.9	2.257			

LSD testing done at $\alpha = 0.05$; ** = highly significant with $p \leq 0.001$, * = significant with $p \leq 0.05$. df= degree of freedom, SS=sum of squares, MS= mean squares, IPCA=Interaction Principal Component Axis

Reaction to Major Diseases

Marara (ETSL101371) sorghum variety showed tolerant to anthracnose *(Colletotrichum sublineolum)* and grain mold which are the major production constraint of sorghum in the country and much severe in western Oromia.

Conclusion

Marara sorghum variety was widely adapted, stable and showed high yield performance than the standard check and the other tested pipeline sorghum genotypes. Generally, GGE biplot and AMMI model analysis results revealed that *Marara (ETSL101371)* is a stable and high yielding (5.35 tha^{-1}) sorghum variety with 40% yield advantage over the best standard check, Gemedi (1.78 tha^{-1}) and also tolerant to major foliar and grain diseases. Therefore, it was officially released for wider production in west Oromia and areas with similar agro-ecologies.

Table 3: Agronomic and morphological characteristics of *Marara* sorghum variety

Adaptation area:	Western Oromia (middle altitude) Bako,Gute, B/Boshe, Uke and similar agro-ecologies
Altitude (masl)	1200 – 1950 m.a.s.l
Seed rate	12 kg/ha
Fertilizer rate	
• NPS	100gk/ha
• UREA	100kg/ha
Spacing b/n rows	0.75m
Days to maturity	150-156
1000 seed weight	26.5gm
Plant height	366.5cm
Crop pest reaction	Tolerant to major sorghum diseases
Yield (tha^{-1})	
• Research station	4.6-5.35
• Farmers field	3.9-5.1

Year of release 2019
Breeder seed maintainer: OARI/BARC

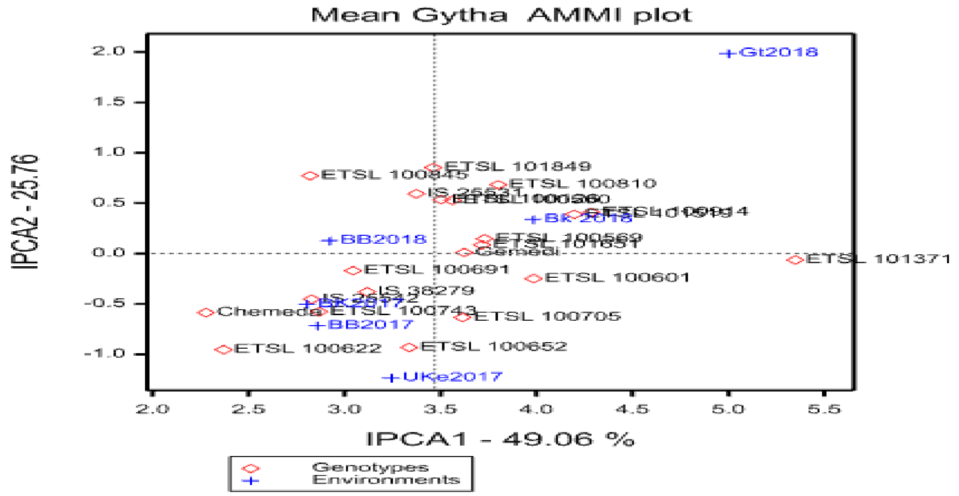

Figure 1. AMMI Biplot showing sorghum genotypes grain yield stability and preferential adaptation over environment

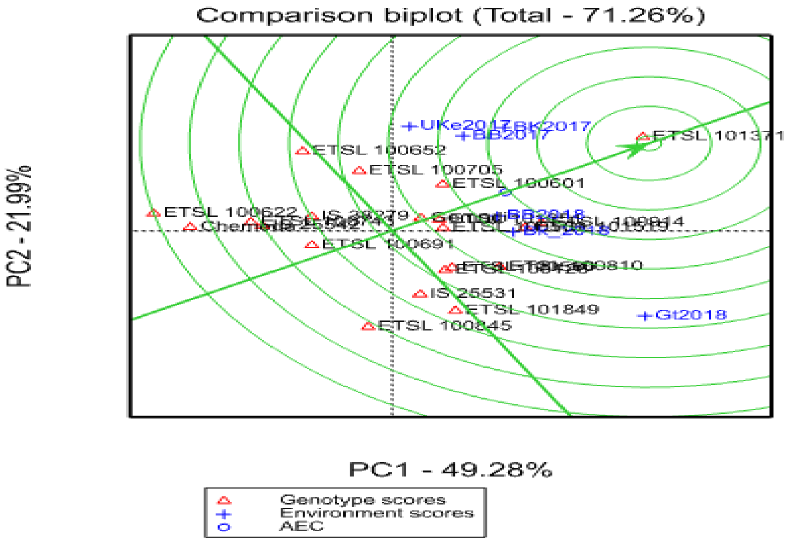

Figure 1. GGE biplot analysis showing stability of genotypes and test environments performance

Acknowledgments
The authors acknowledge Oromia Agricultural Research Institute for funding the project. We thank Bako Agricultural Research centers for the Coordination of the Research Project and logistic facilitates during field trials at respective locations. Cereal technology generation research team members of Bako Agricultural research center is highly acknowledged for their contribution during field experimentations.

References

Berenji, J., Dahlberg, J., Siroka, V., &Latkovic, D. (2011). Origin, history, morphology, production, improvement, and utilization of broomcorn [*Sorghum bicolor* (L.) Moench] in Serbia. Economic Botany, 65, 190–208.

CSA. (2018). Agricultural survey report on area and production of major crops.

Ejeta, G., &Grenier, C. (2005). Sorghum and its weedy hybrids. In J. Gressel (Ed.), Crop Fertility and Volunteerism (pp. 123–135). CRC Press, Boca Raton, Florida, USA.

El Naim, A. M., Ibrahim, I. M., Abdel Rahman, M. E., & Ibrahim, E. A. (2012). Evaluation of some local sorghum (*Sorghum bicolor* L. Moench) genotypes in rain-fed. International Ournal of Plant Research, 2(1), 15-20.

Gauch, H. G., & Zobel, R. (1996). AMMI analysis of yield trials. In M. Kang & H. Gauch (Eds.), Genotype by Environment Interaction (pp. 85–122). Boca Raton. CRC Press, New York.

ICRISAT. (2015). Sorghum (*Sorghum bicolor* L. Moench). International Crops Research Institute for the Semi-Arid Tropics.

Misira, R., Das, S., & MC, P. (2009). AMMI Model Analysis of Stability and Adptability of Late Duration Finger Millet (*Eleusine coracana*) genotypes. World Applied Sciences Journal, 6(12), 1650–1654.

Paterson, A., Bowers, J., Bruggmann, R., Dubchak, I., Rimwood, J., & Ali, M. E. K. (2009). The Sorghum bicolor genome and the diversification of grasses. Nature, 457: 551.

Smith, C., & Frederiksen, R. (2000). Sorghum: origin, history, technology, and production (Issue 824). John Wiley and Sons.

Yan, W. (2001). GGE biplot - A windows application for graphical analysis of multi-environment trial data and other types of two-way data. Agronomy Journal, 93(5), 1111–1118.

Registration of "*Sadii*" Sorghum *(Sorghum bicolor L.)* Variety

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Abstract

Improved crop variety has a crucial role in improving the livelihood of farming communities through maximizing yield. Haro Sabu Agricultural Research Center has developed sorghum variety "*Sadii*" by selection from landraces for West and KellemWollega zones. *Sadii* and other nine genotypes were evaluated against standard checks Lalo and Gemedi from 2016-2018 at Haro Sabu, HawaGelan, Kombo and Gulliso in Western Oromia. *Sadii* variety showed stable yield performance across all locations when compared with other tested genotypes. Therefore, *Sadii* was released as variety in 2020 for its merits like high grain yield potential, stability and resistant to major disease of sorghum and lodging.

Keywords:Sorghum *(Sorghum bicolor L.)*, landraces, *Sadii*, Stability,

Introduction

Sorghum bicolor L. (Moench) is an important cereal crop which is ranked 5th in the world based on its use and production after maize, wheat, rice and pearl millet. Sorghum is the most known crop especially in Africa, central America, south Asia and Ethiopia. It is also major cereal crop in west and KellemWollega zones next to maize (CSA, 2017). The national average production of sorghum is 25.25 $qtha^{-1}$ (CSA 2017). The area coverage, production and yield ($qtha^{-1}$) of sorghum in the Wollegazones were 97,711.83 hectares, 2,989,883.74 quintals production and 30.60 $qtha^{-1}$,respectively (CSA 2017). It used as food, feed, beverage, construction. Sorghum characteristics such as dense and deep roots, ability to reduce transpiration through leaf rolling and stomatal closure among others make the crop able to survive dry periods. Hence sorghum has become a strategic crop in the zones in the face of climate variability. Despite all the crop's advantages over other cereals under different condition, the sorghum crop production is still very low and very low yields are being obtained.

Research donewith the national breeding program has been done for years but with little progress due to limited knowledge on the relationship and effects of genotype and environment and their interaction on the crop yield performance.

It is important to show the relationship between genotypes and environments for selected traits graphically by use of a genotype, genotype by environment interaction (GGE) biplot that allows visual assessment of genotype by environment interaction (GEI) pattern of multi-locational or multi-environment data (Yan et al., 2000; Yan and Hunt, 2001). GGE is the most recent approach for analysis of GEI and increasingly being used in GEI studies in plant breeding research (Butran et al., 2004). The model was proposed by Yan et al. (2000), and has shown extensive usefulness and a more comprehensive tool in quantitative genetics and plant breeding (Yan et al., 2001; Yan and Rajcan, 2002). The model covers very critical areas in the study of stability of multi-locational trials, like the which-won-where pattern, mean performance and stability of genotypes, discriminating ability and representativeness of environments.

The GGE method emphasizes on two concepts, whereby in the first concept, it clearly points out that even though the measured yield is a result of combination effect by Genotype (G), Environment (E) and genotype x environment interaction (GEI), only G and GEI are relevant and must be considered simultaneously when evaluating genotypes, thus the name GGE. The second concept is based on the bi-plot technique which is used to estimate and show the GGE of multi-environmental yield trial (MEYT). The GGE bi-plot is made by the first two principal components (PC), PC1 and PC2.

Among the factors contributing for the low productivity of sorghum is lack of improved and disease tolerant varieties. So, it is important to collect and screen different land races of sorghum from West and KellemWollega zones of Western Oromia to develop high yielder and disease and insect pest tolerant Sorghum Varieties.

Varietal Origin and Evaluation

The Sorghum variety *"Sadii*" is a landrace material collected from KellemWollega zone, YemalogueWalal Woreda, small village called 'Hora Maka'.*Sadii*and other genotypes were evaluated against standard checks Lalo and Gemedi from 2016-2018 at Haro Sabu, HawaGelan, Kombo and Gulliso in Western Oromia with the objective of developing high yielder and disease and insect pest tolerant as well as lodging resistant sorghum variety.

Agronomic and Morphological Characteristics of '*Sadii*' Variety

Sadii variety is an intermediate to days to heading (131.04 days) and maturity (183.42 days). The variety is medium in plant height (344.03cm) which indicates the variety has no opportunity of lodging as far as lodging has direct relationship with plant height. *Sadii* scored minimum lodging (1.1) while the other genotypes evaluated scores up to 3 by scale of 1-5. Average thousand seed weight of the variety is 32.48 g. Other morphological and agronomic characteristics of *Sadii* variety is summarized in Table 3.

Yield Performance

During the early breeding stage, especially at preliminary yield trial *Sadii* variety scored highest grain yield (59.85 qtha^{-1}) at Haro Sabu. During multi-location trial atHaro Sabu, HawaGelan, Kombo and Gulliso, the variety gave 50.17 qtha^{-1}and 48.3 qtha^{-1} on Research field and on farmers' field, respectively.

Table 1: Mean grain yield (qtha^{-1}) of sorghum genotypes evaluated across environments

Genotypes	Grain Yield in qtha^{-1}								
	2016		**2017**			**2018**			
	KM-08A	HS-08A	HS-09A	GU-09A	HG-09A	HS-10A	GU-10A	HG-10A	Comb. Mean
SLRC-010	22.27fg	33.88cd	39.90c	35.61ef	39.61de	37.57d	38.25e	40.05bc	35.89d
Gamadi	28.88d	43.55a-c	42.99b	38.19d	41.21cd	43.99c	41.18d	42.94bc	40.37c
SLRC -043	45.16a	49.19a	51.83a	48.21b	52.80a	53.32a	48.98b	48.79ab	49.79a
SLRC-037	25.75e	28.29de	43.43b	43.95c	43.46bc	47.73b	46.93bc	44.58bc	40.52c
SLRC -028	33.95c	31.31d	36.82d	36.67ed	38.58de	38.30d	38.63e	38.08c	36.54d
SLRC -048	44.91a	31.68d	45.03b	43.45c	46.12b	46.26bc	45.31c	48.09ab	43.86b
SLRC -027	31.12cd	36.59b-d	35.53d	33.61f	36.87e	33.62e	34.61f	23.60d	33.19e
SLRC -06	20.86g	12.76f	28.86e	26.15g	24.75g	27.81f	25.77g	28.64d	24.45f
Local. Check	17.51h	16.87f	25.75f	26.36g	28.18f	25.86f	25.38g	27.28d	24.15f
Lalo	23.84ef	17.93ef	25.01f	23.88g	25.03g	26.44f	26.02g	27.77d	24.49f
SLRC -058	38.57b	38.17b-d	53.32a	50.08b	53.29a	55.64a	49.23b	54.78a	49.14a
SLRC-046/Sadii	32.61c	44.59ab	54.63a	54.78a	53.77a	53.86a	52.54a	54.62a	50.18a
Mean	30.45	32.07	40.26	38.41	40.31	40.87	39.40	39.94	37.71
CV%	5.75	19.54	4.3	3.86	4.21	4.13	3.72	13.05	8.52
LSD (5%)	29.53	10.56	29.20	24.97	28.62	28.47	24.69	87.84	18.29
F test	**	**	**	**	**	**	**	**	**

Key: SLRC- Sorghum Land Race Collection, KM – Kombo, HS-Harosabu, GU -Guliso, HG-Hawa Galan. The number following each location indicates the year (08A = 2016, 09A = 2017, 10A = 2018),CV- Coefficient of variation, LSD- least significant difference

Discriminating ability of the test environments and genotype stability

The concentric circles on the bi-plot help to visualize the length of the environment vectors, which are comparative to the standard deviation within the particular environments and are a measure of the discriminating ability of the environments (Worku et al., 2013). Environments as well as genotypes that fall in the central (concentric) circle are considered as an ideal environments and stable genotypes, respectively (Yan and Rajcan, 2002).Both environments-focused bi-plot and genotype-focused comparison of genotypes shown that genotype G3 (Sadii) fall in the central circle indicating its high yield potential and comparatively stable when compared with other genotypes (Fig5).

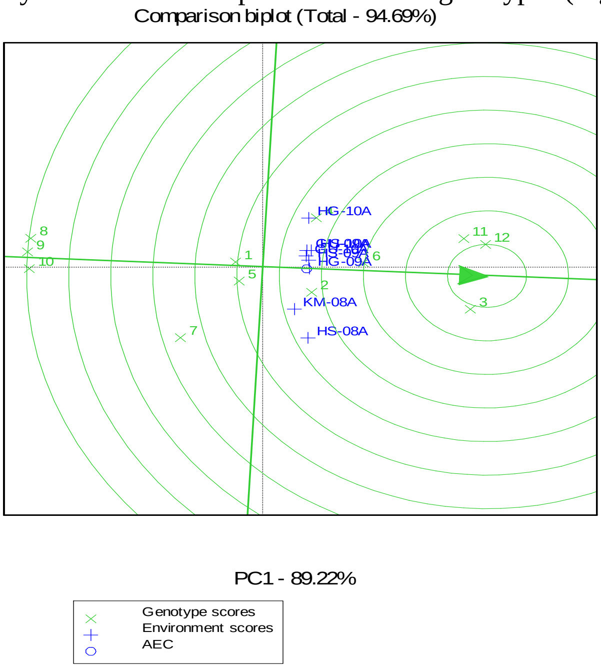

Table 2 : Summary of Pooled Mean Grain yield and other Agronomic traits of tested sorghum genotypes

Genotypes	DH	DM	LDG	PH	HH	HW	TSW	YLD qt/ha	YAD (%)
SLRC-010	127.67d	172.83d	2.5b	420.70a	32.87a	99.82c	24.76e	35.89d	-11.09%
Gamadi	122.60f	172.92d	2.25cd	327.12ef	26.28de	101.50c	32.79ab	40.37c	0%
SLRC -043	130.37bc	174.00d	1.04h	349.80d	33.07a	114.75ab	32.58ab	49.79a	23.33%
SLRC-037	124.02e	165.62f	2.08d	407.95ab	31.66a	106.35bc	26.56c-e	40.52c	0.37%
SLRC -028	124.42e	169.17e	2.62b	388.83c	31.83a	118.88a	25.36e	36.54d	-9.47%
SLRC -048	122.71f	169.17e	1.7ef	353.3d	29.60b	99.32c	25.69de	43.86b	8.64%
SLRC -027	129.83c	175.83c	1.83e	344.05de	28.81bc	103.96bc	27.47c-e	33.19e	-17.77%
SLRC -06	120.02g	163.08g	2.29c	407.08ab	27.24cd	114.03ab	25.36e	24.45f	-39.43%
Local. Check	127.75d	166.17f	1.60f	394.66bc	33.52a	110.00a-c	29.80a-c	24.15f	-40.18%
Lalo	1216.44h	163.08g	2.88a	403.34bc	27.09c-e	110.22c	29.40b-d	24.49f	-39.33%
SLRC -058	132.58a	181.88b	1.29g	326.33f	25.24e	106.56a-	33.45a	49.14a	21.72%

						c			
Sadii	131.04b	183.42a	1.10h	344.03de	29.39b	105.36bc	32.48ab	50.18a	24.3%
Mean	125.78	171.44	1.93	372.26	29.71	106.81	28.83	37.71	
CV%	1.68	1.2	15.83	8.1	11.1	20.5	22.85	8.52	
LSD(5%)	120	1.17	0.17	17.19	1.89	12.47	3.75	18.29	
F test	**	**	**	**	**	**	**	**	

Key: DH=Days to heading, DM=Days to maturity, PH= Plant height, HH= Head height, LDG- Lodging percentage, HW-head weight, TSW- Thousand seed weight, YLD qt/ha- Yield in quintals per hectare, YAD- yield advantage

Disease and Insect Pest Reaction

Sadii variety is tolerant to major disease and insect pests of sorghum like Anthracnose (1.37), leaf blight (1.29) and stock borer (1.083) by 1-5 disease scoring scale when compared to other genotypes.

Table 3. Combined mean of disease and insect pest reactions of sorghum genotypes (1-5 scale)

Genotypes	Stalk borer	Anthracnose	Leaf blight
SLRC-010	1.00e	1.36d	2.04e
Gemedi	1.169a	2.5a	2.88a
SLRC -043	1.027de	1.4d	2.04e
SLRC-037	1.022de	2.29b	2.04e
SLRC-028	1.00e	2.29b	2.54b
SLRC -048	1.078bc	2.417a	2.38c
SLRC -027	1.00e	1.44d	1.88f
SLRC -06	1.11b	1.56c	2.21d
Local	1.056cd	1.08e	2.04e
Lalo	1.167a	2.33b	2.88a
SLR-058	1.00e	1.63c	1.57g
SLR-046 /Sadii	1.083bc	1.37d	1.29h
Mean	1.06	1.72	2.15
CV%	4.79	8.61	1.37
LSD(5%)	0.03	0.09	0.02
F test	**	**	**

Adaptation

Sadii is released for low and mid altitudes of West and KellemWollega zones and other similar agro-ecologies having altitudes range 1400- 1900 meter above sea level. The annual rainfall required for the variety may vary from 1000- 2100mm. *Sadii* respond well when 100 $kgha^{-1}$ of NPS and Urea applied during production of the crop. All NPS fertilizer will be applied at the time of sowing while urea will be applied in split (half at sowing and half at thinning stage). The appropriate time for sowing of the variety is from late May to early June.

Conclusion

Sadii is superior variety released due to its special merits like high grain yield potential, wide adaptation, best agronomic performance, resistant to lodging, tolerant to major disease and insect pests of sorghum like Anthracnose, leaf blight, and stock borer.

Table 4. Agronomic Characters, disease reaction and adaptation area of *Sadii*Variety

Variety	Sadii
Adaptation area	
Altitude (meter above sea level)	1400-1900
Rain fall (mm)	1000-2100
Seed rate (Kg/ha)	10
Fertilizer rate (Kg/ha)	
NPS	100
Urea	100
Fertilizer application time	
NPS	all at planting
Urea	Split application
Fertilizer application method	Ring application
Planting date	Late May to early June
Row Spacing (cm)	75
Plant Spacing (cm)	15
Days to flowering	131.04
Days to Maturity	183.42
Plant height (cm)	344.03
Thousand Seed weight(gm)	32.48
Seed color	Gray
Inflorescence compactness and shape	Semi compact
Crop Pest reaction	Tolerant to major pest of sorghum(Stem borer, Anthracnose, Leaf blight, Leaf spot, Die back etc)
Mean Grain Yield (Qt/ha):	
Research Field	50.17
Farmer s' Field	48.3
Year of Release: 2020	2020
Breeder/Maintainer: HSARC/OARI	HSARC/OARI

Note: HSARC= Haro Sabu Agricultural Research Center, OARI= Oromia Agricultural Research Institute

References

Butran A, Velasco P, Ordas A, Malvar RA (2004). Yield evaluation of maize cultivars across environments with different levels pink stem borer infestation. Crop Sci. 44:741-747.

CSA (Central Statistical Agency) (2017). The Federal Democratic Republic of Ethiopia Agricultural Sample Survey2016/2017: Area and production of major crops, (private peasant holdings, Meher season). Vol. I. Addis Ababa, Ethiopia.

Worku, A., Henry, M., Zewotir, T. and Taye, G. (2013). AMMI model 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 WK, Hunt LA, Sheng Q, Szlavnics Z (2000). Cultivar evaluation and mega-environment investigation based on the GGE biplot. Crop Sci. 40:597-605.
Yan W, Hunt LA (2002). Biplot Analysis of Multi-Environment Trial Data In. Quantitative Genetics, Genomics and Plant Breeding. Kang, M. S., (Ed.), CABI Publishing, New York. pp. 289-303.

AMMI Analysis for Grain yield Stability in Faba bean Genotypes Evaluated in the Highlands of Bale, Southeastern Ethiopia

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Abstract
This study was conducted to determine the effect of genotype × environment interaction (GEI) on grain yield and, to asses yield stability of fourteen faba bean genotypes evaluated using randomized complete block design with four replications tested at Sinana, Agarfa and Sinja for three consecutive years (2017 to 2019) in the highlands of Bale, Southeastern Ethiopia. In this study it was revealed that significant variation for the main effects, Genotypes, Environments and their interaction effect at P<0.01%.. Due to the existence of GEI, genotypes performed differently across the environments. Genotype's mean grain yield ranged from 2.14 tha^{-1} (EK05024-3) to 3.24 tha^{-1} (EK06007-2). The analysis of variance for AMMI also revealed significant variation for genotypes, environment and genotypes by environment interaction. Of the total sum of variation observed in grain yield, environment, genotype and GEI contributed 86.15%, 5.67% and 8.15%, respectively. Using stability parameters like Genotype Selection Index (GSI), genotype G1, G8, G12 and G14 showed general stability over the testing environments, whereas G3, G4, and G10 showed moderate stability since they have the second lowest GSI. But of all these genotypes, G10 gave a the largest mean grain yield with a yield advantage of 21% compared to the checks used in this study. Therefore, G10, because of its yielding potential and moderate stability over the testing environments, this genotype was selected as candidate genotype to be verified for possible release in the highlands of Bale and similar agro-ecologies.
Key words: AMMI, Faba bean, Genotype x environment Interaction, GSI

Introduction
Among pulse crops produced in Ethiopia, Faba bean leading in terms of area coverage and total production (Mesfin*et al.*, 2019). Faba bean is mainly produced in an elevation of 1800 to 3000 m.a.s.l. (Mussa and Gemechu, 2006). As faba bean has wider adaptation in different agro-ecologies, their response differently to the testing environments mainly described as genotype × environment interaction (GEI). Genotype's wider or specific adaptation has determined by the genotype environment interaction. This differential phenotypic response of genotypes to environmental changes cannot be explained by the genotype and the environment main effect, unless and otherwise it is considered along with G × E interaction effects (Mohammad *et al.*,2007). Several methods helped to quantify G × E interaction, all of which are based on evaluation of genotypes under multiple environments. Different

methods were used to explain G x E interaction facilitate the decision to recommend variety have been extensively reviewed by different authorities (Ferreira *et al.,* 2006*;* Hussein *et al.,* 2000; Crossa, 1990; Zobel, 1988). Not all methods are equally effective in analyzing the multi-environment data structure in breeding programs (Zobel, *et al.*, 1988; Navabi*et al.,* 2006). Additive main effects and multiplicative interaction (AMMI) is the most powerful statistical package used to analyze the stability analysis to clearly indicate the interaction. Thus the present study was initiated with the objective to identify high yielding and stable faba bean genotypes that were tolerant or resistant to major faba bean diseases, chocolate spot, aschochyta blight and rust in the study areas, in the highlands of Bale, Southeastern Ethioipa.

Materials and Methods

Including two standard checks, and one local cultivar a total of fourteen faba bean genotypes (Table 1) were evaluated using randomized complete block design with four replications at three locations Sinana, Sinja and Agarfa for three consecutive years 217 to 2019 cropping season in the highlands of Bale. Plot of 6.4m^2 (4 rows at 0.40m spacing and 4m long) was used at all the testing sites. The recommended seeding rate of 200 kgha^{-1}, and NPS fertilizer at a rate of 100 kgha^{-1} was used at all the locations. Analysis of variance of grain yield for each environment was done using the CropStat, ver. 7.2 computer programs.

Stability analysis: The additive main effect and multiplicative interaction (AMMI) analysis was performed using the model suggested by Cross *et al.*, 1991)as:

$Y_{ij}=\mu+g_i+e_j+\sum_{n=1}^{h}\lambda_n\alpha_{ni}.Y_{nj}+R_{ij}$ where,

$Y_{ij}$is the yieldof the ith genotype in the jth environment, μ is the grand mean, g_i is the mean of the ith genotype minus the grand mean e_j is the mean of jth environment minus the grand mean, $\lambda_n$is the square root of the eigen value of the principal component analysis (PCA) axis, α_{ni} and Y_{nj} are the principal and the principal component scores for the PCA axis n of the ith genotype and jth environment, respectively and R_{ij} is the residual. The genotype by environment interaction biplot was plotted for the 14 fababean genotypes tested at 9 environments. The regression of yield for each variety on yield means for each environment was computed with the CropStat 7.2 program.

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 is analyzed by the method 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. The larger the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. The smaller IPCA score indicates a more stable genotype across environments.

Genotype selection index (GSI): was calculated for each genotype, which incorporate both mean grain yield and stability index in a single criteria by the method suggested by Farshadfar, 2008.

$GSI_i= RY_i +RASV_i$

Table 1. Genotype code and the name of 14 faba bean genotypes

SN	Code	Genotypes
1	G1	Shallo x EH98143-1-2-1-0
2	G2	Shallo x EH00100-2-1-3-0
3	G3	Shallo x EH00097-2-1-2-0
4	G4	Shallo x EH00098-7-1-2-0
5	G5	EK 05024-3
6	G6	Shallo x EH 99019-5-2-2-0
7	G7	Shallo x EH00102-5-5-1-0
8	G8	Shallo x EH00100-2-2-4-0
9	G9	EK 06027-2
10	G10	EK 06007-2
11	G11	EK 06007-4
12	G12	Mosisa (Satndard.check)
13	G13	Shallo (Satndard.check)
14	G14	Local check

Result and Discussion

The pooled analysis of variance for grain yield revealed that highly significant variation for environments, genotypes and genotypes by environment interaction at P<0.01% (Table 2). Tamene, *et al.*, 2015, Cathrine, *et al*., 2019, and Getahun*et al.*, 2019, Mesfin, *et al.*, 2019 have also reported the significant variation of environment, genotypes and GEI in their study. The significant of GEI for grain yield indicates the genotypes responded differently to the tested environments. Of the total SS variation for grain yield, 18.07% was accounted by environments followed by genotypes (4.76%) and their interaction (1.97%). From this it is concluded that the environments were more diverse for the variation obtained in grain yield by the tested genotypes.

Table 2. Combined analysis of variance for faba bean genotypes tested at three locations for three consecutive years.

Source of Variation	**Degree freedom**	**Sum Squares**	**Mean Squares**	**% explained of TSS**
YEAR (Y)	2	15.8116	7.90582**	
Location (L)	2	124.791	62.3954**	18.07
Replication	3	1.44178	0.480593	
Genotype (G)	13	32.9046	2.53112**	4.76
Y x L	4	358.95	89.7374**	
L x G	26	13.5915	0.52275**	1.97
Y x L x G	78	33.8156	0.433533*	
Residual	375	109.348	0.291594	
Total	503	690.653		

AMMI Analysis:

The ANOVA for AMMI analysis revealed highly significant variation of environments, GEI, and genotypes (Table 3). This analysis also revealed about 86.15% of the total sum square of variation, for grain yield was due to the environments, whereas 8.18% was due to genotype by environment interaction, and 5.67% was because of the genotypes. This revealed as the testing sites were more diverse for the variation in grain yield observed by the genotype. High percent of variation due to the environment was also reported by Tamen*et al.*, and Tadele*et al.*, 2017, on faba bean; Dagnachew*et al.*, 2014 on Triticale. Since the AMMI model revealed the significance of the GEI, the interaction was partitioned into different IPCA components, The first two AMMI components showed significant variation at P<0.01%. Out of the total GEI explained by the AMMI components, 40.42% was accounted for AMMI I, followed by 22.93 for AMMI 2, 13.04 for AMMI 3 and 10.97 for AMMI 4, respectively. The first two AMMI components in total showed 63.35% of the total variation indicating the two AMMAI components well fit and confirm the use of AMMI model. Cross *et al.*, 1991, and Zobel *et al.*, 1988 describes the interaction sum of square highly predicted by the first two AMMI components.

Table 3. Analysis of Variance of AMMI model for grain yield of faba bean genotypes

Sources	DF.	SS	MS	TSS explained %
Genotypes	13	8.226	0.633	5.67
Environment	8	124.888	15.611	86.15
G x E	104	11.852	0.114	8.18
AMMI I	20	4.791	0.240**	40.42
AMMI 2	18	2.717	0.151**	22.93
AMMI 3	16	1.546	0.097	13.04
AMMI 4	14	1.3	0.093	10.97
G x E Residual	36	1.498	0.633	
Total	125	144.97		

Stability analysis

The analysis using AMMI stability value indicated that G8, G5, G14, G3, G12 and G7 had low ASV is indicating stable performance over the studied areas. Though all these aforementioned genotypes showed stable performance, they gave a mean grain yield lower than the highest yielding check, Shallo (2.68 tha^{-1}) (Table 4). Stability is not the only parameter for selection of high yielding genotypes as the most stable genotypes would not necessarily give the best yield performance. Therefore, the use of GSI which consider both mean grain yield and ASV, is important to identify genotypes that can perform in a stable manner with higher yield. Accordingly, genotypes G8, G1, G12 and G14 showed the lower GSI value indicating general stability. On the other hand, G3, G4, G10 and G13 gave the second lowest GSI value indicating moderate stability. In general, G10 gave the highest mean grain yield with moderate stability.

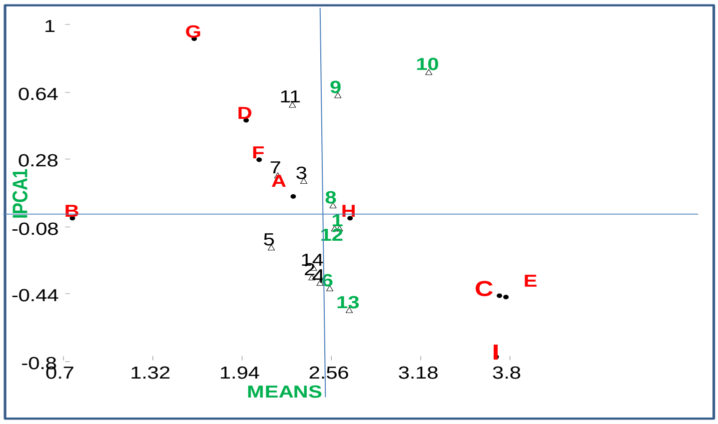
Table 4. Mean grain yield, Slop, deviation from regression IPCA values, ASV and GSI for grain yield of field pea.

SN	Genotypes	Mean	Rank Yi	Slope (bi)	DEV (S^2di)	IPCA1	IPCA2	ASV	Rank ASV	GSI
1	Shallo x EH98143-1-2-1-0	2.61	3	1.15	0.14	-0.09	-0.73	0.75	9	12
2	Shallo x EH00100-2-1-3-0	2.43	10	1.07	0.13	-0.35	0.49	0.79	10	20
3	Shallo x EH00097-2-1-2-0	2.36	11	0.96	0.13	0.16	-0.45	0.53	3	14
4	Shallo x EH00098-7-1-2-0	2.49	8	1.12	0.09	-0.38	-0.05	0.67	7	15
5	EK 05024-3	2.14	14	1	0.07	-0.19	0.19	0.39	2	16
6	Shallo x EH 99019-5-2-2-0	2.55	7	1.18	0.06	-0.41	-0.19	0.74	8	15
7	Shallo x EH00102-5-5-1-0	2.19	13	0.84	0.04	0.2	0.45	0.57	6	19
8	Shallo x EH00100-2-2-4-0	2.58	5	1.01	0.02	0.04	0.06	0.09	1	6
9	EK 06027-2	2.6	**4**	0.84	0.18	0.62	0.07	1.1	**13**	**17**
10	**EK 06007-2**	3.24	1	0.96	0.1	0.75	0.03	1.32	14	15
11	EK 06007-4	2.29	12	0.84	0.12	0.57	-0.19	1.03	12	24
12	Mosisa	2.58	5	0.97	0.13	-0.09	0.53	0.56	5	10
13	Shallo	2.68	**2**	1.25	0.05	-0.52	-0.24	0.96	11	**13**
14	Local check	2.44	9	1.11	0.02	-0.3	0.01	0.53	3	12

Where YRi= rank for grain yield, bi= regression coefficient, DEV= deviation from regression, IPCA= Interaction principal component, ASV= AMMI Stability Value, GSI= Genotype selection Index

AMMI biplots

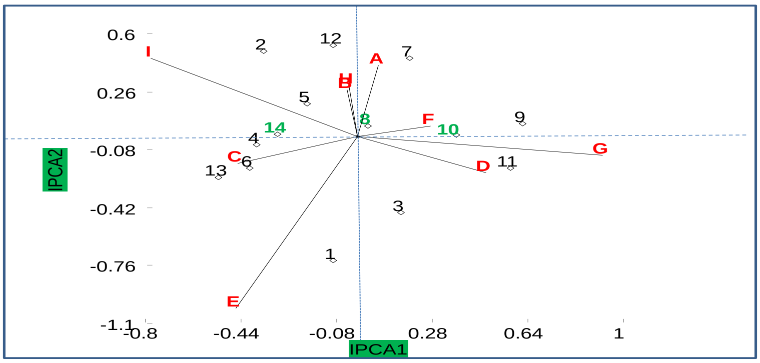
The AMMI1 biplot was constructed from the first interaction principal component value and mean grain yield, indicates that genotype and environments found at the right side of the perpendicular line passing though the origin, gave a mean grain yield greater than the grand mean (2.51tha^{-1}). Accordingly, genotypes G1, G6, G8, G9, G10, G12 and G13; whereas environments C, E, H and I gave mean grain above the grand mean. The rest genotypes and environments gave a mean grain yield below the grand mean (Figure 1).



VARIATE: T/HA DATA FILE: MSFBRV MODEL FIT: 95.1% OF TABLE SS

Figure 1 biplot interaction based on AMMI 1 and the mean grain yield

The second biplot graph (Figure 2) which is constructed by the use of the two interaction principle components also indicates that genotypes found closer to the origin showed stable performance over the testing environments. (Ebdon and Gauch, 2002). 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, G8, G10 and G14, which are found close to the origin showed general stability, whereas, environment B, F, H and D showed less change across seasons allow stability for the genotypes tested in these locations (Figure 2).



VARIATE: T/HA DATA FILE: MSFBRV MODEL FIT: 63.3% OF GXE SS

Figure 2. Interaction biplot for the AMMI 2

Conclusion

The field trial conducted at Sinana, Sinja and Agarfa for three years cropping season revealed that the yield and yield component of faba bean genotypes was highly affected by the environmental factor which allow to have different performance over the tested sites. Furthermore, the adaptability and stability of a genotype are useful parameters for recommending cultivars for known cropping conditions. From the present study it was concluded that G10 which gave the highest mean grain yield than the rest of the genotypes with yield advantage of 21% 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 bing evaluated by the National Variety Releasing Committee.

Acknowledgements

The authors would like to thank the Oromia Agricultural Research Institute for funding, and Sinana Agriculture Research Center, and pulse and oil crop research case team for data collection and trial management.

Reference

Cathrine K., JensNørgaard K. Winnie F. Jens S., Frederick L.Luc Janss1, and Andersen S.U. 2019. Evaluation of yield, yield stability and yield-protein trade-off in commercial faba bean cultivarshttps://doi.org/10.1101/843862;

Crossa J. 1990. Statistical analyses of multi-location trials. Adv.Agron. 44: 55-85.

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

DagnachewL.,, Kassahun T., and Girma M. 2014.Genotype by environment interaction and grain yield stability analysis for advanced triticale (x. *Triticosecale*wittmack) genotypes in western oromia, ethiopia. *Ethiop. J. Sci*., 37(1):63–68, 2014

Ebdon, J., and Gauch, H. 2002. Additive Main Effect and Multiplicative Interaction Analysis of National Turfgrass Performance Trials. I. Interpretation of Genotype × Environment Interaction. Crop Sci., 42(2): 489-496

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(4): 1791-1796

Ferreira DF, Demetrio CGB, Manly BFJ, Machado ADA, Vencovsky R. 2006. Statistical model in agriculture: Biometrical methods for evaluating phenotypic stability in plant breeding. CerneLavras. 12: 373-388.

GetahunMitiku and AbereMnalku. 2019. Faba Bean (*Vicia faba*L.) Yield and Yield Components as Influenced by Inoculation with Indigenous Rhizobial Isolates under Acidic Soil Condition of the Central Highlands of Ethiopia. Ethiop. J. Agric. Sci. 29(3)49-61

Hussein MA,Bjornstad A, Aastveit AH. 2000. SASG x ESTAB: A SAS program for computing genotype x environment stability statistics. Agron. J. 92: 454-459

Mesfin T., Wassu M., Mussa J. 2019. Genetic Variability on Grain Yield and Related Agronomic Traits of Faba Bean (*Vicia faba*L.) Genotypes under Soil Acidity Stress in the Central Highlands of Ethiopia. Chemical and Biomolecular Engineering, 4(4): 52-58. doi: 10.11648/j.cbe.20190404.12

Mohammadi R., Armion M., Shabani A. 2007. DaryaeiA.Identification of stability and adaptability in advanced durum genotypes using AMMI analysis. Asian J. Plant Sci. 6:1261-1268.

Mussa J., Gemechu K. 2006. Vicia faba L. In: Brink, M. and Belay, G. (eds.). Plant Resources of Tropical Africa 1*: Cereals and Pulses*. Wageningen, Netherlands/Backhuys: PROTA Foundation.

Navabi A., Yang RC., Helm J., Spaner DM. 2006. Can spring wheat growing mega-environments in the northern great-plains be dissected for representative locations or niche-adapted genotypes Crop Sci. 46: 1107-1116

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

Tadele T., Behailu M., Gashaw S., Amanuel T. 2017. Genotypes by Environment Interaction of Faba Bean (*Viciafaba L.)* Grain Yield in the Highland of Bale Zone,Southeastern Ethiopia.Plant.Vol. 5, No. 1, 2017, pp. 13-17.doi: 10.11648/j.plant.20170501.13

Tamene , T., Gemechu K., Tadese S., and Mussa J. 2015. Yield stability and relationships among stability parameters in faba bean (Vicia faba L.) genotypes. The crop Journal**3:** 2 5 8 – 2 6 8

Zobel RW, Wright MJ, Gauch HG. 1988. Statistical analysis of a yield trial. Agronomy Journal 80: 388-393.

Evaluation of agronomic performance and grain yield stability of feld pea genotypes in the highlands of Bale, Southeastern Ethiopia

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Abstract
Multi-environment trials (MET) are commonly conducted in plant breeding programs to evaluate cultivars and hybrids. The objective of this trial was to identify stable and high yielding field pea genotype with tolerant or resistant to major field pea diseases in the study areas. Sixteen field pea genotypes were evaluated at three locations for three consecutive years (2017 to 2019) cropping seasons in the highlands of Bale using randomized complete block design with four replications. Combined analysis of variance for grain yield revealed that genotypes, environments, and genotype by environment interaction effect were highly significant ($P \leq 0.01$). The environments, genotype, and GEI, were accounted for 57.5%, 6.33%, and 2.97%, of the total sum squares, respectively, indicating that field pea grain yield was significantly affected by the changes in the environment followed by genotypes and their interaction. From the combined analysis genotypes G8 (EH08003-2) gave the

maximum grain yield (4.03 tha^{-1}) followed by G2 (3.59 tha^{-1}) and G10 (3.58 tha^{-1}). Based on the stability parameters like regression coefficient and deviation from regression G8, G10, G3 and G1 have a regression coefficient equal to unity and their deviation from the regression near to zero indicating these genotypes were very stable. But out of these genotypes, G8 gave grain yield higher than the checks with a yield advantage of 18% over the checks. Therefore, this genotype because of its stability over the tested environments and higher grain yield over the checks, it was identified as candidate genotype to be verified in the coming 2021/22 in the highlands of bale for possible release.
Keyword: deviation from regression, Field pea, regression coefficient, Stability

Introduction

Field pea can be grown on a wide range of soil types, from light sandy to heavy clay. It has moisture requirements similar to those of cereal grains. However, peas have lower tolerance to saline and waterlogged soil conditions than cereal grains. Peas will not survive long in waterlogged conditions. Poorly drained and saline soils should be avoided when growing field pea. Field pea commonly is grown in rotation following small grains. Field pea will fix most of the plants' required nitrogen if the seed is inoculated properly. Pea is highly nutritive, containing high percentage of digestible protein, carbohydrates, fats along with minerals (Ca, P and Mg) and vitamins A, B and C. High quality starch, protein, or oligoside isolates are being extracted from dry pea seeds. Because dry seeds contain little anti-nutritional factors, they are used as a protein source. Even though field pea is grown in a wide range of environments, the yield of several genotypes tested across locations and over years differed due to high GEI, which indicates that some genotypes are adapted to a broad range of environmental conditions, while others have their own specific adaptation. Thus, the performance of test entries over a series of environments when analyzed using ANOVA gives information on GEI, but does not give a measurement of the stability of individual entries (Eberhart and Russell, 1966).

The performance of any character is a combined result of the genotype (G) of the variety, the environment (E) and the interaction between genotype and environment (GE). GE interactions exist when the responses of two genotypes to different levels of environmental stress are not consistent. Better understanding of GE interactions and stability in crops was used as a decision tool, particularly at the final stage of variety introduction process, to generate essential information on pattern of adaptation in breeding lines, screen new varieties for release, and determine the recommendation domains for released varieties (Yan and Kang, 2003). GE interaction was quantified using several procedures based on evaluation of genotypes under multiple environments. These methods divided into univariate and multivariate stability statistics. The most widely used uni-variate methods are based on regressing the mean value of each genotype on the environmental index or marginal means of environments (Yates and Cochran, 1938; Finlay and Wilkinson, 1963; Eberhart and Russell, 1966). The basic cause of differences among genotypes (varieties) in relation to production stabilities is the genotype x environment (GE) interaction, so that the performance of the genotypes depends on the specific environmental conditions where they are grown (Ferreira, et al., 2006). Keeping this in view, the present research study was conducted with objectives to estimate the magnitude of GEI and to identify stable and high yielding field pea genotypes that can adapt under changing environments/ in diverse agro ecological regions of highlands Bale, Southeastern Oromia

Materials and Methods

A total of sixteen field pea genotypes along with two standard checks, and local cultivar (Table 1) were evaluated using a randomized block design with four replications for three consecutive years (2017 to 2019) at three locations, Sinana, Sinja and Agarfa, in the highlands of Bale, Southeastern Ethiopia. Analysis of variance for each environment was done for grain yield and other traits, using the CropStat, ver. 7.2 computer programs. A combined analysis of variance was done from the mean data from each location, to create the means data for the different statistical analysis methods.

Stability analysis: The method of Eberhart and Russell (1966) was used to calculate the regression coefficient (bi), deviation from regression (Sdi2) and coefficient of determination (Ri^2). It was calculated by regressing mean grain yield of individual genotype/environments on the environmental / genotypic index.

The linear model proposed by Eberhart and Russell (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.

The genotype with a value of the regression coefficient (Bi ~1) and smaller value deviation from regression (Sdi 2) value are thus more stable.

Table. Lists of Genotypes and their source

Genotype code	Genotypes	Source of genotypes	Genotype code	Genotypes	Source of genotypes
G1	EH07004-1	Brought from Holeta ARC	G9	EH07007-3	Brought from Holeta ARC
G2	EH07016		G10	EH08003-1	
G3	EH07006-3		G11	EH07005-1	
G4	EH08033-4		G12	EH08036-1	
G5	EH08034-3		G13	EH08036-4	
G6	EH08033-1		G14	Harena	Released from Sinana ARC
G7	EH07006-5		G15	T/shenen	
G8	EH08003-2		G16	Local check	Local cultivar

Result and Discussion

The combined analysis of variance of the mean grain yield of field pea genotypes revealed that highly significant variation for genotypes, environment, and GEI interaction at P<0.01. The environment, genotypes and the interaction accounted for 57.5%, 6.33% and 2.97% of the total variation, respectively (Table 2). This implies that the grain yield was highly

Entry	Treatment code	2017			2018			2019			
		Sinana	Agarfa	Sinja	Sinana	Agarfa	Sinja	Sinana	Agarfa	Sinja	**Means**
EH07004-1	G 1	4.7	3.2	3.6	4.9	1.5	3.5	4.8	1.8	3.7	3.52
EH07016	G 2	4.6	3.6	3.1	5.6	1.6	3.5	4.7	1.9	3.7	3.59
EH07006-3	G 3	4.5	3.2	3.8	4.4	1.3	3.9	4.6	1.5	4.1	3.48
EH08033-4	G 4	4.4	3	3.1	5.3	1.7	3.7	5.5	1.4	3.9	3.56
EH08034-3	G 5	4.6	2.9	3.5	4.7	1.5	3.9	4.4	2	4.1	3.51
EH08033-1	G 6	4	3.2	3.1	4	1.3	3.5	5.3	1.7	3.7	3.31
EH07006-5	G 4	4.2	2.6	2.6	5.6	1.5	3.4	5.1	2.3	3.6	3.43
EH08003-2	**G 8**	**5.2**	**4.1**	**4**	**5.4**	**2.8**	**4.2**	**4.6**	**1.7**	**4.3**	**4.0**
EH07007-3	G 9	4	2.6	3	4.8	1.3	3	4.5	2.3	3.2	3.19
EH08003-1	G 10	4.5	3.3	3.2	5.4	1.6	4	4	2	4.2	3.58
EH07005-1	G 11	4.7	2.9	3.6	4.7	1.5	2.9	5.3	1.4	3.1	3.34
EH08036-1	G 12	4.7	3.2	3.8	5	1.4	2.9	5.2	1.6	3.2	3.44
EH08036-4	G 13	4.2	3.4	2.8	4.4	1.4	3.4	4.4	1.5	3.6	3.23
Harena(stch)	G 14	4	3.2	3.5	3.9	2.2	3.1	3.8	1.7	5.1	3.39
T/shenen	G15	3.3	3	2.9	4	1.2	3.3	2.7	1.3	3.2	2.77
Local check	G16	4.7	3.1	2.3	2.6	1.3	2.7	4.6	1.3	2.6	2.8
Mean		4.39	3.16	3.24	4.67	1.57	3.43	4.59	1.71	3.71	3.39
LSD 5%		0.9	0.8	0.9	0.7	0.6	0.8	14	0.6	0.8	
CV%		14	18	19	11	21.2	16		22.3	15	

affected by the diverse nature of the environments followed by genotypes and interaction respectively. Yasin *et al.*, 2013, Sowmya, *et al.*, 2018 and Hongyu*et al.*, 2014 have reported highly significant variation for Environment, genotypes and GE interaction in the study of field pea, and maize, respectively.

Table 2. ANOVA for combined mean grain yield of field pea genotypes over locations and years

Source of Variation	**Degree freedom**	**Sum Squares**	**Mean Squares**	**%of the variation**
YEAR (Y)	2	14.4316	7.2158**	1.48
Location (L)	2	561.133	280.566**	57.5
Replication	3	2.02404	0.674681	0.21
Genotype (G)	15	61.2433	4.08289**	6.28
Y x L	4	93.6363	23.4091**	9.59
G x E	30	28.0478	0.934928**	2.87
Y x L x G	90	57.6001	0.640001**	5.90
Residual	429	157.746	0.367706	16.16
Total	575	975.9		

The mean grain yield of genotypes across environments ranged from 2.77t/ha for the improved variety, Tullushenen, to 4.03 tha^{-1} for the G8 (EH08003-2). From the nine environments the highest grain yield was obtained at Sinana 2018 followed by Sinana 2019, Sinana 17, Sinja 2019 and Sinja 2018. Whereas the least grain yield was obtained at Agarfa 2018 (Table 3).

Table 3. Mean Grain yield of Sixteen field pea genotypes grown at nine environments in the highlands of Bale, Southeastern Ethiopia

The mean performance of the genotypes for all the parameters studied was summarized in Table 4. From this combined mean data revealed that genotypes need 62 to 67 days to flower, 135 to 140 days to reach physiological maturity whereas they have plant height ranged from 131cm to 149cm, and also gave mean number of pods/plant from 10 to 13. The thousand seed weight for the genotypes ranged from 140 to 224g. The best genotypes G8 gave the highest number of pods/plant, has seed weight better than most of the genotypes with the highest mean grain yield.

Table 4. combined Agronomic performance of for sixteen field pea genotypes over locations and years

Entry	Days to flowering	Days to maturity	Plant height (cm)	No of pod per plant	No of seed per plant	Disease score (1-9 scale)			1000 seed wt.	Seed yield (tha^{-1})
						PM	DM	ASB		
EH07004-1	67	139	136	11	4	6	4	6	176	3.52
EH07016	65	139	141	10	4	7	5	7	200	3.59
EH07006-3	63	140	146	11	4	7	4	6	224	3.48
EH08033-4	65	139	141	10	4	7	4	6	186	3.56
EH08034-3	67	140	140	11	4	7	4	6	201	3.51
EH08033-1	67	140	148	10	4	8	5	6	163	3.31
EH07006-5	66	139	132	10	4	7	5	6	217	3.43
EH08003**-2**	**67**	**139**	**139**	**11**	**4**	**4**	**5**	**4**	**212**	**4.03**
EH07007-3	67	139	131	10	4	7	4	7	218	3.19
EH08003-1	66	139	135	10	3	7	4	5	212	3.58
EH07005-1	65	140	142	11	4	7	4	6	203	3.34
EH08036-1	64	139	149	10	4	8	5	6	183	3.44
EH08036-4	67	140	142	10	4	8	5	6	163	3.23
Harena	63	138	140	11	4	5	4	4	184	3.39
T/shenen	62	138	134	12	4	7	4	6	157	2.77
Local check	62	138	142	13	4	7	5	7	140	2.8
Mean	65	139	140	11	4				190	3.39
LSD 5%	0.68	0.75	6.41	2.1	0.33				9.17	0.28
CV%	2.2	1.2	18.7	9.9	20.7				10.4	17.9

The significant variation of G x E interaction revealed as the tested environments were very diverse and complex and resulted in different response in grain yield among the genotypes tested. Therefore, there is a need to find genotypes that can perform more or less in similar fashion or with stable performance over the tested sites. Thus, to identify the stable genotypes over the study areas, regression model developed by Eberhart and Russel 1996 was used. It is known that the regression of genotype on the environment provides two simple measures of the phenotypic changes to environments, namely, regression coefficient and deviation from the regression slope (Pabale*et al.*, 2010). According to this study the mean grain yield ranged from 2.77 tha^{-1} a to 4.03 tha^{-1}. The genotype G8 gave the highest mean grain yield of 4.03 tha^{-1} and 3.64 tha^{-1} with regression coefficient of 1.01 with 0.14 value of deviation from regression followed by G10 with mean grain yield of 3.64 tha^{-1} and regression coefficient and deviation from regression 1.06 and 0.09, respectively, indicating as these two genotypes were highly stable over the tested environments. Other genotypes *viz.* G2 with a mean grain yield of 3.61 tha^{-1}, and G5 with grain yield of 3.64 tha^{-1} though they gave a mean grain yield better than the checks, they gave regression coefficient of 1.12 and deviation from regression 0.09 and 0.11, respectively. These two genotypes since they have bi>1, were responsive to favorable environments, and showed unstable performance (Table 5).

The square of the correlation coefficient (R^2), is the most powerful to measures of the goodness-of-fit of the regression model to the data have been proposed. It is the proportion of the variation in one factor that is accounted by the variation in another factor. R^2 varies between zero (no linear relationship) and one (perfect linear relationship). Accordingly, in this study, genotype G4, G5, and G8 had the square of the correlation coefficient 0.98, 0.88 and 0.93 respectively, implying these three genotypes were perfectly fit to the data of stability.

Table 5. Mean grain yield, linear regression, deviation from regression and squared correlation for the sixteen field pea genotypes tested over locations and years.

Genotypes	Mean	Slope (bi)	MS-DEV (S^2di)	R^2
EH07004-1	3.48	1.04	0.03	0.66
EH07016	3.61	1.12	0.09	0.24
EH07006-3	3.5	1.07	0.1	0.08
EH08033-4	3.46	1.11	0.06	0.98
EH08034-3	3.63	1.12	0.11	0.88
EH08033-1	3.21	0.91	0.05	0.65
EH07006-5	3.44	1.11	0.32	0.38
EH08003-2	4.08	1.01	0.14	0.93
EH07007-3	3.2	0.94	0.15	0
EH08003-1	3.64	1.06	0.09	0.22
EH07005-1	3.2	1.01	0.15	0.54
EH08036-1	3.46	1.18	0.18	0.62
EH08036-4	3.31	1.08	0.11	0.12
Harena	3.45	0.77	0.36	0.5
T/shenen	2.88	0.84	0.07	0.71
Local check	2.58	0.63	0.54	0.38

Where: bi=slop, S^2di=deviation from regression, R^2= square of the correlation coefficient

Conclusion and recommendation

From the present study for identifying stable and high yielder genotypes, based on different stability parameters used to investigate stability, using Eberhart and Russel model, G8 had stable performance since it had high mean grain yield with yield advantage of 18% over the best check, Harena, has regression coefficient of close to unity and the deviation from regression close to unity. Likewise, G2, G4, G5 and G10 gave a mean grain yield better than the checks, they were unstable because they showed a regression coefficient greater than unity meaning they need more favorable environments. Therefore, based on the mean grain yield performance and its advantage over the checks, and due to its stable performance over the testing environments we identify and recommend this genotype, G8 (EH08003-2) as candidate genotype to be verified in the coming main cropping season of 2021/22 for possible release in the highlands of Bale, Southeastern Ethiopia and similar agro-ecologies.

Reference

Eberhart, S.A, and W.A. Russell.1966. Stability parameter for comparing varieties. *Crop sci* .6: 36-40.

Finlay K.W., Wilkinson G.N. (1963): The analysis of adaptation in a plant-breeding programme. Aust. J.Agric. Res., *14*: 742–754.

Ferreira1, DF., Clarice Garcia Borges Demétrio, Bryan Frederick John Manly, Amauri de Almeida Machado4, Roland Vencovsky. 2006. Statistical Model in Agriculture Biometrical Methods for evaluating Phenotypic Stability in plant Breeding. CERNE, Cerne, Lavras, v. 12, n. 4, p. 373-388, out./dez.

Hongyu, K., Garc´ıa-Pe˜na, M., Ara´ujo, LB., Santos Dias, CT. 2014. Statistical analysis of yield trials by AMMI analysis of genotype × environment interaction**.**Biometrical Letters. Vol. 51 (2014), No. 2, 89-102.

Pabale, S.S. and Pandya, H.R. 2010. A comparison of different stability models for genotype x environment interaction in pearl millet. Electronic Journal of Plant Breeding, 1(5): 1294-1298.

Sowmya, H.H, Kamatar, M.Y., Shanthakumar, G., Brunda, S.M., Shadakshari1, T.V., Showkath, B.M., and Sanjeev, S.R. 2018. Stability Analysis of Maize Hybrids using Eberhart and Russel Model. Int.J.Curr.Microbiol.App.Sci. *7*(2): 3336-3343.

Yan W, Kang MS. 2003. GGE biplot analysis: a graphical tool for breeders, In: MS Kang, eds., Geneticists, and Agronomist. CRC Press, Boca Raton, FL.

Yasin Goa1 and Hussen Mohammed. 2013. Genotype x environment interaction and yield stability in Field pea (*Pisum sativum* L.) tested over different locations in Southern Ethiopia.Journal of Biology, Agriculture and Healthcare. 3:19, 2013.

Yates F., Cochran W.G. 1938. The analysis of groups of experiments. J. Agr. Sci., *28*: 556–580.

Multi-environmental evaluations of kik type field pea genotypes in Western Oromia, Ethiopia.

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Abstract

Sixteen field peas (*Pisum sativum* L.) kik type genotypes brought from Holeta Agricultural Research center were evaluated for their adaptability and potential with the objectives of developing variety/ies that is/are high yielder, disease resistance and adaptable to high lands of western Oromia and similar agro-ecologies. The study was conducted at three locations, Arjo, Gedo and Shambu during 2018 and 2019 main cropping seasons in randomized

complete block design (RCBD) with three replications. Days to 50% flowering (DF), Days to 75% maturity (DM), Plant height (PH), Number of pods per plant (NPPP), hundred seed weight (HSW) and Grain yield (GYLD) data were collected and discussed in separate as phonology and growth traits and yield and yield components. Statistical analysis from combined data of ANOVA showed that there were significant differences, $p \leq 0.05$ among the tested genotypes in terms of GYLD and highly significantly differences $p \leq 0.01$ for DF, DM, PH, HSW. However, highly significantly different, $p \leq 0.01$ G x E interaction was observed only for DM. The three-way interaction, G x E x Y were significant for DF, DM, PH, HSW and GYLD but not for NPPP. The highest pooled mean performance of field pea kik type grain yield was 2680.1 $kgh^{-1}$for EH05011-2 genotypes and followed by EH06003-1, 2659.8 kg/ha genotypes and the lowest was 1995.3 kg/ha for EH08037-1 genotype and the grand mean being 2410.95 kgh^{-1}. Genotypes EH05011-2 and EH06003-1 were high yielder and resistance to powdery Mildews, Downy Mildews and Blotch. The two genotypes were evaluated by technical committee and waited for at least one candidate variety to be released for western Oromia and similar agro-ecologies.
Key words: ANOVA, Field pea, Genotypes, Kik Type, Locations, Yield

Introduction

Field pea (*Pisum sativum* L.) is an important source of food in developing countries and a major feed in the developed world (Nawab, et al., 2008). The Possible centers of origin for field pea was Ethiopia, Western and Central Asia and the Mediterranean region; due to high pea genetic diversity sampled in these regions (Messiaen CM *et.al.*, 2006). Among pulse crops, field pea (*Pisum sativum* L.) stands fourth next to faba bean, haricot bean and chickpea in total production and areas coverage in Ethiopia (CSA, 2018). It grown on 220,508.39 hectares of land with total production of 368,519.065 tones and productivity of 1.671tha^{-1} (CSA, 2018). It covers 13.79% from pulses total area coverage and 12.37% from total production in Ethiopia (CSA, 2018).The crop is widely cultivated in potential mid and high altitude areas of the country characterized with elevations of 1800-3000 meters above sea level and receiving average annual rainfall of 700-1100mm.

It has a great economic merit in the livelihood of the farming communities of Ethiopia Tamene, 2017**.** It serves as a source of food and feed with valuable and cheap sources of protein as a complement to cereals for the majority of the poor population mainly for those who cannot afford to use proteins from animal source and also often called “poor man’s meat” due to its high protein, vitamin and mineral, and prebiotic carbohydrate content yet affordability for poorer consumers (Amarakoon et al., 2012). It is also a good source of cash to the farmers. Due to its pertinent atmospheric nitrogen fixing capacity (up to 60 kg ha^{-1} $year^{-1}$); field pea is suitable rotational crop in areas where cereal mono cropping is abundant like Arsi and Bale of South Eastern Ethiopia. Despite its huge importance in the country, the average production and productivity of field pea is very low as compared to cereals and many other countries of the world FAO, 2017**.** It could be due to the inherent low-yielding potential of land race, diseases like powdery mildew (Erysiphepolygoni) and Ascochyta blight/spot (*Mycosphaerellapinodes*) as well as a biotic stress like frost are the major constraints, causing substantial yield loss and instability in yield (Sahile 2008**,** Teshome 2017).

Evaluating of crop performances across different environments generates important in formations on their adaptation and stability (Crossa, 1990; Ceccarelli, 1996). Among several statistical models, the mostly used statistical analyses for GEI are: The additive main effects

and multiplicative interaction (AMMI) model (Gauch, 2006) and the genotype main effect and the genotype x environment interaction effect (GGE).
Bako Agricultural Research Center has been doing field pea research for the last twenty years. Since then, the center has released five varieties of field pea; four of them have used as ‘kik’. Field pea production and productivity in our country is still low due to lack of improved varieties, lack of control mechanisms of pests. Therefore, the objective of this activity was to evaluate and release varieties that are high yielder, tolerance to disease and adaptable to wide agro-ecologies.

Materials and Methods
Description of the study areas
Field experiment was conducted during 2018 and 2019 main cropping seasons at Arjo, Gedo and Shambu highland agro-ecologies of Oromia Region.

Plant materials, experimental design and management
About sixteen field pea genotypes were evaluated for their potential in randomized complete block design with three replications. Plot size of 4m length x 0.2m inter row spacing x 4 rows= 3.2m^2. To execute the activity, 100kg of NPS fertilizer was applied at the time of planting. All agronomic manage mental aspects were done from planting to harvesting.

Statistical Analysis
The combined analysis’s for the three locations were done. Homogeneity of variance was tested and combined analysis of variance was performed using the linear mixed model (PROC ANOVA). Comparison of varietal means was done using Duncan’s Multiple Range Test (DMRT) at the 5% probability level. The combine analysis revealed that, the G x E was not significantly different. Therefore, further analysis like AMMI analysis and GG Bi-plot will not important to be done.

Results and Discussions
Analysis of variance and mean performance
The mean square from ANOVA of Phonology and growth traits for three characters, Days to flowering, Days to maturity and Plant height showed that, the genotypes were responded differently for the three characters (Table 1). G x E interaction was occurred only for DF; but not for the two characters (DM and PH). Inversely, the evaluated genotypes were influenced by the three way interactions (G x E x Y) Table 1.

Table 1. Mean squares from ANOVA for field pea Kik-Type in phonology and growth traits.

Source of variations	DF	**Mean Squares**					
		DF	DM	PH	NPPP	HSW	GYLD
Loc	2	322.8**	7270.4**	30784.5**	431.3**	149.0**	47735648.8**
Year	1	8.0ns	612.5**	4166.3**	244.6**	17.7**	42860651.81**
Gen	15	8.3*	19.7**	2334.8**	7.1ns	41.1**	867926.6*
Rep	2	22.2**	96. 4**	877.9ns	14.3ns	12.3*	1388428.5*
Gen x Env	30	8.4**	5.2ns	511.6ns	6.8ns	4.7ns	441482.5ns

Gen x Rep	30	9.0**	20.7**	747.7ns	4.5ns	2.9ns	567315.0ns
Gen x Env x Year	47	7.6**	26.4**	908.0*	7.6ns	6.2**	1200930.3**
Error	160	3.7			5.6	3. 2	404491.6
CV (%)		3.13	1.5	14.6	24	8.4	16

Where: DF= Days to Flowering, DM = Days to Maturity, PH = Plant Height, NPPP = Number of Pods Per Plant, HSW = Hundred Seed Weight, GYLD = Grain Yield and *, ** and ns showed significant, highly significant and non significant respectively

The ANOVA of yield and its components for kik type field pea genotypes, number of pods/plant, hundred seed weight and grain yield showed that, the evaluated genotypes were responded differently for its HSW and GYLD but not for NPPP (Table 1). But, the G x E interactions for the three characters have no significantly different; i.e, the evaluated genotypes were performed the same for their yield and its components characters across locations. But, the G x E x Y interactions were there for HSW and GYLD but not for PPP (Table 1).

From pooled mean yield performances, the highest grain yield (2680.1 $kgha^{-1}$) was recorded by genotype **EH05011-2** followed by 2659.8 $kgha^{-1}$ for genotype **EH06003-1**; which have 10.4% and 9.6% yield advantages over standard check Jiidhaa respectively. The evaluated genotypes were not significantly different at Arjo and differently performed at Gedo and Shambu locations. These two high yielder genotypes were evaluated by technical committee along with standard check on the VVT stage in 2020 and we are waiting for decision at least one variety to be released in the future as a kik category.

Table 2. Pooled Mean performance of grain yield for Field pea Kik Type

S.N	Genotypes	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 3. Over years & locations of pooled mean performance for some characters of field pea kik type

S.N	**Genotypes**	**DF**	**DM**	**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

Where: DF = Days to Flowering, DM = Days to Maturity, PH = Plant Height, NPPP = Number of Pods Per Plant, HSW = Hundred Seed Weight and *, ** and ns showed significant, highly significant and non significant respectively

The above two phonology and growth traits (DF and DM) and three yield components (PH, NPP and HSW) recorded for field pea kik type were significantly different which means the sixteen evaluated genotypes were performed differently across locations and years.

The two better genotypes, **EH05011-2 and EH06003-1** are resistant and scored 1.55 and 1.44, 1.55 and 1.22 and 2.66 and 2.22 for downy mildews, powdery mildews and blotch diseases, respectively. The scored diseases were for 2019 cropping season and the diseases were not occurred in the first year, 2018 of RVT trial (Table 4).

Table 4. Pooled means of field pea Kik type diseases scored in 2019 cropping season in 1-9 scale for Gedo, Shambu and Arjo Locations

S.N	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

Conclusion and Recommendation

Classificationof field pea varieties depend on purpose of utilizationis very usefull to boost the satisfaction of the users in one or other case on the same commodity. Multi-environment trial for different years helps to know the varieties weather it performed the same or differently across locations, which identifies the tested genotypes its specific or general adaptability. Due to the tested genotypes had no interaction or performed same across locations, it had general adaptation. EH05011-2 and EH06003-1 genotypes responded high yielder, 2680.1 kgha^{-1} and 2659.8 kgha^{-1} which have 10.4% and 9.6% yield advantages respectively. The candidate varieties were resistant to downy mildews, powdery mildews and blotch diseases and therefore, these two candidate varieties were evaluated by variety release committee for possible release.

References

Amarakoon, D., Thavarajah, D., McPhee, K., Thavarajah, P. 2012. Iron-, zinc-, and magnesium-rich field peas (Pisum sativum L.) with naturally low phytic acid: a potential food-based solution to global micronutrient malnutrition. *J. Food Compost. Anal.* 27 (1), 8–13. doi: 10.1016/J.JFCA.2012.05.007

Ceccarelli, S.1996. positive interpretation of genotype by environment interaction in relation to sustainability and biodiversity. In: Cooper, M. and Hammer. G.L. 9Eds) Plant Adaptation and Crop Improvement. CAB International Wallingford, Uk. PP.467-486.

Crossa,J. 1990. Statistical analysis of multi-location trials. Advances in Agronomy, 44:55-86.

CSA (Central Statistical Authority). 2018. Agricultural sample survey 2009/10. Report on area and production of major crops private peasant holdings, Meher Season. Addis Ababa. Statistical Bulletin no. 586. Volume 1.

Gauch, H.G. 2006. Statistical Analysis of Yield trials by MMI and GGE-biplot. Crop Sci.,46:1488-1500

FAO 2017. Food and Agriculture Organization of the United Nations. Available online at http://www.fao.org/faostat/en/#data/QC/visualize.

Messiaen CM, Seif AA, Jarso M, Keneni GA. 2006. Pisum sativum L. internet record from PROTA4U. In. Brink M, Belay G (Eds.), PROTA: Plant Resources of Tropical Africa, Wageningen, Netherlands

Sahile S, Ahmed S, Fininsa C, Abang M and Sakhuja PK. 2008. Survey of chocolate spot (Botrytis fabae) disease of faba bean (*Vicia faba* L.) and assessment of factors influencing disease epidemics in northern Ethiopia. Crop Protection, 27: 1457-1463.

Tamene TT. 2017. Genetic Variation, Heritability, And Advances From Selection In Elite Breeding Materials Of Field Pea (*Pisum Sativum* L.). Agricultural Research and Technology, 8 (4): 555740. DOI: 10.19080/ARTOAJ.2017.08.555744

Teshome E, and Tegegn A. 2017. Comparative Study of Powdery Mildew (*Erysiphe polygoni*) Disease Severity and Its Effect on Yield and Yield Components of Field Pea (*Pisum sativum* L.) in the Southeastern Oromia, Ethiopia. Journal of Plant Pathology and Microbiology, 8: 410. doi: 10.4172/2157-7471.1000410

Multi-Locations Evaluations of Grain Yield of Field Pea (*Pisum sativum* L.) Shiro Type Genotypes in Western Oromia, Ethiopia.

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Abstract
A field experiment was conducted on eleven field pea shiro type genotypes at Shambu, Gedo and Arjo sub-sites in 2018 and 2019. The objectives of to develop varieties that have high yielder, tolerant to major disease and adaptable to wide agro ecologies. The trial was undertaken in RCBD with three replications on the plot size of 3.2m^2 days to flowering date (FD), days to maturity (MD), number of pods per plant (NPPP), plant height (PH), hundred seed weight (HSW) and grain yield (GYLD) were collected. The pooled ANOVA from combined analysis reveled that, there were highly significantly different at P $\leq$ 0.01 for DM, HSW and GYLD of evaluated genotypes. G x E interaction of DM was highly significantly different and not for grain yield and the three ways interactions, G x E x L were developed for all of the characters studded. From pooled mean grain yield, the performance of EH08027-2 genotypes was recorded 2795.23 kgha^{-1} which has 1015% yield advantages than standard check Lammiif. It is high yielder and resistance to powdery mildews, downy mildews and blotch. Genotype EH08027-2 was evaluated along with check Lammiif by technical committee and waited for release by variety release committee.
Key Words: ANOVA, Field pea, Locations, Shiro Type, Yield

Introductions

Ethiopia is a secondary origin and one of the Vavilovian centers of diversity for field pea (*Pisum sativum* L.) (Vavilov, 1950; Frankel, 1973; Harlan, 1973; Westphal, 1974; Engels et al.,1991; Muehlbauer and Tullu, 1997). Field pea (*Pisum sativum* L.) is an important source of food in developing countries and a major feed in the developed world (Nawab, et al.,

2008). In Ethiopia, the major field pea producer's areas include: the mid and high-altitude areas of Amhara, Oromia, SNNPR and Tigray regional states (CSA, 2015). It has grown on 220,508.39 hectares of land with total production of 368,519.065 tones and productivity of 1.67 tha^{-1} (CSA, 2018). It covers 13.79% from pulses total area coverage and 12.37% from total production in Ethiopia (CSA, 2018). It has a great economic merit in the livelihood of the farming communities of Ethiopia and restores soil fertility and "break" crops to pests when rotated with cereals Tamene, 2017**.** It also serves as a source of food and feed with valuable and cheap sources of protein as a complement to cereals for the majority of the poor population mainly for those who cannot afford to use proteins from animal source and also often called "poor man's meat" due to its high protein, vitamin and mineral, and pre biotic carbohydrate content yet affordability for poorer consumers (Amarakoon et al., 2012). Despite its huge importance in the country, the average production and productivity of field pea is very low as compared to a number of cereals and many other countries of the world FAO, 2017**.** It could be due to the inherent low-yielding potential of landrace, diseases like powdery mildew (*Erysiphepolygoni*) and Ascochyta blight/spot (*Mycosphaerellapinodes*) as well as a biotic stress like frost are the major constraints, causing substantial yield loss and instability in yield (Sahile 2008**,** Teshome 2017).
Evaluating of crop performances across different environments generates important in formations on their adaptation and stability (Crossa, 1990; Ceccarelli, 1996). Among several statistical models, the mostly used statistical analyses for GEI are: The additive main effects and multiplicative interaction (AMMI) model (Gauch, 2006) and the genotype main effect and the genotype x environment interaction effect (GGE). Bako Agricultural Research Center has been doing field pea research for the last twenty years. Since then, the center has released five varieties of field pea; one of them has used as a 'Shiro'. Field pea production and productivity in our country is still low due to lack of improved varieties, lack of control mechanisms of pests. Therefore, the objective of this activity is: to release varieties that are high yielder, tolerance to disease and adaptable to wide agro-ecologies.

Materials and Methods

Description of the study areas

The experiment was conducted at Arjo, Gedo and Shambu high land agro-ecologies during 2018 and 2019 main cropping seasons for two consecutive years of Oromia Region.

Plant materials, experimental design and management

Eleven field pea genotypes were evaluated for their yield potential and disease resistant in RCBD with three replications. The test locations were Gedo, Shambu and Arjo in 2018 and 2019 on plot size of 4m length x 0.2m inter row spacing x 4 rows= $3.2m^2$. To undertake the activity, 100kg of NPS fertilizer was applied at the time of planting. All agronomic managemental aspects were done from planting to harvesting as required.

Results and Discussions

Analysis of Variance

The collected data were analyzed using SAS statistical package software (SAS, 2006 version 9.03). The combined analysis of variance (ANOVA) using the linear mixed model (PROC GLM) for six characters including grain yield and three different field pea diseases for the three locations were done. Variance for homogeneity was tested and comparison of varietal means was done using Duncan's Multiple Range Test (DMRT) at the 5% probability level. The results from combine analysis revealed that, the G x E was not significantly different.

Table 1. Mean square from ANOVA for field pea Shiro-Type in phonology and growth traits**.**

Source of variations	DF	Mean Squares					
		DF	DM	PH	NPPP	HSW	GYLD
Loc	2	4020.95**	8146.10**	1726.70**	185.90**	76.55**	31585187.62**
Year	1	0.05ns	165.50**	22381.04**	11.59ns	8.82ns	11474775.81**
Gen	10	25.49ns	13.64**	568.38ns	4.39ns	46.29**	646661.11**
Rep	2	32.77ns	6.69ns	82.52ns	1.55ns	4.51ns	421110.63ns
Gen x Env	20	30.80ns	17.16**	522.22ns	4.33ns	5.72ns	421769.88ns
Gen x Rep	20	38.17ns	17.15**	324.75ns	7.81ns	5.45ns	175550.18ns
Gen x Env x Year	32	16.37**	8.30**	1301.52**	11.32**	9.42**	793029.63**
Error	110	19.82	4.68	675.32	4.99	3.74	302861.3
CV (%)		7	1.77	15.16	23	9.87	21

Where: DF=days to flowering, DM=days to maturity, PH=plant height and ** and ns showed highly significant and non-significant, respectively.

However, the evaluated genotypes were responded different values for their DM, HSW and GYLD; while characters like DSF, NPP and HSW were not affected by the evaluated genotypes across locations. G x E interaction was only occurred in case of DM. The three-way interactions (G x E x Y) were highly significantly different for all of the six tested characters (Table 1). Therefore, since G x E interaction has no significantly different for grain yield, no further analysis like AMMI and GG Bi-plot analysis will not important to be done.

The pooled mean yield performance showed that, the highest grain yield (2795.23 kgha^{-1}) was recorded for genotype **EH08027-2** which has 10.15% yield advantage over standard check Lammiif. The evaluated genotypes were not significantly different at Shambu and differently performed at Gedo and Arjo locations. This high yielder genotype was evaluated by technical committee along with standard check on the VVT stage in 2020 and we are waiting for possible release in the future as a shiro category.

Table 2. Pooled Mean performance of grain yield for Field pea shiro Type

S. N	Genotypes	Arjo	Gedo	Shambu	GYLD	Y. Ad.
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	
Significant Level		*	**	**Ns**	*	
CV (%)		22	18	20	21	

Table 4. Over years & locations of pooled mean performance for some characters of field pea shiro type

S.N	**Genotypes**	**DF**	**DM**	**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

Where: DF = Days to Flowering, DM = Days to Maturity, PH = Plant Height, NPPP = Number of Pods Per Plant, HSW = Hundred Seed Weight and *, ** and ns showed significant, highly significant and non significant respectively

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

S.N	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	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

Genotype EH08027-2 was resistant and scored 1.77, 1.77, 1.55 and 2.77 for downy mildews, powdery mildews and blotch diseases, respectively. The scored diseases were for 2019 cropping season and there were no any disease development in the first year, 2018 of regional variety trial.

Conclusion and Recommendation

Field pea shiro type was identified by farmers depend on their utilization. Multi-environment trial for different years helps to know the genotypes weather it performed the same or differently across locations, which identifies the tested genotypes its specific or general adaptability. The tested genotypes had no interaction with tested environments or performed same across environments and it had general adaptation. Genotype EH08027-2 is high yielder than standard check Lammiif. This genotype was resistant to downy mildews, powdery mildews and blotch diseases and therefore, it was observed and evaluated by technical committee as a candidate variety and requested for possible release.

References

Amarakoon, D., Thavarajah, D., McPhee, K., Thavarajah, P. 2012. Iron-, zinc-, and magnesium-rich field peas (Pisum sativum L.) with naturally low phytic acid: a potential food-based solution to global micronutrient malnutrition. *J. Food Compost. Anal.* 27 (1), 8–13. doi: 10.1016/J.JFCA.2012.05.007

Ceccarelli, S.1996. positive interpretation of genotype by environment interaction in relation to sustainability and biodiversity. In: Cooper, M. and Hammer. G.L. 9Eds) Plant Adaptation and Crop Improvement. CAB International Wallingford, Uk. PP.467-486.

Crossa,J. 1990. Statistical analysis of multi-locationtrials. Advances in Agronomy, 44:55-86.

CSA (Central Statistical Authority). 2018. Agricultural sample survey 2009/10. Report on area and production of major crops private peasant holdings, Meher Season. Addis Ababa. Statistical Bulletin no. 586. Volume 1.

Engles, J.M.M., J.G. Hawkes and MelakuWerede (eds.). 1991. Plant genetic resources of Ethiopia. Cambridge University Press Falconer, D.S. 1989. Introduction to Quantitative Genetics. 3rd ed. Longman, London, England

FAO. 2017. Food and Agriculture Organization of the United Nations. Available online at http://www.fao.org/faostat/en/#data/QC/visualize.

Frankel, O.H. (eds.). 1973. Survey of genetic resources in their center of diversity. First Report. FAO/IBP, Rome

Gauch, H.G. 2006. Statistical Analysis of Yield trials by MMI and GGE-biplot. Crop Sci.,46:1488-1500

Harlan, J.R. 1973. Genetic resources of some field crops in Africa. In: Survey of crop genetic resources in their center of diversity. First Report. Frankel O.H. (eds.). pp 45-64. FAO/IBP, Rome

Muehlbauer, F.J. and Tullu, A. 1997. Cicer arietinumL: New crop fact sheet (http://www.hort.purdue.edu/newcrop/cropfactsheets/chickpea.html#Origin)

Sahile S, Ahmed S, Fininsa C, Abang M and Sakhuja PK (2008). Survey of chocolate spot (Botrytis fabae) disease of faba bean (Vicia faba L.) and assessment of factors influencing disease epidemics in northern Ethiopia. Crop Protection, 27: 1457-1463.

Tamene TT. 2017. Genetic Variation, Heritability, And Advances From Selection In Elite Breeding Materials Of Field Pea (Pisum Sativum L.). Agrecultural Research and Technology, 8 (4): 555740. DOI: 10.19080/ARTOAJ.2017.08.555744

Teshome E, and Tegegn A. 2017. Comparative Study of Powdery Mildew (Erysiphe polygoni) Disease Severity and Its Effect on Yield and Yield Components of Field Pea (Pisum sativum L.) in the Southeastern Oromia, Ethiopia. Journal of Plant Pathology and Microbiology, 8: 410. doi: 10.4172/2157-7471.1000410

Vavilov, N.I. 1950. The origin, variation, immunity and breeding of cultivated plants. Chronica Botanica13:1-366

Westphal, E. 1974. Pulses in Ethiopia: Their taxonomy and significance. College of Agriculture, Haile Sellessie I University, Ethiopia/Agriculture University, Wageningen, The Netherlands.

Registration of Haro Sabu-1 Common Bean (*Phaseolus vulgaris* L.) Variety

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Abstract
Haro Sabu -1 is a name given for small red common bean (*Phaseolus vulgaris* L.) variety with pedigree name of SCR33 after release. It is a bush food bean variety selected out of common bean lines introduced to Ethiopia (Melkasa Agricultural Research Center) through CIAT program and released in 2019 by Haro Sabu Agricultural Research Center for production in west and kellemWollega Zones of West Oromia, Ethiopia and similar agro-ecologies. It was tested on- research stations from 2015 to 2017 and evaluated on farmers' fields in the year 2018. In multi-location trial, Haro Sabu-1 gave a mean grain yield of 2.01 tha^{-1}. Haro Sabu-1 performed better than the standard check, Ser119, which gave 1.62 tha^{-1} mean grain yield. On farmers' fields a mean yield of 1.804 tha^{-1} was recorded for Haro Sabu-1. Haro Sabu-1 is a bush bean variety with indeterminate semi-bush growth habit. It is a variety with small seed size and red seed color used for domestic consumption. Yield stability study showed that Haro Sabu-1 was stable variety in test locations and requires favorable environments for good seed yield. It is also tolerant to disease and insect pest. The breeder seed of Haro Sabu-1 is maintained by Haro Sabu Agricultural Research Center for different research purposes.
Keywords: Haro Sabu-1; *Phaseolus vulgaris*; Variety Registration

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). According to CSA (2017), the major haricot bean producing regions include Oromia, Amhara and Southern Nations Nationalities and Peoples Region (SNNPR). Their share to the national haricot bean production is Oromia (51%), Amhara (24 %) and for SNNPR (21%). It is an important food crop in eastern and southern Africa, and recognized as the second most important source of human dietary protein and the third most important source of calorie of all the agricultural commodities produced in eastern and southern Africa (Kimani, 1999) cited by Mulugeta*et al*., 2013. A common bean is rich in protein (20 to 28%), especially the amino acids lysine and tryptophan, and is an important source of minerals such as iron and zinc (MOARD, 2006; Ribeiro *et al*., 2007).

In Ethiopia common bean is estimated to be over 85% of export earnings from pulses, exceeding that of other pulses such as lentils, horse (faba) bean and chickpea (Negash, 2007). Overall, common bean ranks third as an export commodity in Ethiopia, contributing about 9.5% of total export value from agriculture (FAO, 2010). Thus, haricot bean is an important crop in addressing the issue of nutrition security in the country in general and in west Oromia where people's diet is dominated with maize in particular.

Haro Sabu-1 (*SCR33*) is common bean variety released in 2019 by Haro Sabu Agricultural Research Center (HSARC). It is small seed size with red color bean type and was obtained from CIAT/ECABREN breeding lines that had been introduced to Ethiopia by National haricot bean coordinating, Melkasa Agricultural Research Center. *Haro Sabu-1* was officially approved in 2019 by Ethiopian National Variety Release Committee in accordance with the national variety release and registration policy of the country to bean produced in areas of West and KellemWollega, west Oromia and areas with similar agro-ecologies. Common bean description used by Grafton *et al.* (1993), Kelly *et al.* (1994) and Saindom*et al.* (1996) was adopted for describing Haro Sabu-1 (SCR33).

Evaluation

Haro Sabu-1 was tested with the standard check, Ser119 and Local check under regional variety trial at seven (7) environments (location x year) in western Oromia, Ethiopia between 2015 and 2017. On-farm evaluation was conducted during 2018 at six sites, with Ser119 at altitude ranging from 1450-1850 meters above sea level.

Agronomic and Morphological Characteristics

The newly released variety; Haro Sabu-1 has light green leaves with intermediate semi-bush and prostrate growth habit. The pod of Haro Sabu-1 is green before maturity. Similarly, it has rounded seed shape and small seed size with red color. Haro Sabu-1 produces 14.52 pods per plant, 4.29 seeds per pod, 20.57g seed weight and 70.58cm plant height, on average base (Table 1). The new variety is a food type/market group preferred by producers mainly because of its high yielding, seed color, and disease tolerance.

Yield Performance

Haro Sabu-1 was evaluated for grain yield from early breeding stage i.e. 2015 to 2017 and had better mean value than the standard check, Ser119. Multi-location yield trial carried out at Haro Sabu research station, Gulliso FTC, Kure Gayib FTC, Sago FTC, Shebeli FTC and

Tole FTC between 2015 and 2017. Haro Sabu-1 was found to be high yielder, stable, well adapted, disease tolerant genotype. The mean grain yield value of 2.01 tha^{-1} was obtained from Haro Sabu-1 compared to the standard check, Ser119 which had a mean value of 1.62 tha^{-1} for grain yield. On farmers' fields, the grain yield of Haro Sabu-1 was 1.80 tha^{-1} (Appendix Table 1), which revealed the increment of yield through new variety deployment.

Yield Stability Test

Haro Sabu-1 was tested for its grain yield performance in areas ranging from 1450-1850 meters above sea level. Its yield stability across test locations was analyzed following the AMMI model with eleven small seed size bush bean genotypes. The result of the study showed that Haro Sabu-1 is better adapted to favorable environments in general.

Disease Reaction

Haro Sabu-1 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 2.8 for Common bacterial blight (*Xanthomonas campestris pv. Phaseoli), 3 for* anthracnose (*Colletotricumlindemuthianum*)

Table 2: Major common bean disease reaction

Major disease	Haro Sabu-1	Ser119
Common bacterial blight	2.8	3
Anthracnose	2.9	2.7

Quality Analysis

Besides its yielding ability, other desirable agronomic traits and disease tolerance, producers and consumers preferred Haro Sabu-1 due to attractive seed physical characteristics like seed color, size and shape, marketability and uniform maturity.

Adaptation

Haro Sabu-1 is released for production in West and KellemWollega Zones of West Oromia, Ethiopia, preferably for areas receiving a well distributed total annual rainfall greater than 1000 mm. Nevertheless, Haro Sabu-1 production can be extended to other regions having similar agro-ecology after adaptation and performance evaluation.

Conclusion

Haro Sabu-1 (SCR33) is a responsive variety to inputs which was officially verified and released in 2019 in West and KellemWollega, West Oromia, Ethiopia. It is high yielding, highly adaptable, stabile and tolerance to major foliar diseases prevailing in areas over the standard check. It was also preference by producers for its better grain yield performance, attractive seed color and marketability. Therefore, Haro Sabu-1 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 financing the experiment, Melkasa Agricultural Research Center for genotypes source and Haro Sabu Agricultural Research Center for facilitation of research activity, 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 HabtamuZelleke. 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.

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

Appendix Table 1: Mean Performance of agronomic characters and disease reaction for Haro Sabu-1 and Ser119

Character	Haro Sabu-1	Ser119
Adaptation area		
Altitude (meter above sea level)	1450-1850	1450-2000
Rain fall (mm)	1000-2100	1000-2100
Seed rate (Kg/ha)	90	90
Fertilizer rate (Kg/ha)-NPS	100	100
Fertilizer application time	At planting	At planting
Fertilizer application method	Drilling in row	Drilling in row
Planting date	Early to mid August	Early to mid August
Row Spacing (cm)	40	40
Plant Spacing (cm)	10	10
Days to flowering	41.33	40.76
Days to Maturity	76.52	74.29
Plant height (cm)	70.58	64.97

Growth habit	Indeterminate semi-bush	Indeterminate semi-bush
Flower color	White	White
Pod/plant	14.52	14.58
Seed/pod	4.29	4.08
Hundred seed weight (gm)	19.57	20.77
Seed color	Red	Dark red
Disease Reaction (1-9 scale)		
Common bacterial blight	2.8	3
Anthracnose	2.9	2.7
Mean Grain Yield (tons/ha):		
Research Field	2.12	1.62
Farmer Field	1.87	1.33
Year of Release: 2019	2019	2014
Breeder/Maintainer: HSARC/OAR	HSARC/OARI	MARC/EARI

Keys: EARI= Ethiopia Agricultural Research Institute, HSARC= Haro Sabu Agricultural Research Center, OARI= Oromia Agricultural Research Institute, MARC= Melkasa Agricultural Research Center

Registration of Gute (Late Set) Soybean Varieties

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Abstract
Gute is the name given to soybean [*Glycine max* (L.) Merr.] variety with pedigree of PM 12-3, brought from Jimma Agricultural Research Center. Gute variety was evaluated against the standard check and other genotypes for seed yield, agronomic characters and disease reaction at Bako, BilloBoshe and Gute experimental sites from 2016/2017 to 2017/2018. Gute-19 variety was verified for possible release in 2019 on farms and on stations, Gute gave seed yield of 2779.1 kgha^{-1}, 39.4% protein content and 22.3% oil content respectively. The result of multi-environment yield trials showed that Gute (PM 12-3) outperformed the standard check (PRAC-3) by 20.1 % in seed yield and comparable in oil content. It was resistant to bacterial blight and bacterial pustule. Stability analysis showed that the variety was relatively stable in grain yield performance across locations than the check variety PARC-3. Therefore, Gut was released in 2020 for its high grain yield potential, disease resistance and farmers preferences and recommended for wider production in the test environments and similar agro-ecologies
Keywords: Commercial Variety; Pedigree, Stability, Soybean

Introduction

Soybean [*Glycine max* (L.) Merrill] is a legume native to East Asia perhaps in North andCentral China (Laswai*et al*., 2005) and it is grown for edible bean, oil and protein around the world. Soybean is found in family Fabaceae and species G. max (Shurtleff and Aoyagi, 2007). Soybean is one of the most important oil grain legume crops in the world. In the International trade market, soybean ranks number one among the major oil crops with an average protein content of 40% on dry matter basis. It has the highest protein content of all field crops and is the 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 the common vegetable or legume food sources in Africa. Soybean is a promising pulse crop proposed for alleviation of acute shortage of protein and oil worldwide (Mahamood*et al*., 2009). Soybean production begins only recently in Africa, during the second half of 20^{th} century is believed introduced to Ethiopia in the 1950's. Soybean research was started in the 1970's since then 25 soybean varieties have been released in Ethiopia. Soybean is the leading oil crop, next to palm with over 250 million metric tons production in 2013 (FAO, 2014). Rich sources of protein 38-46% and 18-20% oil. Soybean containing 2.5 times the protein contents of wheat and four times the protein contents of maize.Soybean is classified in different groups such as early, medium and late maturing varieties. A variety is classified to a specific maturity groups according to the length of period from planting to maturity. This phenological attribute is determined by two abiotic factors: photoperiod and temperature (Mourtzinis and Conley, 2017), and these factors can dictate the most suitable maturity groups of soybean varieties for a particular geographical location. Therefore, development of new varieties under different maturity class of soybean varieties for specific agro-ecologies of western Oromia and similar agro-ecologies is an alternative option to boost soybean production and productivity.

Varietal Origin and Evaluation

Gute soybean *[Glycine max (L.) Merr.]* variety with the pedigree of PM 12-3 was brought from Jimma Agricultural Research Center. This variety was evaluated against twelve other pipeline genotypes and the standard check at Bako, BilloBoshe and Gute experimental sites from 2016/2017 to 2017/2018.

Agronomic and Morphological characteristics

Gute is characterized by round in seed shape, gray seed coat color and creamy seed coat luster. It is indeterminate and has erected growth habit, which enable harvesting at the same time and prevent from pod rot during heavy rain fall. Gute has large seed size compared to the commercial variety, PARC-3 (Table 1). Their leaf size is large and more uniform and is suitable for intercropping with erected leaf type maize verities. The mean data from three locations (Bako, Billo-Boshe and Gute) and for two years (2016/2017 and 2017/2018) revealed that Guteflowered in 74 days and matured in 141 days. Gute has better seed size, hundred seed weight and pod load than the check PARC-3(Table 1).

Yield Performance

Gute soybean variety was evaluated with standard check PARC-3, in multi-locations yield trials. Gute gave a seed yield ranging from 1.8 to 2.7 ton ha^{-1} on research stations and 1.5 to 2.4 ton ha^{-1} on farmers' fields (Table 1). Gute has outperformed than PARC-3 by 20 % and 14 % on station and on-farm in seed yield, respectively.

Oil and protein content

About 22.3 % of oil content was recorded from Gute while 22.6 % recorded from commercial variety PARC-3. The laboratory result revealed that Gute had higher protein content and comparable oil content with that of commercial variety PARC-3. However, the newly released Gute soybean variety had higher protein content 39.4 % than commercial verity PARC-3.

Table 4: Summary of mean grain yield and other agronomic traits of Gute variety

Characteristics	**Gute (PM-12-3)**
Adaptation area	
Altitude m (a.s.l)	1650-1900
Rainfall (mm)	1000-1200
Fertilizer rate (NPS) kg ha^{-2}	100
Fertilizer application time	At sowing
Fertilizer application method	Side dressing & avoid seed contact
Planting and seeding	
Planting date	Mid-June
Seeding rate (kg ha^{-1})	60-70
Row spacing (cm)	60
Plant spacing (cm)	10
Weeding frequency	3-4
Days to flowering	74
Days to maturity	141
Number of pods $plant^{-1}$	81
Number of seeds pod^{-1}	3
Leaf size	Large
Growth habit	Indeterminate
Seed coat color	Light yellow
Seed coat luster	Dull
Helium color	White
Seed shape	Round
Seed size	Medium
100 seeds weight	20
Oil content **(%)**	24.35
Protein content	39.4
Crop pest reaction (1-9 scale)	
Bacterial blight	2.75
Bacterial pustule	2.75
Rust	2.5
Yield (ton $ha^{-1)}$	
Research filed	1.8-2.7
Farmer field	1.5-2.4
Year of release	2020

Stability and Adaptability Performance

Genotype x environments interaction was partitioned into principal component axes and the first IPCA (69.28%) and the second IPCA (22.41%) explained the largest proportion (91.68 %) of the interactions. The result of the study revealed that Gute-19 (PM-12-3) is ideal and stable varieties compared to the commercial variety, PARC-3 (Figure 1). Gute was found to be a more stable new soybean variety and higher in oil content compared to the commercial variety PARC-3.

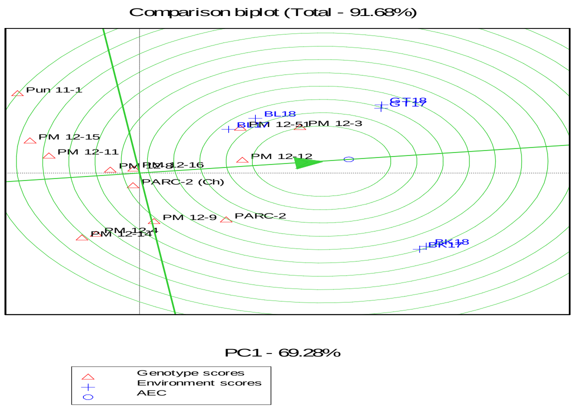

Figure 2: Ranking the genotypes relative to the ideal genotype.

Reaction to Major Diseases

The major soybean diseases in western Oromia such as bacterial blight, bacterial pustule and rust were recorded using 1-9 scale. Accordingly, Gute (PM-12-3) was resistant (< 3 severity score for the three major diseases recorded (Table 1).

Breeder Seed Maintenance

Breeder and foundation seed of the variety is maintained by Oromia Agricultural Research Institute Bako Agricultural Research Center.

Conclusion

The soybean variety Gute had higher seed yields, protein content, comparable oil content and better stability performances than the commercial variety PARC-3. The variety was also resistant to common soybean diseases viz., bacterial blight, rust and bacterial pustule and hence, have been released for the test environments and areas with similar agro-ecologies.

Acknowledgement

We gratefully thank Agricultural Growth Program (AGP-II) of Oromia Agricultural Research Institute for financing the development of the variety. We also thank International Institute of Tropical Agriculture (IITA) and Jimma Agricultural Research Center for germplasm sharing. Our appreciation and thank extended to staff members of Bako Agricultural Research Center for field work and data collection.

Reference

Yan, W. and Tinker, N.A. 2005. An integrated biplot analysis system for displaying, interpreting and exploring genotype x environment interaction. Crop Science 45: 1004-1016.

Laswai HS, Mpagalile JJ, Silayo VCK, Ballegu, WR. 2005. Use of soybeans in food formulation in Tanzania. 52–59. In: Myaka FA, Kirenga G, Malema B (Eds) 2006. Proceedings of the First National Soybean Stakeholders Workshop, November, 10th-11th Morogoro- Tanzania.

Shurtleff W, Aoyagi A. 2007. The Soybean Plant: Botany, Nomenclature, Taxonomy, Domestication and Dissemination. Soy info Center, California 40 p.

Dugje IY, Omoigui LO, Ekeleme F, Lava Kumar RP, Kamara AY. 2009. Guide to soybean production in northern Nigeria. IITA, Ibadan. 21p.

Mahamood J, Abayomi YA, Aduloju MO. 2009. Comparative growth and grain yield responses of soybean genotypes to phosphorous fertilizer application. African Journal of Biotechnology 8(6):10301036

Mourtzinis S, Conley SP. 2017. Delineating Soybean Maturity Groups across the United States. Agronomy Journal 109(4):1397-1403.

Registration of Billo-19 (Medium Set) Soybean Varieties

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Abstract
Billo potential candidate medium set soybeans [*Glycine max* (L.) Merr.] variety with pedigree of PM 12-37 was evaluated against standard checks and other genotypes for seed yield, agronomic characters and disease reaction at Bako, BilloBoshe and Gute experimental sites from 2016/2017 to 2017/2018. That variety was verified for possible release in 2019 on farms and on stations across all areas listed above. The pipeline variety PM 12-37 showed 24.7% oil content and seed yield of 2480.6 $kgha^{-1}$ against commercial variety Korme. It was resistant to bacterial blight and bacterial pustule. The result of multi-environment yield trials showed that Billo-19 (PM 12-37) outperformed the standard check Korme (AGS-129-2) by 31.7 % in seed yield and 4.2 % oil content respectively. The stability analysis showed that both varieties are stable in grain yield performance than the commercial variety of Korme (AGS-129-2). The national variety release standing committee made their annual meeting and recommends genotype Billo-19 (PM-12-37) for possible release based on its field yield performance, farmers preferences, seed yield and oil content.
Keywords: Commercial Variety; Pedigree, Stability, Soybean

Introduction
Soybean [*Glycine max* (L.) Merrill] is a legume native to East Asia perhaps in North and Central China (Laswai et al., 2005) and it is grown for edible bean, oil and protein around the world. Soybean is found in family Fabaceae and species G. max (Shurtleff and Aoyagi, 2007). Soybean is one of the most important oil grain legume crops in the world. In the International trade market, soybean ranks number one among the major oil crops with an average protein content of 40% on dry matter basis. It has the highest protein content of all field crops and is the 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 the common vegetable or legume food sources in Africa. Soybean is a promising pulse crop proposed for alleviation of acute shortage of protein and oil worldwide (Mahamood et al., 2009). Soybean production begins only recently in Africa, during the second half of 20th century is believed introduced to Ethiopia in the 1950's. Soybean research was started in the 1970's since then 25 soybean varieties have been released in Ethiopia. Soybean is the leading oil crop, next to palm with over 250 million metric ton production in 2013 (FAO, 2014). Rich sources of protein 38-46% and 18-20% oil. Soybean containing 2.5 times the protein contents of wheat and four times the protein contents of maize. Soybean is classified in different groups such as early, medium and late maturing varieties. A variety is classified to a specific maturity groups according to the length of period from planting to maturity. This phenological attribute is determined by two abiotic factors: photoperiod and temperature (Mourtzinis and Conley, 2017), and these factors can dictate the most suitable maturity groups of soybean varieties for a particular geographical location. Therefore, development of new varieties under different maturity class of soybean varieties for specific agro-ecologies of western Oromia and similar agro-ecologies is an alternative option to boost soybean production and productivity.

Varietal Origin and Evaluation
Billo soybean [*Glycine max* (L.) Merr.] Variety with pedigree of PM 12-37 was brought from Jimma Agricultural Research Center. This variety was evaluated against twelve other pipeline genotypes and the standard check at Bako, BilloBoshe and Gute experimental sites from 2016/2017 to 2017/2018.

Agronomic and Morphological Characteristics
Billo is characterized by oval in seed shape, yellowish seed coat color and dull seed coat luster. It is indeterminate and has erected growth habit, which enable harvesting at the same time and prevent from pod rot during heavy rain fall. Billo has large seed size compared to the commercial variety, Korme (Table 1). Their leaf size is large and more uniform and is suitable for intercropping with erected leaf type maize verities. The mean data from three locations (Bako, Billo-Boshe and Gute) and for two years (2016/2017 and 2017/2018) revealed that Gute flowered in 65 days and matured in 131 days. Billo has better seed size, hundred seed weight and pod load than the check Korme (Table 1).

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Yield Performance
Billo soybean variety was evaluated with standard check Korme, in multi-locations yield trials. Billo gave a seed yield ranging from 1.8 to 2.4 ton ha^{-1} on research stations and 1.5 to

19 ton ha^{-1} on farmers' fields (Table 1). Billo has outperformed than Korme by 31.7 % and 14 % on station and on-farm in seed yield, respectively.

Oil and Protein Content

About 24.7 % of oil content was recorded from Billo while 23.7 % recorded from commercial variety Korme. The laboratory result revealed that Billo had higher protein content and comparable oil content with that of commercial variety Korme (AGS-129-2).

Table 5: Summary of Mean Grain Yield and other Data of Billo Variety along With Commercial Variety Korme (AGS-129-2) Across Years and Location.

Characteristics	Billo(PM-12-37)
Adaptation area	
Altitude m (a.s.l)	1650-1900
Rainfall (mm)	1000-1200
Fertilizer rate (NPS) kg ha^{-2}	100
Fertilizer application time	At sowing
Fertilizer application method	Side dressing & avoid seed contact
Planting and seeding	
Planting date	Mid-June
Seeding rate (kgha^{-1})	60-70
Row spacing (cm)	60
Plant spacing (cm)	10
Weeding frequency	3-4
Days to flowering	65
Days to maturity	131
Number of pods plant^{-1}	80
Number of seeds pod^{-1}	3
Leaf size	Large
Growth habit	Indeterminate
Seed coat color	Yellow
Seed coat luster	Dull
Helium color	White
Seed shape	Oval
Seed size	Medium
100 seeds weight	18
Oil content **(%)**	24.7
Crop pest reaction (1-9 scale)	
Bacterial blight	3.0
Bacterial pustule	2.5
Rust	3.0
Yield (ton ha$^{-1)}$	
Research filed	1.8-2.4
Farmer field	1.5-1.9
Year of release	2020

Stability and Adaptability Performance

Genotype x environments interaction was partitioned into principal component axes and the first IPCA (42.34 %) and the second IPCA (18.98 %) explained the largest proportion (61.33 %) of the interactions. The result of the study revealed that Billo (PM-12-3) is ideal and stable varieties compared to the commercial variety, Korme (Figure 1). Billo was found to be a more stable soybean variety and higher in oil content compared to the commercial variety Korme.

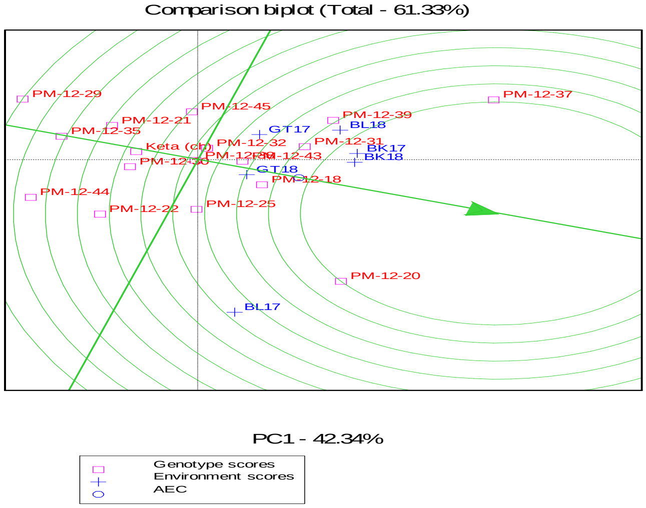

Figure 3: Ranking the genotypes relative to the ideal genotype

Reaction to Major Diseases

The major soybean diseases in western Oromia such as bacterial blight, bacterial pustule and rust were recorded using 1-9 scale. Accordingly, Billo (PM-12-37) was resistant (< 3 severity score for the three major diseases recorded (Table 1).

Breeder Seed Maintenance

Breeder and foundation seed of the variety is maintained by Oromia Agricultural Research Institute Bako Agricultural Research Center.

Conclusion

The soybean variety Billo had higher seed yields, protein content, comparable oil content and better stability performances than the commercial variety Korme. The variety was also resistant to common soybean diseases viz., bacterial blight, rust and bacterial pustule and hence, have been released for the test environments and areas with similar agro-ecologies.

Acknowledgement

We gratefully thank Agricultural Growth Program (AGP-II) of Oromia Agricultural Research Institute for financing the development of the variety. We also thank International Institute of Tropical Agriculture (IITA) and Jimma Agricultural Research Center for germplasm sharing. Our appreciation and thank extended to staff members of Bako Agricultural Research Center for field work and data collection.

Reference

Yan, W. and Tinker, N.A. (2005). An integrated biplot analysis system for displaying, interpreting and exploring genotype x environment interaction. Crop Science 45: 1004-1016.

Laswai HS, Mpagalile JJ, Silayo VCK, Ballegu, WR (2005). Use of soybeans in food formulation in Tanzania.52–59. In: Myaka FA, Kirenga G, Malema B (Eds) 2006. Proceedings of the First National Soybean Stakeholders Workshop, November, 10th-11th Morogoro- Tanzania.

Shurtleff W, Aoyagi A (2007). The Soybean Plant: Botany, Nomenclature, Taxonomy, Domestication and Dissemination. Soy info Center, California 40 p.

Dugje IY, Omoigui LO, Ekeleme F, Lava Kumar RP, Kamara AY (2009). Guide to soybean production in northern Nigeria. IITA, Ibadan. 21p.

Mahamood J, Abayomi YA, Aduloju MO (2009). Comparative growth and grain yield responses of soybean genotypes to phosphorous fertilizer application. African Journal of Biotechnology 8(6):10301036

Mourtzinis S, Conley SP (2017). Delineating Soybean Maturity Groups across the United States. Agronomy Journal 109(4):1397-1403.

Genotype by Environmental Interaction and Yield stability of sesame (*Sesamum indicum L.*) genotypes in Western Oromia, Ethiopia

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Abstract

Genotypes by environment (G x E) interactions is the major factors limiting response to selection and the efficiency of breeding programs. The study was conducted to identify stable high yielding genotypes and the magnitude of GXE interaction. RCBD with three replications was used across the environments. About 16 sesame genotypes including standard check (walin) were evaluated at Bako, Uke and Ose location in 2018 and 2019 main cropping season. The analysis of variance using additive main effect and multiplicative interaction (AMMI) model revealed highly significant ($P \leq 0.01$) variations among environments, G x E interaction and Interaction Principal Component Analysis. This implies that, the tested genotypes respond differently over environments as the test environments are highly variable. Mean of genotype by environmental interaction of 39.54% is explained by IPCA1 and 24.26% is explained by IPCA2. Based on AMMI and GGE-biplot analysis result, G3, G7 and G12 gave high seed yield, better adaptability and more stable performance than all tested sesame genotypes & check. Therefore, G3, G7 and

G12 sesame genotypes are proposed for possible release and recommended for wider adaptability.

Key words: AMMI, G x E, GGE-biplot, stable

Introduction

Sesame (*Sesamum indicum* L.) is a diploid species with 2n = 26 chromosomes which belongs to the family of *pedaliaceae* originated in East Africa and India (Nayar and Mehra, 1970, Bedigan, 2003). 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.

Globally, sesame is produced over an area of 12,821,752 hectares and annual production around 6,549,725 tons with average productivity of 5.2 tha^{-1}, whereas, in Africa, 8,737,270 ha and 3,998,148 tons of annual production with average productivity of 4.6 tha^{-1} (FAO, 2019). In Ethiopia sesame is produced over 375,120 ha with annual production of 262,654 tones with average productivity of 7 tha^{-1} (FAO, 2019). The production and productivity of sesame is very low due to limited number of adaptable varieties with tolerance to biotic and abiotic factors.

The idea that G x E could be considered as the pleiotropic effect of particular variants across environments implies that any given trait when evaluated across more than one environment can be analyzed as genetically correlated traits (Malosetti*et al.*, 2013). In this case, the magnitude of such a correlation indicates the degree of shared genetic control and the sign of the correlation indicates the direction of the allelic effect for the environments being considered. G x E is defined as a phenomenon that phenotypes respond to genotypes differently according to different environmental factors (Kim. *et al.*, 2014).

Adaptability is the result of G x E interaction and generally falls into general adaptability and specific adaptability (Farshadfar and Sutka, 2006). Identifying adaptable and stable high yielding genotypes under different environmental conditions is fundamental for plant breeders prior to release as a variety. The performance of one genotype that is superior in one environment might be inferior in another environment (Falconer and Mackay, 1996). Therefore, this study was conducted with the objective of to identify stable and high yielding sesame genotypes to release in the tested environments and similar agro ecologies.

Materials and Methods

Study area and planting materials

The experiment was conducted at three locations Bako, Ose and Uke for two consecutive year 2018 and 2019 main cropping season. The planting materials were developed by using full diallel method using F2 – derived pedigree breeding method at Bako Agricultural Research Center. Sixteen sesame genotypes including standard check (walin) variety were used as planting materials

No.	Genotypes	No.	Genotypes
1.	EW00 x BG006-7-1-1	**9.**	Dicho xObsa -4-1-1
2.	EW002 x BG006-2-1-1	**10.**	Obsa x BG006-4-1-1
3.	EW006 x EW003 (1)-4-2-1	**11.**	EW003(1) x EW002-4-2-1
4.	EW006 x EW003 (1)-3-1-1	**12.**	EW003(1) x EW002-5-2-1
5.	EW006 x EW003 (1)-7-1-1	**13.**	EW023(2) x BG006-13-1-1
6.	EW006 x EW003 (1)-7-1-1	**14.**	Obsa x EW023(2)-3-3-1
7.	Dicho x EW006-1-1-1	**15.**	EW003(1) x EW019-4-2-1
8.	Dicho x EW006-9-1-1	**16.**	Walin

Experimental design and trial managements

The trial was laid out using Randomized Complete Block design within three replication. Each genotype was planted in 4 rows in plot size of 6.4m^2 (4m row length, 0.40m between rows and 0.10m between plants within row and spacing of 1m between plots and 1.5m between blocks. The seeds were drilled by hand in each row at the rate of five kgha^{-1} and then covered by soil. The plant depth and soil compactions were kept at a minimum. Twenty days after planting, the plants were thinned to maintain the spacing between plants of 10 cm.Fertilizer was applied at the rate of 100 kgha^{-1} of NPS at planting time whereas, 50 kgha^{-1} of Urea was applied two times at planting time and four week after planting. Other cultural practices were kept constantly for all experimental units.

Data collection

All necessary data were collected according to the International Plant Genetic Resources Institute (IPGRI, 2004) descriptor for sesame

Data analysis

Analysis of variance for each environment and combined analysis of variance over environments were computed by SAS 9.1.3 Software and AMMI analysis was computed using GenStat statistical softwre18th edition

Additive main effect and multiplicative interaction model

The AMMI model equation is:

$Y_{ger} = \mu + \alpha_g + \beta_e + \sum_n \lambda_n \gamma_{gn} \delta_{en} + \varepsilon_{ger} + \rho_{ge}$;

Where, Y_{ger} is the observed yield of genotype (g) in environment (e) for replication (r); Additive parameters: μ is the grand mean; αg is the deviation of genotype g from the grand mean, βe is the deviation of the environment e; Multiplicative parameters: λn is the singular value for IPCA, γ_{gn} is the genotype eigenvector for axis n, and δ_{en} is the environment eigenvector; ε_{ger} is error term and ρ_{ge} is PCA residual. Accordingly, genotypes with low magnitude regardless of the sign of interaction principal component analysis scores have general or wider adaptability while genotypes with high magnitude of IPCA scores have specific adaptability.

Result and Discussion

The individual analysis of variance showed that a significant differences between genotypes for the seed yield in all environment except Bako 2019 which is non-significant. This indicated that the presence of variability among tested genotypes across tested environments (Table 3). The pooled Analysis of variance showed that a highly significant differences among genotypes, location and GEIs (Table2). This indicated that presence of variability among tested genotypes across environments and their interaction shows possibility to do stability analysis to understand the nature of GEI and performance of the genotypes over locations.

Table: 2. Combined ANOVA for seed yield of sesame genotypes over six environments

Source	df	SS	MS
Location	2	941481	470740.51**
Year	1	721534	721533.82**
Genotype	15	1367533	91168.90**
Replication	2	6549.3	3274.65^{ns}
Loc*Geno	30	1476710	49223.66**
Loc*Year	2	1271312	635656.01**
Loc*Year*Geno	45	2916547	64812.17**
R^2	0.90	CV (%)	13.52

Key: ** and ns=significant at 0.01probability level and non-significant, respectively, df = degree freedom, SS = sum square, MS = mean square, R^2 = R square and CV (%) = coefficients of variation

The mean seed yield of the individual environments during 2018 - 2019 main cropping season are highly significant at ($p<0.001$) and presented in (Table 3). Overall mean seed yield of sesame genotypes ranged from 228.75 kgha^{-1} for genotype G9 at Bako in 2019 to 988.64 kgha^{-1} for G12 at Ose in 2019. The highest mean seed yields across environments were shown by genotypes; G3, G7 and G12 with overall mean seed yields (634.22, 623.39 and 621.21 kgha^{-1}), respectively, and were higher than the grand mean (524.76 kgha^{-1}). Among high yielder genotypes, G1, G7, and G3 showed 12.81%, 10.88% and 10.5% yield advantage over the standard check (walin). The yield variation among sesame genotypes indicated that selection should be based on mean performances at the respective environments. Fluctuating sesame yield performance in sesame genotypes with environments reported by Fiseha, *et al.*, 2015, Mekonnen, *et al.*, 2015 and Mohammed A, 2015.

Table 3. The mean value of seed yield (kgha^{-1}) among tested 16 sesame genotypes across six environments

	Yield (kgha^{-1})							
	2018			**2019**				
Genotypes	**Bako**	**Uke**	**Ose**	**Bako**	**Uke**	**Ose**	**Pooled mean**	**Yield adv.**
EW00 x BG006-7-1-1	268.33	326.00	541.33	264.69	532.61	283.80	369.46	-34.28
EW002 x BG006-2-1-1	406.00	357.33	562.33	340.52	619.48	444.69	455.06	-19.06
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	-18.04

EW006 x EW003 (1)-7-1-1	517.33	631.67	611.00	319.48	698.96	502.97	546.90	-2.72
EW003 (1) x Wama -9-1-1	490.33	430.00	692.00	303.23	625.83	419.79	493.53	-12.21
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	-8.65
Dicho x Obsa -4-1-1	503.00	345.67	452.00	228.75	622.81	537.08	448.22	-20.27
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	-8.87
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	-5.49
Obsa x EW023(2)-3-3-1	495.00	492.67	650.67	318.54	723.75	370.21	508.47	-9.56
EW003(1) x EW019-4-2-1	441.00	366.00	694.00	290.42	849.59	619.90	543.48	-3.33
Walin	510.33	687.33	681.33	387.71	713.13	393.33	562.20	0.00
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	
Alue	**	**	**	ns	**	**	**	
LSD	119.38	83.52	125.41	115.71	154.73	77.94	96.75	

Key: ** and ns= significant at 0.01probability level and non-significant, respectively

Additive Main Effects and Multiple Interaction (AMMI) model

The AMMI analysis of variance for seed yield of 16 sesame genotypes at six environments showed highly significance difference among genotypes, genotypes by environment and both IPCA (Table 3). From the total variation, 73.09%, 19.01%, 18.93% were explained by environments, genotypes and GEI for seed yield. The large SS and highly significant MS of environment indicated that the environments were diverse, with large differences among environmental means causing most of the variation in grain yield is due to environmental effect. The result is agreed with the previous findingsKindeya*et al., 2020,* Mohammed, *et al.* 2015 and Mekonnen, *et al.*, 2015 in sesame genotypes. The mean square of the first two IPCAs were significant and both together contributed 67.76% of total ss of GEI. The IPCA1 and IPCA2 accounted for 39.81 and 27.95%, respectively for observed variation due to GEI. According to Zobel *et al.*, 1988 finding, AMMI with only the two interaction principal component axes was the best predicative model for seed yield in sesame genotypes.

Table-3. AMMI's analysis of variance for seed yield of sesame genotypes over six environments

Source	**df**	**SS**	**MS**	**V explained (%)**	**G*E explained (%)**	**Cumulative (%)**
Total	287	9659920	33658			
Treatments	95	8696622	91543**	19.01		
Genotypes	15	1367490	91166**	18.93		

Environments	5	2934027	586805**	73.09		
Block	12	96345	8029^{ns}	1.67		
Interactions	75	4395105	58601**	12.17		
IPCA 1	19	1749775	92093**	19.12	39.81	39.81
IPCA 2	17	1228521	72266**	15.00	27.95	67.76
Residuals	39	1416810	36328**	7.54		
Error	180	866953	4816			

Key: ** and ns= significant at 0.01 probability level and non-significant, respectively,df = degree freedom, SS = sum square, MS = mean square

AMMI1bi-plot showing genotype means seed yield against with average seed yield. Genotypes found in quadrant I and IV recorded seed yield above grand mean in the favorable environments, while genotypes found in the quadrant II and III were below the grand mean and low yield in the unfavorable environments. G15, G10, G16, G3, G7, G5, G12 and G13 recorded seed yield above grand mean in the favorable environments, while eight genotypes G1, G8, G11, G2, G14, G6, G9 and G11 were below the grand mean and low yield in the unfavorable environments (Figure 1). Stable genotypes were adaptive to wider areas and give consistency mean yield across the test locations. G13, G7, G3 and G15 were found nearly closer to the origin and the most stable with little responsive to the GEI. Genotypes far from the origin are sensitive to environmental changes. Hence, G1, G10, G12 and G9 were the unstable. Therefore, genotypes with high yield and wider stability performance are the most desirable for wider area. Similar result was reported by Kindeya*et al.*, 2020.

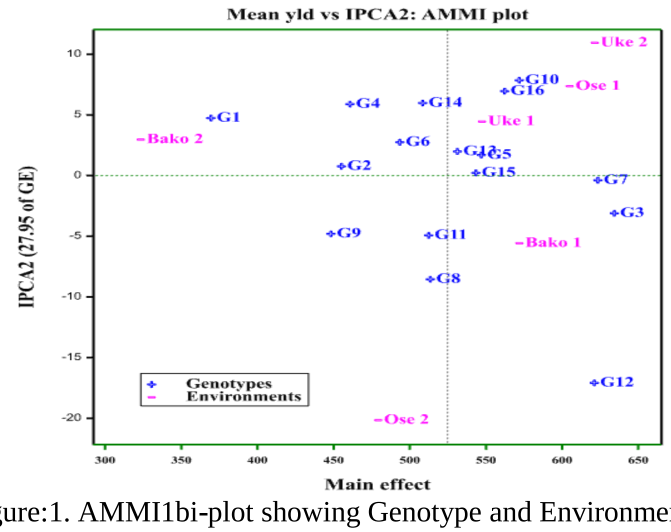

Figure:1. AMMI1bi-plot showing Genotype and Environment means seed yield against IPCA2

Evaluation of genotypes based on GGE-bi-plot model

Genotypes closer to the ideal genotype were the stable ones, while genotypes far from the ideal genotypes were unstable. From this point; G3 is considered as ideal genotype as well as the highest mean seed yield and the most stable across tested environments and used as bench mark to classify the others. G7, G11 and G12 were plotted to the ideal genotype considered as desirable genotypes, while G1, G2 and G4 were far from the ideal genotypes considered as most unstable genotypes with poor performance across locations (figure 2)

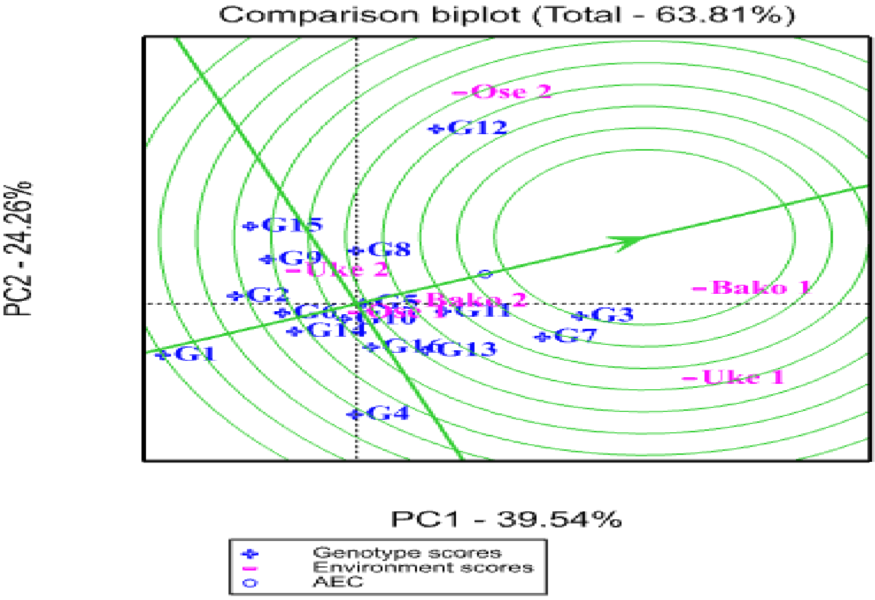

Figure-2. GGE-bi-plot showing the "ideal" genotype

Summary and Conclusion

The study was conducted to analysis the effects of genotype, environments and G x E interaction on seed yield of sesame genotypes at six environments. Pooled analysis of variance revealed highly significant G x E interaction indicated that variation were significant among tested environments. AMMI analysis of variance was computed and a significant effect were observed from genotypes, environment, G x E interaction, IPCA1 and IPCA2. Environment explained 73.09% of the total variation, whereas G and G x E interaction explained 18.93% and 12.17% of the total variation, respectively. Mean G x E interaction of 39.54% is explained by IPCA1 and 24.26% is explained by IPCA2. Based on analysis result, G3, G7 and G12 gave high seed yield, better adaptability and more stable performance than all tested sesame genotypes and check. Accordingly, G3, G7 and G12 were proposed as candidate varieties for verification for possible release at tested environments.

Acknowledgements

The authors acknowledge the Oromia Agricultural Research Institute for financing the research and Bako Agricultural Research Center for facilitation of fund as well as the team members of Pulse and Oil Crop Research of Bako Agricultural Research Center for their technical support on the field work.

References

Bedigian, D., 2003. Sesame in Africa: origin and dispersals. Food, Fuel and Fields-Progress in African Archaeobotany, Africa Prae-Historica, pp.17-36.

Daniel E.G., and Parzies, H.K., 2011. Genetic variability among landraces of sesame in Ethiopia. *African Crop Science Journal,***19(1)**:1-13

Falconer, D.S. and Mackay, T.F.C., 1996. Introduction to quantitative genetics. Essex. UK: Longman Group.

FAO.2017. Food and Agriculture of the United Nations. (http://faostat.fao.org) (Accessed on March 22, 2019)

Farshadfar, E. and Sutka, J., 2006. Biplot analysis of genotype-environment interaction in durum wheat using the AMMI model. Acta AgronomicaHungarica, 54(4), pp.459-467.

Fiseha, B., Yemane, T., and Fetien, A., 2015. "AMMI analysis of Genotype x Environment interaction and stability analysis of sesame genotypes in northern Ethiopia." Asian Journal of Plant Science, vol. 13, pp. 178-183.

Fuller, D.Q., 2003.Further evidence on the prehistory of sesame. *Asian Agri-History*, **7(2)**:127-137

IPGRI, N., 2004. Descriptors for sesame (*Sesamum spp*.). International Plant Genetic Resources Institute, Rome, Italy, National Bureau of Plant Genetic Resources, New Delhi, India

Jaemin Kim, 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.

Kindeya, Y.B., Mekbib, F. and Alle, E.A., 2020. AMMI and GGE Bi-plot Analysis for Seed Yield and Oil Content of Sesame (Sesamum indicum L.) Genotypes in Tigray, Northern Ethiopia. *Journal of Agriculture and Crops*, *6*(4), pp.58-67.

Malosetti, M., J.M. Ribaut, F.A. van Eeuwijk., 2013. The statistical analysis of multi environment data: Modeling genotype-by-environment interaction and its genetic basis. Front. Phys. 4:44. doi:10.3389/fphys.2013.00044. Miller, W., S.C. Schuster, A.J. Welch, A. Ratan.

Mekonnen, M., Firew, M., and Adugna, W., 2015. "Gei interaction of sesame (*sesamum indicum* L.) in eastern amhara region." Ethiopia. African Journal of Agricultural Research, vol. 10, pp. 2226-2239.

Mohammed, A., 2015. "Genotype x environment analysis for seed yield and its components in sesame (*sesamum indicum L.)* Evaluated across diverse agro-ecologies of the awash valleys in Ethiopia." Journal of Advanced Studies in Agricultural, Biological and Environmental Sciences, vol. 4, pp. 1-14.

Mohammed, A., Firew, M., Amsalu, A., and Mandefro, N., 2015. "Genotype x nenvironment and stability analysis of oil content in sesame (sesamum indicum l.) evaluated across diverse agro-ecologies of the awash valleys in Ethiopia." American Journal of Experimental Agriculture, vol. 9, pp. 1-12.

Nayar, N. M., &Mehra, K. L., 1970. Sesame: its uses, botany, cytogenetics, and origin. *Economic Botany*, **24(1)**:20-31

Zobel, R. W., Wright, M. J., and G., G. H., 1988. "Statistical analysis of a yield trial." Agronomy Journal, vol. 80, pp. 388-39.

Performance evaluation of improved Mung bean (*Vigna radiata* (L.) Wilczek) varieties at low moisture areas of East Shewa, Ethiopia

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Abstract
Mung bean is a useful crop in drier areas and has a good potential for crop rotation and relay cropping with cereals using residual moisture. The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC), Lume and Dugda Districts during 2018 and 2019 main cropping seasons with the objective to identify adaptable and high yielder mung bean variety/ies for East Shewa Zone and similar agro ecologies. Four released mung bean varieties namely Shewarobit, Beroda, N-26 and Arkebe were used as a planting material. The experiment was laid down in Randomized Complete Block Design (RCBD) with three replications. The plot size was 1.8m × 2.5 m (4.5 m^2) having 6 rows and a spacing of 0.30 m between rows and 0.50 m between replications, 1 m between blocks. Data of plant height (cm), number of pods per plant, number of seeds per pod, days to days to flowering, days to maturity, grain yield (kg ha^{-1}), 100 seed weight (g) were collected and analyzed using SAS software. The combined analysis of variance showed that there was significant variation at ($P \leq 0.05$ and $P \leq 0.01$) among the studied varieties, locations, and year main effect. There were also significant interaction effect on location by year, varieties by year and location by varieties by year for grain yield and other yield components. But non-significant on varieties by location for all traits except plant height and indicated those varieties were performed similarly across the locations. Shewarobit variety had higher grain yield (1607.4 kg ha^{-1}) followed by N-26 (1542 kg ha^{-1}) and Beroda (1466.1 kg ha^{-1}). While Arkebe variety had lower grain yield (893.4 kg ha^{-1}) as compared with others varieties. Therefore, Shewarobit and N-26 were recommended for the study area and similar agro-ecologies.
Keywords:Grain yield, Mungbean, Varieties

Introduction

Mung bean is described as the binomial name Vigna which belongs to the angiosperm dicot crops with family Fabaceae. Mung bean, *Vigna radiata*(L.Wilczek) also called Greengram an annual food legume belonging to the subgenus *Ceratotropis*in the genus *Vigna*(Joodet *al*., 1989). Ketinge, *et al.* (2011) stated that mung bean is an essential short duration, self-pollinated diploid legume crop with high nutritive significances and nitrogen fixing capacity. It is an eco-friendly food grain leguminous crop of dry land agriculture with wealthy basis of proteins, vitamins, and minerals. It is a quick crop, requiring 75–90 days to mature. It is a useful crop in drier areas and has a good potential for crop rotation and relay cropping with cereals using residual moisture (Asrate*et al*, 2012).

It has been reported by different scholars as mung bean contains nutrition value. Mung bean can provide significant amounts of protein (240 g kg^{-1}), carbohydrate (630 g kg^{-1}) range of micronutrients in diets EPP (2004). Mung bean protein and carbohydrates are easily digested and create less flatulence than those derived from other legumes. Parts of mung bean like pods and sprouts are eaten as ice of vitamins and minerals is a common ingredient in Chinese and Indian cuisines Polhill and vanderMaesen(1985).

Mung bean is the sixth product that Ethiopian Commodity Exchange trading next to coffee, sesame, white pea beans, maize and wheat. It mostly produced in Amhara regional state particularly in areas of North Shewa and South Wollo as well as in woreda’s of Benishangul Gumuz regional state. Its demand in the international market is increasing from time to time and there is a need supply to address the demand.

In Ethiopia mung bean export has grown slightly from time to time Ethiopian commodity exchange (ECX) (2014). But supply is limited in Ethiopia since the production of mung bean is very low due to different factor. Availability and distribution of the varieties is one of factor which affects production of mung bean in Ethiopia particularly in East Shewa Zone. Therefore there is a need to adapt and popularize the released varieties in the area. Therefore, this project is initiated with the objective to identify adaptable and high yielder mung bean variety/ies for East Shewa Zone and similar agro ecologies.

Material and Methods

Study area

The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC), Lume and Dugda districts during 2018 and 2019. ATARC is located in the mid Rift Valley of Ethiopia about 167km south from Addis Ababa. It lies at a latitude of 7° 9’N and longitude of 38° 7’E. It has an altitude of 1650 m.a.s.l. and it receives a bimodal unevenly distributed average annual rainfall of 760.9 mm per annum. The long-term mean minimum and the mean maximum temperature are 12.6 and 27 ^{0}C, respectively. The pH of the soil is 7.88. The soil is fine sandy loam in texture with sand, clay and silt in proportion of 34, 48 and 18% respectively (ATARC, 1998).

Experimental design and management

Released mung bean varieties Shewarobit, Beroda, N-26 and Arkebe were collected from Hawasa Agricultural Research and evaluated in Randomized Complete Block Design with three replications. The plot size was 1.8m × 2.5 m (4.5 m^2) having 6 rows and spacing of 0.30 m between rows and 0.50m between replication, 1 m between blocks. 100 kg ha^{-1} of NPS and 50 kg ha^{-1} urea was set aside homogeneous for all treatments. All agronomic recommendations were followed for managing the production of the crop. All necessary biological and agronomic data were recorded and analyzed.

Data collection and statistical analysis

During the experiment data on individual plant basis plant height (cm), number of pods per plant, number of seeds per pod, and on plot basis days to flowering, days to maturity, grain yield (kg ha^{-1}), 100 seed weight (g) were collected and analyzed. Data on phenological, growth and yield components were subjected to analysis of variance (ANOVA) using SAS software when there were a significant difference among the treatment means the least significant difference (LSD) test was used to compare the mean separations.

Result and discussions

The combined analysis of variance for all varieties at different environmental conditions for grain yield and yield related traits are presented in Table 1. The result revealed that locations showed highly significant (P≤0.01) for grain yield, number of pod per plant, plant height and number of branch. But non-significant for days to flowering, days to maturity, number of pod per cluster, number of seed per pod and hundred seed weight.

Varieties had showed highly significant (P≤0.01) for studied trait except number of seed per pod and significant at (P≤0.05) for number of pod per plant, number of pod per cluster and number of seed per pod Wedajo (2015); Ahmad, *et al.* (2015) and Rasul, *et al.* (2008) stated that mung bean cultivars had significant effect on number of pods plant. Similarly, Mequannit and Terefe (2020) reported that mung bean varieties showed significant effect for grain yield and hundred seed weight. Year had significant influence on the agronomic parameters except days to flowering, number of cluster per plant and plant height.

Varieties across locations showed non-significant variation among studied parameters except plant height. This indicated that varieties were not affected with different locations and revealed that varieties responded similar reactions across locations. Varieties by year interaction effect were significant only for grain yield and hundred seed weight and indicate that season was affecting the response of varieties on grain yield and hundred seed weight. But varieties by year interaction effect were non-significant for other traits. Location x year x varieties was only significant for grain yield but non-significant for other studied parameters. The significance of location over year on varieties indicates that grain yield is affected by locations by year by varieties interaction effect.

Table 1. Combined analysis of mung-bean varieties at ATARC, Dugda and Lume districts tested for two years (2018-2019)

Source of variation	**Df**	Mean Squares									
		GY (kgha^{-1})	DF	DM	NCP	NPC	NPP	NSP	PH (cm)	NB	100SW
Rep	2	472196	6.97ns	38ns	4.305ns	1.43ns	105.7ns	27.05ns	7.73ns	3.122ns	0.03ns
L	2	6704865**	4.76ns	11.51ns	16.13*	2.43ns	374.94**	4.56ns	1381.46**	8.985**	0.05ns
Vr	3	1901761**	18.4**	90.31**	7.5*	9.17*	140.2*	2.09ns	207.78**	0.321ns	7.145**
Yr	1	5688614**	1.12ns	50.0*	58.68**	0.2ns	1071.07**	73.21*	39.43ns	35.14**	6.956**
L*V	6	50915^{ns}	2.28ns	1.38ns	5.9ns	2.4ns	53.4ns	11.53ns	594.46**	1.658ns	0.115ns
L*yr	2	10791786**	0.54ns	12.27ns	3.4ns	3.7ns	57.89ns	53.67*	152.61**	15.12**	0.461*
V*Yr	3	1131331*	1.94ns	1.67ns	3.2ns	2.18ns	31.8ns	22.3ns	37.83ns	1.51ns	0.811*
L*V*Yr	6	1217082*	2.5ns	1.71ns	1.55ns	1.98ns	41.06ns	21.51ns	20.4ns	1.788ns	0.063ns

Key: ns= non-significant, *= significant, **= highly significant, Rep=Replication,

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 , NB= Number of branch per plant, 100SW= Hundred seed weight

Table 2. Combined mean yield and agronomic traits of Mung bean varieties tested at ATARC, Dugda and Lume districts for two years (2018-2019)

Varieties	Combined Means									
	GY (kg ha^{-1})	DF	DM	NCP	NPC	NPP	NSP	PH (cm)	NB	100SW
Sh/Robit	1607.4a	52.78a	91.67a	6.11ab	4.97a	22.79ab	10.94	48.77a	3.53	3.88c
N-26	1542a	50.61b	86.89b	5.81ab	4.2a	20.64b	11.2	47.32a	3.32	5.05a
Beroda	1466.1a	52.67a	91.67a	6.73a	4.92a	26.97a	10.46	46.6a	3.30	3.59d
Arkebe	893.4b	51.67ab	88.61b	5.178b	3.06b	19.3c	10.63	41.10b	3.55	4.16b
LSD	125.38	1.38	2.13	1.21	0.95	4.52	2.589	3.7	0.67ns	0.26
CV	13.4	4	3.6	13.3	12.5	18.2	15.7	12.1	12.8	9.1
SE	335.91	2.06	3.17	1.8	1.41	6.74	3.858	5.55	1.02	0.37

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, LSD= Least significant difference, CV=coefficient of variation, Se=Standard error

Variety Arkebe was early to flower and mature while Shewarobit variety was late to flower and to matur as compared with other varieties. Beroda variety had higher number of clusters per plant (6.73) and number of pods per plant (26.97) followed by Shewarobit (6.11) and (22.79), respectively while Arkebe variety had lower number of clusters per plant (5.17) and number of pod per plant (19.3). Higher plant height (48.77cm) was recorded from Shewarobit variety followed by N-26 (47.32cm) and Beroda (46.6cm). Conversely shorter plant height was recorded from Arkebe (41.10cm) variety. N-26 had higher hundred seed weight (5.05g) followed by Arkebe variety and lower hundred seed weight was recorded from Shewarobit (3.88g) variety.

Grain yield is the result of dry matter production and its transformation in to economic value that takes place in the plant system. There was significant difference on grain yield with the varietal effect on tested mung bean varieties. Shewarobit variety had higher grain yield (1607.4 $kgha^{-1}$) followed by N-26 (1542 $kgha^{-1}$) and Beroda (1466.1 kg/ha). While Arkebe variety had lower grain yield (893.4 $kgha^{-1}$) as compared with other varieties. The variety has lower agronomic performance this might cause of lower yield than other varieties.

Mequannit and Terefe(2020) reported higher grain yield for NUL-1 (2326.8 kg ha^{-1}), Shewarobit (2302.6 $kgha^{-1}$) and N-26 (1946.3 $kgha^{-1}$) of mung bean varieties at Tepi, south western Ethiopia. As opposed to the current finding, Wadajo (2015) reported lower yield performance for Baroda (2.57), N-26 (2.10 $qtha^{-1}$) and Shewarobit (2.07 $qtha^{-1}$) below national average (8.6 qtha^{-1}) for mung bean varieties at Jinka, Ethiopia. Significant effect of mung bean genotypes on grain yield has been reported by Wedajo (2015); Rasul, et al. (2012) and Omid (2008).

Summary and Conclusion

Mung bean is the sixth product that Ethiopian Commodity Exchange trading next to coffee, sesame, white pea beans, maize and wheat. Mung bean is a useful crop in drier areas and has a good potential for crop rotation and relay cropping with cereals using residual moisture. The combined analysis of variance showed that there was significant variation at ($P \leq 0.05$ and $P \leq 0.01$) among the studied varieties, locations, and year main effect.

There were also significant interaction effect on location by year, varieties by year and location by varieties by year for grain yield and other yield components. The analysis of variance revealed that there is significant variation among observed agronomic traits except for number of seed per pod of tested Mung bean varieties. Shewarobit variety had higher grain yield (1607.4 kgha^{-1}) followed by N-26 (1542 kgha^{-1}) and Beroda (1466.1 kgha^{-1}). While Arkebe variety had lower grain yield (893.4 kgha^{-1}) as compared with other varieties. Therefore, Shewarobit, N-26 and Beroda were recommended for the study area and similar agro-ecologies.

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.

Reference

Ahmad, A. A. Khan, S. Ali, I. M. Imran, and M. Habibullah, 2015. Impact of phosphorus levels on yield and yield attributes of Mung bean cultivars under Peshawar valley conditions, Journal of Environment and Earth Science, vol. 5, pp. 18-25.

Asrate, A., Gurum, F., Alemayehu, F. and Rezene, Y. 2012. Analysis of Multi-environment Grain YieldTrials in Mung Bean *Vigna radiate* (L.) Wilczek Based on GGE Bipot in Southern Ethiopia. J. Agric. Sci. Tech.14: 389-398

ATARC (Adami Tulu Agricultural Research Center). 1998. ATARC profile. Oromia Agricultural Research Institute, Addis Ababa, Ethiopia.

ECX (Ethiopian Commodity Exchange), 2014. Ethiopian commodity exchange rings bell for Mung Bean, January 23, 2014 Addis Ababa, Ethiopia.

EPP (Ethiopian Pulses Profile), 2004. Ethiopian export promotion agency, product development & market research directorate, May 2004 Addis Ababa, Ethiopia,

Ethiopia Research Journal of Agriculture and Environmental Management, vol. 4, pp. 339-342.

Ketinge, W. Easdown, A. Yang, R. Chadha, and M. S. Shanmugasundaram, 2011. Overcoming chronic malnutrition in a future warming world: The key importance of mung bean and vegetable soybean, Euphytica, vol. 180, pp. 129-141.

Lambrides C and I. D. Godwin, Mung bean. In: Kole C, editor, 2007. Genome Mapping and Molecular Breeding in Plants, Pulses, Sugar and Tuber Crops vol. 3: Verlag.

Mequannit A. and Tefera A., 2020. Adaptation study of mung bean (*Vigna radiata*) varieties in tepi, south westerEthiopia. Asian Journal of Plant Science and Research, 2020, 10(5):58-61.
Omid, 2008. Effect of withholding irrigation at different growth stages on yield and yield components of mung bean *Vigna radiate* L. Wilczek) varieties.
Polhill and L. J. G. vanderMaesen, 1985. Taxonomy of grain legumes, Journal of Biological Sciences, vol. 1, pp. 21-27.
Rasul, M. A. Cheema, A. Sattar, M. F. Saleem, and M. A. Wahid, 2012. Evaluating the performance of three Mung bean varieties grown under varying inter-row spacing, Journal of Animal & Plant Sciences, vol. 22, pp. 1030-1035.
Uddin, A. K. M. R. Amin, M. J. Ullah, and M. Asaduzzman, 2009. Interaction effect of variety and different fertilizers on the growth and yield of summer Mung bean, American-Eurasian Journal of Agronomy, vol. 2, pp. 180-184.
Wedajo G, 2015. Adaptation study of improved mung bean (*Vigna radiate*) varieties at Alduba, South Omo,

Participatory Selection of Potato (Solanum tuberosum L.) Varieties in the midland areas of Guji zone, Southern Ethiopia

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Abstract
Irish Potato (*Solanum tuberosum* L.) is one of the most important food security and cash crop produced at different agro-ecologies of Guji Zone, Southern Ethiopia. However, in the midland areas of Guji zone an access of improved potato variety is highly limited. Due to this reason and other bottle neck factors, the potential of the area to potato is not exploited. So, there is an urgent need to develop and promote technologies that suit for the area. As a result, an experiment was conducted in the midland areas of Guji Zone (Dibayu, Kiltusorsa, Gobicha and Dole) at four farmers' fields during 2019/20 cropping season to evaluate potato varieties with active participation of farmers and to identify and select adaptable, high yielding, and late blight tolerant potato variety (ies) for midland areas of Guji zone. Seven improved potato varieties Gudanie, Chiro, Zemen, Bubu, Chala, Bedasa, and Gebisa were used in the experiment. The treatments were arranged in randomized completed block design (RCBD) with three replications for mother trial and farmers were used as replication for baby trials. Both agronomic and farmers data were collected based on the recommended standards. Data collected from mother trail were subjected to analysis of variance whereas matrix ranking was used for data collected from baby trial. The analysis of variance indicated that significant differences observed at ($P \leq 0.05$) among the tested Irish potato varieties for stem number per hill, tuber number per hill, marketable and total tuber yield. However, non-significant difference was observed at ($P > 0.05$) among the varieties for days to 50% emergence and flowering, days to 90% maturity, plant height, tuber weight and

unmarketable tuber yield. The highest marketable tuber yield was (41.32t ha^{-1}) was recorded for Zemen followed by Gudanie and Bubu (36.81 and 36.78 t ha^{-1}), respectively. But, the lowest marketable tuber yield 21.85 t ha^{-1} was obtained from improved Gebisa variety. In other cases, farmers were allowed to evaluate the varieties using their own criteria. Accordingly, variety Zemen, Bubu and Gudanie were selected by farmers due to their best performance, high yielder, resistance to disease, number of tubers and marketability. Therefore, these three improved irish potato varieties are selected based on agronomic data result and farmers preference and recommended for production to the midland areas of Guji zone.
Key words*:* Irish Potato, participatory variety selection, improved variety

Introduction

Potato (*Solanum tuberosum* L.) belonging to the family *Solanaceae,* is an important food and cash crop as an income source globally (Fekadu *et al.,* 2013*).* It is an important tuber crop grown widely in humid tropics and used as source of carbohydrates for many people in tropical and sub-tropical areas of the world (Crissman*et al*., 1993). Potatoes are among the most widely-grown crop plants in the world, giving good yield under various soil and weather conditions (Lisinska and Leszcynski, 1989). It is the third most important food security crop in the world after rice and maize (Haverkort*et al*., 2009).

The potential for high yield, early maturity, and excellent food value give the potato great potential for improving food security, increasing household income, and reducing poverty (Devauxe*et al*., 2014). Yields are typically three to five times higher in developed nations (Struik and Wiersema, 1999). Many factors contribute to the low yield, including drought (FAO, 2010), frost, hail, pests, diseases (Bekele and Eshetu, 2008), poor production practices and limited access to high quality seed (Hirpa*et al*., 2010).

So far, different potato varieties have been released and /or registered to satisfy the growing production demands of the farmers in the country. The crop particularly has potential for fertile and waste land where other crops could not survive, to help overcome food shortage (Gebremedhin *et al*., 2013). In Ethiopia, potato production could fill the gap in food supply during the hunger months of July to August before the grain crops are being harvested.

Therefore, assessment of genotype × environment (including end use) interactions answers the adaptation to the environment and end users because, it is unlikely that one of many potential new cultivars would be best in all environments and for all uses Bradshaw *et al*. (2007). Although (Allard, 1960) described the biological complexity underlying genotype and environment. The entire variable encountered in producing a crop can be collectively called an environment, while every factor that is a part of the environment, has the potential to cause differential performance that is associated with genotype, genotype to environment interaction in potatoes (Bradshaw *et al*., 2007).

The low productivity is attributed due to lack of well adapted varieties which is accepted by the farmers, unavailability and high cost of seed tubers, diseases and insect (Bereke, 199;Gebremedhin *et al*.,2008 and Adane*et al*.,2010).This implies that the country has suitable environmental condition; the average national yield (13.92tha^{-1}) productivity of potato during 2017/18 season (CSA, 2018) is very low as compared with world average of 20 tha^{-1}(FAO, 2019). The reason is primarily due to lack of adaptable varieties for marginal ecology and use of lowquality seed tubers for planting (Gildemacher*et al*., 2009). There are also many factors that can contribute directly or indirectly for low yield in Ethiopia, lack of improved technology, low attention to the crop, varieties that were released by different research centers for different agro-ecologies in the country and farmer's potato varieties in the country level is still unidentified.

In midland areas of Guji zone, an access of improved potato variety is highly limited to the available cultivars. In addition, potato yields varied depending on season, weather conditions, cultivar, and location in the study area. Farmers as well as Seed Producer Cooperative are highly demanding better yielding and late blight resistance varieties to maximize their product and improve the livelihood of their families. Participatory varietal selection has been proposed as an option to the problem of fitting the crop to a multitude of both target environments and users 'preferences (Ceccarelli*et al.*, 1996). Identifying farmers' needs; searching for suitable material to test with farmers; and experimentation on farmers' fields (Meaza, 2015). In midland areas of Guji zone, there are no varieties under production still know.Adaptability of crops can vary from location to location depending on the agro-ecology of a particular area. Hence, it is essential to conduct location specific adaptation trial to identify suitable potato variety/varieties (Addis *et al*., 2017). Therefore, to evaluate different varieties of potato crop with active involvement of farmers' is important to increase the production and productivity of potato in study area. This research was conducted with the following objectives:

To evaluate potato varieties with active participation of farmers and

To identify and select adaptable, high yielding, and late blight tolerant potato variety (ies) for midland agro-ecologies of Guji zone.

Materials and Methods

Description of the Experimental Site

The experiment was conducted in the midland areas of Guji Zone (Dibayu, Kiltusorsa, Gobicha and Dole) at four farmers' field during 2019/20 cropping season to select and to evaluate potato varieties with active participation of farmers and to identify and select adaptable, high yielding, and late blight tolerant potato variety/ies for midland agro-ecologies of Guji zone Adola district is located at about 470 to the south from Addis Abeba. Adola district is characterized by three agro-climatic zones, namely highland), midland) and lowland with different coverage. The mean annual rainfall and temperature of the district is about 900mm and 12-34 ^{0}c, respectively. Based on this condition two time cropping season was commonly practiced i.e main cropping season which start from March to April especially for maize, haricot bean, sweet potato and irish potato. The second cropping season isshort cropping season which was practiced as double cropping using small size cereal crops like tef, potato and barley after harvesting the main cropping season crops. This study was also conducted during short cropping season in midland areas of Guji zone.

Treatments and experimental design

About seven improved irish potato varieties (Gudanie, Chiro, Zemen, Bubu, Chala, Bedasa and Gebisa) were used as testing crop. The varieties were brought from Holeta Agricultural Research Center and Haramaya University. The treatments were arranged in randomized completed block design with three replications for mother trial (planted at Dibayu on-farmer field) and three farmers were used as replication for baby trials. For this purpose, one farmer field was used as replication for baby trials in which selected farmer's 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, 3 m length and 2.4 m width =7.2 m^2 having 4 rows with 75 and 30 cm between rows and plants, respectively. In puts (seeds, 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 its component were collected following their own principles and at vegetative and harvest stage of potato the training were given for the farmers, experts, and developmental agents.

Table 1. Description of experimental materials improved potato varieties for midland agro-ecologies of Guji zone

No.	Variety	Breeder	Released year	Recommended Altitude (masl)
1.	Gudanie	Holeta Research Centre	2006	1600-2800
2.	Bubu	Haramaya University	2011	1700-2000
3.	Bedasa	Haramaya University	2001	1700-2000
4.	Chala	Haramaya University	2004	1700-2000
5.	Zemen	Haramaya University	2001	1700-2000
6.	Gabbisa	Haramaya University	2005	1700-2000
7.	Chiro	Haramaya University	1998	1700-2000

Source: MoANR (2017),Holetta Agricultural Research Centre, and Haramaya University

Field management

The experimental field was cultivated by using oxen to fine the soil before planting. Uniform and medium-sized (39-75g) tubers of the test variety with sprout lengths of 1.5 to 2.5 cm (Lung'aho*et al*., 2007) was planted on ridges with inter-and intra-row spacing of 75 cm and 30 cm, respectively. The recommend blended NPS and potassium fertilizer rates were applied at planting at the specified rates and placed in banded application methodsand urea rates were split applied at planting the rate of (1/4 kg N ha^{-1})and half (1/2 kg Nha^{-1}) at 15 days after emergence and one forth (1/4kg Nha^{-1}) at mid-stage (at about and 30days) after emergence, respectively. On the other hand, weed control were 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

Agronomic data were collected from a net plot of two rows and selected plants of the plots. Collected agronomic data includes;Days to 50% emergence, Days to 90% maturity, stem number per hill, Plant height (cm), tuber number per hill, Marketable, Unmarketable and Total tuber yield were based on the recommended recording stage and methods

Farmers data collection

Farmers' evaluation and selectioncriteria data were collected on plot basis from the three baby trials i.e., farmers were grouped around each host farmer of the trials. Farmer's evaluation criteria were employed viz. Resistant to disease, Stem number, Tuber size, Tuber color, Tuber number per hill, Tuber eye depth, Marketability, and high yielder. A rating scale of 1-5 was used for farmer's criteria. Rating of the performance of variety for a given criteria: 5= very good, 4= good, 3= average, 2= poor and 1= very poor.

Data analysis

Field data were analyzed by using Genstat 18th edition software for the data following the standard procedures outlined by Gomez and Gomez (1984). Comparisons among the treatment means were done using Fisher's protected least significant difference (LSD) test at 5% level of significant. Farmers preference, perception, feedback/ data collected from baby trials, matrix ranking suggested by De Boef*et al*. (2007).

Results and discussion

The analysis of variance (ANOVA) for tuber yield and other agronomic characters of seven Irish potato varieties planted at Dibayu on-farm as mother trial is presented in (Table 2). The analysis of variance (ANOVA) indicated presence of significant differences at (P≤0.05 among the evaluated Irish potato varieties for stem number per hill, tuber number per hill, marketable and total tuber yield. However, non-significant difference was observed among the varieties for days to 50% emergence and flowering, days to 90% maturity, plant height, tuber weight and unmarketable tuber yield.

Table 2. Analysis of Variance for different agronomic parameters of different midland areas of potato Varieties from mother trial

Source of variation	Mean square of potato variables									
	DE(days)	DF(days)	DM(days)	STN(no.)	PH(cm)	TN(no.)	Twt (g)	Myld (tha^{-1})	Umyld(tha^{-1})	Tyld(tha^{-1})
Rep(2)	12.19ns	28.05ns	15.48ns	2.72**	64.9ns	7.69**	98.7ns	11.67*	0.58ns	7.88*
Varieties(5)	4.83ns	13ns	24.19ns	6.4**	93.8ns	18.13**	239.6ns	162.89*	1.01ns	152.67*
Error(10)	5.47	9.88	14.48	0.52	263.6	3.43	139.4	53.26	1.43	44.81

** = highly significant at P ≤ 0.001; *= significant at P ≤ 0.05; ns = not significant at P≥0.05; a Numbers in parentheses are degrees of freedom associated with the corresponding source of variation; DE: Days to Emergence, DF: Days to Flowering, DM: Days to maturity, SN: Stem Number per hill, PH: plant height, TN: Tuber Number per hill, Tw: Tuber Weight, Myld: Marketable yield, Umyld: Unmarketable Yield, Tyld: Total yield

Phenology and growth

The mean values for the seven varieties are shown (Table 3). The variation with respect to days to flowering and days to maturity was ranged from 40 to 45.33 and 75.67 to 84 days, respectively. Based on the study result, the longest days to flowering was revealed by Zemen and Bedasa (45.33days) followed by Gudanie (43 days). However, early flowering was recorded for varieties Chiro (40 days) followed by Bubu (41 days). In other cases, variety Chiro was early maturing variety (75.67days) followed by Gebisa (76.33days). Among the tested varieties, Zemen was late maturing with 84 days followed by Bedasa (79.33 days).

The mean values revealed that the highest stem number per hill was recorded by Gudanie variety (6.2) followed by variety Zemen (5.79) respectively. However, the lowest stem number per hill Chala variety (2.58) followed Chiro variety (3.37) respectively. This result is in line with Morena *et al*. (1994) who reported that the difference in number of number main stem among the varieties might be due to the inherent genotypic variation in the number of buds per tuber which is in turn influenced by the size of the tubers, physiological age of the seed, storage condition, and number of viable sprouts at planting, sprout damage at the time of planting and growing conditions. This result is consistent also with that of Zelalem *et al*., 2009) who reported that stem density, which is influenced by genetic makeup, increase tuber yield as stem density increases numbers of tubers, or size of tubers, or both. The longest plant height was exhibited by Gudanie variety (130.3cm) followed by Zemen variety (123.6cm). However, the shortest plant height was revealed by Chiro variety (114.4cm) followed by Bubu, Chala and Gebisa varieties (116.7), respectively (Table 3). 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).

Table 3. Mean Value of DE, DF, DM, PH and STN of potato PVS from mother trial in midland areas of Guji zone, during 2019

Varieties	Phenology and growth variables				
	DE(days)	DF(days)	DM(days)	STN(no.)	PH(cm)
Zemen	15	45.33	84a	5.79a	123.6
Bubu	15	41	77.33ab	5.06a	116.7
Gudanie	15	43	77ab	6.2a	130.3
Bedasa	15.33	45.33	79.33ab	2.86b	120.3
Chala	17.33	42.67	77ab	2.58b	116.7
Chiro	18	40	75.67b	3.37b	114.4
Gebisa	16.67	41.33	76.33b	5.08a	116.7
Lsd (0.05)	4.16	5.59	6.77	1.28	28.88
Cv%	14.6	7.4	4.9	16.3	13.4
P-Value	0.54	0.32	0.21	0.001	0.89

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Yield and yield components

Based on agronomic data result indicates that the highest tuber number per hill was recorded from Zemen variety (14.5) followed Chala variety (13.94) whereas the lowest tuber number per hill from Gebisa variety (7.91). The highest tuber weight was recorded from Bubu variety (77.72g) followed Zemen variety (74.84g) whereas the lowest tuber weight from Chiro variety (53.10g) and followed Chala variety (57.79g). Variation among different varieties in the weight of tubers per plant may be due to the genetics, management practices, the seed quality, or the agro-ecological conditions of the experimental sites (Eaton *et al*. 2017). Significant variations were revealed among potato varieties number and weight of tubers per plant (Addis *et al*., 2017).

The highest marketable tuber yield was obtained from Zemen (41.31 tha^{-1}) followed by Gudanie (36.81tha^{-1}) and Bubu (36.78 tha^{-1}) respectively whereas the lowest marketable tuber yield Gebisa (21.85tha^{-1}) and Chiro (22.52 tha^{-1}) varieties were recorded respectively. The marketable yield is some very important criteria to select potato clones for high yield (De Haan*et al*., 2014).The highest unmarketable tuber yield was obtained from Badesa variety (4.09 tha^{-1}) followed by Chiro variety (3.56 tha^{-1}) respectively whereas the lowest unmarketable tuber yield Gudanie variety (2.44tha^{-1}) followed by Zemen variety (2.63 tha^{-1}) was recorded respectively.In other cases, the highest total tuber yield were obtained from Zemen variety (43.95 tha^{-1}) followed by Bubu variety (39.64 tha^{-1})whereas the lowest total tuber yield Gebisa variety (24.69tha-1) followed by Chiro variety (26.1 tha-1) was recorded respectively (Table 4). Thus, the yield differences between these varieties may be related to their genetic makeup in the efficient utilization of inputs like nutrient as reported by (Tisdale et al., 1995). Similar tuber yield variation results were reported on potato by Seifu and Betewulign(2017). Significant variations were revealed among potato varieties for no marketable and marketable tuber yields (Addis et al., 2017). Tapiwa (2016) reported a significant difference in the yields due to genetic makeup of potato varieties.

Table 4. Mean Value different traits of potato PVS from mother trial in midland areas of Guji zone, during 2019

Varieties	Yield and yield components variables				
	TN(no.)	Twt (g)	Myld (tha^{-1})	Umyld (tha^{-1})	Tyld (tha^{-1})
Zemen	14.5a	74.84ab	41.32a	2.63a	43.95a
Bubu	11.39ab	77.72a	36.78a	2.86a	39.64a
Gudanie	12.61a	70.46ab	36.81a	2.44a	39.25
Bedasa	12.39ab	64.83ab	31.38ab	4.09a	35.47ab
Chala	13.94a	57.79ab	31.88ab	3.31a	35.19ab
Chiro	8.94bc	53.10b	22.52b	3.56a	26.1bc
Gebisa	7.91c	63.06ab	21.85b	2.84a	24.69c
Lsd (0.05)	3.29	21.01	12.98	2.13	11.91
Cv%	11.94	17.9	23.0	38.6	19.2
P-Value	0.007	0.2	0.047	0.66	0.034

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Farmer's variety selection criteria's

In variety selection farmers have a broad knowledge based on their environments, crops and cropping systems built up over many years and do experiments by their own and generate innovations,even though they lack control treatment for comparison and statistical tools to test the hypothesis. Based on this concept, farmers were informed to set criteria for selecting 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 own value.

Accordingly, resistant to disease, stem number per hill, tuber size, tuber color, tuber number per hill, tuber eye depth, 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 Zemen (1st), Bubu (2nd) and Gudanie (3rd) were showed better performance resistant to disease, highest stem number per hill, marketable tuber size, attractive tuber color, highest tuber number per hill, low tuber eye depth, good for marketability, and highest yielder. However, farmers ranked least Chiro (7th) and Chala (6th) potato varieties (Table 5). 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 (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) who 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) who 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 farmer field school approach.

Table 5. Farmers' preference scores and ranking for baby trial in midland areas of Guji zone, during 2019/20 cropping season

Varieties	Locations	Farmers selection criteria/traits and ranks									Total	Average	Ranks
		Resistant to disease	Stem Number	Maturity	Number of tubers	Tuber size	Tuber color	Tuber eye depth	Marketability	High yielder			
Zemen	Gobicha	24	24	24	40	34	23	20	33	50	831	30.78	1
	Dole	31	32	32	55	55	55	36	38	50			
	Kiltu	26	26	26	20	12	16	13	16	20			
Bubu	Gobicha	40	40	40	40	23	32	32	33	23	663	24.55	2
	Dole	22	27	27	14	21	7	16	15	10			
	Kiltu	16	16	16	13	20	20	50	20	30			
Gudanie	Gobicha	19	19	19	22	16	12	20	24	33	661	24.48	3
	Dole	32	20	20	14	15	24	17	21	25			
	Kiltu	24	24	24	27	40	30	40	40	40			
Bedasa	Gobicha	15	15	15	14	14	9	25	11	4	642	23.77	4
	Dole	21	22	22	25	34	25	48	27	41			
	Kiltu	26	26	26	27	30	50	20	30	20			
Chala	Gobicha	8	8	8	37	50	45	21	50	10	566	20.96	6
	Dole	6	8	8	33	26	37	25	38	28			
	Kiltu	14	18	22	16	10	10	10	10	10			
Chiro	Gobicha	26	26	26	9	5	15	12	10	18	342	12.66	7

	Dole	13	11	11	14	5	14	11	23	29			
	Kiltu	16	16	16	16	0	0	0	0	0			
Gebisa	Gobicha	14	14	14	11	10	8	31	19	7	583	21.59	5
	Dole	44	33	33	21	16	13	14	11	13			
	Kiltu	32	32	30	27	24	22	25	35	30			

Conclusion and Recommendation

In midland areas of Guji zone where improved technologies are not widely addressed, it's vital to catch immediate action towards setting appropriate way of addressing new technologies and methods. In such case, Participatory variety selection is an effective tool in facilitating the adoption, extension and selection of the improved technologies. Furthermore, participatory variety selection is a more rapid and cost-effective way of identifying farmer-preferred cultivars if a suitable choice of cultivars exists. The farmers 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 Irish potato varieties through employing their own selection criteria. The farmers need varieties that show high performance for yield and other essential agronomic traits. Improved potato varieties through employing their own selection criteria in order to verified technologies and solve the potato grower problems in short period of time. Therefore, three improved potato varieties i.e., Zemen, Bubu and Gudanie are selected based on agronomic data results, farmer's preference and recommended for midland areas of Guji zone and similar agro-ecologies.

References

Adane H., Meuwissen, M. P., Tesfaye, A., Lommen, W. J., Lansink, A. O., Tsegaye, A., &Struik, P. C. (2010). Analysis of seed potato systems in Ethiopia. *American journal of potato research*, 87(6), 537-552.

Addis S, Dessalegn R, Wakene, T. 2017. Irish Potato (*Solanum tuberosum* L.) variety evaluation at Bule Hora District of Borena Zone. Global Journal of Science Frontier Research: D Agriculture and Veterinary Volume 17 (2)

Allard, R.W. 1999. Principles of plant breeding. John Wiley and Sons, New York, 485 - 486.

Bekele K, Eshetu B (2008) Potato Disease Management. Root and Tuber Crops the Untapped Resources. In: Gebremedhin W, Endale G, et al. (Eds.), Ethiopian Institte of Agricultural Research, Ethiopia, pp. 79-95.

Bellon, M.R. 1996b. The dynamics of crop intraspecific diversity: a conceptual framework at the farmer level. Economic Botany 50(1): 26–39.

BerekeTsehai T. 1994. The utilization of true potato seed (TPS) as an alternative method of potato production. Ph.D. thesis, Wageningen, The Netherlands.

Bradshaw J,,Gebhardet C., Goves F., Mackerron K.L., Mark A., Taylor M. and Ross, H.2007. Potato biology and bitechnology advances and perspectives.

Bradshaw J., christiane G., Francine G., Donald K., MackerronL,, Mark A.T. and Heather A.R., (2007). Potato biology and biotechnology advances and perspectives.

Chambers, R. 1989. Institutions and practical change: reversals, institutions and change. pp. 181-195. In, R. Chambers, A. Pacey, L. A. Thrupp, eds. Farmer first. London: Intermediate Technology Publications.

Crissman CC, Crissman LM, Carli C (1993). Seed potato systems in Kenya: a case study. Lima: CIP.

CSA (Central Statistical Agency). 2018. Report On Area and Production of Major Crops .Agricultural sample survey Addis Ababa Statistical Bulletin Volume 1 pp: 584, 14-68.

De Haan S, Forbes A, Amoros W, Gastelo M, Salas E, Hualla V, De Mendiburu F, Bonierbale M, 2014. Procedures for standard evaluation and data management of advanced potato clones.Module 2: Healthy tuber yield trials. *International Co-operators Guide*. Lima (Peru). International Potato Center. 44 p.

De la Morena, Guillen IA, Garcia del Morel LF .1994.Yield development in potatoes as influenced by cultivar and the timing and level of nitrogen fertilizer. American Potato Journal 71: 165-173.

Devaux, A., P. Kromann, O. Ortiz. 2014. Potatoes for sustainable global food security. Potato Research.

Eaton TE, Azad AK, Kabir H, Siddiq AB.2017. Evaluation of Six Modern Varieties of Potatoes for Yield, Plant Growth Parameters and Resistance to Insects and Diseases. Agricultural Scien ce;8(11):1315–26.

Eskin, N. A. 1989. Quality and Preservation of Vegetables. pp. 2-11. CRS press, Inc. Bocaraton, Florida.

FAO (Food and Agriculture Organization). 2008 .Potato world. Production consumption. International year of the Potato. USA. Rome, Italy.

FAOSTAT (Food and Agricultural Organization Statistic).2019. World food and agricultural organization data of statistics. FAO, Bulletin, Italy 10: 275.

Fekadu, A., Y. Petros and H. Zelleke, 2013. Genetic variability and association between agronomic characters in some potato (*Solanum tuberosum L*.) genotypes in SNNPRS, Ethiopia. Int. J. Biodiversity. Conserv.

Gebremedhin W., Endale G., Kiflu B. 2013. National potato research program report. Ethiopian Agricultural Research Organization, Holetta Agricultural Research Center.pp.125.

Gildemacher, P., Kaguongo, W., Ortiz, O., Tesfaye, A., Woldegiorgis, G., Wagoire, W., Kakuhenzire, R., Kinyae, P., Nyongesa, M. and Struik, P. 2009. 'Improving Potato Production in Kenya, Uganda and Ethiopia: A System Diagnosis'. *American Potato Journal*. 173-205.

Graham, T., E. Van de Fliert, and D. Campilan. 2001. "What happened to participatory research at the International Potato Center?" Agriculture and Human Values 18:429-446.

Haverkort, A.J., P.C. Struik, R.G.F. Visser, and E. Jacobse. E. 2009. Applied biotechnology to combat late blight in potato caused by *Phytophthora infestans*. Potato Research 52:249-264.

Hirpa, A., M.P.M. Meuwissen, A. Tesfaye, W.J.M. Lommen, A.O.Lansink, A. Tsegaye, and P.C. Struick. 2010. Analysis of seed potato systems in Ethiopia. American Journal of Potato Research 87: 537–552.

Lisinska, G., and W. Leszcynski. 1989. Potato science and technology. Elsevier, London.
Lung'aho, C., Lemaga, B., Nyongesa, M., Gildermacher, P., Kinyale, P., Demo, P., Kabira, J. 2007. Commercial seed potato production in eastern and central Africa. Kenya Agriculture Institute,140p.
Meaza Hafiz. 2015. Participatory Variety Selection And Variability Of Potato (*Solanum tuberosum* L.) Varieties AtJimmaZonne, Southwest Ethiopia, Msc Thesis Work At Jimma University Pp.1-87
MOA (Ministry of Agriculture), 2010. Animal and plant healath regulatory Directorate, Crop Variety Registration,No.13, Addis Abeba Ethiopia.
MoANR (Ministry of Agriculture and Natural Resources).2016. Plant Variety Release, Protection and Seed Quality Control Directorate**.** Crop Variety Register Issue No. 19 pp: 1-318
Nunn, N. and N. Qian. 2011. The potato's contribution to population and urbanization: Evidence from a historical experiment. *Journal of Economics* 126: 593–650.
Ortiz O., G. Frias, R. Ho., H Cisneros, R. Nelson, R. Castillo, R. Orrego, W. Pradel, and J. Alcazar. 2008. Organizational learning through participatory research:CIP and Care in Peru. Agriculture and Human Values 25:419-431.
Seifu F, Betewulign E. 2017.Evaluation of Potato (Solanum tuberosum L.) Varieties for Yield Attributes. *Journal of Biology. Agriculture and Healthcare*;7(21):15–22.
Tapiwa R. Mpemba, 2016. 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).
Tisdale SL, Nelson W, Beaton JD, Havlin JL .1995. Soil fertility and fertilizers. 5th edition. Macmillan, USA.
Wiersema, S.G., and P.C. Struik. 1999. Seed potato technology, 383.Wageningen: Wageningen Pers.
Witcombe, J. R., Joshi, A., Joshi, K. D. and Sthapit, B. R., 2008. Farmer Participatory Crop Improvement. I. Varietal Selection and Breeding Methods and Their Impact on Biodiversity. Experimental Agriculture, 32(04), p.445.
Witcombe, J.R, A. Joshi, K.D. Joshi & B.R. Sthapit. 1996. Farmers participatory crop improvement. I. varietal selection and breeding methods and their impacts on biodiversity. Expl Agric 32:445-460.
Zelalem A, Tekalign T, Nigussie D.2009. 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 3(2):16-24.

Participatory Selection of Potato (*Solanium tuberosum* L.) Varieties in the highland areas of Guji zone, Southern Ethiopia

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Abstract

Potato (Solanum tuberosum L.) is one of the most important food security and cash crop for farmers in highland parts of Ethiopia, particularly in Guji zone where it is grown by farmers and seed producers abundantly. However, in the highland areas of Guji zone an access, well adapted, resistance to late blight and high yielder potato variety is highly limited. Due to this reason, there is an urgent need to develop and replace the previous underproduction varieties that suit for the area. As a result, an experiment was conducted in the highland areas of Guji Zone at Bore on-station and three farmers' fields (Abayi kuture, Raya boda, and Bube korsa) during 2019/20 cropping s eason to select and recommend high yielding, and diseases résistance improved potato varie ties through participatory variety selection. Six (6) improved potato varieties (Gudanie, Bel ete, Jalenie, Dagim, Horro, and Bubu) were used as testing crop. The treatments were arranged in randomized completed block design (RCBD) with three replications for mother trial and farmers were used as replication for baby trials. Both agronomic and farmers data were collected based on the recommended standards. Data collected from mother trial were subjected to analysis of variance whereas matrix ranking was used for data collected from baby trials. The analysis of variance indicated that significant differences observed at ($P\leq 0.05$)among the tested Irish potato varieties for day to 50% emergence and flowering, stem number per hill, tuber number per hill, marketable and total tuber yield. However, non-significant difference was observed at ($P> 0.05$) among the varieties for days to 90% maturity, plant height, tuber weight and unmarketable tuber yield. The highest marketable tuber yield was (48.17tha^{-1}) was recorded for Belete followed by Bubu and Gudanie (35.35 and 34.3tha^{-1}) respectively. But, the lowest marketable tuber yield (18.07tha^{-1}) was obtained from improved Dagim variety. In other cases, farmers were allowed to evaluate the varieties using their own criteria. Accordingly, varieties Bubu and Gudanie were selected by farmers due to their resistant to disease, stem number, tuber size, tuber color, tuber eye depth, number of tubers and marketability. Therefore, these two improved Irish potato varieties are selected based on agronomic data result and farmers preference and recommended for production to the highland areas of Guji zone.

Key words: Irish potato, participatory variety selection, improved variety

Introduction

Potato (*Solanum tuberosum* L.) belonging to the family *Solanaceae*, is an important food and cash crop as an income source globally (Fekadu*et al*., 2013). Potato is native to South America (Eskin, 1989). It is an important tuber crop grown widely in humid tropics and used as source of carbohydrates for many people in tropical and sub-tropical areas of the world (Crissman*et al*., 1993). Potatoes are among the most widely grown crop plants in the world, giving good yield under various soil and weather conditions (Lisinska and Leszcynski, 1989). It is the third most important food security crop in the world after rice and potato (Haverkort*et al*., 2009).

The potential for high yield, early maturity, and excellent food value give the potato great potential for improving food security, increasing household income, and reducing poverty(Devaux*et al*.,2014). Yields are typically three to five times higher in developed nations (Wiersema and Struik, 1999). Many factors contribute to the low yield, including frost, hail, pests, diseases (Bekele and Eshetu, 2008), poor production practices and limited access to high quality seed (Hirpa*et al*., 2010).

So far, different potato varieties have been released and /or registered to satisfy the growing production demands of the farmers in the country. The crop particularly has potential for fertile and waste land where other crops could not survive, to overcome food shortage(Gebremedhin *et al*.,2013). In Ethiopia, potato production could fill the gap in food supply during the hunger months of July to August before the grain crops are being harvested.

Therefore, assessment of genotype × environment (including end use) interactions answers the adaptation to the environment and end users because; it is unlikely that one of many potential new cultivars would be best in all environments and for all uses (Bradshaw *et al*., 2007). Although, Alllard (1999) described the biological complexity underlying genotype and environment. The entire variable encountered in producing a crop can be collectively called an environment, while every factor that is a part of the environment, has the potential to cause differential performance that is associated with genotype, genotype to environment interaction in potatoes (Bradshaw *et al*., 2007)

The low productivity is attributed due to lack of well adapted varieties which is accepted by the farmers, unavailability and high cost of seed tubers, diseases and insect (Bereke, 199;Gebremedhin *et al*.,2008 andAdane*et al*.,2010).This implies that the country has suitable environmental condition; the average national yield (14.176 tha^{-1}) productivity of potato during 2018/19 season(CSA,2019)is very low as compared with world average of 17.16 tha^{-1}(FAO,2014). The reason is primarily due to lack of adaptable varieties for marginal ecology and use of low quality seed tubers for planting(Gildemacher*et al*.,2009). There are also many factors that can contribute directly or indirectly for low yield in Ethiopia, lack of improved technology, low attention to the crop, varieties that were released by different research centers for different agro-ecologies in the country and farmer's potato varieties in the country level is still unidentified. In the highland areas of Guji zone, the production of potato is low because of lack of stable, well-adapted, high yielding, acceptable and disease resistant cultivars and limited access to the available cultivars. In addition, potato yields varied depending on season, weather conditions, cultivar, and location in the study area. Farmers as well as Seed Producer Cooperative are highly demanding better yielding and late blight resistance varieties to maximize their product, and improve the livelihood of their families. Participatory varietal selection has been proposed as an option to the problem of fitting the crop to a multitude of both target environments and users preferences (Ceccarelli*et al*., 1996). Identifying farmers' needs; searching for suitable material to test with farmers; and experimentation on farmers' fields (Meaza, 2015). In highlands of Guji zone, the varieties that currently under production are not as much as high yielder and resistance to late blight. Therefore, to evaluate different varieties of potato crop with active involvement of farmers' is important to increase the production and productivity of potato in study area. This research was conducted with the following objectives:

- ✓ To evaluate potato varieties with active participation of farmers
- ✓ To increase farmers' awareness and their access to improved potato varieties that suit them better than existing ones and,
- ✓ To identify and select adaptable, high yielding, and late blight tolerant potato variety (ies) for highland agro-ecologies of Guji zone.

Materials and Methods

Description of the Experimental Site

The experiment was conducted at four locations (Bore on-station, and three farmers' fields) during 2019/20 cropping season to select and recommend high yielding and diseases tolerant improved Irish potato varieties through participatory variety selection. Bore Agricultural Research Center site is located at the distance of about 8 km north of the town of Bore in SongoBericha '*Kebele'* just on the side of the main road to Addis Ababa via Awassa town. Geographically, the experimental site is situated at the latitude of 06º23'55''N and longitude of 38º35'5''E at an altitude of 2728 m above sea level. The soil is clay in texture and strongly acidic with pH value of 6.02(Wakene*et al*., 2014). The traditional farming system of the area is characterized by cultivation of enset as a major crop, maize, potato, head cabbage, barley, wheat and faba bean. As far as fruit and timber crops are concerned, apple and bamboo are the cash crops. Moreover, cattle are an integral part of the farming system (BOARDO, 2015).

Treatments and Experimental design

About six improved Irish potato varieties (Gudanie, Belete, Jalenie, Dagim, Horro and Bubu) were used as testing crop. The varieties were brought from Holeta, Adet and Bako Agricultural Research Center and Haramaya University. The treatments were arranged in randomized completed block design with three replications for mother trial (Bore on-station) and three farmers' fields were used as replication for baby trials. For this purpose, one farmer field was used as replication for baby trials in which selected farmer's 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, 3 m length and 2.4 m width =7.2 m^2 having 4 rows with 75 and 30 cm between rows and plants. In puts (seeds, 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 own principles. At vegetative and harvest stage of potato the training were arranged.

Table 1. Description of experimental materials improved potato varieties for highland agro-ecologies of Guji zone

No.	Variety	Breeder	Released year	Recommended Altitude (masl)
1.	Gudanie	Holeta research centre	2006	1600-2800
2.	Jalenie	Holeta research centre	2002	1600-2800
3.	Dagim	Adet researchcentre	2013	1600-2800
4.	Horro	Bako research centre	2015	2000-2800
5.	Belete	Holeta research centre	2009	1600-2800
6.	Bubu	Haramaya University	2011	1700-2000

Source:(MOANR,2017)

Field management

The experimental field was cultivated by using oxen to fine the soil before planting. Uniform and medium-sized (39-75g) tubers of the test variety with sprout lengths of 1.5 to 2.5 cm was planted on ridges with inter-and intra-row spacing of 75 cm and 30 cm, respectively. The recommend blended NPS and potassium fertilizer rates were applied at planting in the specified rates and placed in banded application methodsand urea rates were split applied at planting the rate of (1/4 kg N ha^{-1})and half (1/2 kg N ha^{-1}) at 15 days after emergence and one forth (1/4kg Nha^{-1}) at mid-stage (at about and 30days) after emergence, respectively. On the other hand, weed control were done timely by hoeing. The first, second and third earthing-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

Agronomic data were collected from a net plot of two rows and selected plants of the plots. Collected agronomic data includes;days to 50% emergence, days to 90% maturity, stem number per hill, plant height (cm), tuber number per hill, marketable, unmarketable and total tuber yield were based on the recommended recording stage and methods.

Farmers Data Collection

Farmers' evaluation and selectioncriteria data were collected on plot basis from the three baby trials i.e., farmers were grouped around each host farmer of the trials. Farmer's evaluation criteria were employed viz. resistant to disease, stem number, tuber size, tuber color, tuber number per hill, tuber eye depth, marketability, and high yielder. A rating scale of 1-5 was used for farmer's criteria. Rating of the performance of variety for a given criteria: 5= very good, 4= good, 3= average, 2= poor and 1= very poor.

Data Analysis

Field data were analyzed by using Genstat 18th edition software for the data following the standard procedures outlined by (Gomez and Gomez, 1984). Comparisons among the treatment means were done using Fisher's protected least significant difference (LSD) test at 5% level of significant. Farmers' data were subjected to analysis using simple ranking method and then ranked in accordance with the given value (Walter and Marja, 2007).

Results and Discussion

Mean square

The analysis of variance (ANOVA) for tuber yield and other agronomic variables of six Irish potato varieties planted at Bore on-station as mother trial. The analysis of variance (ANOVA) indicated presence of significant differences at ($P \leq 0.05$ among the evaluated Irish potato varieties for days to 50% emergence and flowering, stem number per hill, tuber number per hill, marketable and total tuber yield. However, non-significant difference was observed among the varieties for days to days to 90% maturity, plant height, tuber weight and unmarketable tuber yield (Table 2).

Table 2. Analysis of Variance for different agronomic parameters of different highland areas of potato Varieties from mother trial

Source of variation	Mean square									
	DE (days)	DF (days)	DM (days)	STN (no.)	PH (cm)	TN (no.)	Twt (g)	Myld (tha^{-1})	Umyld ($t\ ha^{-1}$)	Tyld ($t\ ha^{-1}$)
Rep (2)	0.39**	2.39**	0.06^{ns}	3.13**	1.24^{ns}	8.17**	30.9^{ns}	28.44**	0.98^{ns}	29.42**
Varieties (5)	27.42**	106.86**	2.09^{ns}	5.58**	17.28^{ns}	15.3**	1372.4^{ns}	275.63**	12.45^{ns}	334.39**
Error (10)	1.06	2.66	2.06	1.16	17.98	3.13	734.8	22.63	5.09	25.19

*** = highly significant at P ≤ 0.001; *= significant at P ≤ 0.05; ns = not significant at P≥0.05; a Numbers in parentheses are degrees of freedom associated with the corresponding source of variation; DE: Days to Emergence, DF: Days to Flowering, DM: Days to maturity, SN: Stem Number per hill, PH: plant height, TN: Tuber Number per hill, Tw: Tuber Weight, Myld: Marketable yield, Umyld: Unmarketable Yield, Tyld: Total yield*

Phenology and growth

The mean values for the six varieties are shown (Table 3). The variation with respect to days to emergence and flowering was ranged from 19 to 27 and 58 to 73 days, respectively. Based on the study result, the longest days to 50% emergence was revealed by Dagim and Bubu (27 and 26.33 days) followed by Belete (24.33 days) respectively. However, early emergence was recorded for varieties Horro (19 days) followed by Gudanie and Jalenie (22 days). In other cases, variety Horro was early flowering variety (58 days) followed by Belete (64.67 days). Among the tested varieties, Jalenie was late maturing with 107 days followed by Horro, Belete, and Gudanie (106 days) respectively.

The mean values revealed that the highest stem number per hill was recorded by Bubu variety (8.44) followed by variety Belete (6.11) respectively. However, the lowest stem number per hill Jalenie variety (4.44) followed Dagim variety (5.01) respectively. Stem density, which is influenced by genetic makeup, increase 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 Horro variety (66.22cm) followed by Belete variety (63.06cm).However, the shortest plant height was recorded by Dagim variety (59.83cm) followed by Gudanie variety (60.06) respectively (Table 3). 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).

Table 3. Mean Value of potato PVS from mother trial in highland areas of Guji zone, during 2019/20

Varieties	**Phenology and growth variables**				
	DE(days)	DF(days)	DM(days)	STN(no.)	PH(cm)
Belete	24.33b	64.67b	106	6.11b	63.06
Gudanie	22c	71.63a	106	6b	60.06
Bubu	26.33a	73a	104.7	8.44a	60.83
Jalenie	22c	73a	107	4.44b	62.17
Horro	19d	58c	106	5.94b	66.22

Dagim	27a	66b	105	5.01b	59.83
Lsd (0.05)	1.87	2.97	2.61	1.96	7.71
Cv%	4.4	2.4	1.4	17.9	6.8
P-Value	0.001	0.001	0.46	0.017	0.49

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Yield and yield components

Based on agronomic data result indicate that the highest tuber number per hill was recorded from Belete variety (12.33) followed Bubu variety (12.17) whereas the lowest tuber number per hill from Dagim variety (6.94) and followed Gudanie variety (7.89). The highest tuber weight was recorded from Gudanie variety (130.53g) followed Jalenie variety (105.7g) whereas the lowest tuber weight from Dagim variety (76.05g) and followed Horro and Bubu varieties (78.96g) respectively. Variation among different varieties in the weight of tubers per plant may be due to the genetics, management practices, the seed quality, or the agro-ecological conditions of the experimental sites (Eaton *et al.*, 2017). Significant variations were revealed among potato varieties number and weight of tubers per plant (Addis *et al.*, 2017). The highest marketable tuber yield were obtained from Belete variety (48.17tha^{-1}) followed by Bubu variety (35.35tha^{-1}) respectively whereas the lowest marketable tuber yield Dagim variety (18.07 tha^{-1}) followed by Horro variety (32.40 tha^{-1}) was recorded respectively. The highest unmarketable tuber yield were obtained from Gudanie variety (9.53 tha^{-1}) followed by Jalenie variety (8.61 tha^{-1}) whereas the lowest unmarketable tuber yield Dagim variety (4.11 tha^{-1}) followed by Horro variety (5.19 tha^{-1}) was recorded. In other cases, the highest total tuber yield were obtained from Belete variety (54.67tha^{-1}) followed by Gudanie variety (43.84tha^{-1}) whereas the lowest total tuber yield Dagim variety (22.18tha^{-1}) followed by Horro variety (3.76tha^{-1}) was recorded respectively (Table 4). Thus, the yield differences between these varieties may be related to their genetic makeup in the efficient utilization of inputs like nutrient as reported by Tapiwa(2016).Significant variations were revealed among potato varieties for no marketable and marketable tuber yields (Addis *et al.*, 2017). Tapiwa (2016) reported a significant difference in the yields due to genetic makeup of potato varieties.

Table 4. Mean Value of TN, TW, Myld, UMyld and Tyld of potato PVS from mother trial in highland areas of Guji zone, during 2019/20

Varieties	**Yield and yield components**				
	TN(no.)	Twt (g)	Myld (tha^{-1})	Umyld(tha^{-1})	Tyld(tha^{-1})
Belete	12.33a	101.12	48.17a	6.49	54.67a
Gudanie	7.89bc	130.53	34.3b	9.53	43.84b
Bubu	12.17a	78.96	35.35b	7.07	41.76b
Jalenie	8.94abc	105.7	32.52b	8.61	41.13b
Horro	10.78ab	78.96	32.40b	5.19	37.6b
Dagim	6.94c	76.05	18.07c	4.11	22.18c

Lsd (0.05)	3.22	49.31	8.65	4.1	9.13
Cv%	18	28.5	14.2	33	12.5
P-Value	0.016	0.19	0.001	0.12	0.001

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Farmer's variety selection criteria's

In variety selection farmers have a broad knowledge based on their environments, crops and cropping systems built up over many years and do experiments by their own and generate innovations,even though they lack control treatment for comparison and statistical tools to test the hypothesis. Based on this concept, farmers were informed to set criteria for selecting 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 own value.

Accordingly, resistant to disease, stem number per hill, tuber size, tuber color, tuber number per hill, tuber eye depth, 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 Gudanie (1^{st}), Bubu (2^{nd}) and Belete (3^{rd}) were showed better performance resistant to disease, highest stem number per hill, marketable tuber size, attractive tuber color, highest tuber number per hill, low tuber eye depth, good for marketability, and highest yielder. However, farmers ranked least Dagim (6^{th}) and Horro (5^{th}) potato varieties respectively (Table 5). 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 (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*. (2011) who 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) who 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 farmer field school approach.

Table 5. Farmers' preference scores and ranking for baby trial in highland areas of Guji zone, during 2019/20 cropping season.

Varieties	Locations	Farmers selection criteria/traits and ranks									Total	Average	Ranks
		Resistant to disease	Stem Number	Maturity	Number of tubers	Tuber size	Tuber color	Tuber eye depth	Marketability	High yielder			
Gudanie	Bube korsa	25	20	30	18	49	37	49	42	47	1188	44	1
	Raya boda	50	25	32	75	60	57	68	73	65			
	Abayikuture	26	26	26	60	48	48	36	48	48			
Bubu	Bube korsa	32	24	20	18	36	71	59	45	44	928	34.38	2
	Raya boda	22	27	27	52	60	46	15	26	15			
	Abayikuture	16	16	16	28	36	60	60	33	24			
Belete	Bube korsa	15	15	15	30	30	37	43	76	61	868	32.5	3
	Raya boda	21	22	22	60	75	47	15	52	70			
	Abayikuture	26	26	26	12	24	12	12	12	12			
Jalenie	Bube korsa	22	18	9	37	50	27	30	17	47	840	31.11	4
	Raya boda	32	20	20	23	45	59	46	27	45			
	Abayikuture	24	24	24	24	20	36	30	24	60			
Horro	Bube korsa	4	8	8	57	59	39	34	36	51	815	30.19	5
	Raya boda	2	6	4	53	30	57	30	51	30			
	Abayikuture	4	6	2	40	60	0	48	60	36			
Dagim	Bube korsa	2	3	8	17	16	28	20	15	15	288	10.67	6
	Raya boda	2	6	11	0	0	3	54	0	0			
	Abayikuture	4	4	8	12	12	24	24	0	0			

Conclusion and Recommendation

In the highland areas of Guji zone an access, well adapted, resistance to late blight and high yielder potato variety is highly limited.In such case, participatory variety selection is an effective tool in facilitating the adoption, extension and selection of the improved technologies. Furthermore, participatory variety selection is more rapid and cost-effective way of identifying farmer-preferred cultivars if a suitable choice of cultivars exists. The farmers 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 Irish potato varieties through employing their own selection criteria. Improved potato varieties through employing their own selection criteria in order to verified technologies and solve the potato grower problems in short period of time. Therefore, two improved potato varieties Gudanie and Bubu are selected based on agronomic data results, farmer’s preference and recommended for highland areas of Guji zone.

References

Adane H., Meuwissen, M. P., Tesfaye, A., Lommen, W. J., Lansink, A. O., Tsegaye, A., &Struik, P. C. (2010). Analysis of seed potato systems in Ethiopia. *American journal of potato research*, 87(6), 537-552.

Addis S, Dessalegn R, Wakene, T. 2017. Irish Potato (*Solanum tuberosum* L.) variety evaluation at Bule Hora District of Borena Zone. Global Journal of Science Frontier Research: D Agriculture and Veterinary Volume 17 (2)

Allard, R.W. 1999. Principles of plant breeding. John Wiley and Sons, New York, 485 - 486.

Bekele K, Eshetu B (2008) Potato Disease Management. Root and Tuber Crops the Untapped Resources. In: Gebremedhin W, Endale G, et al. (Eds.), Ethiopian Institte of Agricultural Research, Ethiopia, pp. 79-95.

Bellon, M.R. 1996b. The dynamics of crop intraspecific diversity: a conceptual framework at the farmer level. Economic Botany 50(1): 26–39.

BerekeTsehai T. 1994. The utilization of true potato seed (TPS) as an alternative method of potato production. Ph.D. thesis, Wageningen, The Netherlands.

BoARDO (Bore Agriculture and Rural Development Office). 2015. Agriculture Report of Bore District.

Bradshaw J,,Gebhardet C., Goves F., Mackerron K.L., Mark A., Taylor M. and Ross, H.2007. Potato biology and bitechnology advances and perspectives.

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.

Chambers, R. 1989. Institutions and practical change: reversals, institutions and change. pp. 181-195. In, R. Chambers, A. Pacey, L. A. Thrupp, eds. Farmer first. London: Intermediate Technology Publications.

Crissman CC, Crissman LM, Carli C.1993. Seed potato systems in Kenya: a case study. Lima: CIP.

CSA (Central Statistical Agency). 2019. Report On Area and Production of Major Crops .Agricultural sample survey Addis Ababa Statistical Bulletin Volume 1 pp: 584, 14-68.

Devaux, A., P. Kromann, O. Ortiz. 2014. Potatoes for sustainable global food security. Potato Research.

Eaton TE, Azad AK, Kabir H, Siddiq AB.2017. Evaluation of Six Modern Varieties of Potatoes for Yield, Plant Growth Parameters and Resistance to Insects and Diseases. Agricultural Scien ce;8(11):1315–26.

Eskin, N. A. 1989. Quality and Preservation of Vegetables. pp. 2-11. CRS press, Inc. Bocaraton, Florida.

FAO (Food and Agriculture Organization). 2014 .Potato world. Production consumption. International year of the Potato. USA. Rome, Italy.

Fekadu, A., Y. Petros and H. Zelleke, 2013. Genetic variability and association between agronomic characters in some potato (*Solanum tuberosum L.*) genotypes in SNNPRS, Ethiopia. Int. J. Biodiversity. Conserv.

Gebremedhin W., Endale G., Kiflu B. 2013. National potato research program report. Ethiopian Agricultural Research Organization, Holetta Agricultural Research Center.pp.125.

Gildemacher, P., Kaguongo, W., Ortiz, O., Tesfaye, A., Woldegiorgis, G., Wagoire, W., Kakuhenzire, R., Kinyae, P., Nyongesa, M. and Struik, P. 2009. 'Improving Potato Production in Kenya, Uganda and Ethiopia: A System Diagnosis'. *American Potato Journal*. 173-205.

Gomez, K.A. and Gomez, A.A. 1984. Statistical Procedures for Agricultural Research, 2nd edition, John Wiley and Sons, New York, p.680.

Graham, T., E. Van de Fliert, and D. Campilan. 2001. "What happened to participatory research at the International Potato Center?" Agriculture and Human Values 18:429-446.

Haverkort, A.J., P.C. Struik, R.G.F. Visser, and E. Jacobse. E. 2009. Applied biotechnology to combat late blight in potato caused by *Phytophthora infestans*. Potato Research 52:249-264.

Hirpa, A., M.P.M. Meuwissen, A. Tesfaye, W.J.M. Lommen, A.O.Lansink, A. Tsegaye, and P.C. Struick. 2010. Analysis of seed potato systems in Ethiopia. American Journal of Potato Research 87: 537–552.

Lisinska, G., and W. Leszcynski. 1989. Potato science and technology. Elsevier, London.

Lung'aho, C., Lemaga, B., Nyongesa, M., Gildermacher, P., Kinyale, P., Demo, P., Kabira, J. 2007. Commercial seed potato production in eastern and central Africa. Kenya Agriculture Institute,140p.

Meaza Hafiz. 2015. Participatory Variety Selection And Variability Of Potato (*Solanum tuberosum* L.) Varieties AtJimmaZonne, Southwest Ethiopia, Msc Thesis Work At Jimma University Pp.1-87.

MoANR (Ministry of Agriculture and Natural Resources).2016. Plant Variety Release, Protection and Seed Quality Control Directorate**.** Crop Variety Register Issue No. 19 pp: 1-318

Ortiz O., G. Frias, R. Ho., H Cisneros, R. Nelson, R. Castillo, R. Orrego, W. Pradel, and J. Alcazar. 2008. Organizational learning through participatory research:CIP and Care in Peru. Agriculture and Human Values 25:419-431.

Tapiwa R. Mpemba, 2016. 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).

Tisdale SL, Nelson W, Beaton JD, Havlin JL .1995. Soil fertility and fertilizers. 5th edition. Macmillan, USA.

Wakene Tigre, WalelignWorku, Wassie Haile. Effects of Nitrogen and Phosphorus Fertilizer Levels on Growth and Development of Barley (Hordeum vulgare L.) at Bore District, Southern Oromia, Ethiopia. American Journal of Life Sciences. Vol. 2, No. 5, 2014, pp. 260-266.

Walter SDB, Marja HT. 2007.Participatory Tools Working with Crops, Varieties and Seeds. Wageningen University and Research Center

Wiersema, S.G., and P.C. Struik. 1999. Seed potato technology, 383.Wageningen: Wageningen Pers.

Witcombe, J. R., Joshi, A., Joshi, K. D. and Sthapit, B. R., 2008. Farmer Participatory Crop Improvement. I. Varietal Selection and Breeding Methods and Their Impact on Biodiversity. Experimental Agriculture, 32(04), p.445.

Witcombe, J.R, A. Joshi, K.D. Joshi & B.R. Sthapit. 1996. Farmers participatory crop improvement. I. varietal selection and breeding methods and their impacts on biodiversity. Expl Agric 32:445-460.

Zelalem A, Tekalign T, Nigussie D.2009. 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 3(2):16-24.

Adaptability and Evaluation of Improved Orange Fleshed Sweet Potato (*Ipomoea batatas* L.) Varieties in the mid altitude of Guji zone, Southern Ethiopia

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Abstract

Low yields and yield instability due to the use of old land races were limiting sweet potato productionin the zone. The Experiment was conducted at Bore Agricultural Research Center during 2018 and 2019 summer cropping season at Adola sub station and on-farm with the objective of identifying the cultivars, which could have wide or specific adaptations, and to select and recommend adaptable, frost and disease tolerant and high yielding orange type sweet potato cultivars for midlands of Guji Zone. To this effect four (Kaboli, Naspot 12, Naspot 13, Kabode and local) improved orange varieties of sweet potato, *Ipomoea batatas* L., based on their yield and disease resistance performance were tested in RCBD in three replications with the spacing of 100cm*30cm between rows and plants, respectively. A widely cultivated variety (Local) was included ascheck.The combined analysis of variance across locations showed significant variation among genotypes and locations interaction for the number of roots, root weight, marketable yield, unmarketable yield and total storage root yield (t/ha). Based on this, the maximum mean value of root number per plot (21.33, 36.66 and 21.33) was recorded from Naspot-13, Naspot-12 and Naspot-13 variety at Dufa, Boke and Gobicha sites, respectively. However, the minimum (16.00, 19.33 and 16.00) mean value of root number was recorded from local variety across locations. The maximum fresh root weight (670.33g and 444g) was recorded for Kabode and Naspot-13 variety over locations. On the other hand, the lowest fresh root weight (447.33, 437.33g and 296.33g) was recorded by Kaboli variety at all locations. The highest mean value of total root yield (65.09 t ha^{-1} and 59.88 t ha^{-1}) was recorded by Naspot-13 at Dufa and Gobicha locations in 2018 and 2019 cropping seasons. While Naspot-12 gave maximum (55.16 t ha^{-1}) total root yield at Boke location. However,Kaboli gave the least (43.09, 27.19 and 37.69 t ha^{-1}) total root yield over locations and years. Therefore Naspot-13 and Naspot-12 sweet potato varieties were more adaptable, disease tolerant and high yielder recommended to be promoted farmers of the study areas for optimum production.

Key words: Cultivar, Improved variety, Ipomoea batatas, Naspot-12, Naspot-13, Sweet potat

Introduction

Root and tuber crops, including cassava, sweet potato, potato and yam are the most important food crops for direct human consumption in Africa. These four crops are grown in varied agro-ecologies and production systems contributing to more than 240 million tons annually, covering around 23 million hectares. There are many compelling reasons for encouraging these humble root and tuber crops for sustainable food production. Among those sweet potatoes are short cycle crops and thus well suited to the double cropping seasons particularly the rain-fed system. Likewise, this crop is one of the root and tuber crops grown in Ethiopia, and it is the third important root crop next to Enset and Potato (Engida*et al*., 2009).

Sweet potato is a member of convolvulaceae family, genus Ipomia and species batatus (Purselglove, 1972). It is accepted that the cultivated sweet potato has originated in Central America or tropical South America. Globally it is grown in an area of about 9.26 million hectares with a production of 126.18 million tons; average productivity being 13.6ton ha-1(Woolf, 1992).Sweet potato is an important low-input crop for many places in sub-Saharan Africa. This crop is also capable in efficiently converting natural resources into a more usable product, caloric energy in the growing season, which is the highest of all major arable crops. As pressure on agricultural land increases, improved productivity of these crops will be needed. Women play a critical role in the production of these crops; therefore, it is critical consider improvement of these crops as a means to relieve gender in-equality within agricultural systems. Strategic investment would ensure effective variety development and adoption to accelerate impact of technology.

The use of bio-fortified orange sweet potato rich in beta-carotene, when introduced along with nutrition education at the community level, is a proven cost-effective strategy for providing vitamin A at high levels of bioavailability to vulnerable populations, in particular young children and pregnant and lactating women. On all these accounts, it enhances the resilience of smallholder farming that is frequently affected by low yields or crop failure of other staple crops due to weather or disease. In parts of Ethiopia sweet potato is a relatively new crop and much less prevalent. However, absence of improved sweet potato varieties in the zone also has been a critical problem to its production and productivity.

There are a number of biophysical and socio-economic constraints that hinder the productivity of sweet potato under farmers' circumstances. Among others, lack of high yielding and acceptable quality, and pest resistant /tolerant varieties and agronomic practices has been the limiting factors. To mitigate the limiting factors and constraints of sweet potato production and productivity, improvement activities with the objectives to develop high yielding with acceptable quality and/or pest resistant/tolerant varieties for different agro-ecological zones has been one of the themes. Therefore, efforts have been made to develop improved technologies such as varieties that are high yielder, resistant to disease and pests, and high above ground biomass for livestock feed.

Literature Review

Origin and Distribution

Sweet potato originated from tropical Central America. Botanically, the underground part is classified as a storage root, rather than a tuber. It can be cultivated in many different climatic conditions; and as a result large areas of sweet potato are cultivated in Asia, Africa, Europe, America and Oceania (Paneque, 1991). Ethiopia ranks fifteenth in the world in terms of sweet potato production (Dan *et al.*, 2013). It has been cultivated as crop in Ethiopia for several years and over 95% of the crop produced in the country is grown in south, south western and eastern parts of the country, where it has remained for centuries as an important staple for the community (Emanna, 1990). In Ethiopia sweet potato ranks the first in total production (42.84%) and the second in area coverage (25.43%) next to Irish potato from root and tuber crops cultivated (CSA, 2014).

Climatic requirements and Importance

Sweet potatoes are of tropical origin; they adapt well to warm climates and grow best during summer. Sweet potatoes are cold sensitive and should not be planted until all danger of frost is past. The optimum temperature to achieve the best growth of sweet potatoes is between 21 and 29 ^{0}C, although they can tolerate temperatures as low as 18 ^{0}C and as high as 35 ^{0}C. A well-drained sandy loam is preferred and heavy clay soils should be avoided as they can retard root development, resulting in growth cracks and poor root shape. Soil pH should be adjusted to about 6.0 by applying lime or dolomite.

Orange-fleshed sweet potato(OFSP) contains high levels of beta-carotene, which is converted by the body into vitamin A. Just 125g of boiled OFSP can provide the recommended daily allowance of vitamin A for children and women who are not breastfeeding. In addition, OFSP contributes significant amounts of vitamins C, E and several B vitamins, as well as dietary fiber, iron and magnesium. Purple-fleshed varieties, on the other hand, are rich sources of antioxidants. Sweet potato leaves are also rich in vitamins, beta-carotene, and functional compounds including protein, amino acids and complex carbohydrates. Cultivated primarily for edible storage roots; vines are used as vegetables in some parts of the world. Both starchy roots and vines can be used as animal feed or feed supplement. Various products such as candy, pastas, flour, drinks are produced in local industries. Sweet potato is a dual-purpose crop, as the roots are edible, and the tops may be consumed as a green vegetable. Although the leaves and shoots are also edible, the starchy tuberous roots are by far the most important product. In some tropical areas, they are a staple food-crop. Apart from the utilization of the roots, stems and leaves are readily eaten by cattle, goats, pigs, poultry and even fish when green or as hay or silage. Humans consume vines as a green vegetable or salad green (Moussa *et a*l., 2011).

Seasonal food shortage is amongst the principal problems of farmers in mid-altitude areas of Southern Ethiopia. Sweet potato is one of the most important root and tuber crop for food and feed value. It is one of the twelve principal plant species utilized as a human feed throughout the world. In some of the world’s poorest nations, taro and sweet potato are important part of food security packages (Yared, 2014). Its root is used as food and feed. As food the root is usually consumed in boiled form. It is one of the cheapest sources of vitamin A. Generally Sweet potatoes productivity is law under farmer condition due to many factors one of which will be lack of improved varieties. Endale*et.al* 1994 indicated that yield in farmers field is low mainly because of unavailability of improved genotypes

and poor agronomic practices. One of the main constraints among others in increasing yield ha^{-1} is lack of varieties of the crop which is adapted to specific condition of the area.
Most sweet potato growers are resource poor, therefore consume imbalanced diets. Most sweet potatoes varieties currently grown by farmers are poorly adapted, have low root yields, less nutritive and white fleshed which have no beta carotene, a precursor to vitamin A (Wariboko and Ogidi, 2014). But among the cheapest and richest sources of vitamin A, orange type varieties, rich in beta carotene are well accepted by young children (Low *et al*., 2007). The intensity of orange colored flesh sweet potatoes root indicates the level of beta carotene (Low *et al*., 2001). Therefore, these OFSP varieties could be useful to combat the widespread of vitamin A deficiency that results in blindness and death of 250,000-500,000 African children yearly (Wariboko and Ogidi, 2014). Therefore developing and making available adaptable, high yielding and pest and disease tolerant varieties of Sweet potato is a priority concern in its productivity increase strategy.The main objective of the present study was to identify the cultivars, which could have wide or specific adaptations, and to select and recommend adaptable, frost and disease tolerant and high yielding sweet potato cultivars for midlands of Guji Zone.

Materials and Methods

Description of the study area

The Experiment was conducted at Bore Agricultural Research Center during 2018 and 2019 summer cropping season at Adola sub-station, Gobicha, and Boke on-farm site with the objective of identifying the cultivars, which could have wide or specific adaptations, and to select and recommend adaptable, frost and disease tolerant and high yielding orange type sweet potato cultivars for midlands of Guji Zone. The area is located inGuji zone southern Ethiopia estimated 470 km far from Addis Ababa. Astronomically the district is located between 05^0 53’ 680’’ and 038^0 59’ 007’’ northing and easting latitude respectively.

Treatments and experimental design

Five (Kabode, Naspot 12, Naspot 13, Kaboli and local) varieties of orange fleshed sweet potato, *Ipomoea batatas* L., varieties based on their yield and disease resistance performance was tested with the spacing of 100cm*30cm between rows and plants, respectively. Area occupied by a single plot is 4mx2.4m, with a spacing of 1.5mx1m between block and plot respectively. Thirty two cuttings of each variety were planted on the plot. A randomized complete block design with three replicates was used.The Net harvestable plot was 2m x 2.4m x (4.8 m^2). Total storage root yield data was taken during the study and the central two rows were harvested from each plot leaving border rows to avoid border effects.

Experimental procedures and field management

The experimental land was ploughed, disked and harrowed and ridges were prepared manually with traditional hoes. At crop stand date of planting, plant height at maturity number of main stem branches and no of population at harvesting was recorded. At harvest average root diameter, average root length, number of root per plot, total root weight per hectare, marketable root yield per hectare and unmarketable root yield per hectare also recorded. 100 kg of UREA and NPS fertilizers was used. Other agronomic and crop protection practices will be adopted uniformly as per recommendation for production.

Harvesting was done five months after planting (5MAP) at all sites and data on final stand count, representing final surviving plants in a net plot was recorded. Using a weighing scale, fresh root yield (kg) per plot was determined with marketable and unmarketable roots considered for analysis.Analysis of variance for the collected parameters was performed as per the methods described by Gomez and Gomez (1984) using SAS computer software (SAS, 2003) for randomized complete block design and treatment mean comparison is done by Fisher's list significance difference (LSD) at 5%. Correlation analysis amonggrowth parameters was also done, using Pearson correlation analysis of SAS version 9.3 statistical software (SAS, 2003).

Table 1: Description of the five orange fleshed sweet potato varieties used as experimental

Name of the variety	Source/breeder	Type
Naspot 13	AwARC	Orange fleshed
Local	Local community	Orange fleshed
Kaboli	AwARC	Orange fleshed
Kabode	AwARC	Orange fleshed
Naspot 12	AwARC	Orange fleshed

Source: Awasa Agricultural Research Center

Result and Discussions

The present experiment was conducted to find out the cultivars, which could have wide or specific adaptations, and to select and recommend adaptable, frost and disease tolerant and high yielding orange fleshed type sweet potato cultivars. Therefore, the difference of cultivars on growth and yield of sweet potato have been presented and discussed in different tables and figures in this chapter. The results of the experiment and possible interpretations have been made under the following headings.

Survival Rate, Days to Maturity, Number of Roots per Plot and Average Root Weight

Survival Rate

All cultivars has a very highly significantly ($P<0.001$) increased most of the growth and yield related parameters considered in this study at Dufa, Gobicha and Boke. So plant survival rate was highly significantly ($P<0.05$) different between varieties. The analysis of variance showed that sweet potato varieties local (90.62%, 90.20% and 90.42%), Kabode (78.12% and 78.12%) and Naspot-13 (84.37%) were recorded the highest survival rate at Dufa, Boke and Gobicha locations, respectively. The lowest survival rate (71.87%) and (67.71%) were recorded by Napot-12 and Kaboli variety at Dufa and Gobicha locations, respectively (Table 2, Table 4 and Table 6).

Days to Maturity

Analysis of data for both varieties revealed non-significant ($P>0.05$) result on maturity date at Dufa and Gobicha site (Table 2 and Table 6). However days to maturity at Boke site showed significant ($P<0.05$) difference among each cultivars. The maximum day to maturity (166.66) was recorded for NASPOT-13and the minimum days to maturity (143.33) was recorded for local variety at Boke location.

Number of Roots per Plot

According to the results of ANOVA, highly significant (P<0.05) differences were occurred in number of roots among the sweet potato varieties at Dufa, Boke and Gobicha (Table 2, Table 6 and Table 6). The highest mean value of root number per plot (21.33, 36.66 and 21.33) was recorded from Naspot-13, Naspot-12 and Naspot-13variety at Dufa, Boke and Gobicha sites, respectively. However, the lowest (16.00, 19.33 and 16.00) mean value of root number was recorded from local check in this experiment compared to the remaining four varieties at Dufa, Boke and Gobicha sites, respectively (Table 2, Table 4 and Table 6). This root number difference may be come from genetic capability of the sweet potato varieties (Maniyam*et al*., 2012).

Average Root Weight

Average Fresh root weight was significantly (P<0.05) different among the sweet potato varieties evaluated for their adaptability at Dufa for two years, Boke and Gobicha(Table 2, Table 4 and Table 6). The maximum fresh root weight (670.33g and 444g) was recorded for Kabode and NASPOT-13Variety at all locations. On the other hand, the lowest fresh root weight (447.33, 437.33g and 296.33g) was recorded byKaboli variety at all locations, which was probably the poorest in fresh weight among the newly introduced five improved varieties tested in the agro ecological zone in the southern Oromia.

Table 2. Pooled Means of phenology and yield related variables of sweet potato variety adaptation trial

	Phenology and yield related			
Treatments	**SR (%)**	**DM**	**NRPP**	**ARW(g)**
Naspot 13	72.91[b]	134.00	21.33[a]	581.66[b]
Local	90.62[a]	152.33	16.00[b]	525.33[bc]
Kaboli	76.04[b]	142.33	18.33[ab]	437.33[d]
Kabode	78.12[b]	136.66	18.00[ab]	670.33[a]
Naspot 12	71.87[b]	135.00	17.66[b]	491.33[cd]
Mean	77.91	140.06	18.26	541.26
Lsd (5%)	12.36	ns	3.63	60.82
CV (%)	8.72	7.2	24.19	6.17

at Dufa during 2018 and 2019 cropping season.

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where SR=survival rate, DM=date to maturity, NRPP=average root number per plot, ARW=average root weight (g).

Marketable Fresh Yield, Unmarketable Fresh Yield and Total Root Yield

Marketable Fresh Yield

Treatments	Yield variables		
	MRK(tha^{-1})	UMRK(tha^{-1})	TRY(tha^{-1})
NASPOT 13	63.28[a]	1.80[b]	65.08[a]
LOCAL	55.22[bc]	1.96[b]	57.19[bc]
KABOLI	39.64[d]	3.45[a]	43.09[d]
KABODE	50.60[c]	1.07[c]	51.68[c]
NASPOT 12	60.21[ab]	2.47[b]	62.69[ab]
Mean	53.79	2.15	55.95
LSD (5%)	6.06	0.72	5.62
CV (%)	6.19	18.37	5.52

The analysis of variance (ANOVA) indicated high significant differences in fresh root yield, unmarketable fresh yield and total root yield (tha^{-1}) among varieties at $P \leq 0.05$ within and among locations and seasons (Table 3, Table 5 and Table 6). From the analysis of the result, there were high significance difference between the varieties at $P<0.05$. The maximum root yield (63.28 $tha^{-1}$and 58.08 tha^{-1}) was recorded by variety Naspot-13 at Dufa and Gobicha locations in 2018 and 2019 cropping seasons. But our anova analysis showed that Naspot-12 was recorded maximum (50.76 t ha^{-1}) fresh root yield at Boke location during 2018 cropping year. However, the lowest tuber yield (39.64, 22.78 and 34.44 tha^{-1}) was recorded by varieties Kaboli at all locations for both seasons (Table 3, 5 and6).The variability in yield by different genotypes indicated their differing responses to diverse environments and seasons (Mulema*et al*., 2008). The difference in performance among the cultivars in a given environment is in part due to genetic variability. Tesfaye *et al.*(2011) also reported that significant variation between sweet potato genotypes in yield and other desirable traits in their adaptation trial in different agro ecologies of Ethiopia. Generally,this signifies the varieties to wider or specific adaptation to maximum or low yielding as compared to other varieties.

Table 3. Pooled Means of yield variables of sweet potato variety adaptation trial at Dufa during 2018 and 2019 cropping season.

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where, MRK=marketable fresh weight per hectare (t); UMRK=unmarketable fresh weight per hectare (t); TRY=total root yield (t).

Table 4. Means of sweet potato variety adaptation trial at Boke during 2018 cropping season.

	Phenology and yield related Variables			
Treatments	**SR (%)**	**DM**	**NRPP**	**ARW(g)**
NASPOT 13	84.37[ab]	166.66[a]	26.66[b]	444[a]
LOCAL	90.20[a]	143.33[c]	19.33[c]	343[b]
KABOLI	67.71[c]	161[b]	14.33[d]	296.33[b]
KABODE	78.12b[c]	145[c]	22b[c]	298[b]
NASPOT 12	82.29[ab]	165.66[ab]	33.66[a]	470.33[a]
Mean	80.62	156.33	23.20	370.33
LSD (5%)	10.68	5.39	4.90	61.39
CV (%)	7.28	1.89	11.61	9.11

Where SR=survival rate, DM=date to maturity, NRPP=average root number per plot, ARW=average root weight (g)
Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. \

Unmarketable Fresh Yield

Analysis of data for cultivars has revealed highly significant (P<0.05) different on unmarketable root yield at Dufa and Gobicha locations. But non-significant (P.0.05) different result at Boke location. The highest unmarketable fresh yield (3.45 and 3.25 t ha^{-1})was recorded for Kaboli variety, while the lowest mean value (1.00 and 1.07 t ha^{-1}) was recorded by Kabode variety. According to the report of Egbe *et al*. (2012), during the growth of sweet potato substantial morphological changes occur which could be different among varieties and these influences the accumulation or distribution of the total dry matter among the major plant organs and directly contributing to the difference in fresh weight.

Total Root Yield

The analysis of variance showed that sweet potato varieties has highly significant (P<0.05) different on total fresh root yield at all locations for both years.The maximum total root yield (65.09 t ha^{-1} and 59.88 t ha^{-1}) was recorded by variety Naspot-13 at Dufa and Gobicha locations in 2018 and 2019 cropping seasons. While variety Naspot-12 gave maximum (55.16 t ha^{-1}) total root yield at Boke site. However variety kaboli gave the least (43.09, 27.19 and 37.69 t ha^{-1}) total root yield at all sites. The variation observed in root yield is expected since the varieties had different origins and adaptability preference.

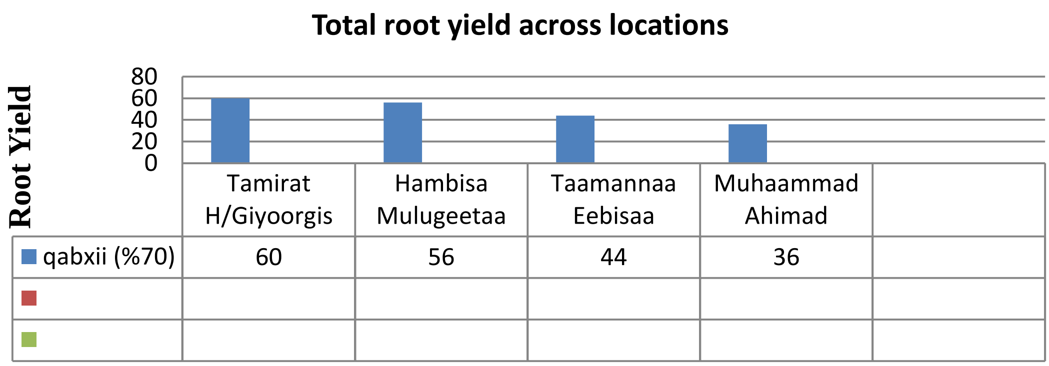

Fig 1. Total fresh root yield of sweet potato at Dufa, Boke and Gobicha locations

Table 5. Means of sweet potato variety adaptation trial at Boke during 2018 cropping season.

Treatments	Yield variables		
	MRK(t/ha)	UMRKkt/ha)	TRY(t/ha)
NASPOT 13	48.86[b]	5.049	53.90[a]
LOCAL	43.209[c]	1.736	44.94[b]
KABOLI	22.78[e]	4.410	27.19[d]

KABODE	38.19[d]	2.00	40.19[c]
NASPOT 12	50.76[a]	4.403	55.16[a]
Mean	40.7.6	3.519	44.28
LSD (5%)	16.53	ns	43.30
CV (%)	2.22	63.14	5.37

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where, MRK=marketable fresh weight per hectare (t); UMRK=unmarketable fresh weight per hectare (t); TRY=total root yield (tha^{-1})

Table 6. Means of sweet potato variety adaptation trial at Gobicha during 2019 cropping season.

Treatments	Phenology, Growth and yield variables						
	SR (%)	**DM**	**NRPP**	**ARW(g)**	**MRK(t/ha)**	**UMRK(t/ha)**	**TRY(t/ha)**
NASPOT 13	72.91[b]	134.00	21.33[a]	591.67[b]	58.08[a]	1.80[b]	59.88[a]
LOCAL	90.42[a]	152.33	16.00[b]	535.33[cb]	50.02[bc]	1.76[b]	51.78[bc]
KABOLI	76.04[b]	142.33	18.33[ab]	447.33[d]	34.44[d]	3.25[a]	37.69[d]
KABODE	78.12[b]	136.66	18.00[ab]	680.00[a]	45.40[c]	1.00[c]	46.4[c]
NASPOT 12	71.87[b]	135.00	17.66[b]	501.67[cd]	55.01[ab]	2.17[b]	57.18[ab]
Mean	77.91	140.06	8.26	541.26	48.59	2.15	50.74
LSD (5%)	12.36	ns	3.63	60.82	6.06	0.72	5.62
CV (%)	8.72	7.20	24.19	6.17	6.19	18.37	5.52

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where SR=survival rate, DM=date to maturity, NRPP=average root number per plot, ARW=average root weight (g),MRK=marketable fresh weight per hectare (t); UMRK=unmarketable fresh weight per hectare (t); TRY=total root yield (t).

Conclusions and Recommendation

Root and tuber cropslike sweet potatoes are the most important crops that need to be cultivated for food security in countries like Ethiopia where population is growing fast, because of the highest yield potential per unit area.Through adaptation trial sweet potato varietal recommendations were made for four targeted areas from the results of the first set of multi-location trials conducted in southern Oromia to address the needs of resource-poor farmers. The result of the current investigation showed that the phenology, growth and yield variables recorded highly significantly different result among the orange fleshed sweet potato varieties evaluated in the study area.The combined analysis of variance of total root yield (tha^{-1}) indicated that there was highly significant ($P<0.05$) difference among varieties, locations and variety by location interaction. The presence of significant variety by location interaction effect showed that some cultivars adapted to wider locations, whereas others to specific locations.

Generally from this study,Naspot-13 and Naspot-12sweet potato varieties weremore adaptable, disease tolerant andhigh yielder and should be promoted to farmers of the study areas for optimum production. Other agronomic packages and nutritional trials should be done further for better consumption of the crop.

Fig 2. Pictures of promising varieties of sweet potato at harvest

References

Central Statistical Agency, 2014. Crop Production Forecast Sample Survey, 2013/14. Report on Area and Production for Major Crops (for Private Peasant Holdings 'Meher' season). Addis Ababa, Ethiopia.

Egbe, O.M., S.O. Afuape and J.A. Idoko, 2012. Performance of improved sweet potato (Ipomea batatas L.) varieties in Makurdi, Southern Guinea Savanna of Nigeria. American Journal of Experimental Agriculture, 2:573-586.

EmannaGutu. 1990. Integrated approach for the control of sweet potato weevil, cylclaspuncticollis Bob (Coleoptera: curclionidae). In: proceedings of the 10th annual meeting of crop protection society of Ethiopia.

Low, J., W. Thomas and H. Robert, 2001. The potential impact of orange fleshed sweet potato on vitamin A intake in sub-Saharan Africa. Proceedings of the Regional Workshop on Food Based Approaches to Human Nutrition Deficiencies, May 9-11, 2001, Nairobi, Kenya.

Low, J.W., M. Arimond, N. Osman, B. Cunguara, F. Zano and D. Tschirley, 2007. A food-based approach introducing orange-fleshed sweet potatoes increased vitamin A intake and serum retinol concentrations in young children in rural Mozambique. J. Nutr., 137: 1320-1327.

ManiyamNedunchezhiyan, GangadharanByju, Susantha K Jata (2012) Sweet Potato Agronomy, Fruit, Vegetable and Cereal Science and Biotechnology. Global Science Books 1: 1-10.

Moussa, S. A.M., A. Hala, A. EI-Al and N. A. EI – Fadi. 2011. Stability study of sweet potato yield and its component characters under different Environments by Joint Regression Analysis., *Journal of Horticultural Science andOrnamental plants.* 3 (1) pp. 43 – 54. Sadat Branch, Egypt.

Mulema JK, Adipala E, Olanya OM, Wagoire W (2008). Yield stability analysis of late blight resistant potato selections. Experimental Agriculture. 44:145-155.

Paneque Ramirez, 1991. Cultivation, Harvesting and Storage of Sweet Potato Products: Roots, Tubers, Plantations and Bananas in animal feeding.

Purseglove, J.W., 1972. Tropical crops: Dicotyledons. London, longman.

SAS., 2003. SAS Online Doc, Version 9.3. SAS Institute Inc., Cary NC., USA.
Tesfaye T., Engida T., Aseffa T., Teshome A., Asfawu K., Yohannis G., Daniel M., 2011. Performance of medium and late maturing sweet potato germplasms in different agro ecologies of Ethiopia. In: Proceedings of the 14th annual conference of the crop science society of Ethiopia. 28-29 April 2011. Addis Ababa, Ethiopia.
Wariboko, C. and I.A. Ogidi, 2014. Evaluation of the performance of improved sweet potato (*Ipomoeabatatas* L. LAM) varieties in Bayelsa State, Nigeria. Afr. J. Environ. Sci. Technol., 8: 48-53.
Woolf, J.A., 1992. Sweet potato: An untapped food resource. Cambridge University, Great Britain.
Yared D., Tewodros M. and Asfaw K., 2014. Development of High Yielding Taro (Colocacia esculenta L.) Variety for Mid Altitude Growing Areas of Southern Ethiopia. Journal of Plant Sciences. Vol. 2, No. 1, 2014, pp. 50-54. doi: 10.11648/j.jps. 0201.19.

Adaptability study of black cumin (*Nigella sativa* L.) varieties in the mid land areas of Guji zone, Southern Ethiopia

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Abstract
Black cumin (*Nigella sativa* L.) is one of the most important spice and cash crop produced in Ethiopia. However, in the midland areas of Guji zone an access of improved Black cumin variety is highly limited. Due to this and other bottle neck factors, the potential of the area to Black cumin crop is not exploited. So, there is an urgent need to develop and promote technologies that suit for the area. As a result, the current experiment was conducted in the midland areas of Guji Zone (Dibayu, Gobicha, and Dole) at three farmers' field to evaluate the growth and yield performance of black cumin varieties and to select and recommend high yielding and diseases resistant Black cumin variety/ies for midlands areas of Guji zone. Six improved black cumin varietiesSilingo, Eden, Gemechis, Derbera, Dershaye, and Sooressaa were used as testing crop. The treatments were arranged in randomized completed block design (RCBD) with three replications. Agronomic data were collected based on the recommended standards. The collected data from the basis of the crop subjected to analysis of variance. The analysis of variance indicated that significant differences observed at ($P \leq 0.05$) among the tested black cumin varieties for days to 50% emergence, numbers of pod per plant and seed yield. However, non-significant difference was observed at ($P \geq 0.05$) among the varieties for day to 50% flowering, day to 90% maturity, plant height, and number seed per pod. The highest seed yield was recorded from Sooressaa**(**11.59 qtha$^{-1)}$ followed by Silingo (11.12qtha^{-1}) improved Black cumin varieties respectively. But, the lowest seed yield was obtained from Dershaye Variety (7.22 qtha$^{-1)}$. Accordingly, Black cumin improved varieties Sooressaa andSilingo were selected by

farmers due to their best performance, adaptability, and highest seed yield. Thereby, these two Sooressaa and Silingo improved black cumin varieties were selected based on agronomic data result and recommended for production to the midland areas of Guji zone.

Key words: Adaptation, Black cumin, improved variety, Spice

Introduction

Black Cumin (*Nigella sativa* L.) is a member of *Apiaceae*(Umbelliferae). S*ativa* species is originated in Egypt and East Mediterranean, but is widely cultivated in Iran, Japan, China and Turkey (Shewaye, 2011). Black cumin is one of the most important medicinal plants and other multipurpose uses (Badary, 1999). It is used as a whole or in crushed. Ethiopia is a homeland for many spices, such as korarima (*Aframonumkorarima*), long red pepper, black cumin, white cumin /bishops weed, coriander, fenugreek, turmeric, sage, cinnamon, and ginger (International Trade Centre, 2010). In Ethiopia, black cumin is one of the most important spice types which are mainly produced to flavor foods, preparation of oil for perfumes and medicinal purpose, source of income, crop diversification, and export purposes (Anshiso and Teshome 2018; Teshome and Anshiso 2019), andthe seeds of Nigella sativa are used to induce an abortion(Inga and Sebsebe ,2000).

The demand of black cumin seed and its oil has also been increasing both in Ethiopian local and national markets for consumption purpose. It is also the second important cash crop which is exported to international market next to ginger (Teshome and Anshiso, 2019). Currently, great deal of attention has been given to the seed and oils yields of black cumin. Their consumption is increasing (Takrun and Dameh, 1998).

Ethiopia is a country with different and favorable agro ecological zones for production of various spices, vegetables and crops (Dessie *et al*. 2019a,b). The country grows more than 14 spice varieties particularly black cumin, white cumin, pepper, paprika, turmeric, fenugreek, garlic, korarima, coriander, ginger, cardamom, and basil for consumption and commercial purposes (Tesfa*et al*. 2017). It is also the top spice producer and consumer countries (Vijayalaxmi and Sreepada 2014) and ranking first and seventh in Africa and global spice production, respectively (FAO, 2019). It is mainly cultivated in Amhara, Oromia, Tigray and SNNPRS and other various places, for own household consumption (Habtewold*et al*., 2007).Nigella sativa is widely cultivated in Amhara Region, Northern Gondar, and Oromia. It is highly cultivated at Kaffa and Keficho Zones and districts of the Southern Nations, Nationalities People's Region (Ermias Assefa *et al*., 2015). It is also particularly growing at Western Arsi (Kofele and Dodola districts) and Arsi Zone (Shirka, Tena and Silitana districts).

Black cumin can be cultivated in the convenient regions for the ecologies of these plants (Yasar, 2005). According to Inga and Sebsebe (2000), Nigella sativa is found in an altitudinal range between 1500-2500m. A rainfall of 120-400mm during its growing season could be enough for its optimum production. It grows in temperature ranges of 5-25^{O}C, with 12-14^{O}C is being the optimum. Although it is known to be low water demanding plant typical of semi-arid areas, availability of water supply over the growing season is very crucial to the timeliness of flower emergence and seed setting. It grows best on well drained sandy loam to loamy soils with a pH range of 6.8 to 8.3. Acidic soils and alkaline soil reduce yield (Weiss, 2002). The sloppy soils of heavy rainfall areas and leveled and well drained soils of moderate rainfall areas are quite suitable for its cultivation. Soil pH of 7.0 to 7.5 is favorable for its production (Orgut, 2007; Weiss, 2002).

Ethiopia has suitable environmental condition for spice production in particular black cumin. Even though, the production and area coverage of black cumin have been increasing; its productivity is still very low in the country.The national average productivity of black cumin was 0.79 t/ha (Kifelew*et al*., 2017). The main factors influencing the production and productivity of black cumin were lack of improved seed, absence of recommended fertilizer rate; postharvest handling problem; lack of improved agriculture practices and extension system, marketing problems (Yosef, 2008). Habtewold*et al*. (2017) also reported that limited production technologies developed for spices so far have yet not multiplied and popularized to farmers. In general, farmers give little attention for spices crops while giving prior attention to food crops (Tiru*et al*.,2017).

Despite its importance, little attention has been given to improve its production and productivity of the crop. Besides, the value-adding to black cumin is low in Ethiopia, with all exports being made in the form of whole grain (Orgut, 2007). Furthermore, taking into account of its use and the suitable midlands of agro ecology Guji zone, there is no research activity conducted to evaluate the adaptability of black cumin varieties. In order to diversify its production, availability and increase the income of the farmers, it is important to evaluate the adaptability of improved black cumin varieties to the midland areas of Guji zone. Therefore, this study was initiated with the objectives:

- ✓ To evaluate the growth and yield performance of Black cumin varieties and
- ✓ To select and recommend adaptable and high yielding Black cumin variety(ies) for midlands areas of Guji zone

Materials and Methods

Description of the Experimental Site

The experiment was conducted at three locations (Adola three on farmers' field) during 2019/20 cropping season to evaluate the growth and yield performance of Black cumin varieties and to select and recommend high yielding and diseases resistant/tolerant Black cumin variety(s) for midlands of Guji zone. Adola district is located at about 470 to the south from Addis Abeba. Adola district is characterized by three agro-climatic zones, highland, midland) and lowlandwith different coverage. The mean annual rainfall and temperature of the district is about 900mm and 12-34 ^{0}c respectively. Based on this condition two-time cropping season was commonly practiced main cropping season which start from March to April especially for maize, haricot bean, sweet potato and irish potato. The second cropping season is short cropping season which was practiced as double cropping using small size cereal crops like tef, potato and barley after harvesting the main cropping season crops. This study was also conducted during short cropping season in midland areas of Guji zone.

Treatments and Experimental Design

The treatments consisted of 6 released improved black cumin varieties (Silingo, Dershaye, Eden,

Darbera, Sooressaa and Gemechis) were brought from Kulumsa, Melkasa and Sinana Agric ultural Research Center and evaluated during 2019/20 cropping season.

Table 1. The improved black cumin varieties released from national and regional research centers in Ethiopia

No.	Name of released variety	Releasing Research Center	Year of release	Altitude (masl)
1.	Dershaye	MARC	2009	1800-2500
2.	Eden	MARC	2009	1800-2500
3.	Darbera	SARC	2006	1650-2400
4	Sooressaa	SARC	2016	1650-2400
5.	Silingo	Tepi& KARC	2017	1800-2500
6.	Gemechis	SARC	2016	1650-2400

Source: MoANR (2017 and from Releasing Research Center)

The design was RCBDwith three replication and plot size will be 2 m x 2.1 m with 0.3m between rows. The spacing between plots and adjacent blocks were 0.4 m and 0.80 m, respectively. Seed rate of 15 kilograms per hectare and fertilizer rates 100 kg of Urea (at planting and top dressing) and 100 kg of blended NPS were applied and all agronomic practices such as land preparation and weeding were done uniformly for all treatments.

Data to be collected

Phenology and Growth (Days to 50% emergence, Days to 50% flowering, Days to 90% maturity,Plant height (cm), Number of branches per plant), Yield and Yield Components (Number of pods per plant, Number of seeds per pod, 1000 seed weight (g) andSeed yield (kg ha^{-1}).

Data Analysis

Field data were analyzed by using appropriate software for the data following the standard procedures outlined by Gomez and Gomez (1984). Comparisons among the treatment means were done using Fisher's protected least significant difference (LSD) test at 5% level of significant.

Results and Discussion

Phenology and growth

The analysis of variance (ANOVA) for phenology and growth variables of six (6) Black cumin varieties planted at Kiltusorsa, Gobicha, and Dole on-farm.Over all locations Analysis of variance showed statistically significant differences ($P<0.05$) among varieties, locations and their interaction for days to 50% emergence and 90% physiological maturity. Thus, variety and lo cations was significant differences observed at ($P<0.05$) for Number of pod per pod. However, non-significant difference at ($P > 0.05$) was observed among the varieties, locations and their interactions for days to 50% flowering (Table 2).

The mean values for the six (6) varieties are shown (Table 2). The variation with respect to days to emergence, and maturity were ranged from 25.11 to 31.22, and 114.7 to 124 days respectively. As over all location mean value indicate that the longest days to 50% emergence was recorded from Gemechis variety (31.22 days) followed by Derbera variety (29.56 days) respectively. However, early emergence was recorded for Eden variety (25.11days) followed by Silingo variety (27 days). In other cases, Sooressaa variety was late maturing (124 days) respectively whereas among the tested varieties, Gemechis variety was early maturing with (114.7days) The overall location mean values revealed that the highest number of capsule per plant was exhibited from Sooressaa variety (14.54)followed by Gemechis variety(13.51). However, the lowest number of capsule per plant was recorded from Dershaye variety (9.57) (Table 2).Nimet*et al*. (2015) who reported that plant height, the number of branches, the number of capsule and 1000-seed weight of populations varied according to locations. These results articulate with that of Ozguven and Sekeroglu (2007) and Tuncturk et al. (2012) stated that yield components such as the number of branches and capsules affects directly seed yield in the black cumin.

Table 2. The overall locations (Dole, Gobicha and Kiltusorsa) mean values of phenology and Growth traits of Black cumin varieties in 2019/20 cropping season
*, **,***= significant at $p < 0.05$, at $p < 0.01$, and at $p < 0.001$ respectively, at $p > 0.05$=non significant(ns) Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance and CV (%) = Coefficient of variation

Yield and yield components

The overall locations Analysis of variance showed statistically significant differences (P<0.05) among varieties and locations for seed yield. In the other hand, variety was significant differences observed at (P<0.05) for number of seed per pod. However, non-significant difference at (P > 0.05) was observed among the locations for number of seed per pod (Table 3).

The overall location mean values revealed that the highest seed yield was obtained from

Variety	Phenology, and Growth traits mean				
	Days to 50% Emergence	Days to 50% Flowering	Days to 90% physiological maturity	Plant height (cm)	No. capsule /plant (Numbers)
Silingo	27d	64.44	117.7d	51.67	12.33abc
Eden	25.11e	65.69	119.7b	51.56	10.32bc
Sooressaa	29.22b	67.33	124 a	49.71	14.54a
Dershaye	28.67c	67.33	118 c	48.04	9.57c
Derbera	29.56b	70.44	116.7e	45.07	10.01bc
Gemechis	31.22a	69.56	114.7f	43.5	13.51ab
Significance level					
Replication	0.02^{ns}	22.89^{ns}	0	168.14^{ns}	6.07^{ns}
Variety	41.04***	44.79^{ns}	96.0***	102.41^{ns}	37.88**
Location	12.07***	30.72^{ns}	0.5***	252.06**	63.23**
Variety * Location	3.14***	44.21^{ns}	353.3***	44.39^{ns}	10.37^{ns}
Error	0.32	28.41	0	62.64	11.2
Cv (%)	1.96	7.89	0	16.36	28.56

Sooressaa variety (11.59qtha^{-1}) followed by Silingo variety (11.12qtha^{-1}) respectively whereas the lowest seed yield Dershaye variety (7.22qtha^{-1}) followed by Eden and Derbera varieties (7.29 and 7.72qtha^{-1}) was recorded respectively (Table 3).This suggestion is lined with that of Tarakanovas and Rusgas (2006) Yield can inexpensively quantify the genetic, physiological and environmental controls that results in yield differences among cultivars, seasons and locations.Nimet*et al*. (2015) also reported that the seed yields of black cumin populations varied according to locations.

Table 3. The overall locations (Dole, Gobicha and Kiltusorsa) mean values of No. seed /pod, and Seed yield traits of Black cumin in 2019/20 cropping season

Variety	**Yield and yield component traits mean**	
	No. seed / capsule (Numbers)	Seed yield(qt/ha)
Silingo	89	11.12a
Eden	83.06	7.29c
Sooressaa	96.28	11.59a
Dershaye	90.33	7.22c
Derbera	86.22	7.72c
Gemechis	94.15	9.57b
	Significance level	
Replication	98.34^{ns}	1.08^{ns}
Variety	216.16^{ns}	34.56***
Location	452.31**	53.06***
Variety* Location	90.15^{ns}	2.36^{ns}
Error	120.28	1.92
Cv (%)	12.21	15.26

Conclusion and Recommendation

In midland areas of Guji zone where new improved spice technologies are not widely addressed, it's vital to catch immediate action towards setting appropriate way of addressing new technologies. In such case, evaluation and adaptation varieties are an effective tool in facilitating selection of the improved Black cumin technologies.The analysis of overall locationmean values revealed that the highest seed yield recorded from Sooressaa(11.59 qtha$^{-1)}$ followed by Silingo (11.12 qtha^{-1}) improved coriander varieties respectively. However, the lowest seed yield was recorded from Dershaye (7.22 qtha$^{-1)}$.Therefore, based on agronomic data results two improved Black cumin varieties i.e., Sooressaa and Silingo are selected and recommended for midland areas of Guji zone.

References

Abebe Birara, TadieMirie, BetelhemTsedalu, TiruTesfa and ShegawGetu. 2020. Estimation of technical efficiency of black cumin (Nigella sativa L.) farming in northwest Ethiopia: a stochastic frontier approach,*Journal of Economic stracture*, 9:18

Anshiso D, Teshome W.2018.Economic Value of Black Cumin (Nigella sativa L.) conservation at bale zone of oromia region, Ethiopia. Am J Bus 6(4):104–109

Badary, O.A., 1999. Thymoquinone attenuates ifosfamide-induced Fanconi syndrome in rats and enhances its antitumor activity in mice. J. Ethnopharmacol., 67: 135-142.

Dessie AB, Abtew AA, Koye AD.2019b).Analysis of smallholder farmers' cooperation in eucalyptus woodlot production in Wegera District, Northern Ethiopia. Small-scale For 18:291–308.

Dessie AB, Koye TD, Koye AD, AbitewAA .2019a.Analysis of red pepper marketing: evidence from northwest Ethiopia. J Econ Struct 8(1):24

ErmiasAssefa, Addis Alemayehu andTeshome Mamo.2015. Adaptability study of Black Cumin (Nigella sativaL.)Varieties in the Mid-and Highland areas of Kaffa Zone, South West Ethiopia.Agriculture, Forestry and Fisheries4(1):14-17.

FAOSTAT .2019).Crop production in Africa. Retrieved 2019, August 21. Countries—Select All; Regions—Africa + (Total); Elements

Farshadfar E, and Sutka E. 2006. Biplot analysis of genotype-environment interacting in durum wheat using the AMMI model. Acta Agron. Hung, 54: 459-467

Habtewold K, Demes F, Tewodros L, Dejene B, Haimanot M, Wakjira G.2017. Seed Spices Production Guideline: Ethiopian institute of agricultural Research.

HabtewoldKifelew, Demes Fikere, Tewodros LulesegedDejene Bekele, HaimanotMitiku and Wakjira Getachew. *2017. Seed spice production Guideline manual.* Addis Ababa, Ethiopia.pp:1-36

Inga, H.and SebsebeDemissew .2000. Flora ofEthiopia.Vol. 2 Part 1. The National Herbarium, Biology Department Science Faculty, Addis Ababa University, Ethiopiaand The Department of Systematic Botany,Uppsala University, Uppsala, Sweden.

International Trade Center.2010. Spice Sub-sector Strategy for Ethiopia. Addis Ababa, Ethiopia.

Kifelew H, Getachew W, Luleseged T, Mitiku H, Bekele D, Fikere D.2017.Seed Spices Production Guideline. Ethiopian institute of agricultural Research

MoANR (Ministry of Agriculture and Natural Resources**)**.2016.Plant Variety Release, Protection and Seed Quality Control Directorate**.** Crop Variety Register Issue No. 19 pp: 1-318

Nimet Kara, Duran Katar, Hasan Baydar.2015.Yield and Quality of Black Cumin (Nigella Sativa L.) Populations: The Effect of Ecological Conditions,Turkish Journal of Field Crops, 20(1), 9-14

Orgut.2007. Market Assessment Study, Ethiopian Nile Irrigation and Drainage Project, Main Report and Annexes, Ministry Of Water Resources, Addis Ababa.

Ozguven, M. and N. Sekeroglu. 2007. Agricultural practices for high yield and quality of black cumin (*Nigella sativa* L.) cultivated in Turkey. Acta Horticulturae. 756:329-337.

Shewaye ,L .2011. Antifungal Substances from Essential Oils.M.Sc. Thesis. Addis Ababa University. p. 8

Takrun, H.R.H. and M.A.F. Dameh, 1998. Study of the nutritional value of black cumin seeds (*Nigella sativa* L.). J. Sci. Agric., 76: 404-410.

Tesfa T, Bayu W, Gashaw A, BeshirH .2017.Spice production, marketing, and utilization in South Wollo, Ethiopia. East Afr J Sci 11(1):27–36.

Teshome W, Anshiso D.2019.Assessment of production and utilization of black cumin (Nigella sativa) at the Oromia Regional State, Ethiopia. Asian J Agric Extens Econ Sociol, pp 1–12

Tuncturk, R., M. Tuncturk and V. Ciftci. 2012. The effects of varying nitrogen doses on yield and some yield components of black cumin (*Nigella sativa* L.). Advances in Environmental Biology. 6(2): 855-858.

Vijayalaxmi, H.,&Sreepada, H.2014. An economic overview of ginger production in Ethiopia. *International Journal of Science and Research* , 3(12), 2052–2054.

Weiss, E.A., 2002. Spice Crops. CABI Publishing, London, UK., Pages: 411.

Yasar, S. 2005. Determinatıon of fixed and essential oil contents and soil characteristic of some perennial medical plants that grow naturally in the campus of Cukurova University. Department of Biology Institute of Natural and Applied Sciences University of Cukurova. MSc Thesis, 43p, Adana. (in Turkish).

Yosef HH .2008. Effect of high levels of nitrogen and phosphorus fertilizer on growth, yield and yield components of Nigella sativa L. Horticulture Department College of Agriculture, Duhok University, Iraq. *Mesopotamia J Agric* 36:1

Adaptability study of Coriander (*Coriandrum sativum* L.) varieties in the mid land areas of Guji zone, Southern Ethiopia

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Abstract

Coriander (*Coriandrum sativum* L,) is one of the most important spice and cash crop produced in Ethiopia. However, information related to potential of the midland areas of Guji zone for coriander production is limited. This experiment was conducted in the Kiltusorsa, Gobicha and Dole areas at three farmers' field to evaluate the growth and yield performance of Coriander varieties and to select and recommend high yielding as well as diseases resistant coriander variety/ies. Five improved Coriander varietiesWalta'i, Batu, Tulu, Indium 01 and Denkinesh were cultivated. The treatments were arranged in randomized completed block design (RCBD) with three replications. Statical analysis indicated significant differences ($P \leq 0.05$) among the coriander varieties for days to 50% emergence, days to 50% flowering, days to 90% physiological maturity, plant height, number of branches per plant,1000 seed weight and seed yield. The highest seed yield was recorded from Denkinesh**(**18.27 $qtha^{-1}$) followed by Tulu (13.86$qtha^{-1}$) improved Coriander varieties respectively. But, the lowest seed yield was obtained from Indium 01variety (1.67 $qtha^{-1}$). Accordingly, Coriander improved varieties Denkinesh and Tulu were selected by farmers due to their best performance, adaptability, and highest seed yield. Therefore, these two Denkinesh and Tulu Coriander varieties are recommended in the study area.

Key words: Adaptation, Coriander, Improved variety, Spice.

Introduction

Coriander (*Coriandrum sativum* L, 2n=2x=22) is a diploid annual plant, belonging to the Apiaceae family (Parthasarathy *et al*., 2008). *C. sativum* is one of the most useful essential oil bearing spices as well as medicinal plants (Mandal and Mandal, 2015). The green herb is used as spice and vegetable (Dyulgerov*et al.*, 2013). The essential and fatty oil of the fruits are used as raw materials for industry and for further processing. In the list of centers of origin of cultivated plants Vavilov (1992) mentioned coriander for Central Asia, the Near East and Abyssinia. It is a culinary and medicinal plant native to Mediterranean and Western Asian regions (Maroufi*et al*., 2010) and cultivated worldwide (Weiss *et al*., 2002).

Ethiopia is considered as the homeland for many spices such as korarima, long pepper, black cumin, white cumin/bishops weed and coriander (International Trade Centre, 2010; Hilde and Daphne, 2003). It is also known as a center of origin and diversity for several plant species including Coriander (Singh *et al*., 2006). In Ethiopia, coriander is grown mainly for income generation in addition to local consumption. It is used as a spice in culinary (Diederichsen, 1996), medicine (Kubo *et al*., 2004; Delaquis*et al*., 2002) and in perfumery, food, beverage, and pharmaceuticals industries (Jansen, 1981). Coriander plays also an important role in the Ethiopian domestic spice trade and its seeds are used for the flavoring of 'berbere' (which is a spiced, hot red pepper powder used for numerous meat and vegetarian dishes), 'injera', cakes and bread and its leaves added as an aromatic herb to 'wot' and tea (Jansen, 1981).

Coriander is also a good melliferous plant and studies indicated that one hectare of coriander allows honey bees to collect about 500 kg of honey (Romanenko*et al*., 1991). The seed contains significant quantities of carotene, thiamine, riboflavin, niacin, tryptophase, vitamin B6, folate, vitamin C and E (Holland *et al*., 1991); it also contains iron, manganese, magnesium and dietary fiber to the diet (Ensminger and Esminger, 1986). In traditional medicine, one or two teaspoons of coriander juice, added to fresh buttermilk, is highly valuable in treating digestive disorders such as dysentery, indigestion, nausea, hepatitis, ulcer and it is also helpful in typhoid fever. Dry coriander treats chronic dysentery, diarrhea and as well as acidity problems and indigestion (Jansen and Wageningen, 1981).

The major producers of coriander in the world are Ukraine, Russia, India, Morocco, Argentina, Mexico, and Romania. Producers form Africa includes Algeria, Egypt, Ethiopia, Somalia and Tunisia. In Ethiopia, coriander is an important cash crop for farmers in the relatively highland areas. It is often cultivated in altitude ranges from 1200 to 2200 m above sea level. It also requires 120 to 400 mm rainfall per growing period. The success of coriander production is influenced by genetic, weather and agronomic factors (Nowak and Szemplinski, 2014). Even though, Ethiopia is a center of diversity for the crop, the attention given so far in research and development was very limited. In order to diversify its production, availability and increase the income of the farmers, it is important to evaluate the adaptability of improved Coriander varieties to the midland areas of Guji zone. Therefore, this study was initiated with the following objectives:

- ✓ To evaluate the growth and yield performance of coriander varieties and
- ✓ To select and recommend adaptable and high yielding coriander variety(s) for midlands of Guji zone.

Materials and Methods

Description of the Experimental Site

The experiment was conducted at three locations of Adola district during 2019/2020 cropping season to evaluate the growth and yield performance of Coriander varieties and to select and recommend high yielding and diseases resistant Coriander variety(s) for midlands of Guji zone. The district is located at about 470 to the south from Addis Abeba. Adola district is characterized by three agro-climatic zones, namely Dega (high land), Weina-dega (mid land) and Kola (low land) with different coverage. The mean annual rain fall and temperature of the district is about 900 mm and 12-34 ^{0}c respectively. There are two cropping seasons i.eArfasa (main cropping season) which start from March to April especially for maize, haricot bean, sweet potato and Irish potato. The second cropping season is called Gana (short cropping season) which is practiced as double cropping using small size cereal crops like tef, potato and barley after harvesting the main cropping season crops. This study was also conducted during short cropping season in midland areas of Guji zone.

Treatments and Experimental Design

The treatments consisted of five released improved Coriander varieties (Indium 01, Walta'i, Batu, Tulu and Denkinesh) were obtained from Tepi and Kulumsa, Sinana and Adami Tulu Agricultural Research Center and evaluated at three on-farms.

Table 1.The improved Coriander varieties released from national and regional research centers in Ethiopia

No.	Name of released variety	Releasing Research Center	Year of release
1.	Walta'i	Sinana research center	2006
2.	Denkinesh	Tepi and Kulumsa ARC	2017
3.	Indium	Debre Zeit research center	2008
4.	Tulu	Adami Tulu research center	2018
5.	Batu	AdamiTulu research center	2018

Source: MoANR (2017 and from Releasing Research Center)

The experimental design was RCBD with three replication and plot size was 2 m * 2.1 m with 0.3m between rows. The spacing between plots and adjacent blocks were 0.4 m and 0.80 m, respectively. Seed rate of 15 kilograms per hectare and fertilizer rates 100 kg of urea (at planting and top dressing) and 100 kg of blended were applied and all agronomic practices such as land preparation and weeding were done uniformly for all treatments.

Data collected

Phenology and Growth (days to 50% emergence, days to 50% flowering, days to 90% maturity,plant height (cm), Number of branches per plant), yield and yield components (number of pods per plant, number of seeds per pod, 1000 seed weight (g) andseed yield (kg ha^{-1})

Data analysis

Field data were analyzed by using software (Gen-stat 18 editions) following the standard procedures outlined by Gomez and Gomez (1984). Comparisons among the treatment means were done using Fisher's protected least significant difference (LSD) test at 5% level of significant.

Results and Discussion

Phenology and growth

The analysis of variance (ANOVA) was performed for phenology and growth variables of five Coriander varieties planted at Kiltusorsa, Gobicha, and Dole on-farm.Over all locations

Analysis of variance showed statistically significant differences ($P<0.05$) were observed among
varieties, locations and their interaction for days to 90% physiological maturity, and plant he ight. However, non-significant difference at ($P > 0.05$) was observed among the locations for days to 50% emergence and flowering, and number of branches (Table 2).
The mean values for the five (5) varieties are shown (Table 2). The variation with respect to days to emergence, flowering, and maturity were ranged from 17.67 to 20.22, 53.67 to 58, and 96 to 110.3 days respectively. As over all location mean value indicate that the longest days to 50% emergence was recorded from walta'i variety (20.22 days) followed by Batu variety (19.22 days) respectively. However, early emergence was recorded for Indium 01 variety (17.67days) followed by Tulu variety (18.78 days). In other cases, Denkinesh and Tulu varieties were late flowering and maturing (58 and 110.3 days) respectively whereas among the tested varieties, Tulu and Batu, and Indium 01 were early flowering and maturing with (53.67 and 96 days) respectively. The overall location mean values revealed that the longest plant height and highest number of branches per plant was exhibited from Denkinesh variety (118.24cm and 4.07) respectively. However, the shortest plant height and lowest number of branches per plant was recorded Indium 01variety (59.83cm and 1.02) respectively (Table 2)

Table 2. The overall locations (Dole, Gobicha and Kiltusorsa) mean values of phenology and Growth traits of coriander varieties in 2019/20 cropping season

Variety	Phenology, and Growth traits mean				
	Days to 50% Emergence	Days to 50% Flowering	Days to 90% physiological maturity	Plant height (cm)	No. branches /plant
Denkinesh	19.13[ab]	58[a]	106[b]	118.24[a]	4.07[a]
Tulu	18.78[bc]	53.67[b]	110.3[a]	94.14[b]	2.56[b]
Batu	19.22[ab]	53.67[b]	100[c]	86.69[b]	2.36[b]
Walta'i	20.22[a]	54.33[b]	96.4[d]	69.44[c]	1.96[c]
Indium 01	17.67[c]	58[a]	96[d]	47.69[d]	1.02[d]
Significance level					
Replication	5.36**	14.6**	0.36[ns]	399.55**	0.03[ns]
Variety	7.81**	46.3***	351.02***	6320.92***	11.09***
Location	0.16[ns]	12.8[ns]	6.69***	1398.72***	0.05[ns]
Variety * Location	1.04[ns]	3.1[ns]	3.52***	291.14**	0.24[ns]
Error	47.28	4.23	0.36	102.72	0.11
Cv (%)	6.82	3.7	0.59	12.18	13.9

*, **,***= significant at $p < 0.05$, at $p < 0.01$, and at $p < 0.001$ respectively, at $p > 0.05$=non significant(ns) Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance and CV (%) = Coefficient of variation

Yield and yield components

The overall locations analysis of variance showed statistically significant differences ($P<0.05$) among varieties and locations for seed yield. In the other hand, among varieties significant differences were observed at ($P<0.05$) for thousand seed weight. However, non-significant difference at ($P > 0.05$) was observed among the locations for thousand seed weight (Table 3).

The overall location mean values revealed that the highest thousand seed weight were obtained from Denkinesh variety (42.78 g) followed by Tulu variety (37.11 g) respectively whereas the lowest thousand seed weight from Indium 01variety (21.67 g) followed by Walta'i variety (32 g) was recorded respectively. The weight of thousand seeds of the tested accessions ranged from 9.8 to 12.8 g, which is in agreement with the previous studies of Arganosa*et al*. (1998). In other cases, the highest seed yield was obtained from Denkinesh variety (18.27 $qtha^{-1}$) followed by Tulu variety (13.86 $qtha^{-1}$) respectively whereas the lowest seed yield Indium 01 variety (1.67 $qtha^{-1}$) followed by Walta'i variety (8.68 $qtha^{-1}$) was recorded respectively (Table 3). The results of this study are also consistent with that of (Nowak and Szemplinski, 2014) who reported that the success of coriander production is influenced by genetic, weather and agronomic factors. Moreover, this suggestion is in agreement with that of Golam *et al*. (2014) Environmental and genetic parameters can affect plants performance. Furthermore, no similar with that of Diederichsen (1996) reported a seed yield of 30 qt/ha under optimum conditions.

Table 3. The overall locations (Dole, Gobicha and Kiltusorsa) mean values of thousand seed weight, and Seed yield traits of Coriander in 2019/20 cropping season

Variety	**Yield and yield component traits mean**	
	1000 seed weight(g)	Seed yield($qtha^{-1}$)
Denkinesh	42.78a	18.27a
Tulu	37.11b	13.86ab
Batu	32.44c	13.59ab
Walta'i	32c	8.68b
Indium 01	21.67d	1.67c
	Significance level	
Replication	2.07	3.33^{ns}
Variety	544.63***	359.88***
Location	6.47^{ns}	128.49**
Variety* Location	12.72^{ns}	42.02^{ns}
Error	8.85	31.40
Cv (%)	8.96	14.9

*, **,***= significant at $p < 0.05$, at $p < 0.01$, and at $p < 0.001$ respectively, at $p > 0.05$=non significant(ns) Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance and CV (%) = Coefficient of variation

Conclusion

In midland areas of Guji zone where new improved spice are not widely addressed, it's vital to catch immediate action towards setting appropriate way of addressing new technologies. In such case, evaluation and adaptation varieties are an effective tool in facilitating selection of the improved coriander technologies. The analysis of overall location mean values revealed that the highest seed yield recorded from Denkinesh(18.27 qtha$^{-1)}$ followed by Tulu (13.86 qtha^{-1}) improved coriander varieties respectively. However, the lowest seed yield was recorded from Indium 01(1.67 qtha$^{-1)}$.Therefore, based on agronomic data results two improved coriander varieties i.e.Denkinesh and Tulu are selected and recommended for midland areas of Guji zone.

References

Arganosa GC, Sosulski FW, Slinkard AE (1998). Seed yields and essential oil of northerngrown coriander (*Coriandrum sativum* L.). *J. Herbs, Spices & Medicinal Plants*. 6(2): 23-32.

Carrubba AR, Torre L, Calabrese I (2006). Effect of sowing time on coriander (*Corindrum sativum* L.) in Simi arid Mediterranean environment. *Crop Sci*. 46: 437-447.

Delaquis PJ, Stanich K, Girard B, Mazza G (2002). Antimicrobial activity of individual and mixed fractions of dill, cilantro, coriander and eucalyptus essential oils. International Journal of Food Microbiology 74:101–109.

Diederichsen A (1996). Coriander (Corianderum sativum L). Promoting the conservation and use of underutilized and neglected crops. 3. Institute of Plant Genetics and Crop Plant Research, Gaterslbebn/International Plant Genetic Resources Institute, Rome, Italy. 83pp.

Diederichsen A (1996). Coriander (*Corianderum sativum* L). Promoting the conservation and use of underutilized and neglected crops. 3. Institute of Plant Genetics and Crop Plant Research, Gaterslbebn/ International Plant Genetic Resources Institute, Rome. 83p.

Dyulgerov N, Dyulgerova B (2013).Variation of yield components in coriander (*Coriandrum Sativum L*.) Agricultural Science & Technology.

EnsmingerAH, Esminger MKJ (1986). Food for health: A Nutrition Encyclopedia. Clovis, California: Pegus Press, USA

Golam F, Zaidi K, Nezhadahmadi A, Osman M (2014). Genetic analysis of F1 hybrids derived from aromatic (Exotic) × aromatic (Malaysian) rice crosses and their callus induction performance for haploid production. Indian Journal of Science and Technology.7(11):1852–60.

Hilde D, Daphne W (2003). Factsheet-spices Ethiopia. Netherlands-African Business Council. International Journal of Current Microbiol. Applied Science, 3(1): 315-328.

Holland B, Unwin ID, Buss DH (1991).Vegetables, Herbs and Spices. 4th ed. Cambridge, UK. 163pp.

International Trade Center (2010). Spice Sub-sector Strategy for Ethiopia. Addis Ababa, Ethiopia.

Jansen PCM (1981). Spices, condiments and medicinal plants in Ethiopia; their taxonomy and agricultural significance. Center for Agricultural Publishing and Documentation, Wageningen, Netherlands. 294pp.

Jansen PCM (1981). Spices, condiments and medicinal plants in Ethiopia, their taxonomy and agricultural significance. Wageningan: PUDOC.; 56-67.

Kubo I, Fujita K, Kubo A, Nihei K, Ogura T (2004). Antibacterial activity of coriander volatile compounds against Salmonellacholeraesuis. Journal of Agriculture and Food Chemistry 52(11):3329-3332

Mandal S, Mandal M (2015). Coriander (*Coriandrum sativum* L.) essential oil: Chemistry and biological activity – a review. Asian Pac J Trop Biomed; 5(6): 421–428.

Maroufi K, Aliabadi H, Farahani J, Darvishi H (2010). Importance of coriander (*Coriandrumsativum* L.) between the medicinal and aromatic plants. Advance in Environmental Biology; 4(3):433-436.

MoANR**(**Ministry of Agriculture and Natural Resources**)** (2016). Plant Variety Release, Protection and Seed Quality Control Directorate**.** Crop Variety Register Issue No. 19 pp: 1-318

Nowak J . , Szemplinski W. 2014. Influence of sowing date on yield and fruit quality of Coriander (*Coriandrum sativum L.*) . actasci .pol .,horto rum cultus, 13(2) : 83-96.

Nowak J, Szemplinski W (2014). *Influence of sowing date on yield and fruit quality of coriander (Coriandrum sativum* L.*).* - Acta Sci. Pol., Hortorum Cultus, 13(2): 83-96.

Parthasarathy V, Chempakam B, Zachariah TJ (2008).Chemistry of spices. CAB International; 455.

Romanenko LG, NevkrytajaNV, Kuznecova EJU (1991). Features of pollination in coriander. Rome, Italy. 83pp.

Singh D, Jain UK, Rajput SS, Khandelwal V, Shiva KN (2006). Genetic variation for seed yield and its components and their association in coriander (*Coriandrum sativum* L.) germplasm. *Journal of Spices and Aromatic Crops* 15: 25-29.

Vavilov NI (1992). The phyto-geographical basis for plant breeding - Studies of the original material used for plant breeding. Pp.316-366.

Weiss EA(2002). Spice crops. CABI Publishing, New York, USA.;411.

Performance evaluation of Groundnut Varieties in Eastern Parts of Ethiopia

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Abstract

Groundnut plays an important role as a food as well as cash crop in Ethiopia. Its production in Ethiopia is found to be constrained by several biotic and abiotic factors. To this end, this study was conducted with the objective of identifying high yielding, biotic and abiotic stresses resistance or tolerance varieties. A total of six varieties were evaluated in RCBD. 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 the AMMI bi-plot. The variation for seed yield among the varieties for each variety was significant at different environments. Varieties such as G1 (Bulki), G6

*(Babile2) and G4 (Werer962) were specifically adapted to high yielding environments while, G2 (Shulamiz) was the most unstable variety. G1 (Bulki) was more stable in comparison to other varieties. In GGE bi-plot analysis; $IPCA_1$ and $IPCA_2$ explained 48.07% and 25.93% of variation, respectively, of groundnut variety by environment interaction and made a total of 74.00% of variation. Therefore, Bulki (*1075*kg ha^{-1}) and Babile2 (*1030*kg ha^{-1}) were identified as most stable and thus recommended for production in the study area and similar agro-ecologies and Fedis is identified as the ideal environment for groundnut production.*

Key word: AMMI, G x E interaction, Groundnut

Introduction

Groundnut (*Arachis hypogaea* L.) plays an important role as a food as well as a cash crop in Ethiopia (Dereje A. *et al*., 2012). Currently the crop is becoming one of the high value crops that are growing in the lowlands areas of the eastern Oromia. Groundnut, or peanut, is commonly called the poor man's nut. Today it is an important oilseed and food crop (FAO, 2002). Groundnuts are produced in the tropical and subtropical regions of the world, on sandy soils. In Ethiopia, groundnut is cultivated predominantly by the traditional and undeveloped farming community under rain-fed conditions. The yields of groundnut in Ethiopia compared to other countries are very low i.e. below 1.1 ton ha^{-1} as compared to average yields on a global scale i.e. 1.52 ton ha^{-1} but with good management practices, yields can be reached to 3.0 ton ha-1 (FAOSTAT, 2009). Groundnut production in Ethiopia is found to be constrained by several biotic and abiotic factors i.e. critical moisture stress especially during flowering and then after, lack of improved varieties and appropriate production and post-harvest practices, and diseases affecting both above- and underground parts of the plant (Mohammed, A. and Chala, A., 2014). Inview of the above production constraints in the study area, the current study was initiated with the following objective:

- To evaluate and recommend the best high yielding and early maturing varieties for the study areas.

Materials and Methods

This activity was conducted at Fedis experimental on station and at Erer, Kile and Diredawa on farm sites. A total of seven recently released varieties of groundnut were collected from Bako Agricultural Research Center and Haramaya University and one local check and were used as planting materials. The experiment was arranged in RCBD with three replications. These test varieties were grown under rain fed conditions during 2017, 2018 and 2019 cropping season at Fadis, Erer, Kile and Diredawa. The experimental plots consisted of six rows of 4 m length, 3.6 m width and 0.6 m row space. The central four rows were harvested to estimate grain yield. The spacing between adjacent replications and plots were 1 m, and 1 m, respectively.

2.1. Data collected: Plant height, pod per plants, seeds per pod, number of branches per plants and yielded were collected.

Pods per plant: This was recorded by mean number of pods obtained from ten randomly taken plants at harvest.

Seeds per pod: Mean numbers of seeds obtained from five plants were selected at random from each plot and the total number of seeds was counted, the average was calculated and recorded as the number of seeds per plant.
Grain yield per hectare: Grain yield obtained from each experimental plot and converted to grain yield per hectare and corrected to 13% humidity

2.2. Statistical analysis: Analysis variances and least significant difference (LSD) were determined by Genstat 18th .

Result and Discussion

3.1. Combined Analysis of Variance

Analysis of variance was carried out to determine the effects of varieties, location and their interaction on Grain yield of groundnut varieties. Accordingly, Environment and Genotype for seed yield showed statistical highly significant variation ($P<0.01$) indicating the presence of genetic variation and possible selection and recommendation of high yielding and stable varieties (Table 1). Besides, this result indicates the big influence of environment and varieties on yield performance of groundnut varieties. The significant effect of environments indicated that the testing environments were significantly different from each other for expressing their yield potential. Similarly, Sunday C. *et al*., (2013) were reported the different performance of genotypes across environments could also be indicative of wide variation in climatic conditions and soil types in the different growing environments. The mean yield potential of the varieties varying across environments and among varieties indicating the varieties were expressing their potentials even though they were affected by environments and genetic variations.

Table 1. Analysis of variance for seed yield of groundnut varieties evaluated across three years at different locations.

Source of variation	d.f.	mean square
Block	2	3.75
Genotypes	7	11.667*
Environment	5	154.47**
Interaction	35	7.083
Error	94	5.081
Total	143	

3.2. Mean seed yield of groundnut varieties evaluated at six environments

The average environmental seed yield across varieties ranged from the lowest of 6.44 Qtha^{-1} at E2 (Erer 2017) to the highest of 12.85 Qtha^{-1} at E1 (Fadis 2017), with a grand mean of 9.59 Qtha^{-1}(Table 2). The varieties average seed yield across environments ranged from the lowest of 8.06 Qtha^{-1} for Shumaliz to the highest of 10.75 Qtha^{-1} for Bulki (Table 2). This difference could be due to their genetic potential of the varieties and also due to difference of growing environments.

Table 2: Mean seed yield (Qt/ha) of groundnut varieties evaluated at six environments

Varieties	Mean of seed yield across environment						mean
	E1(Fadis 2017)	E2(Erer 2017)	E3(Fadis 2018)	E4(Dire 2018)	E5(Qile 2018)	E6(Qile 2019)	
Bulki	10.99	7.23	11.73	9.50	16.20	8.88	10.75a
Shumaliz	12.46	6.61	9.04	4.27	8.60	7.38	8.06c
Werer961	14.17	5.32	14.06	5.75	9.05	7.05	9.23bc
Werer962	13.56	6.37	13.03	9.05	9.25	7.69	9.83ab
Roba	14.22	7.16	10.94	7.36	9.81	8.78	9.71ab
Babile2	12.68	6.72	12.96	11.18	9.46	8.79	10.30ab
Baha Jiddu	13.33	6.57	12.73	7.86	9.08	8.04	9.60ab
Local Variety	11.42	5.56	12.30	8.62	9.57	7.84	9.22bc
Mean	12.85	6.44	12.10	7.95	10.13	8.06	9.59

3.3. Additive Main Effects and Multiple Interaction (AMMI) model

AMMI analysis of variance for seed yield of eight groundnut varieties tested in seven environments showed that, environment, varieties and their interaction effects were highly significant at ($P<0.01$) (Table 3) demonstrating the importance of applying AMMI analysis to investigate the main effects of varieties and environment and the complex patterns of their interaction. The environment modeled significant effect on the seed yield of groundnut, which explained 48.67% of the total variation indicating the existence of a considerable amount of deferential response among the varieties to changes in growing environments and the differential discriminating ability of the test environments. GEI contribute 15.62% of total variation while the varieties contribute only 5.15% of the total variation. Similarly, Amare K. and Adisu G. (2017) were reported the analysis of variance showing variations of (8.8%) due to genotypes (69.8%) due to environment and (21.4%) due to GEI at ($P < 0.01$).

Table 3. Partitioning of the Explained Sum of square (Ex.SS) and Mean of square (MS) from AMMI analysis for seed yield of eight groundnut varieties evaluated at six environments

Source of variation	d.f.	Sum square	Ex Sum square	Mean square
Total	143	1587.1	100	11.1
Treatments	47	1101.9	69.43	23.45**
Genotypes	7	81.7	5.15	11.67**
Environments	5	772.4	48.67	154.47**
Block	12	174.3	10.98	14.53**
Interactions	35	247.9	15.62	7.08**
IPCA 1	11	136.1	8.58	12.37**
IPCA 2	9	74.3	4.68	8.25*
Error	15	37.5	2.36	2.5
Pooled Error	84	310.8	19.58	3.7

As reported by Purchase *et al*., 2000, genotype with least ASV score is the most stable varieties. Accordingly, Bulki and Babile2 were most stable and Werer 961 and Baha Jiddu were the most unstable (table 4). This measure is essential in order to quantify and rank varieties according to their seed yield stability. The least Genotype Selection Index (GSI) is considered as the most stable with high grain yield (Hagos *et al.*, 2011). Based on the GSI, the most desirable variety for selection of both stability and high seed yield was Bulki followed by Babile2. Based on grain yield mean values, Bulki variety rank first and Babile-2 second rank. According to AMMI stability value, Bulki variety had showed low value of ASV indicating that it is the most stable variety as compared to other varieties.

Table 4. $IPCA_1$, $IPCA_2$ scores, AMMI stability value and Genotype Selection Index of eight groundnut varieties

Variety	Mean yield	RYi	IPCA1	IPCA2	ASVi	RASVi	GSI
Bulki	10.754	1	-2.28129	0.2415	0.933	1	2
Shumaliz	8.06	8	0.23873	1.42978	1.80	3	11
Werer961	9.233	6	0.95733	0.24238	3.533	8	14
Werer962	9.826	3	0.43839	-0.56141	2.067	5	8
Roba	9.713	4	0.29972	0.69252	2.867	6	10
Babile2	10.301	2	0.04194	-1.23832	1.733	2	4
Baha Jiddu	9.601	5	0.48956	-0.11966	3.40	7	12
Local Variety	9.217	7	-0.18438	-0.68679	1.933	4	11

The stability and high yielding ability of the varieties is graphically depicted using the AMMI bi-plot. Environments E3 (Fadis 2018) and E1 (Fadis 2017) relatively had showed high IPCA scores, contributed largely to GEI. These environments were favorable for high yielding varieties based on mean yield as they had showed higher seed yield than the grand mean. Environment E2 (Erer 2017) is the least favorable environment for almost all the varieties with low yield and smaller $IPCA_1$ score (Fig 1). The variation of yield for each variety was significant at different environments. Varieties G1 (Bulki), G6 (Babile2) and G4 (Werer 962) were specifically adapted to high yielding environments (Fig 2). Considering the IPCA1 score, G2 (Shulamiz) was the most unstable variety and also adapted to higher yielding environments. G1 (Bulki) was more stable in comparison to other varieties. Generally, Fadis was the most favorable environment for ground nut production with maximum mean of yield potential.

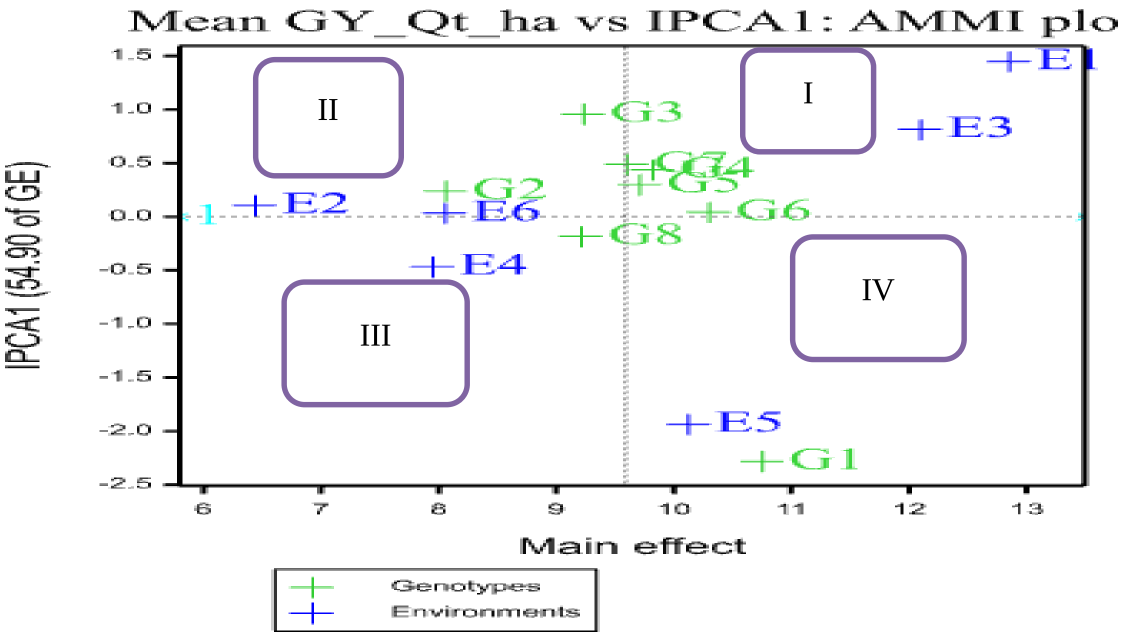

Figure 4 Biplot of interaction principal component axis ($IPCA_1$) against mean Seed yield of eight groundnut varieties and six environments

3.4. Genotype and Genotype by Environment interaction (GGE) bi-plot analysis

In GGE bi-plot (Figure 2), $IPCA_1$ and $IPCA_2$ explained 48.07% and 25.93% of variation, respectively, of groundnut variety by environment interaction and made a total of 74.00%. The other study conducted on the same crop showed 81.8% total of $IPCA_1$ and $IPCA_2$ (Guchi, E., 2015). Environments and genotypes that fall in the central (concentric) circle are considered as ideal environments and stable genotypes, respectively (Yan, 2002). A genotype is more desirable if it is located closer to the ideal genotype. Thus, using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype. Therefore, the ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important (Ashna, A., 2014). Fig. 2 revealed that G6 (Werer 962), which fell into the center of concentric circles, was ideal variety in terms of higher yielding ability and stability, compared with the rest of varieties. In addition, G1 located on the next concentric circle, may be regarded as desirable varieties. An environment is more desirable and discriminating when located closer to the center circle or to an ideal environment (Naroui *et al*., 2013). In the present study, E4 and E6 were the most discriminating and representative environments followed by E5 (Fig.2). E1 was non-discriminating and less representative sites. This implied that, varietal stability could be challenged not only due to the change in the test environment but also due to differential response of tested varieties per environment.

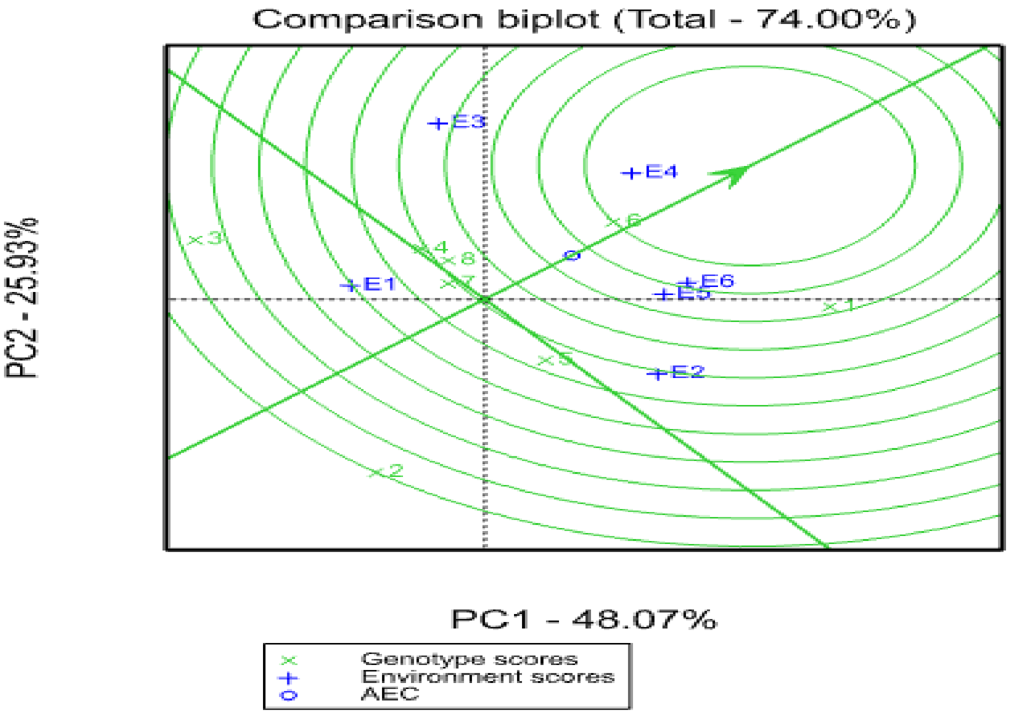

Fig. 2. The vector view of the GGE bi-plot based on environment focused scaling for environments to show relationship among testing environments.
G and E letters stand for genotypes and environments respectively.

3.5. GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability

Figure 3 provides the summary of the interrelationships among the environments. The varieties that connect the bi-plot origin and the markers for the environments are called environment vectors. The angle between the vectors of two environments is related to the correlation coefficient between them. The cosine of the angle between the vectors of two environments approximates the correlation coefficient between them (Sendekie, Y *et al*., (2014). Based on the angles of environment vectors, the six environments are grouped in to two groups. Group one includes E1 and E3 and Group two includes E2, E4, E5 and E6. For instance, the smallest angle between E1 and E3 is implying that there is the highest correlation between these two environments. The angle between E1 and E2; E3 and E2 are bigger than others showing the poor correlation between them (Figure 3). Two criteria are required to suggest existence of different mega-environments. First, there are different winning genotypes in different test locations. Second, the between-group variation should be significantly greater than the within-group variation, common criteria for clustering. Dividing the target environment into different mega-environments and deploying different genotypes in different mega-environments is the best way to utilize GE interaction.

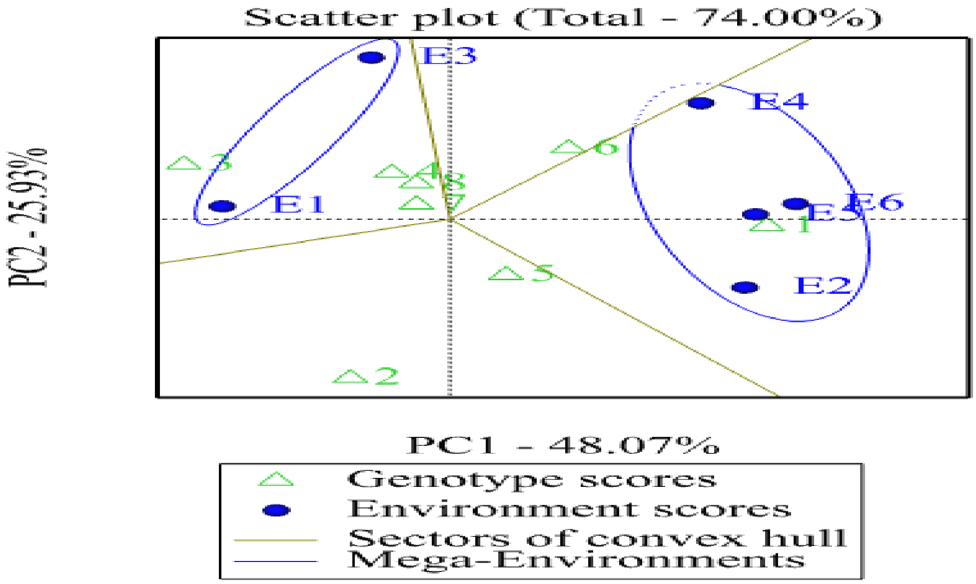

Fig. 3. GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability

Analysis of variance showed that, environment and genotype for seed yield were statistically highly significant differences (P<0.01) indicating the presence of genetic variation and possible selection of high yielding and stable varieties. The average environmental seed yield across varieties ranged from the lowest of 6.44 $Qtha^{-1}$ at E2 (Erer 2017) to the highest of 12.85 $Qtha^{-1}$ at E1 (Fadis 2017), with a grand mean of 9.59 $Qtha^{-1}$. AMMI analysis of variance for seed yield of eight groundnut varieties tested in six environments showed that environments, varieties and their interaction effects were significantly different (P<0.01). The environment modeled significant effect, which explained 48.67% of the total variation indicating the existence of a considerable amount of deferential response among the varieties to changes in growing environments and the differential discriminating ability of the test environments. Accordingly, Bulki and Babile2 were most stable and Werer 961 and Baha Jiddu were the most unstable. The stability and high yielding ability of the varieties has been graphically depicted by the AMMI bi-plot. Environments E3 (Fadis 2018) and E1 (Fadis 2017) relatively showed high IPCA scores, contributed largely to GEI. These environments were favorable for high yielding varieties based on mean yield as they had more than the grand mean. The variation of yield for each variety was significant at different environments. Varieties G1 (Bulki), G6 (Babile2) and G4 (Werer962) were specifically adapted to high yielding environments. G2 (Shulamiz) was the most unstable variety and also adapted to higher yielding environments. G1 (Bulki) was more stable in comparison to other varieties. Generally, Fadis was the most favorable environment for ground nut production with maximum mean of yield potential. In GGE bi-plot; $IPCA_1$ and $IPCA_2$ explained 48.07% and 25.93%, respectively, of groundnut variety by environment interaction and made a total of 74.00%. GGE bi-plot revealed that G6 (Werer 962), which fell into the center of concentric circles, was ideal variety in terms of higher yielding ability and stability, compared with the rest of varieties. In addition, G1 located on the next concentric circle, may be regarded as desirable varieties. In the present study, E4 and E6 were the most discriminating and representative environments followed by E5. E1 was non-discriminating and less representative sites.

Summary and Conclusion

Analysis of variance stated that significant variations were observed among the varieties for days to maturity, number of pods per plant, number of seeds per pod, and seed yield. The AMMI analysis showed highly significant variation ($P < 0.01$) for the Environment, Interaction and IPCA1; while Genotypes and IPCA 2 were showed significant variation ($P < 0.05$). GGE biplot analysis showed that G6 (Babile-2) and G1 (Bulki) were found in concentric circle showing high stability. AMMI analysis and GGE biplot analysis revealed that Babile-2 and Bulki are stable and high yielding varieties over the local variety. Therefore these varieties Babil-2 and Bulki were recommended for further multiplication

Reference

Amare Kebede and Adisu Getahun, 2017. Adaptability and Stability Analysis of Groundnut Genotypes Using AMMI Model and GGE-biplot. *Journal of Crop Science and Biotechnology* 20 (5): 343 ~ 349

Ashna, A., 2014. Screening of Groundnut (Arachis hypogaea L.) Genotypes for Heat Tolerance (Doctoral dissertation, Bihar Agricultural University, Sabour, Bihar).

Dereje Assefa,Muez Teare and Helge Skinnes, 2012. Natural Occurrence of Toxigenic Fungi Species and Aflatoxin in Freshly Harvested Groundnut Kernels in Tigray, Northern Ethiopia. *Journal of the Dry lands* 5 (1): 377-384

Ezatollah F, Hassan Z, Reza M. 2011. Evaluation of phenotypic stability in chickpea genotypes using GGE-Biplot. *Annals of Biological Research* 2 (6): 282-292.

FAO/WHO Expert Committee on Food Additives, Joint FAO/WHO Expert Committee on Food Additives. Meeting and World Health Organization, 2002. Evaluation of Certain Food Additives and Contaminants: Fifty-seventh Report of the Joint FAO/WHO Expert Committee on Food Additives (Vol. 57). World Health Organization.

Faostat, F.A.O., 2009. Statistical databases. *Food and Agriculture Organization of the United Nations*.

Guchi, E., 2015. Aflatoxin contamination in groundnut (Arachis hypogaea L.) caused by Aspergillus species in Ethiopia. *Journal of applied & environmental microbiology*, *3*(1), pp.11-19.

Hagos T, and Fetien A. 2011. Additive Main Effects and Multiplicative Interactions Analysis of Yield Performance of Sesame Genotypes across Environments in Northern Ethiopia. *Journal of the Dry lands* 4(1): 259-266

Mohammed, A. and Chala, A., 2014. Incidence of Aspergillus contamination of groundnut (Arachis hypogaea L.) in Eastern Ethiopia. *African Journal of Microbiology Research*, *8*(8), pp.759-765.

Naroui Rad, M.R., Abdul Kadir, M., Rafii, M.Y., Hawa, Z.E. and Jaafar, F.A., 2013. Genotype x environment interaction by AMMI and GGE biplot analysis in three consecutive generations of wheat. Triticum aestivum.

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.
Sendekie, Y., Abate, B. and Atinaf, M., 2014. Kernel Yield Evaluation of Groundnut (Arachis hypogaea L.) Genotypes in North Western Part of Ethiopia.
Sunday Clement O. Makinde, Omolayo Johnson Ariyo, and Raphael Ilesanmi Akinbowale, 2013. Assessment of groundnut performance in different environments using Additive Main effects and Multiplicative Interaction (AMMI) model. *Canadian Journal of Plant Breeding*. -1(2):60-66
Yan W, Rajcan I, 2002. Biplots analysis of the test sites and trait relations of soybean in Ontario. *Crop. Science*. 42:11-20.

Evaluation of Chickpea Kabuli type (*Cicerarietinum L)* Varieties for yield and yield related traits at Eastern Hararghe Zone

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Abstract
The present study was envisaged to assess the adaptability of seven improved chickpea kabuli type varieties viz.Arerti, Teji, DZ-10-4, Hora, Harbu, Chefe, Ejere along with one standard check (Shasho) at Fedis Agricultural Research Center on station at Eastern Hararghe zone. These varieties were sown in RCBD with three replications during 2018/19-2019/2020 in rain cropping season. Combined analyses of data from the two years (Bokko station) revealed highly significant varietal differences (P < 0.05) in grain yield, days to 50% flowering and seed per pod, pod per plant and plant height. However, there were no significant varietal differences observed in days to 95% maturity. Regarding the mean performances of varieties over the two years, Hora variety was the highest in grain yield (940.2 kg ht^{-1}), followed by Arerti (849.4 kg ht^{-1}). On the contrary, the lowest grain yield was obtained from Harbu (563.6 kg ht^{-1}).Therefore, based on the mean grain yield performance, Hora and Arerti varieties were recommended to chickpea growers in study area for further promotion.

Keywords: Adaptability, Chickpea, Yield and Varieties

1. INTRODUCTION

Chickpea (*Cicerarietinum* L.) is produced worldwide particularly India, Australia, Pakistan, Turkey, Myanmar, Ethiopia, Iran, USA and Canada and are considered as the main producers worldwide (ICRISAT, 2013). Ethiopia is the largest chickpea growing country in Africa, with a contribution of about 37% in area and 48% in production. Amhara and Oromia regions cover more than 90% of the entire chickpea area and constitute about 92% of the total chickpea production of the country (IFPRI, 2010). It is one of the major pulse crop cultivated in the country, which occupies about 233,440 hectares of land annually with estimated production of 3,120,800qt (CSA, 2010). The current average farm yield of chickpea in Ethiopia is about 55% of the yield potential of the crop, suggesting that farmers can still have rooms to substantially increase yield using improved practices (korbu, L., *et al*., 2020).

Chick pea has one of the highest nutritional compositions of among any dry edible legume. On an average, chickpea seed contains 23% protein, 47% starch, 56% fat, 6% crude fiber, 6% soluble sugar, and 3% ash (Munyua, B, 2013). According to Gaur, P. *et al*., (2008), the Ethiopian chick pea production is predominately about 95% by desi chickpea but in recent years, the interest of farmers in producing the large seeded kabuli varieties increasing due to domestic and export market. Having high protein content, it is so rich in zinc, dietary fiber, calcium, magnesium, phosphorus, potassium, iron and vitamins (Güler *et al*., 2001).

Climate change is projected to alter the growing conditions of chickpea in many areas and there would be substantial reduction in grain yield of the crop due to drought but CROPGRO-Chickpea model simulation indicated that chickpea grain yield could increase by12% and 13% during the 2030s and 2050s time periods without the direct effect of CO2 fertilization (Adem M. *et al*., 2016). The usage of improved seeds is one of the most efficient ways of raising crop production, but in Ethiopia less than 10% of farmers use improved seeds (FAO, 2010). However most of the cultivated especially extra-bold-seeded Kabuli varieties are poorly adapted. Lack of access to improved varieties in Eastern part of Ethiopia is the main problem that hampers production of this crop. Therefore, the present study was envisaged to assess the adaptability of improved Kabuli chickpea varieties that give best yield under agro ecology of Eastern Oromia.

2. MATERIALS AND METHODS

2.1. Description of the Experimental Site

The study was conducted under rain fed conditions for two consecutive years (2018 to 2019) at one location (Fadis; Bokko site), Fadis 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 meters above sea level, with a prevalence of lowlands. The area is situated at the distance of about 24 km away from Harar town in the southerly direction. The experimental area is characterized as midland climate. The soil of the experimental site is black with surface soil texture of sand clay loam. The mean rainfall is about 860.4 mm for the last five 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 maximum and minimum annual temperatures are 28.2 ^{0}C and 10.2 ^{0}C respectively, for the last five years (Fadis Agricultural Research Center Metrological station, 2013).

Treatments and Experimental Design

Seven Chickpea varieties were used as the experiment materials with one standard check. These planting materials includes, Arerti, Teji, DZ-10-4, Hora, Harbu, Chefe, and Ejere, were collected from Debrazeyit Agricultural research center and standard check (Shasho) was used. The experimental plots were laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental plots consisted of eight rows of 3 m length 3 m width and 0.4 m row space. The central six rows were harvested to estimate grain yield. The spacing between adjacent replications and plots were 1 m and 0.5 m respectively. Quantitative data (Flowering date, Maturity date, Plant height Pod per plant, Seed per pod and Grain yield (t/ha) were collected. Data were analyzed using Genstat statistical software package and mean values or Least Significant Differences (LSD) were compared using the procedures of Duncan's at the 5% level of significance.

Table1. List of chick pea (Kabuli type) varieties used as planting materials

No	Variety Name	Year of Release
1	Teji	2007
2	Monino	2009
3	Hora	2016
4	Harbu	2004
5	Arerti	1999
6	Chefe	2004
7	Ejeri	2005
8	Shasho (St. Check)	1999

3. RESULTS AND DISCUSSIONS

Combined analyses of data from the two years revealed that high significant varietal differences ($P < 0.05$) for grain yield, days to 50% flowering, seed per pod, pod per plant, plant height but not significant for days to maturity. Similarly (Ejigu, *et al.*, 2020) were reported significant variation among varieties for most agronomic traits.

Table.2 Combined mean of Seed yield and yield related for Chickpea (Kabuli type) over two years.

V. Name	Df	Dm	Dr	PH	P/P	nbp	S/P	hsw	GY (t/ha)
Teji	54ab	112	4.333a	35.2ab	18.8c	2.89ab	1.3bc	30.75a	1.11bc
Monino	56a	104	4ab	38.2a	26.1b	2.28b	1.0d	10.53d	1.13bc
Harbu	56a	103	4.5a	29.5c	18.2c	2.83ab	1.1cd	29.03a	1.06c
Hora	50b	102	1.67c	37.8a	36.6ab	3.56a	1.8a	28.93a	1.44a
Arerti	55a	110	3b	28.3c	39.2a	3.39ab	1.5ab	23.38c	1.35ab
Chefe	53ab	101	4.5a	33.6b	23.4bc	3.22ab	1.3bcd	29.65a	1.23a-c
Ejere	50b	107	4ab	33.6b	30.3a-c	3.11ab	1.4b	26.12b	1.10bc
Shasho(St.check	54ab	102	3.83ab	36.2ab	23.1bc	3.67a	1.1cd	25.5b	1.12bc
LSD (5%)	4.207	NS	1.432	3.007	14.05	1.467	0.3061	2.962	0.3
CV (%)	6.7	2.1	3.5	7.5	20.7	15.2	19.9	7.0	11.9

NB; Means with the same letter are not significantly different.,Df=days to flowering, Dm=days to maturity, Dr=disease reaction(pod borer), PH=Plant hieght, P/P=pod/plant, nbp number of branches/plant, S/P=seed/pods, hsw=hundred seeds weight and GY(t/ha)= Grain yield in tons/ha

However, no significant difference was observed in days to 95% maturity. Regarding the mean performances of varieties over the two year Hora was the highest in grain yield (940.2 kg ht-1) followed by Arerti (849.4 kg ht-1) while the lowest (563.6 kg ht^{-1}) obtained from Habru variety. Similarly (Ejigu, *et al*., 2020) MinjaVarieties showed a grain yield as high as 1087.5kg/ha and 873.79kg/ha. The presence of significant differences among varieties indicates the presence of genetic variability for each of the characters among the tested varieties. Similarly Goa, Y., (2014), and Alemu B. *et al. (*2014), reported that the significant difference among chickpea varieties for all traits. The highest number of pod per plant was obtained from Shasho, Hora and DZ-10-4 (39.2, 36.6, 36.1) respectively. While the lowest pod per plant was obtained from Teji (18.8) and Habru (18.2) varieties. **Similarly Gonzales** and Fernando R., (2014) reported that number of pod per plant were genetically influenced by the breeding material for development of chick pea cultivars developed in different environmental conditions. Another yield component measured was the mean number of days to 50% flowering. The days to 50% flowering was recorded significant ($P<0.05$) differences among varieties for (Table 1).The highest number of days to 50% flowering were recorded from DZ-10-4 (56.), Habru (56) and Arerti (54) while the lowest were from Hora (50) and Ejere (50) varieties. **Similarly** Goa, Y., (2014) who reported considerable variation in the plant height of different chick pea varieties when planted under various environments.
One of the other hand, yield component measured was the mean number of plant height were recorded significant ($P<0.05$) differences from, DZ-10-4 (38.2cm) and Hora (37.8cm). On the contrary, the lowest plant height was obtained from Arerti and Habru (28.3cm, 29.5cm) respectively. These results were further supported by Ines C. and Fernando R. (2014) who reported considerable variation in the plant height of different chick pea varieties when planted under various environments. The other yield components measured was the mean number of seed per pod were recorded significant ($P<0.05$) differences from, Monino (1.8). While the lowest seed per pod was obtained from Shasho (1.1) variety. Similarly, Tena Alemu, (2016) reported grain yield in pulse influence by number of pods and number of seed in pod.

4. Conclusion and Recommendation

Significant variation was inquired among varieties for different traits (days to flowering, plant height, pods per plant, seed per pod and seed yield). Pod/plant and seed/pod affects grain yield per hectare. Maximum grain yield (1.44 t/ha) was harvested from Hora followed by Arerti (1.35 t/ha). Therefore the variety (Hora) and Arereti was recommended for further multiplication in study areas and similar agro-ecologies.

Reference

Adem Mohammed, Tamado Tana, Piara Singh and Adamu Molla , 2016. Modeling climate change impact on chickpea production and adaptation options in the semi-arid

North-Eastern Ethiopia. Journal of Agriculture and Environment for International Development - JAEID, 110 (2): 377-395DOI: 10.12895/jaeid.20162.510

Alemu, B., Abera, D., Adugna, A. and Terefe, M., 2014. Adaptation Study of Improved Kabuli Chickpea (Cicer Arietinum L) Varieties at Kellem Wollega Zone, Haro Sabu, Ethiopia. *seed*, *4*(18).

Ejigu Ejara, Kemal Kitaba, Zinash Misganaa and Ganene Tesama, 2020. "Performance Evaluation of Chickpea Varieties (*Cicer arietinum* L.) at Bule Hora and Abaya Southern Ethiopia," Journal of Biotechnology Research, Academic Research Publishing Group, vol. 6(5), pages 34-40, 05-2020.

Federal Democratic Republic, 2010. Central Statistical Agency Agricultural Sample Survey.

Gaur, P.M., Kumar, J., Gowda, C.L.L., Pande, S., Siddique, K.H.M., Khan, T.N., Warkentin, T.D., Chaturvedi, S.K., Than, A.M. and Ketema, D., 2008. Breeding chickpea for early phenology: perspectives, progress and prospects.

Goa, Y., 2014. Evaluation of Chick Pea (Cicerarietinum L.) Varieties for Yield Performance and Adaptability to Southern Ethiopia. *Evaluation*, *4*(17).

Guler, M.; Adak, M.S.; Ulukan, H. (2001), Determining relationships among yield and some yield components using path coefficient analysis in chickpea (Cicer arietinum L.). European Journal of Agronomy, 4, p.161-166

korbu, L., Tafes, B., Kassa, G.*2020.* Unlocking the genetic potential of chickpea through improved crop management practices in Ethiopia. A review. *Agron. Sustain. Dev.* **40,** 13 (2020). https://doi.org/10.1007/s13593-020-00618-3

Munyua, B., Orr, A. and Okwadi, J., 2013. Open Sesame: A value chain analysis of sesame marketing in northern Uganda. *International Crops Research Institute for Sem-arid tropics (ICRISAT), Nairobi, Kenya*.

Adaptation Study of Improved Dessi Chickpea (*Cicerarietinum L)* Varieties at Eastern Hararghe Zone

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Abstract

The study was conducted at the Fedis Agricultural Research Center from 2018/9 to 2019/20 cropping season to evaluate adaptable and identify chick pea improved varieties at Eastern Hararghe. Eight improved dessi type chickpea varieties were evaauted in RCBD with three replications for two consecutive years. Combined analyses of variance from the two years (Boko station) revealed significant varietal differences (P < 0.05) in grain yield, plant height and pod per plant. However, there were no significant varietal differences observed for days to 95% maturity and seed per pod. Significant variation was also observed among the varieties for other traits. Highest seed yield was obtained from variety Dalota with grain *yield of 1.777 t/ha followed by Teketay (1.774 t/ha) and Fetenech (1.570 t/ha). On the contrary, the lowest grain yield was obtained from variety Mastewa (1.233 t/ha).Therefore, based on the overall performance, varieties Dalota and Teketay were recommended to chickpea growers in study area for further promotion.*

Keywords: Adaptability, Chickpea Yield, and Varieties

1. INTRODUCTION

Chickpea (*Cicerarietinum* L.) is the second most important pulse crop with 11.2 million cultivated areas in the world (Boyen, X. and Waters, B., 2006). Chickpea is one of the most economically important food legumes, and a significant source of proteins (Rani A. 2020) and It also experiences drought stress at various growth stages; terminal drought, along with heat stress at flowering and seed filling can reduce yields by 40–45%. It is a cool-season annual pulse crop that is grown in tropical, subtropical, and temperate regions of the world (Muehlbauer and Tulu, 1997). Most production and consumption of chickpea (95%) takes place in developing countries. It is also an excellent source of human and animal food and also plays an important role in the maintenance of soil fertility, particularly in the dry, rain fed areas (Katerji *et al*, 2001) and it fixes Rhzobium bacteria on roots(Akcin,1988). Chick pea is produced in various zones; some special woreda's and pocket areas in the Eastern Oromia Regional State, East Ethiopia. The reason for low yields in the region includes lack of improved chickpea varieties, resistance to a biotic and biotic stresses. Therefore the work was initiated with the objective of to identify adapted, stable and high yielding varieties with desirable agronomic traits for the study areas and similar agro-ecologies.

2. MATERIALS AND METHODS

2.1. Description of the Experimental Site

The study was conducted under rain fed conditions at one location (Fadis; Boko site). Fadis, is located at the latitude of 9° 07' North and longitude of 42° 04' East, in the middle and lowland areas with an altitude of 1702 meters above sea level, with a prevalence of lowlands. The area is situated at the distance of about 24 km away from Harar town in the Southerly direction. The experimental area is characterized as lowland climate. The soil of the experimental site is black with surface soil texture of sand clay loam. The mean annual rainfall is about 860.4 mm for the last five 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 temperatures are 28.2 ^{0}C and 10.2 ^{0}C respectively, for five last years (Fadis Agricultural Research Center Metrological station, 2013).

2.2. Treatments and Experimental Design

Eight chickpea varieties (Table 1) were used as the experiment materials with one standard check. These planting materials such as Natoli, Mariye, Minjar, Teketay, Dimtu, Dalota, Mastewa, Fetenech with one standard check (Worku) were collected from Debrezeyit Agricultural research center. The study was conducted under rain fed condition for two consecutive years during 2018 and 2019. The experimental plots were laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental plots consisted of eight rows of 3 m length, 3 m width and 0.4 m row space. The central six rows were harvested to estimate grain yield. The spacing between adjacent replications and plots were 1 m, and 0.5 m, respectively. All quantitative data (Flowering date, Maturity date, Plant height Pod per plant, Seed per pod and Grain yield (t/ha)) were collected. Data were analyzed using Gen STAT statistical software package and mean values were compared using Least Significant Differences (LSD) procedures of Duncan's at the 5% level of significance.

Table1. List of Chick pea varieties used during experimentation

No	V. Name	Year of Release
1	Teji	2007
2	Monino	2009
3	Hora	2016
4	Harbu	2004
5	Arerti	1999
6	Chefe	2004
7	Ejeri	2005
8	Shasho(St. Check)	1999

3. Results and Discussions

Analysis of variance (ANOVA) depicted that significant variations were observed for most traits considered in this study except for few traits.

Table2. Combined mean of seed yield and yield related components of Chick pea (Desi Type) over two years at Fadis Boko station.

V. Name	Df	Dm	PH	PPP	SPP	HSW	GY(t/ha)
Natoli	60.83ab	107.4	33.3bc	30.5b	1.3	25.33a	1.31c
Mariye	57.17ab	106.1	33.4bc	46.6ab	1.4	21.45b	1.37bc
Minjar	60.67ab	106.3	37.3ab	45.9ab	1.4	18b	1.35c
Teketay	54.83a	109.7	39.0a	53.8a	1.4	25.3a	1.74ab
Worku(St. check)	56.67a	109.7	35.5abc	37.4b	1.3	19.7b	1.34c
Dimtu	62.00ab	105.3	37.3ab	49.0a	1.3	28.63a	1.47bc
Dalota	55.83a	106.8	37.3ab	53.4a	1.2	25.82a	1.77a
Mastewa	65.17b	105.3	33.7bc	42.4ab	1.5	19.48b	1.23c
Fetenech	58.83ab	107.2	31.9c	49.4a	1.2	18.42b	1.57a-c
CV (%)	8.207	4.9	12.2	26.7	23.8	13.9	27.7
LSD (0.05)	11.9	NS	4.079	16.06	NS	5.167	0.38

N.B VN/ varietal name, DF/ days to 50% flowering, DM/ days to 95% maturity date, PH/pant height, PP/ pod per plant, SPP/ Seed per pod, GY/grain yield.

The results of analysis of variance based on randomized complete block design experiment for two years at Bokko station was presented in (Table.2). Combined analyses of data from the two year revealed that highly significant varietal differences ($P < 0.05$) in grain yield, days to 50% flowering, seed per pod, pod per plant, plant height. However, no significant varietal differences were observed for days to 95% maturity and seed per pod. Regarding the mean performances of varieties over the two years, variety Dalota was the highest in grain yield (1.777 t hec^{-1}), followed by Teketay (1.774 t hec^{-1}), while the lowest grain yield was obtained from variety Mastewa (1.233 t hec^{-1}*)*. The presence of significant differences among varieties indicates the presence of genetic variability for each of the characters among the tested varieties. Similarly Biru Alemu *et al. (*2014) were reported a significant difference among chickpea varieties tested and the highest grain yield harvested was from Arerti variety. One of the yield component measured was the mean number of pod per plant. The number of pod per plant was influenced significantly ($P<0.05$) and different varieties of chickpea varied markedly differ for their pod per plant. The numbers of pod per plant was highest for variety Teketay, followed by variety Fetenech, Dalota, and Dimtu, with grain yield values of 53.8, 53.4, 49.4 and 49 respectively. Another yield component measured was the mean number of days to 50% flowering. The days to 50% flowering was showed significant ($P<0.05$) differences among test varieties (Table 2).The highest number of days to 50% flowering was recorded from variety Mastewa (65.17), while the lowest was recorded from Teketay (54.83) variety. The other yield component measured was the plant height which showed significant ($P<0.05$) differences among the test varieties with the height value from variety Teketay (39cm). On the contrary, the lowest plant height was obtained from variety Fetenech (31.9cm). Also the presence of significant differences among varieties indicates the presence of high genetic variability for each of the characters among the tested varieties.

4. Conclusion and Recommendation

Seven chickpea varieties along with one standard check were evaluated for two years for yield and adaptability in Eastern Hararghe zone, Oromia. Differences among varieties were significant for grain yield and some other traits. From this study, it showed that varieties Dalota and Teketay had showed the highest yield as compared to other test varieties. Significant variation was obtained among the test varieties for different traits. Highest numbers of pods per plant was counted from variety Dalota which showed significant difference as compared to the standard check (Worku). Thus, variety Dalota is recommended for further demonstration and multiplication in the study area.

REFERENCES

Akcin A 1988. Edible pulses publications of Agril. Faculty of selcuk university No:8 konya-Turkey (in Turkish).

Katerji N,Van Hoorn JW,Hamdy A,Mastrorilli M,Owies T,Malhotra Rs(2001).Response to soil salinity of chick pea varieties differing in drought tolerance .Agri.water mange,50:83-96

Muehlbauer F.J., and Tullu A. 1997. CicerarietinumL.New Crop Fact SHEET. Center for New Crops and Plant Products, Purdue Univ

Boyen, X. and Waters, B., 2006, August. Anonymous hierarchical identity-based encryption (without random oracles). In *Annual International Cryptology Conference* (pp. 290-307). Springer, Berlin, Heidelberg.

Rani A,Devi P,Jha UC,Sharma KD,Siddique KHM and Nayyar H (2020). Developing Climate-Resilient Chickpea Involving Physiological and Molecular Approaches With a Focus on Temperature and Drought Stresses .Front. Plant Sci. 10:1759.doi: 10.3389/fpls.2019.01759

Genotypes by Environment interaction on Yield of groundnut in Eastern Hararghe, Oromia

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Abstract

Performance of 12 genotypes of groundnut was evaluated under six environments in four locations using Additive Main effects and Multiplicative Interaction (AMMI) analysis. The mean squares of the analysis of variance revealed highly significant genotypes and G×E interactions on seed yield per hectare. Differences between environments accounted for 53.25% of the total variation while genotype accounted for 43.73% of the total variation. The biplot accounted for 84.93% of the total variation. The AMMI model identified genotypes 19748 and 19750 as most stable. Thus, these genotypes are considered as the best genotypes for the study areas. The candidate variety 19748 is stable and high yielder having about 18% of yield advantage than the standard check Babile-2.Therefore, this genotype is identified as a candidate variety for verification in the coming cropping season for possible release.

Key words: - AMMI, biplot, candidate and variety

1. Introduction

Groundnut (*Arachis hypogaea* L.) plays an important role as a food as well as a cash crop in Ethiopia. The crop is best adapted to well drained, loose, finable, medium texture soils (Asif R. *et al*., 2017).Similarly the study areas were characterized by well drained, loose with medium soil texture. Groundnut is rich in very essential source of oil (43-55%) and protein (25-28%), hence used as food and feed (Din *et al*. 2009). Groundnut is a good source of edible oil as it contains about 50% oil of good quality. Groundnut oil is one of the best cooking oils due to its high smoking point and is desirable for use in ghee, margarine, shortening and salad oil. The meal contains 25% protein and considered best meal for human consumption and livestock feed. Groundnut is also an excellent source of vitamins and contains high levels of thiamine, riboflavin and niacin (Asif R. *et al*., 2017).

Currently the crop is becoming one of the high value crops that are growing in the lowlands areas of the eastern Oromia. Particularly, Gursum, Babile, Fadis, Midhaga tola and other lowland areas of eastern Hararghe. However, despite the importance of the Groundnut among smallholder farmers in the country, its production has continued to decline due to the absence of improved Variety, presence of pests and diseases. Therefore this study undertaken to identify and release; stable, high yielding, tolerant to major diseases and other a biotic stresses genotypes with better agronomic performances (traits).

2. Materials and Methods

2.1. Experimental area

The study was conducted at four locations viz.FARC on station “Bokko”, FARC sub-station “Erer”, MARC station and Diredawa for two years (2018-2020).

2.2. Experimental Materials

Eleven Groundnut genotypes along with one standard check variety (Babile-2) were used. The materials were collected from Ethiopian Biodiversity Institute and developed in to pure line in the past breeding stages. Lists of the test genotypes are indicated in the Table 1 below.

Table1 List of groundnut genotypes used as planting materials during the study

G. Code	Genotypes name	Source the Genotypes	G. Code	Genotypes name	Source the Genotypes
G1	19739	EBI	G7	19768	EBI
G2	19750	EBI	G8	19769	EBI
G3	19749	EBI	G9	19770	EBI
G4	19748	EBI	G10	19776	EBI
G5	19753	EBI	G11	24208	EBI
G6	19755	EBI	G12	Babile-2 St check	EBI

NB: - EBI=Ethiopian Biodiversity Institute

2.3. Experimental Design

The field experiment was laid out in RCBD designs with three replications. The experimental plots consisted of six rows of 4 m length with row spacing of 60 cm and 10 cm between plants. The spacing between adjacent replications, blocks and plots were 1 m, 1 m and 0.5 m, respectively. The central four rows were harvested to estimate grain yield. All the recommended agronomical practices such as fertilizer application, weeding, hoeing, harvesting and threshing were undertaken to raise the healthy crop.

2.4. Data Collection

Days to maturity, pod per plants, seed per pod, number of branches per plants and grain yield were collected and analysed.

2.5. Analysis of variance (ANOVA)

Analysis of variance was carried out using Proc lattice and Proc GLM procedures of SAS version 9.0, (SAS, 2002). The differences among treatments means were compared using DMRT at 5% probability level. The AMMI stability value (ASV) as described by Purchase (2000) was calculated as follow:-

ASV=

$$\sqrt{[(IPCA1sum\ of\ square \div IPCA2sum\ of\ square)\ * IPCA1score]\,2\ +\ (IPCA\,2\,Score)\,2}$$

3. Results and Discussions

3.1. ANOVA for seed yield and yield related traits

Analysis of variance revealed that location, year and interaction of location by year were showing highly significant variation, while Genotypes, Genotypes by Location and interaction of Genotypes and location by year shows significant variation. Similarly, Danquah *et al*., (2017) reported highly significant effects of genotype, environment, and genotype by environment interaction were observed for traits studied.

Table2. Analysis of variance Seed of Groundnut tested across years and location

Source of variation	d.f.	Sum square	Mean square	F pr.
Replication	2	37.02	18.51	
Genotypes	11	377.85	34.35	0.003
Location	3	6652.75	2217.58	<.001
Year	1	1180.41	1180.41	<.001
Genotypes*Location	33	774.11	23.46	0.005
Genotypes*Year	11	146.45	13.31	0.382
Location*Year	1	159.55	159.55	<.001
Interaction	11	293.85	26.71	0.019
Residual	142	1750.86	12.33	
Total	215	11372.85		

ANOVA showed significant variations among the test genotypes for days to maturity, number of pods per plant, number of seeds per pod, hundred seeds weight and seed yield.

Table 3. Combined mean of seed yield and other parameters for GXE, of Groundnut at three locations over two years

Genotypes	Days to Maturity	Pods/plant	Seeds/pod	HSW(g)	Seed yield(qt/ha)
19739	173.9a	54.88ab	1.83bc	42.48e	20.1d
19750	172.5ab	59.61a	1.83bc	50.94ab	23.78ab
19749	172.9ab	51.52bc	1.87ab	49.58bc	21.26cd
19748	174.8a	55.37ab	1.91ab	52.98a	24.12a
19753	172.0ab	55.26ab	1.83bc	49.18bc	21.95a-d
19755	171.8ab	51.86bc	1.89ab	45.28d	20.5d
19768	173.0ab	55.37ab	1.87ab	48.49bc	21.28cd
19,769	173.6a	49.29b-d	1.91ab	48.70bc	21.6b-d
19770	171.9ab	54.69ab	1.86a-c	48.92bc	21.48cd
19,776	172.9ab	47.85cd	1.86a-c	51.01ab	22.95a-c
24208	173.9a	50.21b-d	1.78c	48.28c	21.24cd
Babile-2	169.6b	44.37d	1.92a	49.11bc	20.07d

CV	3.5	20.9	8.2	8.8	16.7
LSD	3.699	6.68	0.1	2.6	2.217

Maximum number of pods per plant was obtained from the genotype G4 (59.61) followed by G2 (55.37), G7 (55.37) and G5 (55.26) whereas the minimum number of pods per plant was obtained from standard check Babile-2 (44.37). Similar report was also reported by Borkar and Dharanguttikar (2014).The genotypes, ICG-8075 (43.90), ICG-8539 (42.00) and ICG-8506 (41.40) recorded highest number of pods per plant. Significant variation was also observed for hundred seeds weight among the genotypes. Accordingly, highest seed weight was measured for G2 (52.98) and followed by G10 (51.01) and G4 (50.94) While, minimum weight of hundred seeds weight was measured from G1 (42.48). Highly significant variations were obtained among the genotypes for seed yield. Accordingly three genotypes namely G2 (19748) (2.4 ton ha^{-1}) G4 (19750) (2.38 ton ha^{-1}), and G10 (19776) (2.29 ton ha^{-1}) are a stable, and high yielding genotypes with yield advantage of 18%, 15% and 12% over the standard check, G12 (Babile-2) (2.01ton ha^{-1}) respectively.

3.2. Mean seed yield of groundnut Genotypes

Significant variation was found among the genotypes for seed yield (Table2). According maximum seed yield was harvested from G4 (19748) 24.12qt/ha followed by G2 (19750) 23.78qt/ha.

Table 4. Mean performance of Seed yield of Groundnut Genotypes across testing environments in regional variety trial against standard checks over locations and years

	Testing Environments							
Genotypes	(E1)Fadis 2018	(E2)Dire 2018	(E3)Mechara 2018	(E4)Dire 2019	(E5)Fadis 2019	(E6)Erer 2019	E7(Mechara 2019)	Mean
19739	10.69	17.78	29.78	16.71	19.5	16.1	30.15	20.
19750	15.16	16.85	36.11	25.49	19.33	25.13	28.37	24
19749	15.07	13.18	35.78	15.05	21.18	17.67	30.93	21
19748	17.04	14.92	26.78	25.84	24.98	22.79	36.52	24
19753	9.38	15.55	33.67	17.06	23.9	18.38	35.7	22
19755	11.71	17.85	34.22	17.62	16.87	15.44	29.81	21
19768	13.26	13.44	35.67	15.4	21.27	15.72	34.19	21
19,769	14.28	15.92	31.37	17.42	21.04	17.93	33.22	22
19770	16.45	12.7	33.22	16.9	21.39	19.64	30.04	22
19,776	16.49	16.05	30.07	24.55	20.17	20.61	32.74	23
24208	10.57	13.89	29.85	18.73	22.61	18.05	35	21
Babile-	12.79	15.44	32.22	16.24	24.63	16.26	26.41	20
Mean	10.69	17.78	29.78	16.71	19.5	16.1	30.15	22

A large yield variation explained by environments also indicated the existence of diverse mega environments, i.e., a group of environments which share the same cultivars that consistently performed the best with large differences among environmental means, causing most of the variation in grain yield (Tolessa, *et al.*, 2013). The average environmental seed yield across genotypes ranged from the lowest of 10.69 Qtha^{-1} at E1 (Fadis 2018) to the highest of 30.15 Qtha^{-1} at E7 (Mechara 2019), with a grand mean of 21.69 Qtha^{-1}(Table 4). The genotype average Seed yield across environments ranged from the lowest of 20.1 Qtha^{-1} for G1 (19739) to the highest of 24.12 Qtha^{-1} for G2 (19748) (Table 4). This difference could be due to their genetic potential of the genotypes. G2 (19748) was the top ranking genotypes at three environments E1 (Fadis 2018), E4 (Diredawa 2019) and E7 (Mechara 2019) as well as G4 was ranked first at two environments E3 (Mechara 2018) and E6 (Erer 2019).

3.3. Additive Main Effects and Multiple Interaction (AMMI) model:

The Groundnut yield data were subjected to AMMI analysis which is a combination of analysis of variance and multiplication effect analysis. Briefly, analysis of variance is used to partition variance into three components: genotype deviations from the grand mean, environment deviations from the grand mean, and GE deviations from the grand mean. Subsequently, multiplication effect analysis is used to partition GE deviations into different interaction principal component axes (IPCA), which can be tested for statistical significance through ANOVA.

Table 5: Analysis of variance for grain yield using AMMI model

Source of variation	df	Sum square	Mean square	%TSS
Total	251	16508	65.8	
Treatments	83	14265	171.9**	11.55
Genotypes	11	372	33.8*	43.73
Environments	6	12351	2058.4**	53.25
Block	14	300	21.5	1.57
Interactions	66	1543	23.4**	1.72
IPCA 1	16	619	38.7**	3.32
IPCA 2	14	449	32*	1.96
Error	36	475	13.2	0.92
Pooled Error	154	1942	12.6	

*, ** significant at 0.05 and 0.01 probability levels, respectively df= degree of freedom, IPCA1=Interaction Principal Component Axis

The importance of applying AMMI analysis to investigate the main effects of genotypes and environment and the complex patterns of their interaction was demonstrated through this experimental study. AMMI analysis of variance for seed yield of twelve groundnut genotypes tested in seven testing environments showed that environments, IPCA 1 and their interaction effects were significantly different (P<0.01) (Table 5). The Environment significant effect on the seed yield of groundnut, which explained 53.3% of the total variations while, the genotypes contributed 43.7% of the variation. This indicate the existence of a considerable amount of deferential response among the genotypes to changes in growing environments and the differential discriminating ability of the test environments. Similar result was reported by (Rezene, Y *et al.*, 2014). The interaction of the twelve groundnut genotypes with six environments was best predicted by the first 2 principal components of genotypes and environments. $IPCA_1$ was also statistically significant ($P<0.01$) while PCA2 statistically significant ($p<0.05$) and explaining 3.32% and 1.96% for seed yield (Table 5). Because of their maximum, the first two principal components ($IPCA_1$ and $IPCA_2$) were used to plot a two-dimensional GGE bi-plot (Amare *et al.*, 2014) suggested that the most accurate model for AMMI can be predicted by using the first two IPCAs.

Table 6. Analysis of variance using AMMI model for grain yield and other yield related characters

Source of variation	df	DM	PPP	SPP	HSW	GY
Total	251	253	173.1	0.03597	26.58	65.8
Treatments	83	691**	275.3**	0.06236**	42.83**	171.9**
Genotypes	11	37*	362.4**	0.03668	153.47**	33.8*
Environments	6	9117**	986.7**	0.55658**	126.92**	2058.4**
Block	14	63	159.7	0.03131	8.96	21.5
Interactions	66	34	196.1*	0.02171	16.74	23.4**
IPCA 1	16	73	405.2**	0.03704	43.23	38.7**
IPCA 2	14	39	175.9	0.02417	14.96	32*
Error	36	14	111	0.01394	5.67	13.2
Pooled Error	154	34	119.3	0.02217	19.43	12.6

Analysis of variance for AMMI shows highly significant variation for Environment in number of pods per plant, number of seeds per pods, hundred seeds weight and seed yield traits. Significant variations for genotypes in terms of days to maturity, number of pods per plant and number of seeds per pod.

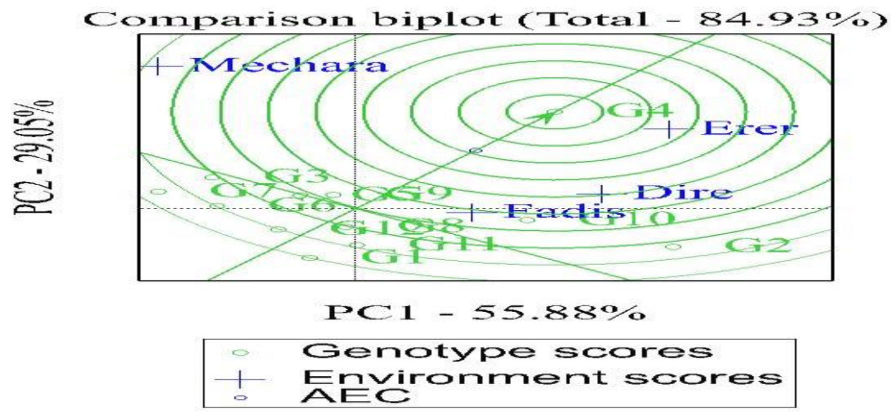

Figure 5 GGE Biplot of the seed yield of Groundnut tested at different locations and Years

Environments and genotypes that fall in the central (concentric) circle are considered ideal environments and stable genotypes, respectively (Yan, 2002). Accordingly the genotype found in the concentric circle G4 was most stable, and high yielding.

4. Conclusion and recommendation

ANOVA revealed that significant variation were obtained among the varieties for genotype, environment and their interaction. AMMI analysis shows highly significant (P< 0.01) variation for Environment, Interaction and IPCA1 while Genotypes and IPCA 2 shows significant (P< 0.05). The candidate variety 19748 is stable and high yielder having about 18% of yield advantage than the standard check Babile-2. Then suggested to release as a commercial variety.

Reference

Asif R, Zafar H., Kamran K., and Anjum,2017. Evaluation of Groundnut Varieties for the Agro-Ecological Zone of Malak and Division. International Journal of Environmental Science National Research. 5(5): 555671. DOI: 10.19080/IJESNR.2017.05.555671.

Borkar V., and Dharanguttikar V.M, 2014. Evaluation of Groundnut (*Arachis hypogaea* L.) Genotypes for Physiological Traits. *International Journal of Scientific and Research Publications*, 4(1)

Danquah, Joseph Manu-Aduening, Vernon Edward Gracen, Isaac Kwadwo Asante, and Samuel Kwame Office, 2017. AMMI Stability Analysis and Estimation of Genetic Parameters for Growth and Yield Components in Cassava in the Forest and Guinea Savannah Ecologies of Ghana

Din N., A Mahmood, G., Khattak, I. Saeed, M. Hassan 2009. High yielding groundnut (Arachis hypogaea L) variety Golden. Pakistan Journal of Botany 41(5): 2217-2222

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.

Rezene, Y., Bekele, A., and Goa, Y. 2014. GGE and AMMI biplot analysis for field pea yield stability in SNNPR state, Ethiopia. *Internal. Journal. Sustainable. Agricultural. Research*, *1*(1), 28-38.

Tolessa, T., Keneni, G., Sefera, T., Jarso, M. and Bekele, Y., 2013. Genotype× environment interaction and performance stability for grain yield in field pea (Pisum sativum L.) genotypes. *International Journal of plant breeding*, *7*(2), pp.116-123.

Yan, W. and Kang, M., 2002. *GGE biplot analysis: A graphical tool for breeders, geneticists, and agronomists*. CRC press.

Genotype by environment interaction and yield stability analysis ofearly maturing Sorghum [*Sorghum bicolor* (L.) Moench] Genotypes in Eastern Hararghe zone, Ethiopia

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Abstract
Sorghum [Sorghum bicolor (L.) Moench] *is the second most important cereal food crop in Ethiopia after maize. It* is a high-yielding, nutrient-use efficient, and drought tolerant crop that can be cultivated on over 80 percent ofthe world's agricultural land. However, a number of biotic and abiotic factorsare limiting grain yield increase. *In spite of biotic and abiotic stress tolerance, the procedures in the selection of good performing and stable genotypes are complicated by the phenomenon of genotype by environment interaction. The present study was done with the objectives to estimate genotype by environment interaction and to determine the stable and high yielder early maturing sorghum genotypes suitable for low moisture stress areas of Eastern Hararghe and similar agro-ecologies. A total of six (6) sorghum genotypes including one standard check (Dekeba) were evaluated for three years and two locations during 2016/17, 2017/18 and 2019/20 main cropping season. The experiment was laid out in Randomly Completed Block Design (RCBD) with three replications and on plot size of 5 m x 5 m.* The combined analysis of variance across environments revealedhighly significant differences among environments, genotypes and non-significant for G × E interactions of grain yield suggesting no further analysis of the G × E interaction. *Analysis of variance revealed that considerable variation for all traits except days to physiological maturity was observed among the genotypes across locations and years. The highest grain yield was recorded from the genotypes of IESV92168-DL (39.15 Qt/ha), 2005MI5064 (37.64 Qt/ha) and 2005MI5081 (37.29 Qt/ha) respectively. These genotypes are also high yielder and more stable across environment and thus recommended to be verified for possible release.*

Key words: Genotype, Additive Main Effect and Multiplicative Interaction(AMMI), Genotype and Genotype by Environment (GGE), Genotypes &Stability

Introduction

Sorghum [Sorghum bicolor (L.) Moench] is a high-yielding, nutrient-use efficient, and drought tolerant crop that can be cultivated on over 80 percent of theworld's agricultural land. Its geographic distribution spans temperate to tropicalclimates, and its rich genetic diversity allows for multiple specialized uses. Sorghum is cultivated in dry lowland, intermediate and highlandagro-ecological zones of Ethiopia(Gorfu *et al.,* 2011).The crop has a wider agro-ecological adaptation, however, is best suited and widely grown in the dry land areas, where water scarcity is limiting for crop production.Sorghum is considered as major food security crop in Ethiopia which is contributing 18% of the total grain production (USDA,2017).

Globally, sorghum is the fifth most important cereal crop after rice, maize,wheat and barley (FAOSTAT, 2019) and its production is estimated to be 62.3 million tons from42 million hectares of land (USDA, 2017). Whereas, in Ethiopia it ranks third in area coverage after maize and teff and it has a contribution of 16.4% of the total annualcereal grain production. Currently sorghum is produced by 6 million holdersand its production is estimated to be 5.1 million metric tons from 1.9 millionhectares of land giving the national average grain yield of around 2.71 tons perhectare (CSA, 2018).

Sorghum is the most important crop in the moisture deficit areas of eastern Hararghe. It is used as whole flour mostly for making injera. The flour is also used for the preparation of kita (non-fermented unraised bread or unleavened bread) and porridge (CSA, 2018). Besides the grain, sorghum straw is an important feed for livestock. However, the productivity of sorghum is low 1520 kg/ha (CSA, 2018). Hence, variety development considered dual purpose interest both grain and biomass yield.

The low productivity is contributed by drought, poor soil fertility and lower-yielding varieties.Because of the significance of sorghum for food security in the drought prone areas, development of early maturing varieties with reasonable yields have been a main focus of breeding programs in Ethiopia and in Sub-Saharan Africa (Adugna, 2007; Mekbib, 2006).

Ethiopia has a wealth of sorghum genetic resources that could be used for increasing productivity and nutritional quality of sorghum. Exploitation of genetic variability is the most important tool in plant breeding, and this has to be inferred by phenotypic expression. The consequences of the phenotypic variation depend largely on theenvironment. This variation is further complicated by the fact that not all genotypes react similar ways to the changing environment. If relative performance of genotypes is different in different environments, then G × E interaction becomes a major challenge to crop improvement. Genotype by environment interaction is the variation arising from the lack of correspondence between the genetic and non-genetic effects in multi-location trials

Therefore, theobjectives of the present study were to estimate genotype by environment interaction and todetermine the stable and high yielder early maturing sorghum genotypes suitable for low moisture stress areas of Eastern Hararghe and similar agro-ecologies.

Materials and Methods

Plant materials and experimental design

The experiment was conducted at twolocation of Eastern Hararghe (Fadis and Erer) for three years under rain fed. A total of six (6)sorghum genotypesincluding one potential variety as standard check (Dekeba) were used as experimental materials and evaluated for three consecutive years(2016/17, 2017/18 and 2019/20) during main cropping season (Table 1). The genotypes were obtained from Malkassa Agricultural Research Center (MARC) as breeding lines during the initial breeding stage of evaluation as epreliminary observationnursery.Thefield experiment was conducted using Randomly Completed Block Design (RCBD) with three replications. Each variety was sown in plotsize of 5 m x 5 m with a distance between rows and plants of 75 cm and 15-20 cm respectively. Fertilizer wasapplied at the rate of 100/100 kg/ha of NPS and Urea in which all NPS was applied at sowing and Urea was applied at knee height. All agronomic and crop management practiceswere applied uniformly to all genotypes as per the recommendation for sorghum.

Table 1: Lists of early maturing sorghum genotypes with their pedigree name used as experimental materials

No.	Genotype name	Pedigree name
1	IESV92168-DL	IESV 92168-DL
2	2005MI5064	WSV387 X P9404

3	12MW6440	Local Bulk (White)X SRN-39X76 T1/#23
4	12MW6469	IESV 92084 X E-36-1
5	2005MI5081	3443-2- OP X P9403
6	Dekeba (S.check)	

Data Collection

Data were collected from both plot base and plant base. Days to 50% flowering, Days to physiological maturity, thousand seed weight (TSW), grain yield were collected from plot base and panicle length and plant height was collected from plant base.

Statistical Data Analysis Methods

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 statisticalsoftware.The combined ANOVAfor this experimentwas conducted by using the following linearAdditive model:

$$y_{ijr} = \mu + \alpha i + \beta j + \alpha\beta ij + b_j + \varepsilon_{ijr}$$

where yijr, is the value of the dependent variable of genotype i in environment javerage over block r, μ is overall mean, αi is the effect of the ith genotype in the jthenvironment, βj is the effect of the jth environment for all genotypes, αβij is theeffect of the ith genotype by the jth environment, bj is the block effect at the jth environment and εijr is the residual error term.

The combined ANOVA method sufficiently identified G × E interaction as asignificant source of variation but it is not able to explore the nature of G × Einteraction which could not show the true performance of genotypes in certainenvironments (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).

$$\mathbf{Yij = \mu + Gi + Ej + (\Sigma KnUniSnj) + Qij + eij}$$

Where (i = 1, 2,…35: j = 1, …6); Yij = The performance of the i genotype in the jenvironment; μ = The grand mean; G = Additive effect of the i genotype (genotype meanminus the grand mean); K = Eigen value of the PCA axis n; E = Additive effect of the jthenvironment (environment mean deviation); U and S = Scorer of genotype i and environmentj for the PCA axis n; Q = Residual for the first n multiplicative components and; e = error.

AMMI stability analysis

An initial analysis of variance was performed for each environment to verify the existence of differences between varieties. After these analyses, the homogeneity between residual variances was determined, and a joint analysis of variance was used to test the genotype and environment effects and the magnitude of the G×E interaction. AMMI analysis was used to adjust the main or additive genotype and environmental effects by analysis of variance, in addition to the adjustment of the multiplicative effects for the G×E interaction by principal component analysis.AMMI is the best model to estimate stability of genotypes grown in multi environment trial due to its degree of visualizing GEI in graphic structure and separate the additive portion from interaction by the analysis of variance.

Once the AMMI model had been selected, we investigated the adaptability and phenotypic stability using biplot graphs. Biplot graph interpretation is based on the variation of the additive main effects (genotype and environment) and the multiplier effect of the G×E interaction. The abscissa represents the main effects (average of varieties evaluated), and the ordinate the interactionamong the axes (IPCA). In this case, the lower the IPCA value (absolute value) the lower the contribution of the G×E interaction and the greater the genotype stability. An ideal genotype is one with a high yield and IPCA values close to zero. An undesirable genotype is one with low stability, which is associated with low yields. The average predictions were estimated according to the AMMI model selected.

RESULT AND DISCUSSION

Analysis of Variance

The analysis of variance showed significant differences among the tested genotypes ($P < 0.05$) for all the traits measured. However, mean squares for replication were not significant for all the traits measured (Table 2). The tested genotypes have showed highly significant variation ($P \leq 0.001$) days to 50% flowering, plant height, panicle length and grain yield, whereas, days to physiological maturity was not significantly different ($P > 0.05$) for the evaluated genotypes across years and locations. Significance variation was recorded on genotypes evaluated across years and different location for all parameters evaluated except plant height which was not significant across years. The interaction of genotype by environment and genotype by location was not significant for grain yield showing genotypes performed very well and similar across location and years.

Table 1: Combined mean ANOVA of mean square over seasons and locationsfor the tested traits

Source of variation	df	Mean Squares				
		DtF	DtM	PLH(cm)	PL(cm)	Yield
Rep	2	6.619^{ns}	107.53^{ns}	415.1^{ns}	0.775^{ns}	1037900^{ns}
Genotype(G)	5	78.758***	48.21^{ns}	5305.2***	18.918***	43360708***
Location (L)	1	746.815***	2380.08***	16789.3***	30.542**	4321315***
Year(Y)	2	943.287***	5279.36***	126.5^{ns}	60.806***	355095***
G x L	5	12.63^{ns}	47.64*	845.9***	13.503**	254789^{ns}
G x Y	10	19.602***	15.93^{ns}	265.8*	6.259^{ns}	2830220^{ns}
L x Y	2	152.343***	165.19***	8602.5***	136.385***	759519***
G x L x Y	10	7.675^{ns}	23.76^{ns}	848.1***	9.062*	759519**
Residual	70	5.514	16.92	132.9	3.631	321116

df = degree of freedom, DtF= Days to flowering DtM= Days to Maturity, PLH= Plant height, PL= Panicle Length, ***and ** = Significant at 0.001 and 0.01 probability levels, respectively, ns = non-significant at 5% probability level.

Mean Performance of Test Genotypes

Combined mean analysis of variance (ANOVA) showed significance variation of the genotypes for all traits evaluated except days to maturity. The overall mean grain performance of all genotypes across all two environments and three yearswas 3053.5 kg/hawith a range 30.19 to 39.15Qt/ha. Comparingthe test genotypes with the standard check variety Dekeba, four genotypeshad performed better than the check with a grain yield advantage which rangedfrom 1.29% to 21.94% (Table 3).

Table 3: Combined mean performance of 6 test genotypes including standard check for agronomic traits

Genotypes	DF	DM	PH(cm)	PL(cm)	TSW(g)	GYLD(Qt/ha)
3443-2- OP X P9403	83.78 a	133.7	163.7 ab	22.71 abc	30.41 b	37.29 ab
Dhakaba (S. Check)	84.44 ab	132.3	120.8 c	23.87 ab	32.31 ab	30.56 c
IESV 92084 X E-36-1	82.94 a	130.4	159.6 ab	21.96 bc	34.41 ab	30.19 c
IESV 92168-DL	82.62 a	129.2	164.4 ab	23.29 abc	34.98 a	39.15 a
Local Bulk (White)X SRN-39X76 T1/#23	88.35 b	132.3	165.5 a	24.03 a	30.37 b	30.96 bc
WSV387 X P9404	85.31 ab	132.6	157.7 b	21.5 c	35.72 a	37.64 a
LSD (5%)	4.00	NS	16.10	1.98	4.50	6.35
CV%	7.2	9.3	15.6	13.1	20.7	28.0

The genotype with a pedigree name of IESV92168-DL gave thehighest mean grain yield (39.15 Qt/ha) across location and years followed by genotype WSV387 X P9404 and 3443-2- OP X P9403 with a mean grain yield of 37.64 and 37.29 Qt/ha respectively. The result showed significant variation in days to flowering among the tested genotypes across year and location. The overall average days to flowering was 85 days with a range of 82.62 days for the genotype IESV 92168-DL to 88.35 days for the genotype Local Bulk (White)X SRN-39X76 T1/#23 (Table 3). Genotypes IESV 92084 X E-36-1, 3443-2- OP X P9403 and WSV387 X P9404 were earlier in days to flowering and were not statistically significant from the earliest genotype IESV 92168-DL and standard check (Dekeba).

The overall mean plant height was 155.3 cm, Local Bulk (White)X SRN-39X76 T1/#23 being the tallest genotype with height of 165.5 cm followed by IESV 92168-DL and 3443-2- OP X P9403 genotypes with a mean values of 164.4 and 163.7 cm respectively. The standard check variety Dekeba had the lowest mean plant height (120 cm) (Table 3). This may be in line with Hesse and Lenné (1999) who stated that variability in plant height among sorghum progenies was attributed to genetic differences.

Additive main effect and Multiplicative interaction (AMMI)

The results showed that there werehighly significant ($p \leq 0.001$) differences among genotypes, environments (Table 4). The proportion of the variability accounted by theenvironment; genotype and G × E interaction contribution of each source ofvariation varies enormously. The AMMI analysis of variance for grain yield revealed that the largest sources of variation are attributed toenvironment effects (52.64%) of the total sum square (TSS). Genotype and GEI contributed 14.07% and 10.88% of the total sum of squares, respectively. Large proportions of variability explained by environmental effects obviously indicate that the larger contribution of the environmental effects on the sorghum performance. Since the combined analysisof variance only depicts whether the G × E interaction component is significantor not, further analysis to identify the stable and widely adapted genotypes isrequired. In this case, we analyzed the data using AMMI and GGE biplot.

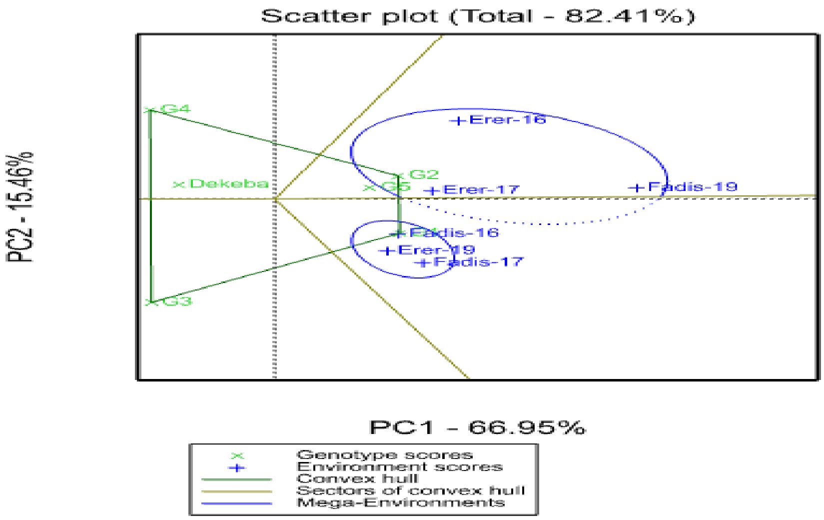
Table 5: AMMI G × E interaction analysis of variance of grain yield (kg/ha) of sorghumgenotypes evaluated across location from 2016/17-2019/20 main cropping season in Eastern Hararghe zone, Oromia

Source	d.f.	SS	MS	% Total	% Treatment	% G x E	% Cumulative
Total	107	109548735	1023820				
Treatments	35	84994842	2428424***	77.59			
Genotypes	5	15412514	3082503***		14.07		
Environments	5	57663778	11532756***		52.64		
Block	12	6249805	520817ns				
Interactions	25	11918550	476742ns		10.88		
IPCA 1	9	5445121	605013ns			45.69	45.69
IPCA 2	7	3505668	500810ns			29.41	75.10
Residuals	9	2967761	329751			24.90	100.00
pooled Error	60	18304088	305068	16.71			

Stability Analysis

The ANOVA revealed highly significant variation ($p < 0.001$) for the environments, genotypes whereas non-significance for G × E, Blocks, IPCA1 and IPCA2. The total percentage of variation which has been explained by the model was 77.59% for treatments and 16.71% for error. The greater contribution of the treatments than the error indicates the reliability of this multi-environment experiment (Table 5). High percentage of the environmental variation is an indication that the major factor that affects grain yield performance of sorghum inlowland areas of Eastern Hararghe is the environmental effect. Similar results have beenreported for different sorghum genotypes evaluated in various environments (Abiy et al., 2016; Yitayeh et al., 2019).

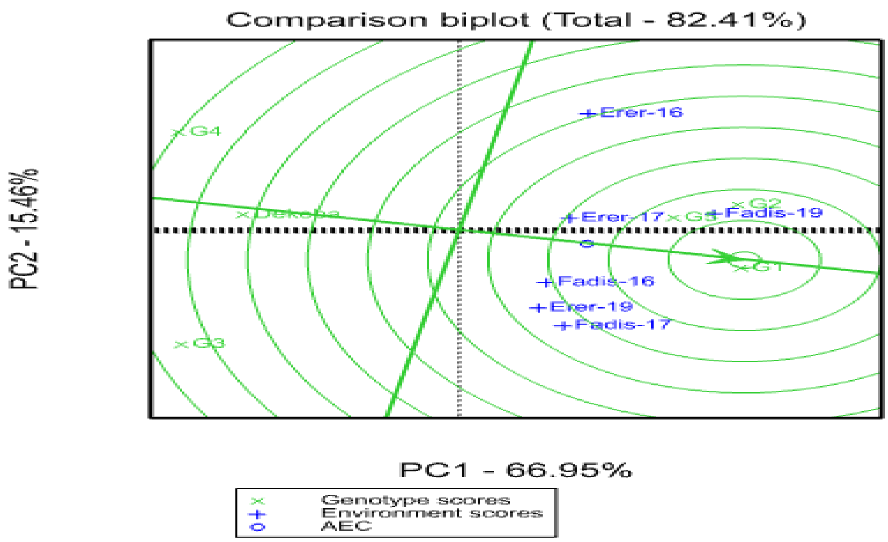
The ANOVA table of AMMI showed that genotype by environmental interaction was not significant indicating the genotypes performed similarly across different environments. This showed that the stability of genotypes across different environment. However, it does not indicate whether the highest or lowest yielded genotypes were more stable. The interaction principal component 1 (IPCA1) plotted in the x-axis and the interaction principal component two (IPCA2) plotted in the yaxis (Figure 2) showed that the first Interaction Principal Component (IPC1) explained 45.69% while the second interaction principal component explained 29.41% the two interaction principal components with a cumulative effect of 75.1% of the genotype by environment interaction effect.



Stability analysis of the genotypes based on their IPCA scores using the GGEbiplot analysis

is shown in Figure 1 and Figure 2. The polygon of lines in Figure1is made by connecting vertex genotypes, by connecting straight lines and restof genotypes fall inside the polygon. The vertex genotypes were G1, G2, G3 and G4 (Figure 1). These genotypes are either the

Figure 1. The which-won-where view of the GGE biplot to show which sorghum genotypes performed best in which environments (mega-environment identification)



Comparison biplot of six test environments: The average environments coordinate (AEC) is a line that pass through the average environment(represented by small circle) and biplot origin. A test environment that has asmall angle with the AEC is more representative of other test environments. An ideal genotype should have high mean grain yield performance across environments (Figure 6). It is the one which is close or at the center of the concentric circle, and is also a genotype to be on average environmental coordinate(AEC) on positive direction and has vector length equal to the longest vector ofthe genotype and designated by an arrow pointed to it [17] [31]. Genotypes plotted to the center are considered to be stable across the test environments. Hence, genotypes G1 (IESV92168-DL), G2 (2005MI5064) and G5 (2005MI5081) were found to be the most stable across environments.

Conclusion and recommendation

GEI is an important factor for developing a stable variety that fits wider adaptation areas. In this study, six promising genotypes were tested at Fadis research station and Erer sub-station for three years to examine the grain yield performance and stability status of the genotypes and select the best genotype for variety release for commercial use.The combined analysis of variance is not appropriate for selecting a promising genotype to handle GEI. So, AMMI model is the most widely used technique to handle GEIs. In this experiment, ANOVA table of AMMI model and Biplot Analysis are effective and most appropriate tools to describe and identify stable and superior genotypes for most crops. Significance variation were observed among the genotypes tested across environments and years for all traits evaluated except days to physiological maturity.

Analysis of variance table for AMMI model described significance variation for genotypes and Environment, whereas genotype by environment interaction was non-significant. Environment was the highest contribution (52.64%) for the variability of genotypes for grain yield. From the combined mean analysis and AMMI analysis genotypes IESV 92084 X E-36-1, 3443-2- OP X P9403 and WSV387 X P9404 was the highest yielder and more stable across the six environments evaluated. However, genotypes IESV 92084 X E-36-1, and 3443-2- OP X P9403 were recommended for variety verification for possible release in the study areas and similar agro-ecologies.

Abiy, L. and Firew, M. (2016) should come first and the remaining should follow accordingly**)**

Crossa, J., Gauch, H.G. and Zobel, R.W. (1990) Additive Main Effects and Multiplicative Interaction Analysis of Two International Maize Cultivar Trials. CropScience, 30, 493-500. https://doi.org/10.2135/cropsci1990.0011183X003000030003x

Gorfu, D. and Ahmed, E. (2011) Crops and Agro Ecological Zones in Ethiopia. RNTIGRAY 2, April 2009.

FAOSTAT (2019) Food and Agriculture Organization of the United Nations STAT. http://www.fao.org/faostat/en/#data/QC

USDA (2017) World Agricultural Production U.S. Department of Agriculture Foreign Agricultural Service/Office of Global Analysis International Production Assessment Division (IPAD), Washington DC, 20250-21051.

Central Statistical Agency of Ethiopia (2018) Agricultural Sample Survey 2017/2018.

Adugnua, A. (2007) Assessment of Yield Stability in Sorghum. African Crop ScienceJournal, 15, 83-92. https://doi.org/10.4314/acsj.v15i2.54421

Zobel, R. W., Wright, M. J. and Gauch, H. G. 1988. Statistical analysis of a yield trial. *Agron.*
J.**80**: 388-393.
Yitayeh, Z.S., Bisetegn, K.B., Mindaye, T.T. and Bisetegn, K.B. (2019) AMMI andGGE Analysis of G × E and Yield Stability of Early Maturing Sorghum [Sorghumbicolor (L.) Moench] Genotypes in Dry Lowland Areas of Ethiopia. Advances inCrop Science and Technology, 5, 425.
Abiy, L. and Firew, M. (2016) Genotype × Environment Interaction and Stability ofEarly Maturing Sorghum [Sorghum bicolor (L.) Moench] Genotypes in Ethiopia.M.Sc. Thesis, Haramaya University of Agriculture, Haramaya.

Participatory Evaluation of Improved Bread Wheat (*Triticum aestivum*) Varieties in High-land areas of East Hararghe

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Abstract
Wheat (Triticum aestivum) is one of the major cereals grown for use as food and industrial raw materials in Ethiopia. Participatory Variety Selection (PVS) can effectively be used to identify farmer-acceptable varieties and thereby overcome the constraints that cause farmers to grow old varieties which are low yielder and susceptible to disease diseases. Sixteen improved bread wheat varieties including one local check were evaluated during 2018/19 and 2019/20 cropping season in high-land areas of Eastern Hararghe with the objectives to select varieties with good agronomic, morphological performance and high grain yield and to select and identify the best performing varieties which meet the farmers'selection criteria. Completely randomized Block Design (CRBD) with three replications was used during experimentation. Significance difference was observed for the parameter studied among the bread wheat varieties studied. The analyzed data indicated Sanate and Buluq recorded the highest grain yield over years and environment with the mean values of 4436 kg/ha and 3991 kg/ha respectively and the lowest yield was recorded from Hidase (1847 kg/ha) and Kingbird (2664 kg/ha). Based on the farmers' preference t, varieties of Sanate and Buluq got the highest score with values of 1.80 and 1.89 respectively. Therefore, these two varieties should be demonstrated and disseminated to the farmers of the study areas and similar agro-ecologies.
Key words: Bread wheat, Participatory varietal selection, Variety, Grain yield, farmers

INTRODUCTION

Wheat (*Triticum aestivum*) is one of the major cereals grown for use as food and industrial raw materials in Ethiopia. It is an important staple food in the diets of many Ethiopians, providing an estimated 12% of the daily per capita caloric intake for the country's over 90 million populations (FAO, 2017). It is annually grown in 1.7 million hectares of land which is 13.38% of the total area of land used for cereal production (CSA, 2018). It ranks second after maize contributing 15.17% of the total annual cereal production. Among the nine National Regional States of Ethiopia , Oromia and Amhara, accountfor 898,455.57 ha (52.9%) and 554,284.49 ha (32.7%) respectively of the total national wheat production area, while the remaining 14.4% is covered by the Southern Nations Nationalities and Peoples Regional State(SNNPR) and other regional states (CSA, 2018).

Out of the total land cultivated under cereals (9,848,745.96 ha) wheat ranks fourth covering 12.94 % of land allocated by cereals (1,605,653.90 ha) following teff, maize and sorghum respectively. Conversely, with regard to estimated crop yield, bread wheat have shown an increment, that ranges from 18.39 to 24.45 qt/ha over the last four years from 2010/11 to 2013/14 (CSA, 2014) which is still low compared to its potential on research fields (up to 70 qt/ha) and world average. Even though research on wheat has been going on for a long time in the country, the highland environments of Eastern Hararghe zones have not been considered among the target agro-ecologies. This was mainly due to the fact that priorities were given to the central highlandsand varieties which are currently in production were bred and selected specifically for their adaptation to the central highlands where combined use of those improved varieties and their improved production packages have played an immense role in significantly improving wheat productivity.

The most important limiting factors that reduce yield of wheat in Ethiopia are poor yielding varieties, diseases, insects, poor soil fertility, water logging, and weed competition. On average, diseases and other pests destroy 20% or more of potential grain harvest either in the field or in storage. The major diseases caused by obligate pathogens of wheat are yellow rust (Puccinia striiformis), stem rust (Puccinia graminis f.sp. tritici) and leaf rust (Puccinia recondita f.sp. tritici). The rusts infect the foliage, stem and sometimes the spikes, resulting in maximum yield losses of 30-50%.In Eastern Hararghe, farmers are producing bread wheat varieties in different agro-ecologies.However, the yield is low mainly due to cultivation of late maturing and old varieties and disease susceptible variety.

Participatory Variety Selection (PVS) can effectively be used to identify farmer-acceptable varietiesand thereby overcome the constraints that cause farmers to grow late maturing varieties which is susceptible todrought and old or obsolete varieties (Witcombe et al., 1996). Moreover, participatoryresearch increases the job efficiency of the scientists (Bellon, 2001) and farmers' knowledge that enables to beretained 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).Thus, it is necessary to evaluate and promote recently released varieties in our context.

Thus, one of the planned activities under this project is adaptation and participatory evaluation of rust tolerant, high yielding, and farmers preferred improved wheat technologies along with their updated agronomic practices with the participation of farmers and other stakeholders in wheat growing districts of eastern Ethiopia. Thus, the study was undertaken with the objectives to select and promote varieties that are resistant to rusts and have good agronomic, morphological performance and high grain yield that meet farmers' criteria.

METERIALS AND METHODS

The study was conducted at Gurawa, Kurfacele, Jarso and Meta districts on both farmers and FTC of Eastern Hararghe during 2018/19 and 2019/20 cropping season. Fifteen (15) improved bread wheat varieties and one local check (old variety) were used during the study. The experimental materials used were Alidoro, Sanate, Buluq, Shorima, Pavon, Kingbird, Biqa, Dembel, Hidase, Huluka, Jalene, Liban, Mandoyu, Obora, Ogolcho and one local check. The materials were collected from different regional and federal research centers of the country. The experiment was evaluated in high-land areas of Eastern Hararghe zone in wheat growing potential areas.

Randomized complete block design (RCBD) with three replications for mother trial (planted on FTC) and farmers were used as replication for baby trials.The seed rate of 150 kg/ha were drilled in a 3-4 cm depth withspacing of 0.2 m between rows and 150 kg ha-1 Urea and 100 kg ha-1 NPS.One-third (1/3) of the UREA fertilizer and the whole NPS were applied at thetime of planting while the remaining two-third (2/3) UREAwas applied after fourweeks of emergence and weeding and other management practices were done as required.

Participatory evaluation methodology was used to acquaint the farming communities and extension workers with the improved bread wheat varieties for facilitating their wider dissemination of the selected varieties in the future. Theselection of the farmer's field was done in collaboration withdevelopment agents. Frequentmonitoring of the trials by researchers and farmers was madethroughout the cropping seasons to collect data onagronomic traits and farmers' assessments. Farmersevaluated the varieties throughout the growth period and at physiological maturity by their own indigenous criteria they set. The criteriathey used for evaluation was recorded. Scores were given ona scale from 1(very good) to 5 (very poor) for the criteriathey set. Data were collected on days to 50%flowering, days to physiological maturity, plant height from five pre-tagged plants; grain yielding/plot at 12.5% moisture content and converted to kg/hectareand farmers selection criteria.

Analyses of variance (ANOVA) were conducted separately forindividual environments according to Gomez and Gomez (1984).Bartlett's test was used to assess the homogeneity of error variances between environments to determine the validity of thecombined analysis of variance across environments.The data collected from the experiment had been subjected to statistical analysis using GENSTAT 15th edition software and test of mean separation was employed depending on the significance of meansquare of each trait using Duncan's Multiple Range Test (DMRT) at 5% probability level. Farmers' selection datawere analyzed using simpleranking method in accordancewith the given value (De Boef and Thijssen, 2007).

The followingstatistical model was used for combined analysis of variance overenvironments:

$$Yijk = \mu + Gi + Ej + GEij + Bk(j) + \epsilon ijk$$

where, Yijk, Observed value of genotype i in block k of environment(location) j; μ, grand mean; Gi, effect of genotype I; Ej, environmentor location effect; GEij, the interaction effect of genotype i withenvironment j; Bk(j), The effect of block k in location (environment) jand ϵijk, error (residual) effect of genotype i in block k ofenvironment j. The combined analysis of variance was carried out to estimateeffects of environment (E), genotype (G) and GXE interaction.Levels of significance of these variables were determined by usingF-test.

Genotype main effect and genotype by environment interaction effect (GGE) biplot analysis

The GGE biplot analysis was conducted by using Genstat version 18th software. GGE biplot methodology which is composed of two concepts, the biplot concept (Gabriel, 1971) and the GGE concept (Yan et al., 2000) were used to visually analyze the wheat varieties. This methodology uses a biplot to show the factors (G and G X E) that are important in genotype evaluation and that are also the sources of variation in G X E interaction analysis of MLPET data (Yan, 2001). The general model for GGE Biplot is as follow:

$Yij - \mu - \beta j = \lambda 1 \mathcal{E} i1 \eta j1 + \lambda 2 \mathcal{E} i2 \eta j2 + \mathcal{E} ij$

where, Yij, the performance of the ith genotype in the jth environment; μ, The grand mean; Bj, the main effect of the environment j; λl and λ2, singular value for IPCA1 and IPCA2, respectively; Ɛi1 and Ɛi2, Eigen vectors of genotype i IPCA1 and IPCA2, respectively; ηj1 and ηj2, eigen vectors of environment j for IPCA1 and IPCA2, respectively and Ɛij = Residual associated with genotype i and environment j

RESULT AND DISCUSSION

The combined analysis of variance (ANOVA) over locations and over years forgrain yield and other agronomic characters of 16 bread wheat varieties is presented in Table 1. The analysis of variance (ANOVA) for most of tested traits are highly significant ($P \leq 0.01$)mean squares due to genotype, environments and GxE interaction except spike length and grain yield which are significant ($p < 0.05$) and days to maturity (not significant) mean square due to GxE interaction. Thisindicates presence of variability among the evaluated bread wheatvarieties as well as the testing sites.Several authors were also reported presence of highly significant differenceamong bread wheat genotypes for grain yield due to genetic variability of the genotypes and environments.

Table 1: Mean square of yield and yield related parameters studied for the bread wheat varieties evaluated during 2018/19 and 2019/20 main cropping season

		Mean Square					
Source of variation	d.f.	DF	DM	SL	SPS	PH	GYLD
Replication	2	1.286ns	199.85ns	2.2457ns	7.875	465.31ns	1258890ns
Genotype (G)	15	79.783***	187***	7.594***	341.55***	319.01***	3799622***
Environment(E)	3	149.96***	303.02**	23.0104***	0	144.13***	17199516***
G x E	45	30.97***	59.57ns	0.861*	0	39.77***	1080320*
Residual	128	8.438	55.75	0.3018	0.1116	19.44	683376
CV %		3.8	6.9	5.5	0.5	4.4	25.5

Environment, genotype and GXE interaction explained 21.09, 23.29 and 19.87% of the total sum of squares, respectively (Table 2). This agrees very well with a previous study which reported that environment accounted for 80% of the total variation while genotype and G XE interaction accounted for the remaining 20% of the total variation in MLPET of bread wheat (Kaya et al., 2006). High percentage of sum of squares attached to environment indicated that environment played a dominant role in influencing yield performance of the bread wheat genotypes. The GXE interaction was highly significant ($p<0.001$) and accounted for 15.80% of the sum of squares implying the need for investigating the nature of variable responses of the genotypes to environments. Presence of the GXE interaction 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.

Table 2: ANOVA table for AMMI model of Bread wheat

Source	d.f.	SS	%SS	MS
Genotypes (G)	15	56994332	23.29	3799622***
Environments (E)	3	51598547	21.09	17199516***
Block	8	21322975	8.71	2665372***
Interactions (G x E)	45	48614406	19.87	1080320**
IPCA 1	17	29718756	61.13	1748162***
IPCA 2	15	10483981	21.57	698932ns
Error	120	66149156	27.04	551243
Total	191	244679416	100	1281044

d.f= degree of freedom; SS= Sum of square; %sum of square; MS= Mean square

The analysis of variance (ANOVA) revealed that the parameters; plant height, Days to flowering, days to maturity, spike length, seed per spike, grain yield per hectare were significantly different ($p<0.05$). Analysis of variance revealed that highly significant ($P< 0.001$) difference was observed among varieties evaluated. From the study plant height was ranged from 92.04 cm to 81.58 cm. The highest plant height (92.04cm) was recorded from Alidoro variety followed by Ogolcho and Buluq with values of 85.48, 84.56 cm respectively whereas the lowest (69.27cm) plant height was recorded from Mandoyu. The maximum days to flowering(81.58) was recorded from Obora followed by Hulluka (78.83 days) whereas the minimum days to flowering (72.33) was recorded from Pavon followed by Hidase, Mandoyu, Kingbird, and Jalene which were not statistically significant from each other. The maximum period for maturity (114.5) was recorded from Obora and Biqa whereas the minimum days to maturity (102.8) were recorded from Kingbird and Buluq (Table 1)

Table 3: combined mean of yield and other traits of Bread wheat varieties tested across years and locations

Variety	DF	DM	SL-cm	SPS	PH (cm)	Gy_kg_ha
Alidoro	77.5 b-d	109.2 b-f	11.778 a	63 f	92.04 a	3364 b-d
Biqa	74.92 a-c	114.5 f	8.722 cd	64.67 e	78.74 e-h	3425 b-d
Buluq	76.67 b-d	102.8 a	10.222 b	55 j	84.56 bc	3991 ab
Dembel	74.92 a-c	104.2 a-d	8.722 cd	49.33 m	83.67 b-d	3038 cd
Hidase	72.92 a	105.7 a-d	7.333 ef	58.33 h	74.89 i	1847 e
Huluka	78.83 de	107.5 a-e	8.667 cd	52.33 i	81.29 c-g	3275 b-d
Jalene	73.33 a	103.8 a-c	8.5 cd	65.33 d	84.29 bc	3486 b-d
Kingbird	73.25 a	102.8 a	8.389 cd	56.33 i	78.56 f-i	2664 de
Liben	76.75 b-d	107.3 a-e	8.222 c-e	67.33 c	77.93 f-i	3113 cd
Mandoye	73.17 a	103.1 ab	6.917 f	68 b	69.27 j	3504 bc
Obora	81.58 e	114.5 f	8.722 cd	56.33 i	77.59 g-i	3513 bc
Ogolcho	75.58 a-d	106.7 a-e	9.111 c	67 c	85.48 b	3022 cd
Pavon	72.33 a	107.4 a-e	8.194 c-e	64.33 e	76.62 hi	2952 cd
Sanate	74.33 ab	109.7 c-f	8 de	79.33 a	81.4 c-f	4436 a
Shorima	77.83 cd	110.4 d-f	9.139 c	54.33 k	82.48 b-e	3262 b-d
Standard check	78 cd	112.7 ef	7.861d-f	59 g	80.37 d-h	3045 cd
LSD (< 0.05)	3.3	6.21	0.96	0.34	3.76	1326.79
CV%	5.4	7.2	9.7	0.5	5.8	25.3

PH= plant height, GY= grain yield, DF= days to flowering, DM= days to maturity,

From the combined analysis across years and location significant variation was observed between varieties evaluated. Accordingly, the highest and the lowest mean grain yields were 44.36 Qt/ha obtained from variety Sanate and 18.47 Qt/ha obtained from variety Hidase. The highest yield was recorded from Sanate (44.36 Qt-ha) followed by variety Buluq (39.91 Qt-ha) which were not significant statistically, whereas the lowest yield (1847 kg-ha) was obtained from variety Hidase.The variation in grain yield of the tested varieties showed the difference in adaptability of these varieties to the study areas. The highly performed varieties revealed that the most adaptability to this environment.

Farmers' Evaluation

The farmers who participated and evaluated the trial were representative to the area and having long experience in farming. Among the sixteen (16) bread wheat varieties farmers were ordered to select eight (8) best performing varieties with their own criteria . Before beginning of the selection process, selected farmers from the four districts were asked to set their priority selection criteria. Accordingly, grain size, number of seeds per spike, high yield, plant height, tiller number and disease (rust) resistance were identified as the most important farmers' selection criteria. Ranking of varieties were done on a scale of 1-5, 1 being very good and 5 being very poor.

Table 4. Birbira Village Farmers Varietal Assessment Result in Gurawa district of Eastern Hararghe of Ethiopia (2018/19)

	Varieties							
Criteria	**Sanate**	**Ogolcho**	**Alidoro**	**Liban**	**Bulluq**	**Obora**	**Mandoyu**	**L.check**
Seed size	2.5	1.5	1.5	2.5	1	3	3.5	1.5
Plant height	3	2	1	3	1	2	4	1.5
Seed per spike	1	2	2.5	4	1.5	3	4	3
Grain yield	2.5	1.5	2.5	3.5	1	2.5	3.5	3
Disease resistant	1	3	4	2.5	2	3.5	4.5	4
Tiller number	2	3.5	3	4	1.5	2.5	4	2
Overall Score	11	13.5	14.5	19.5	8	16.5	23.5	15
Average Score	1.83	2.25	2.42	3.25	1.33	2.75	3.92	2.50
Rank	2	3	4	7	1	6	8	5

Table 5. Chelenqo Village Farmers Varietal Assessment Result in Metta district of Eastern Hararghe of Ethiopia (2018/19 and 2019/20)

	Varieties							
Criteria	**Sanate**	**Ogolcho**	**Alidoro**	**Liban**	**Bulluq**	**Obora**	**Mandoy**	**L.check**
Seed size	4	1	1.5	3	2	3	3.5	1
Plant height	3	1	2	4	2	4	4	2
Seed per spike	1	2	1	3.5	1.5	3	4	1
Grain yield	3	1.5	2	3	3	3.5	4	1
Disease resistant	1	2.5	1	2	3	4	3.5	1.5
Tiller number	2	2	3	4	3	2.5	3.5	2
Overall Score	14.00	10.00	10.50	19.50	14.50	20.00	22.50	8.50
Average Score	2.33	1.67	1.75	3.25	2.42	3.33	3.75	1.42
Rank	4	2	3	6	5	7	8	1

Table 6. Afgug-Village Farmers Varietal Assessment Result in Jarso district of Eastern Hararghe of Ethiopia (2018/19)

	Varieties							
Criteria	**Sanate**	**Ogolcho**	**Alidoro**	**Liban**	**Bulluq**	**Obora**	**Mandoyu**	**L.check**
Seed size	1	2	1.5	1	1	3	1.5	4
Plant height	1.5	1.5	2	2	1.5	3	2	2.5
Seed per spike	1	3	1	2	2	3	2	3
Grain yield	1	3	2	1.5	2	3.5	2.5	4
Disease resistant	1	2.5	3.5	1.5	2.5	4	2.5	4
Tiller number	2	2	3	2.5	2.5	3	2	3
Overall Score	7.5	14	13	10.5	11.5	19.5	12.5	20.5
Average Score	1.25	2.33	2.17	1.75	1.92	3.25	2.08	3.42
Rank	1	6	5	2	3	7	4	8

Table 4. Farmers two years Average Varietal Assessment Result in three districts of Eastern Hararghe highlands (2018/19 and 2019/20)

Variety	Gurawa distr.	Metta distr.	Jarso distr.	Average	Rank
Sanate	1.83	2.33	1.25	1.80	1
Ogolcho	2.25	1.67	2.33	2.08	3
Alidoro	2.42	1.75	2.17	2.11	4
Liban	3.25	3.25	1.75	2.75	6
Bulluq	1.33	2.42	1.92	1.89	2
Obora	2.75	3.33	3.25	3.11	7
Mandoyu	3.92	3.75	2.08	3.25	8
L.check	2.5	1.42	3.42	2.45	5

In overall trial, Sanate and Bulluq were selected by farmers due to their plant height, tiller number, better spike length, better resistance to disease (rust) and better grain yield . The use of PVS proved to be a useful selection method. Farmer participation creates a feeling of ownership (Weltzeinet al., 2003). It is a rapid and cost effective way to assess and select potential varieties (Abidin, 2004). Joshi and Witcombe (1996) reported that adoption rates of cultivars would be improved through increased farmers' participation. Poor farmers can adopt new varieties as rapidly as wealthier ones through participatory varietal selection.

CONCLUSION AND RECOMMENDATION

In areas where improved technologies are not widely addressed like Eastern Hararghe Zone of Eastern Oromia, it'sparamount to take immediate action towards setting appropriate research methods. Using improved varieties of bread wheat could make an important contribution to increase agricultural production and productivity in areas like Eastern Hararghewhere there is low practice of using improved technologies such as improved crop varieties. In such case, Participatoryvariety selection is an effective tool in facilitating the adoption and extension of the improved technologies.Farmers may require multiple traits from one key crop such as bread wheat. However, researchers may not know the traitsthat are important to farmers and vice versa. During the study farmers' selection criteria was almost similar in the three villages and they were Seed size, plant height, grain yield, number of seed per spike, high grain yield, disease (rust) resistance and plant tillering capacity.

The analyzed data indicated Sanate and Buluq recorded the highest grain yield over years and environment with the mean values of 4436 kg/ha and 3991 kg/ha respectively and the lowest yield was recorded from Hidase (1847 kg/ha) and Kingbird (2664 kg/ha). Based on the farmers preference and their own criteria they set,varieties of Sanate and Buluq got the highest score with values of 1.80 and 1.89 respectively followed by Ogolcho, Alidoro, farmers variety (local check), Liban, Obora and Mandoye. Researchers also recommend these two varieties for the study area based on the data analysis, agro ecologically suitability. Therefore, these two varieties should be demonstrated and disseminated to the farmers' of the study areas and similar agro-ecologies.

Reference

Abidin, PE, 2004. Sweet potato breeding for northeast Uganda: Farmer varieties, farmer-participatory selection and stability of performance. PhD thesis Wageningen University, The Netherlands, pp. 69-86.

Bellon, M.R., 2001. Participatory Research Methods for Technology Evaluation: A Manual for Scientists Working with Farmers. Mexico, D.F., CIMMYT.

Central Statistical Agency (CSA) (2018). Agricultural sample survey2017/18 (2010 E.C.) Volume 1. Report on area and production ofmajor crops (Private peasant holdings, Mehere season). StatisticalBulletin 586. Addis Ababa, Ethiopia

CSA (Central Statistical Authority). 2014. Agricultural survey sample. Report on area and production of crops peasant holding, meher season). Statistical Bulletin No 278. Addis Ababa, Ethiopia.

Dawson JC, Murphy KM, Jones SS, 2007. Decentralized selection and participatory approaches in plant breeding for low-input systems.Euphytica 160: 143-154.

Food and Agricultural Organization of the United Nations (FAO) (2017).Crop Prospects and Food Situation. Rome, Italy

Grisley, W. and Shamambo, M. (1993) An analysis of the adoption and diffusion of carioca beans in Zambia resulting from an experimental distribution of seed. Exp. Agric., 29: 379-386.

Joshi, K. D., Rana, R. B., Subedi, M., Kadayat, K. B. & Sthapit, B. R. (1995). Addressing diversity through farmer participatory variety testing and dissemination approach: A

case study of Chaite rice in the Western Hills of Nepal. LARC Seminar Paper No. 95/5. Pokhara, Nepal: Lumle Agricultural Research Centre.
Weltzien E, Smith ME, Meitzner LS, Sperling L, 2003. Technical and institutional issues in participatory plant breeding – from the perspective of formal plant breeding. A global analysis of issues, results, and current experience PPB Monograph No. 1.PRGA Programme, Cali, Colombia.
Witcombe, J. R., Joshi, A., Joshi, K. D. & Sthapit, B. R. (1996). Farmer participatory cultivar improvement. I: Methods for varietal selection and breeding and their impact on biodiversity. Experimental Agriculture (this issue).

Participatory Evaluation of Improved Bread Wheat Varieties in Mid lands of Eastern Hararghe, Ethiopia

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Abstract
Bread wheat (Triticum aestivum L.) is one of the most important small cereal crops widely produced in Ethiopia. A total of eight (8) improved bread wheat varieties including one standard check (Jafferson) were evaluated for two consecutive years during 2018/19 and 2019/20 main cropping season. The experiment was done to evaluate the best performing varieties in-terms of yield and yield related traits and resistant to rust diseases that meets the farmers' selection criteria. The field experiment was laid out in Randomized Complete Block Design (RCBD) with three replications for mother trials. Analysis of variance revealed that highly significance variation was recorded among lowland bread wheat varieties for grain yield. From the combined data analysis across location and years Amiber-2 (31.55 Qt/ha) and Neijam (31.01 Qt/ha) recorded the highest grain yield. Farmers' had given their important selection crieteria to select bread wheat varieties. Accordingly, earliness, spike length, seed size, drought tolerant, grain yield, plant height, and disease (rust) resistance were identified as the most important farmers' selection criteria.Therefore, based on objectively measured traits, farmers' preferred Amibera-1 with average score of (1.21), followed by Gambo and Neijam with average score of 1.5 and 1.57 respectively. Therefore, Amibera-1 and Neijam were the best performing varieties and recommended for further demonstration and scale-up for the study areas and similar agro-ecologies.
Key words: Bread wheat, Grain yield, Participatory varietal selection, Varieties

INTROUCTION

Wheat (Triticum spp.) belongs to the family Graminae. It is an annual temperate cereal crop but also it can grow in a wide range of environments around the world. Production is most successful between the latitudes of 30 and 60ºN, and longitudes of 27 to 40ºS, respectively (Heyne, 1987). The optimum growing temperature is about 25°C, with minimum and maximum growth temperatures of 3-4°C and 30-32°C, respectively (Briggle, 1980).

Bread wheat (Triticum aestivum L.) is one of the most important small cereal crops widely produced in Ethiopia. It grows on 1.5 million ha with a total production of 3.78 million tons and ranks fourth both in area and production among cereal crops in different regions of Ethiopia (CSA, 2012). Smallholders are major producers and suppliers of bread wheat, accounting for more than 89% of the market supply (USAID, 2010). Wheat is one of a major cereal of choice in the country, due to its higher productivity, broader adaptation and input responsive high yielding improved varieties (Tarekenge et al., 1995).

Out of the total land cultivated under cereals (9,848,745.96 ha) wheat ranks fourth covering 12.94 % of land allocated by cereals (1,605,653.90 ha) following teff, maize and sorghum respectively. Conversely, with regard to estimated crop yield, bread wheat has shown an increment, that ranges from 18.39 to 24.45 qt/ha over the last four years from 2010/11 to 2013/14 (CSA, 2014) which is still low compared to its potential on research fields (up to 70 qt/ha) and world average. Consequently, so many varieties have been released since 2011/12 after promotion was conducted in wheat growing areas of eastern Ethiopia. Thus, it is necessary to evaluate and promote recently released varieties in our context. Thus, one of the planned activities under this project was adaptation and participatory evaluation of rust tolerant, high yielding, and farmers preferred improved wheat technologies along with their updated agronomic practices with the participation of farmers and other stakeholders in wheat growing districts of eastern Ethiopia. Thus, this activity had been undertaken with the objectives of:

- To select and promote varieties good agronomic, morphological performance and high grain yield that meet farmers' criteria.
- To identify the farmers selection criteria in lowland bread wheat varieties

MATERIALS AND METHOD

Treatment and Experimental Design

The experiment was conducted at Fadis Agricultural Research Center at three locations (Fadis on station and Umer kulle FTC) during 2018/19 and 2019/20 cropping season to select and recommend high yielding, early maturing, and moisture stress and diseases tolerant improved bread wheat varieties through PVS.The study areas have an altitude of 1700-1776 m above sea level. The mean annual rainfall of the areas is 200-400 mm with erratic distribution having bimodal pattern increasing from April to August with peak rain section in April to August and the average mean Minimum and Maximum temperature of the area are 20 – 25 °C and 30 – 35 °C respectively. The participatory varietal selection was done both on Fadis research station and Umer kulle FTC. FREG is a participatory research approach whereby multidisciplinary team of researchers, extension workers, group of farmers and other pertinent actors jointly conduct research on farmers' field on selected topics (Bedru et al, 2009). A total of 62 farmers having 45 male and 17 female members were invited and participated during the evaluation. Farmers around the experimental station and woredas' were selected based on wheat production potential and were participated in varietal selection by their own criteria. Farmers were evaluated the varieties throughout the growth period and at physiological maturity by their own indigenous criteria they set. The criteriathey used for evaluation was recorded. Scores were given ona scale from 1(very good) to 5 (very poor) for the criteriathey set.

Seven moisture stress tolerant improved bread wheat varieties (Adel-6, Amibera-1, Amibera-2, Fantale-1, Fantale-2, Gambo, and Neijam) were used as testing materials with one standard check (Jaferson). The treatments were arranged in Randomized Complete Block Design (RCBD) with three replications and recommended spacing of 20 cm between rows and 150 kg/ha seed rate was used and management practices were applied as recommended for wheat production. Data was collected in two ways: agronomic data & farmer's data.

Data was collected from a net plot and selected plants of the plot for agronomic and diseases data. Collected data includes; days to 50% maturity, plant height from five pre-tagged plants, number of kernels per spike (from five plants), Spike length, Stem rust incidence and severity, leaf rust incidence and, grain yield per hectare. Farmers' preferred variety and farmers' selection criteria had been collected. The collected data were subjected to statistical analysis using GENSTAT 18th edition software and LSD-test were used to compare treatment mean differences at the probability level of $\alpha = 0.05$. Error variance of the individual location was tested for homogeneity; and the combined analysis of variance over the two locations was performed as per the formula given by Gomez and Gomez (1984). The ANOVA was performed to determine the significance of differences between varieties and between variety-location combinations. Additionally, AMMI and GGE Bi plot had been done to determine stability of tested varieties over locations and years. For data's collected from farmers evaluation, matrix ranking suggested by De Boef et al., (2007) was employed.

RESULT AND DISCUSSION

Analysis of variance revealed significance differences ($P < 0.05$) was observed among moisture stress (low-land) bread wheat varieties evaluated. Highly significance variation ($P < 0.001$) were recorded on Days to maturity, plant height, spike length and grain yield per hectare whereas, significance difference ($P < 0.05$) was observed on seeds per spike (Table 1). As the study result indicated, early maturity was revealed by standard check variety Jefferson (85.67 days) and variety Amibera-2 (90.67 days) whereas late maturity was depicted by Gambo (107.67 days).

Table 1: Mean squares from analysis of variance (ANOVA) of measured phenological and agronomic traits of moisture stress bread wheat in 2018 and 2019/20 main cropping seasons at the study area

S.V	Df	Mean Square				
		DM	**PH(cm)**	**SL(cm)**	**SPS(cm)**	**GYLD (kg/ha)**
Replication	2	7.156	17.82	0.115	135.6	211735
Treatment	7	411.84***	279.34***	11.06***	119.7*	1059323***
Error	46	9.82	13.49	0.424	40.78	94097
Mean		95.3	68.6	8.5	39	2736.1
CV %		3.3	5.4	7.6	16.4	11.2

The analysis of variance (ANOVA) revealed that there wassignificant difference among varieties for yield (Table 2). Thegrain yield ranged from 3155 kg/ha to 2236 kg/ha and grand
mean of 2736.1 kg/ha. The highest yield (3155 kg/ha) wasgained from Amibera-2 variety followed by the varieties Neijam(3101 kg/ha), Gambo (2840 kg ha-1) and Fantale-1 (2822 kg/ha) while the lowest yield (2236 kg/ha) was obtained from standard check Jefferson variety. Statistically, significance difference was notobserved among mid-land bread wheat varieties of Amibera-2 and Neijam. The variation in grain yield of the tested varietiesshowed the difference in adaptability of these varieties to themoisture stress areas of the study. The highly performed varietiesrevealed that the most adaptability to this environment.

There was highly significant difference($p<0.01$) among varieties for plant height (Table 2). The plantheight ranged between 62.52 cm to 78.63 cm. The highest height wasgiven by variety “Gambo” while the lowest was by variety “Adel-6”. As the data indicated; Gambo, Fantale-1, Amibera-1 and Fantale-2 were recorded tallerstanding;78.63, 72.19, 71.89 & 68.74 cm respectively, while Adel-6, Jefferson and Neijamhad recorded shorter in plant heightwith a mean values of 62.52, 63.56 and 63.07 cm respectively.

Table 2: Combined Mean values of phenological, yield and yield related traits of moisture stress tolerant bread wheat tested during cropping season of 2018 and 2019/20

Variety	DM	PH(cm)	SL(cm)	SPS	GYld(kg/ha)
Adel-6	95.5 c	62.52 d	6.881 f	37.07 bc	2754 c
Amibera-1	94.5 c	71.89 bc	9.207 bc	42 ab	2741 c
Amibera-2	90.67 b	68.44 c	8.322 de	36.89 bc	3155 a
Fantale-1	96.67 c	72.19 b	9.719 ab	45.96 a	2822 bc
Fantale-2	90.83 b	68.74 bc	8.704 cd	36.48 bc	2240 d
Gambo	107.67 e	78.63 a	10.063 a	40.93 abc	2840 bc
Jaferson	85.67 a	63.07 d	7.378 f	35.22 c	2236 d
Neijam	100.83 d	63.56 d	8.019 e	37.22 bc	3101 ab
LSD (5%)	l2.83	6.57	0.97	8.27	631.28
CV%	3.3	5.4	7.6	16.4	11.2

The spike length ranged between 10.063 cm and 6.881 cm. The highest spike length was recorded by variety Gambo (10.063) and the lowest was recorded by variety Adel-6 (6.881

cm). Varieties Gambo and Fantale-1 revealed the longest spike length while Adel-6 and Jafferson had the shortest head size respectively. Significance difference was recorded among the tested materials and the seed per spike ranged between 45.96 and 35.22. The highest seed count pe spike was obtained from Fantale-1, Amibera-1 and Gambo and the fewest seed count was obtained from Jaferson. As the data of study indicates, seed per spike has direct effect on grain yield and thus the highest seed per spike gave the highest grain yield and similarly, the lowest seed per spike recorded the lowest grain yield (Table 2).

Farmers' Evaluation

The farmers who participated and evaluated the trial were representative to the area and having long experience in farming. Before beginning of the selection process, selected farmers from the district were asked to set their priority selection criteria. Accordingly, Earliness, spike length, seed size, drought tolerant, grain yield, plant height, and disease (rust) resistance were identified as the most important farmers' selection criteria. Ranking of varieties were done on a scale of 1-5, 1 being very good and 5 being very poor.

Table 3. Overall Farmers mid-land varietalassessment result in Fadis district

	Varieties							
Criteria	**Adel-6**	**Amibera-1**	**Amibera-2**	**Fantale-1**	**Fantale-2**	**Gambo**	**Jaferson**	**Neijam**
Earliness	3	2.5	1	3	2.5	2.5	1	2
Drought Tolerant	4	4	1	4	3	1.5	1.5	1
Spike length	3.5	3.5	1	3	2.5	1	3.5	1.5
Seed size	2	3	1.5	2.5	2	1.5	4	1
Plant Height	3.5	2.5	2	3	1	1	4	2
Grain yield	4	4	1	3.5	2	1	3.5	2.5
Disease resistance	4	4	1	3	2.5	2	4	1
Overall score	24.0	23.5	8.5	22.0	15.5	10.5	21.5	11.0
Average Score	3.43	3.36	1.21	3.14	2.21	1.50	3.07	1.57
Rank	8	7	1	6	4	2	5	3

Table 3 showed farmers evaluation of the varieties based on the criteria they set. In overall Farmers' varietal assessment Amibera-2, Gambo and Neijam were recorded 1st to 3rdwith a mean score of 1.21, 1.50 and 1.57 respectively, followed by Fantale-2, Jefferson, Fantale-1, Amibera-1 and Adel-6. Therefore, from the farmers assessment the first three varieties of bread wheat; Amibera-2 (1.21), Gambo (1.50) and Neijam (1.57) were the best performing varieties.

The rank given by researchers and farmers (Table 4) below showed that researchers rank did not match with farmers rank except for the variety Amibera-2 which was ranked 1stby both. This result clearly showed that farmers' selection criterion is not mainly yield rather combination of other yield component parameters. The present investigation confirms the observation by Bellon(2002) that farmers' perception about crop varieties are not always the same as researchers and if given the opportunity, farmers are able to express their preferences differently.

Table 4. Ranking of the varieties according to farmers and researchers

Varieties	Researchers Rank	Farmers Rank
Adel-6	5	8
Amibera-1	6	7
Amibera-2	1	1
Fantale-1	4	6
Fantale-2	7	4
Gambo	3	2
Jaferson	8	5
Neijam	2	3

Scale: 1=very good; 5=Very poor

CONCLUSION AND RECOMMENDATION

Farmers may require multiple traits during the selection process of important cropssuch as maize. However, researchers may not know the traits that are important to farmers and vice versa. Participatory varietal selection has significant role in technology adaptation and dissemination in short time than conventional approach.In participatory varietal selection, farmers are given a wide range of new cultivars to test for themselves in their own fields. significance differences ($P < 0.05$) was observed among moisture stress (low-land) bread wheat varieties evaluated. Highly significance variation ($P < 0.001$) were recorded on Days to maturity, plant height, spike length and grain yield per hectare whereas, significance difference ($P <0.05$) was observed on seeds per spike. Thegrain yield ranged from 3155 kg/ha to 2236 kg/ha and grandmean of 2736.1 kg/ha. The highest yield (3155 kg/ha) wasgained from Amibera-2 variety followed by the varieties Neijam(3101 kg/ha), Gambo (2840 kg ha-1) and Fantale-1 (2822 kg/ha) while the lowest yield (2236 kg/ha) was obtained from standard check Jefferson variety.

The results also revealed that farmers' preferences in some cases were not coincide with the researchers' selection. This result clearly showed that farmers selection criterion is not only yield rather combination of other yield component parameters.Accordingly, Earliness, spike length, seed size, drought tolerant, grain yield, plant height, and disease (rust) resistance were identified as the most important farmers' selection criteria.Based on these criteria, the highest score was recorded by Amibera-2, Gambo and Neijam with a mean score of 1.21, 1.50 and 1.57 respectively whereas, the lowest value was observed from Adel-6 (3.43). Therefore, from the farmers assessment the first three varieties of bread wheat; Amibera-2 (1.21), Gambo (1.50) and Neijam (1.57) were the best performing varieties. From the combined analysis of agronomic data Amiber-2 (31.55 Qt/ha) and Neijam (31.01 Qt/ha) was recorded the highest yield and best performing varieties for moisture stress areas. Similarly, from the result of farmers' selection criteria variety Amibera, Gambo and Neijam got 1st and 3rd rank respectively. Therefore, these varieties were recommended for farther demonstration and scaling-up to the study area and similar agro-ecologies.

Briggle, L.W., 1980. Origin and botany of wheat. In E. Häfliger, ed. Wheat Documenta cibageigy, p. 6-13. Basle, Switzerland.

Heyne, E. G. (eds.), 1987. Wheat and Wheat Improvememt. 2nd eds. American Society of Agronomy, Inc. Crop science society of America, Inc., Soil Science of America, Inc.Madison, Wisconsin, USA.

Tarekenge A, Tanner DG, Gebeyehu G(1995). Implementation in yield of bread wheat cultivars released inEthiopia from 1947 to 1987. Africa Crop Sci. J. 3: 41-49
CSA, 2014. Agricultural sample survey: Report on area and production for major crops. Statistical Bulletin 227. Addis Ababa, Ethiopia.

Adaptation trial of Hybrid Maize (*Zea Mays*) in the Highlands of Eastern Hararghe, Ethiopia

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Abstract
Maize is one of a major crop in Ethiopia in production, consumption and income generation for both resource constrained men and women. Although, productivity of maize in Ethiopia is showing increment in recent years, productivity in Eastern Hararghe is still low 24.06 qt/ha compared to the national and regional average. The experiment was conducted at high-land areas of East Hararghe namely Kurfa chele and Meta districts in 2018/19 and 2019/20 cropping seasons. The study was done with the objectivesto 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 randomized complete block design with three replications. There was significance variation in hybrid maize varieties for the traits evaluated. The variety SPRH (145.3) had the earliest in maturity which is not significantly different from varieties, SBRH, Shonee, Damote, BH-140 and BH-146 with a mean values of 146.6, 147.2, 148.3, 149.2 and 149.6 days respectively. Damote variety had the highest grain yield (54.62 qt ha^{-1}), while BH-547 had the lowest grain yield (36.47 Qt ha^{-1}). The second and third varieties for grain yield was recorded from SPRH1 and Shone which was not significant from the highest grain yield (Damote). Thus, it can be concluded that hybrid maize varieties Damote andSPRH resulted in best results in terms of yield and yielding component across the study area. Therefore, for sustainable maize production in thestudy area these varieties had been recommended and need to be demonstrated with local varieties tousers 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 largely produced in Western, Central, Southern and Eastern parts of Ethiopia. Maize is widely grown in most parts of the world over a wide range of environmental conditions ranging between 480 latitude North to about 400South latitude all over the world (Geremew *et al.,* 2009). Maize, which is originated from South

America, is first introduced in Ethiopia in the 1thto 17thCentury (Abdisa et al., 2001).However, it is increasingly becoming more important than most of the indigenous crops of the country and has been widely accepted in several ways, namely for human consumption, as feed grain, fodder crop and for many industrial purposes.The popularity of maize in Ethiopia is partly because of its high value as a food crop as well as the growing demand for the Stover as animal fodder and source of fuel for rural families (Tsedeke *et al.*, 2015). Although, productivity of maize in Ethiopia is showing increment in recent years however productivity in Eastern Hararghe is still low 24.06 qt/ha compared to the national and regional average of Oromia 32.54 and 33.19 quintal/ha respectively (CSA, 2013/14).

In maize farming system of Eastern Ethiopia, especially Eastern Hararghe, farmers traditionally use local variety of maize, for production and productivity for a long period of time. Lack of insufficient knowledge and awareness of farmers on the production and benefits of these new and high yielding varieties with good agronomic practice is a leading constraint. Identification of adaptable variety minimizes the magnitude of scale or rank shift of their performance across or specific environment (Die et al., 2016a; Die et al., 2016b; Die et al., 2016c).

Hence, it is important to test adaptability of these medium to early maturing maize varieties the highlands of eastern Hararghe. Thus, the study was conducted to compare the performance of commercial varieties for their adaptability, stability and to recommend a suitable one for the local maize growers of eastern Hararghe, highlands of Ethiopia and similar agro-ecologies.

MATERIALS AND METHODS

Treatments and Experimental Design

The experiment was conducted for two consecutive growing years (2018/19 and 2019/20) at the highland areas of Eastern Hararghe. The experiment was conducted at three sites of Meta (two sites) and Kurfa chele districts on farmers' fields. A total of eight recently released hybrid maize varieties namely; Damote, SPRH1, SBRH1, BH-661, Shone, BH-546, BH-547 and BH- 140 were used as experimental materials to evaluate the agronomic performance to the study areas. The experiment was laid out as a RCBD design with three replications in a plot size of 3 m × 4 m. Seeds were planted in rows with two seeds per hill at a rateof 25 kg/ha in a plot consisting of four row each of 4 m long and 3 m wide and seedlings were thinned into one plant with spacing of 0.25 m and 0.75 m between plant and rows respectively.

Table 1: Lists of improved hybrid maize varieties used as experimental materials

Name of Varieties	Year of released	Organization/center released
BH-140	1988	BARC/EIAR
Damote	2015	Du Pont Pioneer
Shone	2006	Du Pont Pioneer
BH-547	2013	BARC/EIAR
BH-546	2013	BARC/EIAR
BH-660	1993	BARC/EIAR
SPRH1	2015	BARC/EIAR
SBRH1	2015	BARC/EIAR

Fertilizers were applied at the rate of 100/100 kg/ha NPS/Urea. Urea was applied in split (half at planting and the other half at knee height). First weed control was carried out after three weeks of planting after 21 days of plantingand other managementpractices were undertaken as per the recommendation for maize production.

Data were collected on both individual plant base and plot base data on five important traits like days to 50% tasseling. Days to 50% silking, days to physiological maturity, plant height and grain yield per hectare. Days to 50% tasseling, days to 50% silking, days to physiological maturity and grain yield per hectarewere collected on plot base and plant height was collected from individual plant base (five randomly selected plants). The data collected from the experiment had been subjected to statistical analysis using GENSTAT 18^{th} edition software and least significance difference (LSD)was used to compare treatment mean differences at the probability level of $\alpha = 0.05$. Additionally, AMMI and GGE Bi plot had beendone to determine performance and stability of tested varieties over environments and year.

RESULTS AND DISCUSSION

The analysis of variance revealed that significant ($P<0.05$) differences in the parameters studied of all maize varieties over location and year. The mean square data indicated that hybrid maize varieties differ significantly in days to tasseling (DT), days to silking (DS) grain yield per hectares whereas, highly significant difference ($P< 0.001$) for days to physiological maturity (DM) and plant height.

Table 2: Mean squares from analysis of variance (ANOVA) of measured phonological and agronomic traitsof hybrid maize

		Mean square				
S.V	**d.f.**	**DT**	**DS**	**DM**	**PH(m)**	**GYLD(Qt/ha)**
Rep stratum	2	2.042	0.31	10.18	0.04443	691
Variety	7	2.34*	3.27*	65.27**	0.19827**	33332*
Error	46	8.613	9.03	11.85	0.0196	11116
Mean		92.42	101.71	149	1.9	43.55
CV		3.2	3	2.3	7.4	24.2

*and ** represent statistically significant differences at 0.05 and 0.01 probability levels, respectively; DT= Days to 50% tasseling; DS= Days to 50% silking; DM= Days to physiological maturity; PH= plant height and GYLD= grain yield in quintal per hectare

Analysis of variance revealed that significance difference was observed for all traits evaluated among the varieties tested across location and year (Table 3). The varieties were ranged from 88.67 to 95.67 in days to tasseling and 97.7 to 108 in days to silking. The earliest in days to tasseling was recorded from the variety SPRH1 (88.67 days) followed by Shone, SBRH1, Damote and BH-140 which were statistically not significant and BH-661 takes the longer time to tasseling with a values of 95.67 days. The variation in days to tasseling may be due to genetic variation of the evaluated varieties.

Table 3: Combined mean of yield and other traits of hybrid maize tested across years and locations during 2018/19 and 2019/20 cropping season

Variety	**DT**	**DS**	**DM**	**PH (m)**	**GYLD_(Qt/ha)**
BH-140	93.33abc	98.7a	149.2 abc	1.898 b	36.84 cd
BH-546	95bc	102.7a	149.7 abc	1.924 b	41.59 bcd
BH-547	94.67bc	102a	151.6 bc	1.871 bc	36.47 d
BH-661	95.67c	108b	153.6 c	2.203 a	40.37 bcd
Damote	91.33abc	100.3a	148.3 ab	1.876 bc	54.62 a
SBRH1	90.33ab	97.7a	146.6 a	1.746 c	44.07 bcd
Shonee	90.33ab	101.7a	147.2 ab	1.982 b	46.81 abc
SPRH1	88.67a	102.7a	145.3 a	1.743 c	47.65 ab
LSD (5%)	**5.139**	**5.262**	**4.5**	**0.15**	**17.33**
CV%	**3.2**	**3.00**	**3.2**	**8.2**	**24.2**

NB: Means with the same letter was not significant and means with different letters are significant; DM: Days to physiological maturity; PH (m)= Plant height in meter and GYLD_Qt_ha= Grain yield in quintal per hectares

The present result revealed that the height of plant was highly significantly affected due to various maize varieties (Table 3). The tallest plants were observed in BH-661 (2.203 m) followed by Shone and BH-546 with height of 1.982 and 1.924 m, respectively whereas, the shortest plant height was recorded from the variety SPRH (1.743 m) followed by SBRH (1.746 m).Analysis of the data revealed significant variations among the tested varieties of maize for days to physiological maturity. The variety SPRH (88.67 days)recorded the earliest in days to anthesis where no significance difference between the varieties; Shonee, SBRH, Damote and BH-140. However, maize variety BH-661 recorded the latest in days to anthesis. Similarly, variety SPRH (145.3) had the earliest in maturity which is not significant different from varieties, SBRH, Shonee, Damote, BH-140 and BH-146 with a mean values of 146.6, 147.2, 148.3, 149.2 and 149.6 days respectively.
In present investigations grain yield was found to be highly significant (Table 3). Accordingly, the variety, Damote had the highest grain yield (54.62qt ha-1), while BH-547 had the lowest grain yield (36.47 Qt ha-1). The second and third varieties for grain yield was recorded from SPRH1 and Shone which was not significant from the highest grain yield (Damote). The possible reason for the observed differences could be variation in their genetic make-up. This studyis in line with those of Mosisa and Habtamu (2007), who evaluated different improved maize varieties and reported that mean grain yield across environments varied from 4300 to 7300 kg ha-1.

CONCLUSION AND RECOMMENDATION

Using improved varieties of hybrid maize could make an important contribution to increase agriculturalproduction and productivity in areas like eastern Hararghe where there is low practice of using improved technologies such as improved crop varieties.To this end, the use of improved hybrid maize technologies such as improved varieties could be one of thealternatives to improve productivity by small farmers. During the field implementation, eight improved Hybrid maize varieties were used. According to the results of analysis of variance, all of theagronomic traits evaluated were revealed significant statistical variation. Hybrid maize variety Damote, SPRH and Shonee gave the highest grain yield of all the test varietiesrespectively, while BH-547, BH-140 and BH-661varieties showed the smallest grain yield respectively.
Thus, it can be concluded that hybrid maize varieties Damote andSPRH resulted in best results in terms of yield and yielding component across the study area. Therefore, for sustainable maize production in thestudy area these varietieshad been recommended and need to be demonstrated with local varieties tousers along with their improved production packages.

References

Abdisa Gemeda, Girma Aboma and Hugo Verkuijl. 2001. Farmer’s Maize Seed Systems in Western Oromia, Ethiopia.

Central Statistical Agency (CSA), "Agricultural sample survey 2013/14 (2006 E.C.) (September –December 2009)," Report on Area and Production of Crops (Private Peasant Holdings, Meher Season). Addis Ababa 2014.

Dia, M., T.C Wehner, C. Arellano 2016c. Analysis of genotype x environment interaction (GxE) using SAS programming. Agron. J. 108 (5): 1-15.doi: 10.2134/agronj2016.02.0085

Dia, M., T.C Wehner, R. Hassell, D.S Price, G.E. Boyhan, S. Olson, S. King, A.R. Davis, G.E.Tolla., 2016a. Genotype x environment interaction and stability analysis for watermelon fruit yield in the U.S. Crop Sci. 56: 1645-1661 doi: 10.2135/cropsci2015.10.0625.

Dia, M., T.C Wehner, R. Hassell, D.S Price, G.E. Boyhan, S. Olson, S. King, A.R. Davis, G.E.Tolla., 2016. Values of locations for representing mega-environment and for discriminating yield of watermelon in the US. Crop Sci. 56: 1726-1735. doi: 10.2135/cropsci2015.11.0698.

Geremewu Taye, 2009. Effect of Nitrogen and Phosphorus Fertilizers on the Growth, Yieldand Yield Components of Maize (Zea mays L) at Nejo Western Wollega, Ethiopia. MSc Thesis. School of Graduate Studies Haramaya University. p16 - 24.

Mosisa, W. and Z. Habtamu, 2007. Advances in improving harvest index and grain yield of maize in Ethiopia. East African Journal of Sciences 1(2): 112-119.

Tsedeke A., Bekele S., Abebe M., Dagne W., Yilma K., Kindie T., Menale K., Gezahegn B., Birhanu T. and Tolera K, 2015. Factors that transformed maize productivity in ethiopia. Food sec. DOI 10.1007/s12571-015-0488-z

Adaptation Trial of Finger Millet [Eleusine coracana (L.) Gaertn] Varieties in East Hararghe Zone, Ethiopia

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Abstract

Developing improved varieties with high yield and wide adaptation is one of the major objectives in crop improvement program. This indicates that there are some localities which are not fully addressed to satisfy the need for maximizing yield, using high yielder, disease resistant and early maturing variety of the crop is very important. Therefore, a field experiment was conducted during the main cropping season of 2018 and 2019 at Chelenko ATVET Collage and Boko Agricultural Research sites in Meta and Fadis Districts (Woredas), respectively, with an objective to select adaptable, high yielder, early maturing and disease resistant or tolerant varieties across moisture stressed areas of eastern Oromia, Ethiopia. eleven finger millet varieties including standard check were used as planting materials. The experiment was laid out as a randomized complete block design and replicated three times. The combined mean analysis of variance revealed that highly significant difference ($P < 0.01$) for days to maturity, plant height, finger per plant, finger length and grain yield whereas, significant difference ($P < 0.05$) were observed for days to 50% flowering, effective tiller per plant and thousand seed weight. The earliest days to flowering were observed on Tesema variety with 84.33 days but there was no significantly different with other tested varieties. The results showed that Mereb was the earliest in terms

of maturity taking only 126.9 days. The results of combined mean values indicated that, Aksum (3090 kgha^{-1}) followed by Gute (2807 kgha^{-1}) were found to be high yielding finger millet varieties whereas, Mereb (2103 kgha^{-1}) was identified as the least seed yielding variety as compared to all tested varieties. These results depicted that across location Aksum variety was significantly higher grain yield advantage by about 11.11% over standard check followed by Gute. Therefore, Aksum and Gute varieties were showed consistency over locations in this study and recommended to demonstrate with production packages in Meta and Fedis districts and similar agro ecologies.
Keywords: Finger millet; Varieties; yield.

Introduction

Finger millet [Eleusine coracana (L.) Gaertn] is one of the orphan crops indigenous to east Africa (Vavilov, 1951). In Ethiopia finger millet is one of the most important indigenous cereal crop grown largely by small holder farmers. It has wide agro-ecology adaptation (Mwikya *et al.* 2000). Finger millet has been mainly grown in Amhara, Benishangul-Gumuz, Oromia, Southern Nations, Nationalities and People's Region of Ethiopia, and Tigray. Finger millet covers about 453,909.38 ha of land with production of 915,314.518 tons (CSA, 2015). It had 3.62 and 3.39% share as compared to the national cereal crops area and production, respectively. Nutritionally, the crop is rich containing high ash, calcium and iron content, which is essential for strengthening bone and teeth and reduce incidence of anemia (Singh and Raghuvanshi, 2012).

Finger millet is an important crop grown in low input farming systems by resource poor farmers in eastern and western Oromia. It is valued for nutrition, preparation of cultural food and brewing, source income which fetches more than double the price of maize and sorghum, livestock feed, thatch and basket weaving. Some varieties contain high levels of methionine, an amino acid lacking in the diet of hundreds of millions of poor people who live on starch food of root crops such as sweet potato, cassava, etc. (NRC, 1996). It can be grown under condition of low rain fall and can with stand in drought, reviving again with a good shower of rain with remarkable vigor which is favorable agro- ecology for Hararghe condition. Among suitable areas for producing finger millet, Eastern Hararghe has the potential. While as compared to its genetic potential of 4-5ton ha^{-1} (Dida *et al.*, 2008), yield in Ethiopia is low, which is mainly due shortage of seed of improved variety, poor agronomic managements, high lodging, moisture stress, disease mainly blast and weeds (Fentie *et al*., 2013, Mulualem and Melak, 2013). However, plant breeding has been instrumental in boosting crop production in the world. Increased crop yield is the preliminary aim of most plant breeding programs (Fentie *et al*., 2013). Similarly, several researchers reported that finger millet received less emphasis from research and development for generating improved new varieties, crop management practice and enhancement of adoption of improved technologies (Andualem, 2008; Degu et al., 2009; Molla, 2010; Altaye, 2012; Tafere and Melak, 2013). However, advantages of new varieties developed include adaptation of new agricultural technologies, greater resistance to diseases and insects, greater yield of useful parts. This indicates that, in eastern Hararghe it is not fully addressed to satisfy the need for maximizing yield, using high yielder, disease resistant and early maturing variety of the crop. Developing or adapting improved finger millet varieties with high yield and wide adaptation could be the major objectives to address these gaps in the study area . Therefore, the main objective of this activity was to select adaptable, high yielder, early maturing and disease resistant or tolerant of finger millet varieties across moisture stressed areas of eastern Hararghe, Oromia.

Materials and Methods

Description of Experimental Site

Fadis and Meta districts were the testing sites found in Eastern Hararghe Zone, Ethiopia. Their geographical and edaphic (Table 1) characteristics are indicated in tabular form

Table1. Description of experimental sites in the two districts of Eastern Hararghe

Description	Parameters	Meta(Chelenko)	Fadis(Boko)
Edaphic factor	PH	*	7.97
	Class	Clay loam	Clay loam
	soil type	Vartisoil	Vartisoil
	%OM	*	1.64
	%total N	*	0.11
	available P	*	5.45
Geographical positioning	Altitude	2130	1200-1765
	Latitude	$9^{0}35$’N	9^{o} 07’N
	Longitude	$41^{0}51$’E	42^{o} 04’E
Weather conditions	Maximum temp	$27C^{o}$	25^{0}
	Minimum temp	$12c^{o}$	15^{0}
	Rainfall (mm)	*	710

*** =information not available**

Treatments and Experimental Design

The experiment was conducted at Fadis and Meta districts. The treatments consisted of eight testing varieties (Addis-01, Aksum, Bako-09, Boneya, Gudetu, Gute, Meba, Padet and Mereb) and two standard checks (Tadese and Tesema) of finger millet. The experiment was laid out as a Randomized Complete Block Design (RCBD) and each treatment receiving the same management. The seed of each variety was obtained from Melkasa, Bako and Aksum Agricultural Research Centers. Some of the major characteristics of the varieties are indicated below (Table 2). Each experimental plot had an area of 3.6 m2 with five rows of 1.8m length spaced at 0.40 m between rows and 0.15 m between plants which is equivalent to seed rate of 15 $kgha^{-1}$. Fertilizer was applied at the rate of 100/50 kg /ha NPS and N, respectively.The total required amount of NPS applied at basal, but from the total nitrogen applied half was used at planting and the remaining was top dressed at tillering stage. Sowing was done on June 23, 2019 and June 26, 2019 at Fadis and Chelenko experimental sites, respectively. At the same time the guard rows were planted at both end side of experimental area.Hand hoeing and weeding was made one and two times, respectively, over the growing season to put the experimental plots free of weeds. There was no major insect pest incidence in the season and hence plants were not sprayed with any agro-pesticide. Other agronomic management practices were done as per their recommendation.

Agronomic Data Collected

Days to Flowering (DTF): This parameter was recorded as number of days from sowing to stage when ears emerged from 50% of the tillers per plot.

Days to Physiological Maturity (DPM): It was recorded as number of days from sowing to stage when 50% of the tillers per plot had matured ears (detected by yellowing of leaves).

Plant Height (PH) (cm): It was recorded by measuring the height of plants from ground level to the tip of inflorescence (ear), at dough stage.

Number of effective Tillers per Plant (NET/p): The number of effective tillers per plant was number of basal tillers that bear mature fingers and recorded from five randomly taken plants of each plot at harvest.

Number of finger per Plant (NF/p): The number of finger per plant was recorded as the total number of finger produced from all tillers and recorded from five randomly taken plants of each plot at harvest.

Finger Length (FL) (cm): The finger length was recorded from the base of the ear to the tip of the finger at each five randomly taken plants of main tillers, at dough stage.

Seed Yield (SYD) (kg ha^{-1}): Seed yield was determined by harvesting all plants from the five rows of each plot, since there was no space between plots to remove the border effect. Seeds were weighed by sensitive balance and approximately adjusted to 10% moisture content by drying in the sun.

Thousand Seed Weight (TSW) (g): Thousand seeds were counted manually from a bulk of threshed seeds of each plot, their moisture were adjusted and weighed in the same way as seed yield data.

Data Analysis

Analysis of variance (ANOVA) was done for all the traits following procedures of Gomez and Gomez (1984) using statistical analysis system (Gen stat 15th edition). Combined data analysis was done on the measured parameters in the two districts, since the error variances were homogenous. The mean separation was done with Fisher unprotected Test method. The level of significance used in 'F' and't' test was P =0.05. When the treatment effects found to be significant, the means was separated using the least significant difference at 5% level of probability. Additionally, GGE Bi plot was analyzed to determine stability of tested varieties over location.

Results and Discussions

Performance of Tested Finger Millet Varieties in Two Locations

The analysis of variance (ANOVA) revealed that highly significant ($P \leq 0.01$) difference for the parameters studied of plant height, number of finger per plant, finger length , and days to maturity. Similarly, significant ($P \leq 0.05$) difference for the effective tiller per plant and days to flowering (Table 2).

Even though , the results of combined analysis for days to flowering ranged from 84.33 to 87.89 days, there was no significance difference in days to reach flowering among tested varieties as compared to check (Tadese). The most prolonged duration (87.89 day) to reach 50% flowering was observed by Boneya variety whereas the minimum/earlier duration (84.33 day) to reach 50% flowering was observed on Tesema variety(Table 2**).** Days to physiological maturity ranged from126.9 to 154.7 days. Thus, Mereb variety was matured earlier than the rest varieties and recorded 126.9 days followed by Aksum (144.2days), Gute (146.1days), Addis-01(146.1days) and Tesema (146.3days) varieties whereas Tadese variety matured later (154.7 days) (Table 2)**.** The physiological maturity for the varieties Mereb and Aksum agreed with that of the observation by Molla (2012).The Tesema was the tallest (73.67 cm) variety, while Mereb was the shortest (71.8 cm) variety compared to check (Tadese) (Table 2). As far as finger length is concerned, Gute had the longest (10 cm) followed by Tesema (9.4cm) and Aksum (9.3 cm); however, the varieties Padet (7.2cm) and Meba (7.2 cm) had the shortest lengths when compared to check, Tadese (7.3cm) and other tested varieties(Table 2). The highest number of fingers was recorded by the varieties Bako-09 and Aksum followed by the variety Gudatu (7.23) and Boneya (7.17) whereas small number of fingers were recorded for the varieties Mereb as compared to check, Tadese(6.4)and the rest varieties. The highest mean numbers of effective tillers were recorded by the varieties Padet (6.9) followed by Mereb (6.3) and Gudetu (6.3). Correspondingly, less numbers of fingers were recorded by the varieties of Aksum (5.3) and Gute (5.4) as compared to standard check (Tadese). The results indicated the presence of sufficient variability, which could be attributed to the genetic potential of the varieties used among the evaluated varieties and for the traits under consideration

Previously Molla (2012) reported similar results with the current findings with reference to plant height, finger length and number of fingers tested under various environments. The varieties evaluated in the present study had a wide adaptation across the various agro-ecologies of the study areas. The differences in plant heights, finger lengths, and numbers of fingers and numbers of tillers among the finger millet varieties might be due to inherent characters of the varieties and the variability in the rainfall distribution in the study areas. Finger length, number of fingers and number of effective tillers per plant are important features of the crop in determining the yield potential, however, this result contradicts with the tested finger millet performance that illustrated maximum yield (i.e. Aksum and Gute varieties). Aksum and Gute varieties showed higher seed yield and long finger length with large number of seeds per finger. The present research results are consistent with the investigation by Molla (2012)

Table 2. Combined mean values for different traits of tested finger millet varieties in two districts of Eastern Hararghe Zone in 2018 and 2019 main cropping season

Varieties	**Days to flowering**	**Days to maturity**	**Plant height**	**Number of tiller**	**Number of finger**	**Finger length**
Addis-01	86.67^{ab}	146.1^{b}	85.28^{c}	5.89^{ab}	6.85^{bcd}	7.44^{d}
Aksum	86.00^{ab}	144.2^{b}	97.18^{ab}	5.33^{b}	8.04^{a}	9.29^{b}
Bako-09	87.56^{ab}	151.8^{c}	81.37^{cd}	6.07^{ab}	8.15^{a}	8.22^{c}
Boneya	87.89^{b}	152.9^{c}	92.66^{b}	6.11^{ab}	7.78^{ab}	7.86cd

Gudetu	86.33^{ab}	153.7^{c}	78.55^{d}	6.26^{ab}	7.82^{ab}	7.48^{d}
Gute	86.78^{ab}	146.1^{b}	94.85^{ab}	5.41^{b}	6.96^{bcd}	9.96^{a}
Meba	86.67^{ab}	151.7^{c}	92.63^{b}	5.78^{ab}	7.00^{bcd}	7.18^{d}
Mereb	85.22^{ab}	126.9^{a}	71.68^{e}	6.29^{ab}	6.11^{d}	7.56^{d}
Padet	85.78^{ab}	153.4^{c}	92.62^{b}	6.93^{a}	7.18^{abc}	7.18^{d}
Tadese	87.33^{ab}	154.7^{c}	97.28^{ab}	6.00^{ab}	6.44^{cd}	7.24^{d}
Tesema	84.33^{a}	146.3^{b}	99.42^{a}	5.41^{b}	7.04^{bcd}	9.44^{ab}
LSD (5%)	**3.5**	**4.1**	**6.6**	**1.3**	**1.0**	**0.6**
CV (%)	**4.3**	**2.9**	**7.9**	**23.2**	**14.7**	**8.3**

The analysis of variance (ANOVA) showed that highly significant (P≤0.01) difference for phenological and agronomic traits of plant height, days to flowering and days to maturity whereas not significant (P≤0.01) difference for the effective tiller, number of finger and finger length per plant between locations **(**Table 3).

Nevertheless, the results obtained from the experiment indicated that combined analysis for flowering was early (83.9 days) at Fadis, while it was late (87.92 days) at Meta. However, short duration (145.5 days) was required for physiological maturity at Fadis. On the contrary, plants required long duration (149.2 days) to mature at Meta (Table 3). Differences among varieties for phenological traits could be due to the inherent genetic ability of the varieties, altitude and climate differences. Hence, the longest duration (days) to physiological maturity was suitable to areas having long production season, but the early maturing ones are suited to short crop production season (Molla, 2012).

Table.3 Combined mean values for phenological and agronomic traits of finger millet tested varieties across locations in 2018 and 2019 main cropping season.

Location	Days to flowering	Days to maturity	Plant height	Number of tiller	Number of finger	Finger length
Meta	87.92	149.21	94.9	6.17	7.48	8.15
Fadis	83.39	145.52	86.67	5.77	7.08	8.04
LSD (5%)	**3.5**	**4.1**	**6.6**	**1.3**	**1.0**	**0.6**
CV (%)	**4.3**	**2.9**	**7.9**	**23.2**	**14.7**	**8.3**

Yield and YieldComponent

The analysis of variance (ANOVA) revealed that highly significant (P ≤ 0.01) difference in seed yield and significant (P ≤ 0.05) difference in thousand seed weight among the tested finger millet varieties (Table 4). However, the highest seed yield was recorded by Aksum (3090 kg ha^{-1}) followed by Gute (2807 kg ha-^{1}) as compared to all tested varieties. On the contrary, Mereb (2103 kg ha^{-1}) and Addis-01 (2121 kg ha^{-1}) were low yielding varieties as compared to standard check, Tadese (Table 4). Though, the high value of thousand seed weight was recorded for the varieties Addis-01(3.56g) followed by Boneya and Mereb (3.44 g) but there was no significant difference with that of Aksum(3.11g), which had large seed sizes, whereas, Gudetu(2.67g) had the low values of thousand seed weight (Table 4).

Therefore, the significant seed yield and thousand seed weight variations among varieties could be due to inherent genetic characters of the varieties, uneven rainfall distribution and variation in altitudes.The variation for seed yield and thousand seed weight might be due to the inherent genetic difference of the tested finger millet varieties (Molla, 2012). Similar results in their investigations and stated the presence of significant difference among varieties in seed yield of finger millet (Andualem, 2008; Chrispus, 2008; Molla, 2012). The varieties Aksum and Gute showed consistent performance in Finger length, number of fingers per plant and seed yield, which in turn, contributed to their selection preferences by farmers and plant breeders.

In the present study it has been observed that the higher yielding varieties were found to have both higher Finger length and number of fingers per plant than standard check. Therefore, Aksum and Gute had genetic differences in more than one preferred character, namely seed yield, higher Finger length and number of fingers per plant, could use as parent material in breeding program to improve finger millet.

Table.4: Combined mean values for yield and yield components of tested finger millet varieties in two districts of Eastern Hararghe Zone in 2018 and 2019 main cropping season

Variety	**1000 seed weight (g)**	**Seed yield (kg ha^{-1})**
Addis-01	3.56^{a}	2121^{d}
Aksum	3.11^{abc}	3090^{a}
Bako-09	3.11^{abc}	2554^{bcd}
Boneya	3.44^{ab}	2186^{cd}
Gudetu	2.67^{c}	2558^{bcd}
Gute	2.78^{bc}	2807^{ab}
Meba	3.11^{abc}	2603^{bc}
Mereb	3.44^{ab}	2103^{d}
Padet	2.89^{abc}	2542^{bcd}
Tadese	2.89^{abc}	2781^{ab}
Tesema	2.78^{bc}	2756^{ab}
LSD (5%)	**0.7**	**464.3**
CV (%)	**26.0**	**19.3**

The analysis of variance (ANOVA) revealed that highly significant ($p \leq 0.01$) difference in yield components between locations but there was not significant ($p \leq 0.01$) difference for thousand seed weight (Table 5), indicating the presence of sufficient genotypic differences in finger millet for the traits under consideration. The variability among the evaluated traits could be attributed to the genetic potential of the varieties used, which is in concurrence with the results of sorghum (Yalemtesfa *et al*., 2014; Mihret, 2015). Highest seed yield was obtained at Meta (2797 kgha^{-1}) as compared to Fadis (2434k gha^{-1})(Table 5). Generally, the performance of tested finger millet varieties was recorded higher at Meta than at Fadis. This might be because of occurrence of favorable weather conditions throughout the growing season of the crop at Meta.

Table. 5 Combined mean values for yield and yield components of the varieties across locations in 2018 and 2019 main cropping season

Location	1000 seed weight (g)	Seed yield (kg ha^{-1})
Meta	3.06	2797
Fadis	3.08	2434
LSD (5%)	**0.7**	**464.3**
CV (%)	**26.0**	**19.3**

References

Altaye Sisaye. 2012. Analysis of research-extensionfarmer linkage in finger millet technology development and delivery in Mecha District of Amhara Region, Ethiopia. Journal of Agricultural Economics and Development, 1(6): 121-129.

Andualem Wollie. 2008. Characterization, Evaluation and Variability for Grain Yield and Related Traits of Finger Millet [Eleusine coracana (L.) Gaertn.] Germplasm. M.Sc Thesis, Haramaya University, Haramaya, Ethiopia.

Chrispus, O.A. 2008. Breeding Investigation of Finger millet Characteristics including blast disease and striga resistance in Western Kenya. PhD thesis, University of KwaZulu-Natal, Republic of South Africa.

CSA (Central Statistical Agency). 2015. Agricultural sample survey report on area and production for major crops (Private peasant holdings meher season). Central Statistical Agency, Statistical Bulletin, 1(578). Addis Ababa, Ethiopia.

Degu Erenso, Asfaw Adugna, Taye Tadesse and Tesfaye Tesso. 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, 19-21 September 2007. Bern, Switzerland. Edition. John Wiley and Sons, New York. 680 pp.

Dida M.M., Srinivasachary, S. Ramakrishnan, J.L. Bennetzen, M.D. Gale and K. Devos (2008) Population structure and diversity in finger millet (Eleusine coracana) germplasm. Tropical Plant Biol. 1:131-141.

Fentie, M, A Assefa and K Belete. 2013. AMMI analysis of yield performance and stability of finger millet genotypes across different environments. World J of Agric. Sci. 9: 231-237.

Gomez, A.K. and Gomez, A.A. 1984. Statistical procedures for Agricultural Research, 2nd IBPGR (International Board for Plant Genetic Resources).1985. International Board for Plant Genetic Resources. pp. 1-20. Descriptors for Finger millet. IBPGR Secretariat. FAO, Rome, Italy.

Mihret Yirgu. 2015. Genetic gain in lowland sorghum [Sorghum bicolor (L.) Moench] varieties in Ethiopia. International Journal of Horticulture and Plant Breeding Sciences, 2(1): 1 -13

Molla Fentie. 2010. Genotype x Environment Interaction and Stability Analyses of Yield and Yield Related Traits of Finger Millet (Eleusine coracana (L) Gaertn) Varieties in Northwestern Ethiopia. M.Sc Thesis, Haramaya University, Haramaya, Ethiopia.

Molla Fentie. 2012. Participatory evaluation and selection of improved finger millet varieties in Northwestern Ethiopia. International Research Journal of Plant Science, 3: 141-146.

Mulualem T., Melak A. (2013). A survey on the status and constraints of finger millet (Eleusine coracana L.) production in Metekel Zone, North Western Ethiopia. Direct Research Journal of Agriculture and Food Science 1, 67-72.

S Mbithi-Mwikya, John Van Camp, Y Yiru and André Huyghebaert. 2000. Lebensmittel-Wissenschaft Und-Technologie-Food Science and Technology. 33(1). p.9-14

NSRC (National Soil Research Center). 2006. Soils of Adet Agricultural Research Center Testing Sites. Addis Abeba, Ethiopia.

Singh P. and R.S. Raghuvanshi (2012) Finger millet for food and security. African Journal of Food Science. 6:77-84. Available online at http://www.academicjournals.org/AJFS. Accessed June 2016.

Tafere Mulualem and Melak Adane. 2013. A survey on the status and constraints of finger millet (Eleusine coracana L.) production in Metekel Zone, Northwestern Ethiopia. Pawe Agricultural Research Center, Pawe, Ethiopia. Journal of Agriculture and Food Science, 1(5): 67-72.

Vavilov, N.I. 1951. The Origin, Variation, Immunity and Breeding of Cultivated Plants (Translated by S. K. Chestitee). Chronica Botonica, 13, 1-366.

Yalemtesfa Firew, Firew Mekbib and Asfaw Adugna. 2014. Performance and Farmers' Evaluation of Released Sorghum [Sorghum bicolor (L.) Moenech) Varieties in Benishangul-Gumuz Region of Ethiopia. MSc Thesis: Haramaya University, Haramaya, Ethiopia.

Agronomy

Effect of Different Rates of Inorganic N_2-P_2O_5 Fertilizer and Farmyard Manure application on Yield and Yield Components of Irish Potato (*SolanumTuberosum L.*) at Bore Area, Southern Oromia, Ethiopia

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Abstract:

*The field trial was conducted during 2018 and 2019 main cropping season at Bore Agricultural Research Centre which is located in GujiZoneof Southern Ethiopia with the objective of determining the effect of combined application of inorganic (N_2-P_2O_5)fertilizer and FYM rates on growth, yield and yield components of Irish potato and to identify their economically appropriate rates that maximize the yield of Irish potato. The experiment was arranged in factorial combination of four level of farmyard manure (0, 3, 6 and 10 tons ha^{-1}) with five level of Urea (0, 44, 88, 132 and 176 kg ha^{-1}) and NPS (0, 49, 98, 147 and 197 kg ha^{-1}) in combination in RCBD with 3 replications. The longest days to physiological maturity (122.33) was recorded at the interaction of 4 t FYM ha^{-1} and 176*197 kg N_2-P2O5 ha^{-1}, but the shortest days (86) was observed at 4 t FYM ha^{-1} and 88*98 kg N_2-P_2O_5 ha^{-1}. The highest plant height (64.33 cm and 64.08 cm) was obtained from the combination of 0 and 6 t ha^{-1} FYM with 176*197 kg of N_2-P_2O_5 fertilizers rates respectively, while the lowest plant height (37.66 and 38.58 cm) was recorded at control treatment (0 kg N_2-P_2O_5) and 6 t ha^{-1} FYM ha^{-1}. Data analysis showed that maximum number of stems per plant (10) was recorded in plants planted with fertilizer rate of 132 kg N_2+ 147 kg P_2O_5 and 6 t ha^{-1} FYM, While minimum number of stem number per plant (4.66) was recorded for 0 kg N_2-$P_2O_5$and 3 t ha^{-1} FYM treatment. Combined application rates of 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with 6 t ha^{-1} FYMrecorded maximum (14.77) tuber number per plant while application of zero N_2-P_2O_5 fertilizers + 6 t ha^{-1}FYMrecorded the smallest (8.22) tuber number per plant. Similarly, the combined application of 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg $P_2O_5$$ha^{-1}$ produced the highest marketable root yield (39.4 t ha^{-1}) while the lowest yield (12.55 t ha^{-1}) was obtained from 4 t ha^{-1}FYMand0 kg P_2O_5 ha^{-1}. Maximum total tuber yield (45.98 t ha^{-1}) was obtained from 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1}whereas the lowest (17.71 t ha^{-1}, 18.29 t ha^{-1} and 18.65 t ha^{-1}) was obtained at combined application of 0 N_2-P_2O_5+ 4 t FYM ha^{-1} and 0 N_2-P_2O_5 + 6 t FYM ha^{-1} application rates, respectively. The marginal rate of returns, which determines the acceptability of any treatment shows that, treatment receiving 132 kg N_2 + 147 kg P_2O_5 ha^{-1} fertilizer rates in combination with 6 t ha^{-1} of FYM yielded good results of 26943.2% marginal revenue. Therefore the most attractive rates for producers with low cost of production and higher benefits were 132 kg N_2 and 147 kg P_2O_5 ha^{-1}in combination with 6 t ha^{-1} farmyard manure can be recommended for farmers in Bore and areas with similar agro ecological condition.*

Key Words: Combined, Factorial, Farmyard Manure, Inorganic, Marginal Rate of Return, Rate

1.

1. INTRODUCTION

Potato *(Solanumtuberosum L.)* is one of the most widely grown tuber crops in the high and mid altitude areas of southern region. The crop is widely grown in Bore and Anasora areas (Personal). As a high yielding crop, it can greatly contribute in securing food in these highly populated areas. Declining soil fertility is one of the major problems causing yield reduction in Ethiopia. Farmers at Bore and Anasora apply both organic and inorganic fertilizers to overcome the problem of soil fertility and increase yield. A research conducted in Taiwan indicated that application of manures increased the availability of N and P (Chen *et al.*, 2001). In addition to providing essential nutrients, compost also improve soil structure and benefit soil organisms (Pretty, 1995).

In Ethiopia root and tuber crops are part of the traditional food systems of the people especially in the southern, southwestern and western part of the country. There is enormous possibility for millions of poor farmers to boost production and their livelihood using root and tuber crops which are strategic crops for the country's economy (Amsalu*et al.*, 2008).Ethiopia has the highest livestock resource in Africaandhence, achieving sustainable increases of agricultural production has been the highest priority of the country. Especially in areas with high livestock resource like Guji, FYM would be an excellent input for crop production. Highland parts of Guji Zone have humid and sub humid moisture condition, with longer growing season. Most cereal crops like maize take longer times to mature. But root and tuber crops like Irish potato which are dominantly cultivated by the farmers matures in short growing season. However, since manures contains less nutrient concentration as compared to chemical fertilizers and it releases nutrients slowly, it doesn't provide all the nutrients which are highly required by the crops (Emiru, 2004).

Use of integrated nutrient management and correct agricultural practices such as optimum application of nutrients has to be adhered for successful vegetable production (Bulluck*et al.*, 2002). Yazachew and Kasahun (2011) reported that the area was well known with the livestock resource. Livestock population size of the District was about 1095916 during year 2000 out of which cattle, goats and sheep account for 709722, 338386 and 36523 respectively.These abundant resources are a good quality source of organic fertilizer. However, the productivity of Irish potato per unit area is quite low as compared to developed countries of the world.Therefore, the use of integrated nutrient management is very important and best approach to maintain and improve soil fertility. So thatintegrated use of both manure and chemical (inorganic) fertilizers is the best alternative to provide balanced and efficient use of plant nutrients and increase productivity of soil. Therefore, the current project was proposed to determine the effect of combined application of inorganic Nitrogen, NPS fertilizer and FYM rates on growth, yield and yield components of Irish potato and to identify their economically appropriate rates that maximize yield of Irish potato.

LITERATURE REVIEW

Origin and Ecology

The potato was first cultivated in South America between three and seven thousand years ago, though scientists believe they may have grown wild in the region as long as 13,000 years ago. The genetic patterns of potato distribution indicate that the potato probably originated in the mountainous west-central region of South American, Peru. There are strongly evidences that potato was widely distributed throughout the Andes from Colombia to Peru and also in Southern Chile (Nonnechke, 1989; Hawkes, 1990). Globally, it is one of most important crop in terms of production as well as consumption and ranks fourth after wheat, rice and maize (FAO, 2008). It also ranks first among root and tuber crops followed by Cassava, Sweet potatoes and Yams (Hawkes, 1990; FAO, 2008). Potato was introduced to Ethiopia in 1859 by the German botanist Schimper (Gebremedhin*et al.*, 2008). Potato production has increased considerably through the twentieth century.

Potato is best adapted to a high altitude 2000- 3000 meters above sea level and the frost resistant species grow from 3000-4000 masl best yielders at 2500-3500 masl (Poehlman, 1995). In Ethiopia Most of the Central Highlands, at altitudes ranging from 1,500-3,000 masl and annual precipitation of 600-1200 millimeters are more favorable (Gebremedhin*et.al.* 2008).

Response of Vegetables to Nutrient Application

In developing countries, it is common that excessive fertilizer rates are applied to vegetable gardens and fields to attain high yield. High application rates of fertilizers in urban areas are thought to be economically reasonable due to limited agricultural land and low cost of organic fertilizer inputs as compared to the value of the marketable product. However, proper fertilizer balance is required for optimum growth and development of vegetables since excessive rates increases their susceptibility to fungal diseases and deterioration of keeping quality (Moeskops*et al*., 2010). Nkoa*et al*, (2002) found that using mineral fertilizer (N, P, and K) increasing leafy vegetables vegetative growth, yield and quality.

Both yield and tubers qualities are affected by variety, environmental conditions and cultural practices. Fertilizer application has important effects on the yield and quality of potatoes (Westermann, 2005). Potato is highly responded to N fertilizer and it is usually the most specific essential nutrient for potato plant growth on all soils, especially on sandy soils (Errebhi*et al.*, 1998). Previous studies have shown that nitrogen fertilizer can increase the growth characteristics, such as plant height, shoot dry matter, leaf area index and tubers yield (Kumar *et al.*, 2007; Sincik*etal.*, 2008; Zelalem*et al.*, 2009). Appropriate use of nitrogen fertilizer can lead to accomplishment of optimum foliage development and subsequently increases tubers yield. The excessive use of nitrogen can lead to increase vegetative growth rather than tubers production and delay potato maturity (Love *et al.*, 2005; Kumar *et al.*, 2007) and reduces tubers quality (Zebarth and Rosen, 2007). Likewise, Ahmed *et al.* (2009) indicated that vegetative growth characters, tubers yield, marketable tubers percentage and tubers quality were influenced by different rates of nitrogen fertilizer.

Response of Irish Potato to Nitrogen, Phosphorus and Manure Application

Plant nutrition is the practice of providing to the plant the right nutrient, in the right amount, in the right place, at the right time. Nutrients can be applied in various ways to meet the requirements for potato production. Singh and Grewal (1986) have shown that the high yield and good quality of potato can be achieved by an efficient use of fertilizers. Various factors affect crop growth in addition to the nutrient supply. However, yields have been significantly increased by applying the recommended doses of mineral nutrients in time, provided that all other factors are in a reasonable balance. Some work has been done on the efficient use of fertilizer in the Sudan. Nahdi, (1977) reported that the optimum rate of nitrogen fertilizer for potato in the Sudan was 169.28 kg N/ha applied in two equal doses.

But Ali (1986) stated that the applied nitrogen should be in bands at the rate of 5.4 kg of pure nitrogen per feddan in two equal doses.

Despite the negative effects of excessive chemical N fertilizer, application of chemical nitrogen fertilizer has remarkably increased during the last years (Freire and Sa, 2006). So, the developments of new methods become an urgent need for potato producers to use other nutrient sources (Goffart*et al.*, 2008). Today, the price of mineral fertilization has been raised so much. It becomes more than the ability of the majority of framers. Besides, the high price of mineral fertilization increases the production costs.

Using of chemical fertilizers alone may not be sufficient under intensive agricultural management and result in a possible depletion of essential micronutrients thereby resulting in an overall reduction in total crop productivity (Hepperly*et al.*, 2009) and significant soil problems such as soil degradation and soil pollution causes by high application rates of chemical fertilizers (Singh, 2000). The animal manure such as cattle manure is another source of N and other nutrients, which can decease the demand of chemical fertilizer and it has been used for many centuries to increase soil fertility Except for the supply of nitrogen fraction, animal manure can improve chemical, physical and biological characteristics of the soil (Benke*et al.*, 2008).

Nitrogen is the motor of plant growth. It makes up 1-4% of dry matter of the plant. It is taken up from the soil in the form of nitrate ($NO3^{-}$) or ammonium ($NH4^{+}$). In the plant, it combines with compounds produced by carbohydrate metabolism to form amino acids and proteins. Being the essential constituent of proteins, it is involved in all the major processes of plant development and yield formation. A good supply of nitrogen for the plant is also important for the uptake of the other nutrients (Bell, 2016).

Firew*et al*. (2016) conduct an experiment to know the effects of nitrogen and phosphorus on growth and yield of potato using Babu Potato variety. The authors applied four rates of nitrogen (0, 56, 112 and 168 Kg N ha^{-1}) and four rates of phosphorus (0, 46, 92 and 138 Kg P2O5 ha^{-1}) and observed that plant height increase with increasing of nitrogen level up to 168 kg ha^{-1}. Maximum (88.67 cm) plant height was recorded at a rate of 168 kg ha^{-1}. Birtukan (2016) stated that Phosphorus fertilization significantly increased the marketable tuber yield. Increasing application of phosphorus has increased marketable tuber yield per hectare. Maximum tuber yield was recorded at a rate of 135 kg ha^{-1} with 98% yield advantage over control treatment. Phosphorus performs functions in plants, such as a structural element forming part of the macromolecular structures such as nucleic acids (RNA and DNA) and in the phospholipids of cell membranes (Marschner, 2002).

MATERIAL AND METHODS

Description of the Study Sites

The climatic condition of the area is mostly humid and sub humid moisture condition and relatively with longer growing season. Bore is found at Latitude of 6^{o}26'52” N and Longitude 38^{o}56'21” E at an altitude of 2736m.a.s.l. The annual rainfall ranges from1400-1800 mm with bimodal pattern that extended from April to November. The mean annual minimum and maximum temperature is around 10.1 and 20 ^{0}C, respectively (Anonymous, 2014). The soil is clay in texture and very strongly acidic with pH around 4.01-5.33.

Description of Experimental Materials

Irish potato variety "Gudene" was used as experimental material andthe seed of the variety was obtained from the team of seed maintenance program. The choice of this variety was due to its good adaptability and high yield. The variety ispopular among farmers and widely cultivated and consumed in different highland parts of the GujiZone and best variety for highlands of the area.

Experimental Design and Treatments

The field trial was conducted during 2018 and 2019 main cropping season at Bore Agricultural Research Centre which is located in GujiZoneof Southern Ethiopia with the objective of determining the effect of combined application of inorganic N_2, P_2O_5 fertilizer and FYM rates on growth, yield and yield components of Irish potato and to identify their economically appropriate rates that maximize yield of Irish potato.

The experiment was arranged in factorial combination of four level of farmyard manure (0, 3, 6 and 10 tons ha^{-1}) with five level of Urea (0, 44, 88, 132 and 176 kg ha^{-1}) and NPS (0, 49, 98, 147 and 197 kg ha^{-1}) in combination. The experiment was laid out in RCBD with 3 replications. Urea (46% N) and NPS (38% P_2O_5 + 19% N + 7% S) fertilizers was used as sources of N and P, respectively. The spacing of the plants was 75 cm between rows and 30 cm between plants. The distance between plot and block was 1.5 m and 0.60m, respectively. Four rows per plot,seven plants per rowand totally 35 plants per plot were established in gross plot size of 3m*2.1 m (6.30m^2).

Soil and Farmyard Manure Sampling and Analysis

Soil samples to a depth of 30 cm were collected in a zigzag way from different spots of the experimental field before land preparation and composited. After harvest soil samplesweretaken in the same manner to the pre planting in a zizag way from 15 different plots. Then the composite samples were analyzed for physico-chemical properties of the soil mainly for organic carbon, total N, soil pH, available phosphorus, cation exchangeable capacity (CEC) and texture at Horticoop EthiopiaPlclaboratory for soil and manure, respectively. The soil pH was measured potentiometrically in the supernatant suspension of 1:2.5 soil-water suspensions with standard glass electrode pH meter (Van Reeuwijk, 1992). The Walkley and Black (1934) method was used to determine the organic matter content and the result was obtained by multiplying percent organic carbon by conversion factor of 1.724. The total nitrogen content of the sampled soil was determined following Kjeldahl digestion, distillation and titration procedure as described by Cottenie (1980). Besides, available phosphorus was determined by Olsen *et al.*, (1954) method. The cation exchange capacity (CEC) was measured using 1Mneutral ammonium acetate (Jackson, 1967). The soil particle size distribution was determined using the hydrometer technique (Ryan *et al.*, 1965). The manure sample was taken from the well decomposed material and collected from known farmer near to the experimental site and composted in the research station and air dried, and analyzed at laboratory for pH, total N, available P, available K, available S, CEC, organic carbon content and Textural class.

Crop Data Collection

Days to 50% emergency, flowering, maturity, plant height (cm), stem number, average tuber weight (g), average tuber number per plant, marketable and unmarketable yield and total yield (kg) per plot was measured and converted to hectares. Cost benefit analysis was done to determine the relative economic returns on the applied treatments using the prevailing market prices.

Partial Budget Analysis

Variable cost of fertilizer and wage for incorporation was largely used for partial budget analysis. Price fluctuations during the production season were considered. 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 potato due to the application of each rate to the total cost of fertilizer and FYM applied at each rate. This enables to identify the most economic rate and source of N and P fertilizer for cabbage production. This was achieved by dividing the total variable cost by the net benefit multiplied by 100.

$$MRR (\%) = \frac{\text{Marginal benefit}}{\text{Marginal Cost}} \times 100$$

Statistical Data Analysis

Analysis of variance procedures was used on every measured parameter to determine the significance of differences between means of treatments using the SAS 9.1.3 systems software for each parametersand separated by the least significant difference (LSD) using the statistical package. The collected data on various parameters of the crop under study was statistically analyzed using SAS statistical package. The Least Significant Difference (LSD) test at 5% level of significance was used to separate the means.

RESULT AND DISCUSSIONS

Soil and Farmyard Manure Sampling and Analysis

Soil Physicochemical Properties of Site before Planting

From the soil analysis result before sowing it was clearly revealed that the soil textural class was clay with constituents of sand (28%), clay (42%) and silt (28%) which is ideal for Irish potato as the crop is grown mostly on light-textured soils ranging from coarse and fine sands to sandy clay loams (Onwueme and Sinha, 1991). The soil pH (H_2O) of 4.35 rated as strongly acidic, total nitrogen (0.31%) is as high, available phosphorus (4.62 ppm) as low, cation exchange capacity (23.12 Meq/100g) as moderate according to the classification by Landon (1991) and available potassium concentration of (269.5 mg/kg (ppm)) as high according to the rating of Moore (2001) (Table 1). Thus, moderate to low mineral content of the soil implied that there was necessity of applying or ignoring essential nutrients to the experimental plot of the study area and also need to improve the physical nature of the soil including soil acidity.

Table 1. Soil Physiochemical properties of experimental site before planting.

Soil characters	Values	Examination standards
pH (by 1: 2.5 soil water ratio)	4.35	ES ISO 10390:2014(1:2.5)
Total nitrogen (%)	0.31	ES ISO 11261:2015(Kjeldahl Method)
Organic carbon (%)	3.09	Walkley and Black Method
Available phosphorous (mg/kg (ppm))	4.62	ES ISO 11261:2015(Olsens Method)
Cation exchange capacity (Meq/100g)	23.12	Ammonium Acetate Method

Available potassium (mg/kg (ppm))	269.50	Ammonium Acetate Method
C:N	9.97	
Available sulfur (mg/kg (ppm))	31.19	Turbidometreic
Soil texture:		Bouyoucos Hydrometer Method
Sand	28	
Clay	42	
Silt	30	
Class	Clay	

Source: Tekalignet al. (1991), Berhanu (1980), Moore (2001), Olsen et al. (1954), Jones, J. Benton (2003) and Hazelton and Murphy (2007)

Table.2 Chemical properties of farmyard manure used in the experiment

FYM characters	Values	Examination standards
pH (by 1: 2.5 soil water ratio)	7.64	ES ISO 10390:2014(1:2.5)
Total nitrogen (%)	1.76	ES ISO 11261:2015(Kjeldahl Method)
Organic carbon (%)	33.99	Walkley and Black Method
Available phosphorous (mg/kg (ppm))	859.74	ES ISO 11261:2015(Olsens Method)
Cation exchange capacity (Meq/100g)	42.63	Ammonium Acetate Method
Available potassium (mg/kg (ppm))	15189	Ammonium Acetate Method
Available sulfur (mg/kg (ppm))	164.65	Turbidometreic

Source: Horticoop EthiopiaPlc

Soil Physicochemical Properties of Site after Crop Harvest

The analysis of the experimental soil after harvest for pH, available phosphorus, total nitrogen, sulfur, available potassium, organic carbon, cation exchange capacity and texture is indicated in Table3.

The analysisresults indicated that the textural class of the soil was clay loam soil profile. The result obtained from soil analysis showed that the treatments with combined rate of 132 kg N ha^{-1} and 147 kg P ha^{-1} with 10 t ha^{-1} of FYM gave an increase of 5.7 % pH. However control treatment gave an increased available P of 23.23 mg/kg of soil and high (31.23 Meq/100g) level of CEC. According to Booker CEC 25-40 Meq/100g valued as high. Similarly, the combined application of 132 kg N ha^{-1} and 147 kg P ha^{-1} with 4 t ha^{-1} of FYM increased the OC level from 3.32 % after harvest. Below the analysis result shows as the rate of FYM increases up to 6 t ha^{-1}, the soil OM characteristic parameters were increased with increase in nitrogen and phosphorus concentration. Maximum available K (283.5 mg/kg) was recovered, when control nutrient with 4 t ha^{-1} FYM applied with relatively higher rate of potassium. This implies that FYM application possibly increased the pH, total nitrogen of the soil and organic matter so that Irish potato utilized the nutrients for proper growth and development that lead to higher yield. Moreover, the addition of 132 kg N ha^{-1} and 147 kg P ha^{-1} fertilizer rate increased the level of available S in the soil by 1.44 mg/kg. Generally, the soil physical and chemical analysis results indicated that the soils of the experimental fields are potentially productive from the perspectives of chemical properties of soils for potato growth and had a potential to respond to fertilizer application.

Table 3. Soil analysis result of experimental site after crop harvest

Treatment		PH	P(mg/kg)	S(mg/kg)	K(mg/kg)	CEC(Meq/100g)	OC (%)	OM (%)	TN (%)	C:N ratio	Sand	Clay	Silt	Class
NP(kg/ha)	FYM(t/ha)													
0	0	4.85	23.23	12.53	124.8	31.23	3.11	5.37	0.3	10.24	18	44	38	clay
0	4	4.76	7.08	13.6	283.5	23.49	3.14	5.42	0.31	10.01	30	44	26	clay
0	6	4.39	8.13	15.02	84	29.11	3.15	5.44	0.31	10.07	26	44	30	clay
0	10	4.1	10.02	14.54	99.75	27.41	3.03	5.22	0.3	10.03	26	44	30	clay
44*49	0	4.45	8.13	15.02	120.75	22.64	2.95	5.08	0.3	9.66	26	46	28	clay
44*49	4	4.53	9.69	14.2	106	28.66	3.06	5.27	0.31	9.77	26	46	28	clay
44*49	6	4.7	8.63	9.49	206.7	19.74	2.95	5.08	0.3	9.76	26	46	28	clay
44*49	10	5.31	9.69	14.68	79.5	21.33	3.07	5.29	0.31	10	26	42	32	clay
88*98	0	5.64	21.77	15.64	116.6	22.18	3.07	5.29	0.3	10.41	30	42	28	clay
88*98	4	5.61	14.14	15.64	127.2	20.31	2.87	4.94	0.31	9.3	28	44	28	clay
88*98	6	5.62	12.75	15.96	215.25	20.03	3.2	5.52	0.33	9.8	28	42	30	clay
88*98	10	5.37	10.4	13.13	130.8	22.37	3.24	5.59	0.32	10.03	30	40	30	clay
132*147	0	5.37	11.38	18.44	127.2	24.13	3.27	5.65	0.32	10.36	30	42	28	clay
132*147	4	5.5	8.34	3.78	189	22.01	3.32	5.73	0.31	10.2	30	44	26	clay
132*147	6	5.51	13.8	10.82	105	21.25	3.24	5.59	0.32	10.26	30	42	28	clay
132*147	10	5.7	18.42	10.82	126	22.13	3.24	5.59	0.3	10.74	30	42	28	clay
176*197	0	5.46	12.66	14.68	106	22.07	3.08	5.31	0.3	10.45	30	44	26	clay
176*197	4	5.34	10.23	17.38	105	18.98	3.15	5.43	0.3	10.58	28	44	28	clay
176*197	6	5.53	18.84	13.6	99.75	22.47	3.16	5.45	0.3	10.47	28	42	30	clay
176*197	10	5.44	10.23	14.07	105	20.16	3.08	5.31	0.32	9.72	28	42	30	clay

Phenological Parameters of Irish Potato

Days to Emergency

The interaction effects of Mineral NP and FYM were significantly ($P<0.05$) influenced due to days to emergency bud sprouting of sweet potato Moreover, this trait was significantly influenced by the interaction effect of FYM and phosphorus. Data of table 4 demonstrated that application of farmyard manure and N_2-P_2O_5 had positive influence on phenological characters days to emergency, flowering and maturity of potato plants.

The fastest days to emergency (12 days) was recorded at combination of 10 t ha^{-1} FYM with all rates of N_2-P_2O_5, which may be due to better water holding capacity of the applied FYM around root zone of the cuttings which enables initiation of roots and make the seed emerge early. The longest days to emergency (17 days) was recorded at combination of control application of N2-P_2O_5 with all rates of FYM. Days to emergency was delayed at treatments with no fertilizer and minimum rates which indicated that application of nutrients is crucial for root initiation which speeds up emergency of tubers (Tables 4).

Days to 50% flowering

The combined analysis of data showed that in both consecutive two years,the interaction effects of treatments between different farmyard manure levels and inorganic nitrogen and phosphorus fertilizer rates significantly (P<0.05) different due to days to flowering. The highest days (79) to flowering was recorded by the combined application of 176*197 and 132*147 kg ha^{-1} N_2-P_2O_5 with 6 t ha^{-1} FYM.

Days to 90% Maturity

The main and interactioneffectsof N_2,P_2O_5 andFYMsignificantly (P<0.05) different on days to maturity of potato. The highest days to physiological maturity (122.33) was observed at the interaction of 4 t FYM ha^{-1} and 176*197 kg N_2-P2O5 ha^{-1}, but the lowest day (86) was observed at 4 t FYM ha^{-1} and 88*98 kg N_2-P2O5 ha^{-1}. The result indicated that increasing rate of FYM delayed time of maturity of Irish potato which may be attributed to the role that nutrient plays significant role in promoting vegetative growth before the start of tuberous root development as nitrogen promotes vegetative growth thereby delaying plant maturity.

Table 4. Combined Interaction effects of FYM and N-P_2O_5 fertilizers on days to emergency, days to flowering, maturity, plant height and stem number per plant of Irish potato at Bore in 2018 and 2019

Treatments		Yield and yield related Parameters				
NP(kg/ha)	FYM(t /ha)	DE (days)	DF (days)	DM (days)	PH (cm)	STMN (No)
0	0	12^{d}	74^{bc}	95^{ef}	55.58^{a-f}	7.33^{bc}
0	4	13.33^{bc}	71^{cd}	113^{a-e}	46.41^{fghi}	6^{bcd}
0	6	12^{d}	74.66^{bc}	104.33^{a-e}	63.33^{a}	8.33^{ab}
0	10	14^{b}	74^{bc}	103.33^{b-f}	50.91^{d-h}	6.66^{bcd}
44*49	0	14^{b}	68.33^{d}	104.66^{a-e}	52.50^{c-g}	6.66^{bcd}
44*49	4	17^{a}	68^{d}	102.33^{def}	37.66^{i}	5.66^{cd}
44*49	6	13.33^{bc}	70^{d}	86^{f}	56.83^{a-e}	7^{bcd}
44*49	10	14^{b}	74^{bc}	105^{a-e}	49.41^{efgh}	6.33^{bcd}
88*98	0	17^{a}	69^{d}	111^{a-e}	38.58^{i}	5.33^{cd}
88*98	4	12^{d}	76.33^{ab}	122.33^{a}	62.08^{ab}	7.66^{abc}
88*98	6	16^{a}	70^{d}	112.66^{a-e}	52.66^{c-g}	7^{bcd}
88*98	10	17^{a}	69.66^{d}	102.33^{def}	42^{hi}	6^{bcd}
132*147	0	12^{d}	79^{a}	119.33^{a-d}	61.08^{abc}	7.33^{bc}
132*147	4	12^{d}	75.33^{ab}	116^{a-d}	64.08^{a}	5.66^{cd}
132*147	6	12^{d}	79^{a}	116.33^{a-d}	55.33^{a-f}	8.33^{ab}
132*147	10	12^{d}	77.66^{ab}	119.33^{a-d}	54.08^{b-f}	10^{a}
176*197	0	13.33^{bc}	74.66^{bc}	108.66^{a-e}	56.16^{a-e}	7.33^{bc}
176*197	4	12^{d}	77.33^{ab}	120.66^{abc}	57.25^{a-e}	7.66^{abc}
176*197	6	12.66^{cd}	75^{b}	121.33^{ab}	59.66^{a-d}	7.66^{abc}
176*197	10	17^{a}	67.33^{d}	102.66^{cdef}	44.08^{ghi}	4.66^{d}
	Mean	13.73	73.21	109.31	52.98	6.93
	LSD (5%)	1.06	3.67	18.20	9.19	2.47
	CV (%)	4.7	3.03	10.09	10.51	21.63

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where DE=days to emergency, DF=days to flowering, DM=days to maturity, PH=plant height, STMN=stem no per plant, T= NP rate, F= FYM rate, LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Growth Parameters of Irish Potato

Plant height and Stem number of the plant

Significant variation was found in plant height at different application rates of N_2-P_2O_5 fertilizers and FYM (Table 4).The combined mean result showed that plant height of potato plants was significantly ($P<0.05$) affected by application of different inorganic N_2-P_2O_5 fertilizers and FYM rates at Bore. The highest plant height (63.33 cm and 64.08 cm) was obtained at combination rate of 0 N_2-$P_2O_5$and 6 t ha^{-1} FYM and when 176*197 kg of N_2-P_2O_5 fertilizers and 4 t ha^{-1} FYM combined , while the shortest plant height (37.66 and 38.58 cm) was recorded at control treatment and 6 t ha^{-1} FYM with 0 kg N_2-P_2O_5 ha^{-1}. In our result the plant was benefited from inorganic fertilizers for plant height development that may be due to nutrients of FYM is not readily available. Also this might indicate that potato uses little from NP to increase its height compared to the good effect that it derived from farmyard manure.

Stem Number of the Plant

The results of analysis of data revealed that main effects of FYM and different NPS fertilizer rates and their interactions had significant ($P<0.05$) effect on stem number of Irish potato plant in both years (Table 4).

Data analysis showed that maximum number of stems per plant (10) was recorded in plants planted with fertilizer rate of 132 kg N_2+ 147 kg P_2O_5 and 6 t ha^{-1} FYM, meanwhile minimum number of stem number per plant (4.66) was recorded for 0 kg N_2-$P_2O_5$and 3 t ha^{-1} FYMtreatment. The more is the number of stems per plant the more will be the number of tubers per plant. Number of stems per plant is also important for tuber size. Less number of stems per plant had tubers of large size and vice versa. This parameter is primarily recorded to see the impact of total sun shine received as well as spread of the root system of the plant (Solomon *et al.,* 2019).

Yield Components and Yield of Irish Potato

Tuber Number per Plant

The analysis results revealed that main effects of planting date and different NP fertilizer rates and their interactions had significant ($P<0.05$) effect on tuber number of Irish potato plant. The maximum (14.77) tuber number per plant was recorded with the interaction effects of 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with 6 t ha^{-1} FYM treatment and the least (8.22) tuber number per plant was recorded at rate of zero N_2-P_2O_5 fertilizers + 6 t ha^{-1} FYM, respectively. This may be due to optimum nutrient addition which enriched the soil for the uptake of macro and micro nutrients which are important for increasing tuber number. Warren (2004) showed that organic manure such as cow dung improved the soil pH which facilitated nutrient uptake by the plant. Addition of farmyard manure in combination with N fertilizer helped in maintaining the original organic matter status of the soil thereby facilitating for better tuber set.

Average Tuber Weight

The analysis of variance indicated that the average tuber weight was influenced significantly ($P<0.05$) by the interaction effect of FYM and N_2-P_2O_5. The maximum (187 g) average tuber weight was recorded at 10 t FYM ha^{-1}+ 132 kg N_2 + 174 kg P_2O_5 ha^{-1} and the lowest yield (109 g) was recorded at control treatment. The different between each treatment may be due to the fact that since the nutrient content and the rate of nutrient release vary among organic fertilizers and the level of growth is affected either positively or negatively.

Table 5. Combined interaction effects of FYM and N_2-P_2O_5 fertilizers on tuber number per plant, and average tuber weight, of Irish potato at Bore in 2018 and 2019

Treatments		TNP	ATW
NP(kg/ha)	FYM(t/ha)	(No)	(g)
0	0	11.55^{a-d}	147^{bcd}
0	4	10.89^{bcd}	133.33^{b-e}
0	6	11.16^{a-d}	139^{b-e}
0	10	11^{a-d}	151.67^{bc}
44*49	0	9.50^{cd}	149.33^{bc}
44*49	4	11.66^{a-d}	109^{e}
44*49	6	9.89^{cd}	138.33^{b-e}
44*49	10	12.22^{abc}	134.33^{b-e}
88*98	0	8.22^{d}	132.33^{b-e}
88*98	4	11.16^{a-d}	126.33^{cde}
88*98	6	9.16^{cd}	133.67^{b-e}
88*98	10	9.94^{bcd}	$150b^{c}$
132*147	0	10.33^{bcd}	152.67^{c}
132*147	4	10.77^{bcd}	140.67^{bcd}
132*147	6	12.72^{abc}	187^{a}
132*147	10	14.77^{a}	158.33^{ab}
176*197	0	11.11^{a-d}	137.67^{b-e}
176*197	4	11.55^{a-d}	156.33^{abc}
176*197	6	13.78^{ab}	154.67^{bc}
176*197	10	11.11^{a-d}	117.67^{de}
Mean		11.12	142.46
LSD (5%)		3.84	30.79
CV (%)		20.92	13.09

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where TNP=Tuber number per plant, ATW=Average tuber weight, T= NP rate, F= FYM rate, LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Marketable Tuber Yield

Theoverallmean result demonstrated that combined application of different FYM and N_2-P_2O_5 fertilizers rate highly significantly ($P<0.05$) influenced Irish potato yield.

The combination of 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} produced the highest marketable root yield (39.4 t ha^{-1}) while the lowest yield (12.55 t ha^{-1}) was from 4 t ha^{-1} FYM+0 kg P_2O_5 ha^{-1}. The highest yield at the highest rates of both FYM and N_2-P_2O_5 fertilizers rate may be due to the nutrient use efficiency of a crop increased through a combined application of organic manure and inorganic fertilizer as result of positive interaction and complementarities between them. These results are in agreement with those obtained by the studies (Alva, 2004 and Saeidi, 2009) who reported that the increase in nitrogen application amounts up to a definite point, increases growth parameters including tuber but beyond that, reversely decreases them. Over-application of nitrogen may result decrease in yield. This might be attributed to the fact that in such conditions, vegetative growth of the aerial parts can be increased and hencedecresingtransfer of photosynthetically matters into the tubers.

The yield difference between treatments was in line with the findings of Forbes and Watson (1994) who reported a positive interaction between organic and inorganic inputs when applied simultaneously. Integrated nutrient management implies the maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity on one hand and to minimize nutrient losses to the environment on the other hand (Singh *et al*., 2002).

Unmarketable Tuber Yield

Combined application of FYM and N_2-P_2O_5 fertilizers had significantly ($P < 0.05$) affect unmarketable tuber yield. The highest (9.28 t ha^{-1}) unmarketable tuber yield was obtained at 3 t FYM ha^{-1}+ 176 kg N_2 + 197 kg P_2O_5 ha^{-1}whereas the lowest (3.18 t ha^{-1}) unmarketable tuber yield was recorded at control treatment at Bore, respectively (Table 6).Plants grown at minimum and over nutrient application produced high unmarketable tuber yield than plants grown at optimum rate. When increased nutrient application rate, also increased the yield of unmarketable tuber yield. This might be zero and minimum rates had high competition of plants for growth factors due to nutrient deficiency than over nutrient application which led to produce high tubers size which was high unmarketable tuber yield.

Total Fresh Tuber Yield

Interaction effect of different FYM and N_2-P_2O_5 fertilizers application rates had significantly ($P < 0.05$) affected total tuber yield. Maximum total tuber yield (45.98 t ha^{-1}) was obtained at 6 tFYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1}whereas the lowest (17.71 t ha^{-1}, 18.29 t ha^{-1} and 18.65 t ha^{-1}) was obtained at combined application of control treatment, 0 N_2-P_2O_5+ 4 t FYM ha^{-1} and 0 N_2-P_2O_5 + 6 t FYM ha^{-1} application rates, respectively.The production difference between the treatments may be due to the low fertility level of the experimental site which gives lowest yield at control and at treatments which are treated with low level of FYM combined with nitrogen and phosphorus due to low level of the experimental site which made the yield not consistent but when it was treated with FYM in combination with N and P, the soil became productive and enabled to give optimum yield.According to the reports of Xiao *et al.(*2006) soil treated with manure was found to be loose, which probably provided adequate aeration and moisture into the soil and improved soil microbial activities which resulted in higher growth and maximum root yield and above ground biomass of crops.

Table 6. Combined Interaction effects of FYM and N-P_2O_5 fertilizers on of Irish potato at Bore in 2018 and 2019

Treatments		MY	UMY	TY
NP(kg/ha)	FYM(t/ha)	(t ha^{-1})	(t ha^{-1})	(t ha^{-1})
0	0	23.17^{fgh}	5.90^{b-g}	29.07^{def}
0	4	20.32^{g-j}	6.08^{b-f}	26.41^{efg}
0	6	19.19^{hij}	6.68^{a-d}	25.88^{e-h}
0	10	18.72^{hij}	3.47^{fg}	22.19^{gh}
44*49	0	25.25^{efg}	8.13^{abc}	33.39^{c}

44*49	4	15.11^{jk}	3.18^{g}	18.29^{i}
44*49	6	20.86^{f-i}	4.13^{d-g}	25^{fgh}
44*49	10	24.07^{fgh}	3.89^{efg}	27.25^{efg}
88*98	0	15.03^{jk}	3.61^{fg}	18.65^{i}
88*98	4	31.05^{cd}	9.28^{a}	40.33^{ab}
88*98	6	16.79^{ijk}	3.63^{fg}	20.42^{hi}
88*98	10	15.53^{jk}	3.80^{efg}	19.33^{hi}
132*147	0	26.11^{def}	4.93^{d-g}	31.04^{cd}
132*147	4	20.24^{g-j}	5.49^{c-g}	25.73^{e-h}
132*147	6	37.12^{ab}	6.02^{b-f}	43.15^{ab}
132*147	10	39.4^{a}	6.56^{a-e}	45.98^{a}
176*197	0	21.93^{f-i}	5.91^{b-g}	27.85^{d-g}
176*197	4	32.02^{bc}	3.62^{fg}	35.64^{b}
176*197	6	30.01^{cde}	8.23^{ab}	38.24^{b}
176*197	10	12.55^{k}	5.16^{d-g}	17.71^{i}
Mean		23.51	5.71	29.21
LSD (5%)		5.49	2.73	5.68
CV (%)		14.17	29.05	11.78

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. Where MY=Marketable yield, UMY=Unmarketable yield, TY=Total yield, T= NP rate, F= FYM rate, LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

Correlation Coefficient Analysis

Simple correlation coefficient values (r) computed to display the association between and within agronomic parameters of Irish potato as shown in Table 7. Days to maturity and tuber weight did not significantly correlate with an application of N_2-P_2O_5. Among the several parameters, days to emergency was strongly negatively correlated with the N_2-P_2O_5 application rates but not significantly negatively correlated with application rates of FYM indicating that as the rate of nitrogen increased, days to emergency was decreased. Days to flowering, plant height, tuber number per hill, marketable yield and total yield of the plant had a significant positive correlation with application rates of N2-P2O5 and FYM. Similarly, unmarketable yield responded moderately negatively correlated to the rates of N2-P2O5 and farmyard manure but not significantly.

The correlation analysis between total yield (t ha^{-1}) and growth characters indicated that, total yield was strongly positively correlated with mean days to flowering (r=0.451**), plant height (r=0.588**), tuber per hill (r=0.49**), marketable yield (r=0.988**) and unmarketable yield (r=0.464**). However, days to maturity and average tuber weight were weakly correlated (r=0.15^{ns}) and (r=0.16^{ns}) with the total yield respectively, but stem number per plant (r=-0.34**) was moderately positively correlated to the total yield. Days to emergency was highly and significantly negatively correlated with the total yield of Irish potato (r= -0.727**). This shows that improving any of these parameters may lead to the improvement in total yield of Irish potato. Therefore, total fresh tuber yield was significantly positively correlated with most growth; yield and yield related traits with the exception of days to emergency strongly negatively correlated with phenological traits.

Table 7. Simple linear coefficient (r) for phenological, growth, yield and yield components of Irish potato

	T	R	DE	DF	DM	PH	STM	TNP	TW	MKY	UMK	TYD
T	1.000	0.00^{ns}	-0.841**	0.691**	0.324^{ns}	0.80**	0.454*	0.624**	0.112^{ns}	0.754**	0.14^{ns}	0.728**
R		1.000	-0.209^{ns}	0.406**	0.192^{ns}	-0.016^{ns}	0.034^{ns}	0.33*	0.24^{ns}	0.127^{ns}	-0.384**	0.058^{ns}
DE			1.000	-0.758**	-0.223^{ns}	-0.762**	-0.504**	-0.682**	-0.192^{ns}	-0.788**	0.069^{ns}	-0.727**
DF				1.000	0.349**	0.496**	0.547**	0.691**	0.227^{ns}	0.521**	-0.235^{ns}	0.451**
DM					1.000	0.324*	-0.045^{ns}	0.412**	-0.021^{ns}	0.162^{ns}	-0.016^{ns}	0.15^{ns}
PH						1.000	0.296*	0.456**	0.092^{ns}	0.614**	0.079^{ns}	0.588**
STM							1.000	0.605**	0.322*	0.388**	-0.157^{ns}	0.339**
TNP								1.000	0.335**	0.538**	-0.093^{ns}	0.49**
TW									1.000	0.178^{ns}	-0.04^{ns}	0.161^{ns}
MKY										1.000	0.327*	0.988**
UMK											1.000	0.464**
TYD												1.000

Where T=N_2-P_2O_5, R=Farmyard manure, DE=days to emergency, DF=days to flowering, DM=days to maturity, PH=plant height, STM=stem number per plant, TNP=tuber number per hill, TW=tuber weight, MKT=marketable yield, UMK=unmarketable yield, TYD=total yield, ns=non-significant difference, * indicates significant at 5%, ** indicates significant at 1%.

Partial budget analysis of FYM and N_2-P_2O_5 Fertilizers application

In this study, the costs of FYM application, transport, weeding andcost of fertilizers were varied while other costs were constant for each treatment.In order to recommend the present result for end users, it is important to estimate the minimum rate of return acceptable to farmers in the recommendation interest. Based on the economic analysis, the net benefit gained from the experiment ranged from N_2-P_2O_5 fertilizers application alone is birr 177023 to 266507 per hectare compared with non-application of nutrients which is birr 161388 per hectare (Table 8).For the FYM treatments alone net benefit ranged from birr 133290 to 164949 per hectare benefit. According to our economic analysis is an indication of the level of profitability of the inorganic fertilizers application treatments. This may be due to not readily availability of nutrients and slow release of nutrients from FYM. The highest marketable tuber yield (39.4 t ha^{-1}) was recorded at 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1}fertilizer rates. The partial budget analysis indicated that the highest net benefit of 416843 Birr ha^{-1} was recorded at 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1}fertilizer rates. From the above results, it was apparent that the treatment with 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1}fertilizer rates was more profitable than other treatment combinations.

Marginal rate of tuber analysis was operated on non-dominated treatments to recognize treatments with the optimum return to the farmers' effort.The marginal rate of returns, which determines the acceptability of any treatment shows that, treatment receiving 132 kg N_2 + 147 kg P_2O_5 ha^{-1}fertilizer rates in combination with 6 t ha^{-1} of FYM yielded good results of 26943.2% marginal revenue.This means that for every 1.00 birr invested for 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} fertilizer input and its application in the field, farmers can expect to recover the 1.00 birr and obtain an additional 269.43 birr. Therefore the most attractive rates for producers with low cost of production and higher benefits in this case were 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with 6 t ha^{-1} farmyard manure combination and can be recommended for farmers in Bore area and other areas with similar agro ecological condition.

Table 8.Cost Benefit Analysis of Irish potato

Treatments	**Adjusted yield (t ha^{-1})**	**Gross Benefit (Birr ha^{-1})**	**Total variable cost (Birr ha^{-1})**	**Net Benefit(Birr ha^{-1})**	**Dominance Analysis**	**MRR**
T1F1	15.11	13.60	1800	161388	ND	0
T1F2	12.55	11.30	2250	133290	D	0.00
T1F3	15.03	13.53	2625	159699	D	7042.40
T1F4	15.53	13.98	2775	164949	ND	3500.00
T2F1	16.79	15.11	4309	177023	ND	787.09
T2F2	18.72	16.85	4534	197642	ND	9164.00
T2F3	20.32	18.29	4909	214547	ND	4508.00
T2F4	24.07	21.66	5059	254797	ND	16100.00
T3F1	25.25	22.73	6193	266507	ND	1132.50
T3F2	20.86	18.77	6418	218870	D	D
T3F3	23.17	20.85	6793	243443	D	D
T3F4	32.02	28.82	7943	338873	ND	8298.26
T4F1	21.93	19.74	8077	228767	D	D

Treatments	Adjusted yield (t ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net Benefit(Birr ha^{-1})	Dominance Analysis	MRR
T4F2	30.01	27.01	8302	315806	D	D
T4F3	39.4	35.46	8677	416843	ND	26943.20
T4F4	37.12	33.41	8827	392069	D	D
T5F1	19.19	17.27	9999	197253	D	D
T5F2	31.05	27.95	10224	325116	D	D
T5F3	20.24	18.22	10599	207993	D	D
T5F4	26.11	23.50	10749	271239	D	D

Where, t=tone, ha=hectare and MRR= marginal rate of return, ND= non-dominant, D=dominance

CONCLUSIONS AND RECOMMENDATION

Potato is one of the most widely cultivated vegetable crops in the highlands of Ethiopia. Yield and productivity of potato are far below the world national average yield. Among different factors, soil fertility and nutrient management are the key factors affecting crop productivity and soil nutrient depletion. To enhance the productivity of potato soil fertility management has to be the primary role of the producers. Different experiments conducted in Ethiopia show that application of nutrient has a positive relation to producing a higher yield of potato. The experiments confirmed that adequate application of nitrogen and phosphorus increases the production of potato (Workat, 2019).

Besides, application of organic fertilizer integrated with mineral fertilizer decreases the cost of production due to the continuous increase in the prices of mineral fertilization.Application of the FYM not only increased crop productivity, but also improved product quality as expressed in terms of its highest marketable to unmarketable yield ratio, mainly due to improved size, particularly for the optimum application of fertilizer. Many reports in the literature have showed that continuous use of sole artificial fertilizer nutrient sources may lead to shortage of nutrients not supplied by the chemical fertilizers which will in turn lead to chemical soil degradation (Mafongoya*et al.*, 2006). On the other hand, sole application of organic matter is constrained by low availability of N to the current crop, low or imbalanced nutrient content, unfavorable quality and high labor demands for transporting bulky materials. The low P content of most organic materials indicates that in the long term addition of external sources of P will be needed to sustain crop productivity. The alternative is to combine application of organic matter and fertilizer so that improved crop yields are maintained without degrading soil fertility status.

Besides, farmers in the study area have no awareness of using farm yard manure in combination with inorganic fertilizer and appropriate rate. In view of this, an experiment was conducted during the 2018 and 2019 cropping season in Boresouthern Oromia. The objective of the study was to assess the effects of combined application of FYM and N_2-P_2O_5 fertilizer on yield relatedand tuber yield of potato and to identify economically feasible rates of FYM and N_2-P_2O_5 fertilizer rates for sweet potato production in the study area.The experiment was arranged in factorial combination of four level of farmyard manure (0, 3, 6 and 10 tons ha^{-1}) with five level of Urea (0, 44, 88, 132 and 176 kg ha^{-1}) and NPS (0, 49, 98,

147 and 197 kg ha^{-1}) in combination. The experiment was laid out in RCBD with 3 replications.
Applied FYM and N_2-P_2O_5 fertilizer levels revealed significant differences ($P<0.05$) on days to emergency, days to flowering, days to maturity, plant height, number of stem numbers, average tuber weight, tuber number per hill, marketable, unmarketable and total yield. The maximum (14.77) tuber number per plant was recorded with the interaction effects of 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with 6 t ha^{-1} FYM treatment and the least (8.22) tuber number per plant was recorded at rate of zero N_2-P_2O_5 fertilizers + 6 t ha^{-1} FYM, respectively. In the same manner the maximum (187 g) average tuber weight was recorded at 10 t FYM ha^{-1}+ 132 kg N_2 + 174 kg P_2O_5 ha^{-1} and the lowest yield (109 g) was recorded at control treatment. On the other hand the combination of 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} produced the highest marketable root yield (39.4 t ha^{-1}) while the lowest yield (12.55 t ha^{-1}) was from 4 t ha^{-1} FYM+0 kg P_2O_5 ha^{-1}.
Combined application of FYM and N_2-P_2O_5 fertilizers had significantly ($P < 0.05$) affect unmarketable tuber yield. The highest (9.28 t ha^{-1}) unmarketable tuber yield was obtained at 3 t FYM ha^{-1}+ 176 kg N_2 + 197 kg P_2O_5 ha^{-1}whereas the lowest (3.18 t ha^{-1}) unmarketable tuber yield was recorded at control treatment at Bore over years, respectively. Generally the maximum total tuber yield (45.98 t ha^{-1}) was obtained at 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1}whereas the lowest (17.71 t ha^{-1}, 18.29 t ha^{-1} and 18.65 t ha^{-1}) was obtained at combined application of control treatment, 0 N_2-P_2O_5+ 4 t FYM ha^{-1} and 0 N_2-P_2O_5 + 6 t FYM ha^{-1} application rates, respectively.Though most of the Irish potato growth and yield parametersshowed good response to commercial fertilizers, promising yield was observed when farm yard manure was combined with inorganic fertilizers. Thus, unless it is integrated with inorganic fertilizers, the use of farmyard manure alone may not fully give crop nutrient demand especially in the year of application.
Based on partial budget analysis the highest net benefit 416843 Birr $ha^{-1}$was obtained from treatment combinations of 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1} with a marginal rate of return of 26943.2 %. Therefore the most attractive rates for the producers with low cost of production and higher benefits in this case were treatment combination 6 t FYM ha^{-1}+ 132 kg N_2 + 147 kg P_2O_5 ha^{-1}. More importantly farmers in the study areas should be motivated to use integrated nutrient management system rather than inorganic fertilizer alone because of the systemhelps in maintenance or adjustment of soil fertility and of plant nutrient supply to an optimum level for sustaining the desired crop productivity on one hand and to minimize nutrient losses to the environment on the other hand

ACKNOWLEDGEMENT
We sincerely thank Oromia Agricultural research institute for all necessary support. We also want to thanks all the data collectors who help us in data collection and for all their concern and moral support. Finally, all the reference materials used in this article are dully acknowledged.

REFERENCES
[1] Ahmed, M.S., Quadri, S.M.K., 2009. Decision support systems: concepts, progress and issues, a review. In: Lichtfouse, E. (Ed.), Climate change, intercropping pest control and beneficial microorganisms, Sustainable agriculture review 2. Springer Science and Business Media B.V. Dordrecht, Netherlands. Pp. 373-399.

[2] Ali, S. B., 1986. Studies on the degeneration of seed potato, seed multiplication and the mineral fertilization on the potato under the arid condition of the Sudan. M.Sc Thesis, Khartoum University Sudan.
[3] Alva, A., 2004. Potato nitrogen management. Journal of Vegetable Crop Production, 10: 97-130.
[4] Amsalu N., Weyessa G., Assefa T., Wubishet A., Asefa k. and Edossa E., 2008. Other root and tuber crops. pp 301-326. In: Gebremedhin*et al*., (eds.), Root and tuber crops, the untapped resources, by Ethiopian Institute of Agricultural Research, EIAR, Addis Abeba, Ethiopian.
[5] Bell, C. (2016). The importance of nitrogen for plant health and productivity. Growcentia: Mammoth.
[6] Benke, M.B., Hao, X., Chang, C., 2008. Effects of long term cattle manure applications on soil, water and crops: implications for animal and human health. In: Banuelos, G.S., Lin, Z.Q.
[7] Birtukan, B., 2016. Effect Of nitrogen and phosphorus rates on growth, yield, yield components and quality of potato (SolanumTuberosum L.) at Dedo, South West Ethiopia (Msc). Jimma University, Jimma, Ethiopia.
[8] Bulluck, L.R., Brosius M., Evanylo G.K. and Ristaino J.B., 2002. Organic and Synthetic Fertility Amendments Influence Soil Microbial, Physical and Chemical Properties on Organic and Conventional Farms. Applied Soil Ecology. 19:147-160.
[9] Chen Y., Clapp C.E., Magen H., 2004. Mechanisms of plant growth stimulation by humic substances: The role of organic-iron complexes. Soil Science and Plant Nutrition, **50**: 1089-1095.
[10] Errebhi, M., Rosen, C.J., Gupta, S.C., Birong, D.E., 1998. Potato yield response and nitrate leaching as influenced by nitrogen management. *Agronomy Journal.* 90: 10-15.
[11] FAO, 2008. Highlighting the role of potato in fighting against hunger and poverty. Food and Agricultural Organization of the United Nation. Rome, Italy.
[12] Firew, G., Nigussie, D., and Wassu, M., 2016. Response of potato (SolanumTuberosum L.) to the application of mineral nitrogen and phosphorus fertilizers under irrigation in Dire Dawa, Eastern Ethiopia. Journal of Natural Sciences Research, 6. 19-37.
[13] Forbes J.C, Watson D., 1994. Plant in Agriculture. Cambridge University Press.
[14] Freire, J.R.J., Sa, E.L.S., 2006. Sustainable agriculture and the rhizobia/legumes symbiosis. In: Rai, M.K. (Ed.), Handbook of microbial bio-fertilizers, Food Products Press. Pp: 183-203.
[15] Gebremedhin, W., G. Endale, and B. Lemaga, 2008. Potato variety development. In Root and tuber crops: The untapped resources, ed. W. GebreGebremedhin, G. Endale, and B. Lemaga, 15-32. Addis Ababa: Ethiopian Institute of Agricultural Research.
[16] Goffart, J.P., Olivier, M., Frankinet, M. 2008. Potato crop nitrogen status assessment to improve fertilization management and efficiency: past present future. *Potato Research.* 51: 355-383.
[17] Hawkes, J.G. 1990, The Potato: Evolution, Biodiversity and Genetic Resources. Pp1-198 by Belhaven Press, London.
[18] Hepperly, P., Lotter, D., Ulsh, C.Z., Siedel, R., Reider, C., 2009. Compost, manure and synthetic fertilizer influences crop yields, soil properties, nitrate leaching and crop nutrient content. *Compost ScienceUtilization.* 17: 117-126.

[19] Horton, D., 1987. Potatoes: Production, Marketing, and Program for Developing Countries. West vies Press. Boulder. pp.243.
[20] Kumar, P., Pandey, S.K., Singh, B.P., Singh, S.V., Kumar, D., 2007. Effect of nitrogen rate on growth, yield, economics and crisps quality of Indian potato processing cultivars. *Potato Research.* 50: 143-155.
[21] Love, S.L., Stark, J.C., Salaiz, T., 2005. Response of four potato cultivars to rate and timing of nitrogen fertilizer. *American Journal of Potato Research.* 82: 21-31.
[22] Mafongoya, P.L., Bationo, A., Kihara, J. and Waswa, B.S., 2006. Appropriate technologies to replenish soil fertility in Southern Africa. Nutrition cycle Agro-ecosystem, 76:pp.137-151.
[23] Marschner, H., 2002. Mineral nutrition of higher plants (2nd ed.). Londres: Academic Press.
[24] Moeskops, B., Sukristiyonubowo B., Sleutel S., Herawaty L., Husen E., Saraswati R., Setyorini D., Neve S., 2010. Soil microbial communities and activities under intensive organic and conventional vegetable farming in West Java, Indonesia. Applied Soil Ecology. 45:3. Pp112-120.
[25] Moore, Geoff. (2001). Soil Guide: A Hand Book For Understanding and Managing Agricultural Soils. Compiled and Edited By Geoff Moore, Bulletin 4343.
[26] Nahdi, S.S., 1977. The effect of fertilizer and planting date on growth development yield of the potato under the arid conditions of the Sudan .M.Sc. Thesis. Khartoum University. Sudan.
[27] Nkoa, R. J. Coulombe, Y. Desjardins, J. Owen and Tremblay N., 2002. Nitrogen supply phasing increases broccoli (Brassica aleraceaevar.italica) growth and yield, Acta-Horticulture 571: 163-170.
[28] Onwueme, I.C. and Sinha, T.D., 1991. Field crop production in Tropical Africa, Principles and practice, CTA (Technical Center for Agriculture and Rural Cooperation). The Netherlands.
[29] Poehlman J. M., Devid Allen sleeper, 1995. Breeding of field crops. 4th ed, pp 419-433 by Iowan state university press USA.
[30] Saeidi, M., A. Tobeh, Y. Raei, A. Roohi, Sh. Jamaati-eSomarin and M. Hassanzadeh, 2009. Evaluation of tuber size and nitrogen fertilizer on nitrogen uptake and nitrate accumulation in potato tuber. Agricultural Research Journal of Environmental Science, 3 (3): 278-284.
[31] Sincik, M., Turan, Z.M., Goksoy, A.T., 2008. Response of potato *(Solanumtuberosum L.)* to green manure cover crops and nitrogen fertilization rates. *American Journal of Potato Research*. 85: 150-158.
[32] Singh, J.P.and Grewal, J. S., 1986. Effect of time and method of Urea application on its efficiency for potato in alluvial soil of Panta. Potato Abs. 11(1). Pp: 3.
[33] Singh, R.B., 2000. Intensive agriculture during the green revolution has brought significant land and water problems relating to soil degradation over exploitation of ground water and soil pollution due to the uses of high doses of fertilizers and pesticides. *Agriculture Ecosystem and Environment.* 82: 97-103.
[34] Singh, R.B., Kumar, P. and Woodhead, T., 2002.small holder farmers in India: Food security and agricultural policy. RAP publication,3.

[35] Solomon T., Daba F., Tekile B., Arega A., 2019. Evaluation of Planting Date and Different Inorganic NP Fertilizer Rates for Irish Potato (Solanumtuberosum L.) Production at Bore, Southern Ethiopia. Plant. Vol. 7, No. 2, 2019, pp. 13-20.
[36] Warren, C. 2004. Soil analysis and interpretation. *New York Fruit Q.*, 12(1): 5 8.
[37] Westermann, D.T., 2005. Nutritional Requirements of potatoes. *American Journal of Potato Research*. 82: 301-307.
[38] WorkatSebnie, 2019. Effects of nitrogen and phosphorus on potatoes production in Ethiopia: A review, Cogent Food and Agriculture, 5:1, 1572985
[39] Xiao C, Fauci M, Bezdicek D.F, Mckean W.T, Pan W.L, 2006. Soil microbial response to potassium based black liquor from straw pulping. Soil Science Society of American Journal. 70: 72-77.
[40] YazachewEtefa and KasahunDibaba, 2011. Physical and Socio Economic Profile of Guji Zone Districts'. Bureau of Finance and Economic Development: Regional Data and Information Core Process. Pp: 7-11.
[41] Zebarth, B.J., Rosen, C.J., 2007. Research perspective on nitrogen BMP development for potato. *American Journal of Potato Research*. 84: 3-18.
[42] Zelalem, A., Tekalign, T., Nigussie, D., 2009. Response of potato *(Solanumtuberosum L.)* to different rates of nitrogen and phosphorus fertilization on verti-soils at DebreBerham, in the Central High Lands of Ethiopia. *African Journal of Plant sciemce.* 3(2).

Response of Potato (S*olanumtuberosum*L.) to Blended NPS and Potassium Fertilizers at Bore, Southern Ethiopia

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ABSTRACT
Potato (*Solanumtuberosum* L.) is one of the most important food security and cash crops in Ethiopia. However, its productivity is generally low. The low yields of the crop could be attributed to a number of factors among which low soil fertility is an important constraint and there is little information on the type and rates of fertilizers to be applied for optimum production of the crop under different agro-ecological conditions of the country. Therefore, an experiment was conducted at Bore Agricultural Research Center, Southern Ethiopia during the 2018 and 2019 cropping season to determine the effect of blended NPS and potassium fertilizer rates on potato, and to assess the cost and benefit of different rates of blended NPS and potassium fertilizers on potato. The treatments consisted of six rates of blended NPS (0, 100, 150, 200, 250 and 300 kg NPS ha^{-1}) and three rates of potassium (0, 100 and 200 kg KCL ha^{-1}) fertilizers, plus100 kg Urea ha^{-1} applied to all plots equally. The experiment was laid out as a Randomized Complete Block Design (RCBD) in a 6*3

factorial arrangement replicated three times. An improved potato variety called Gudanie (CIP-386423-13) was used as a test crop. The two years analysis of the data revealed that the main effects of blended NPS and potassium fertilizers influenced significantly ($P < 0.01$) plant height, number of main stems per hill, average tuber number per hill, marketable and total tuber yields)However, their interaction effects did not influence all measured parameters of the crop. The highest marketable tuber yields were obtained in response to the application of 200 kg blended NPS ha^{-1} (34.63 t ha^{-1}) and the application of 200 kg ha^{-1} KCL (36.39 t ha^{-1}). On the other hand, the lowest marketable yield 23.67 t ha^{-1} and 26.01 t ha^{-1}were obtained in response to the application of nil applications of the two fertilizers respectively. The partial budget analysis revealed that application of 200 kg ha^{-1} blended NPS and 200 kg KCL ha^{-1} resulted in the net benefits of 369,654and 389,262ETB $ha^{-1}$with 2968.69 and 2693.60% marginal rate of return respectively. The application of 200 kg KCL ha^{-1} (200 kg KCL + 46 kg N ha^{-1}) or application of 200 kg blended NPS with 46 kg N ha^{-1}(84 kg N ha^{-1} + 76 kg P_2O_5 +14 kg S ha^{-1}) fertilizer rates led to optimum potato tuber production, economic returns and recommended for potato growers in the highland areas of Guji zone.

Key words: Gudanie, Marketable tuber yield and Partial budget analysis

INTRODUCTION

Potato (*SolanumtuberosumL.*) belongs to the family *Solanaceae* and genus *Solanum*(Thompson and Kelly, 1972). It is considered to be the world's fourth important food crop after maize, wheat, and rice because of its high yield potential and nutritive value (Kumar *et al*., 2013; Pandey *et al*., 2014) and the third most important food crop after rice and wheat is being grown and consumed in all over the world (Devaux*et al*., 2014 and FAO, 2015). It is native to South America (Eskin*et al*, 1989). Potato was first cultivated by the Incas of Peru 6000 years ago by Incas in Peru (Ugent*et al*., 1982). Potato is cultivated worldwide in over one hundred countries throughout Africa, Asia, Australia, Europe, and North and South America (USDA, 2014).Potato is one of the widely grown root and tuber crops of the world being a rich source of nutrients for human nutrition. It contains about 79% water,18% starch as a good source of energy, 2% protein and 1% vitamins including vitamin C, minerals including calcium and magnesium and many trace elements (Ahmad *et al*., 2011).The past few decades have seen a dramatic increase in potato production and demand in many developing countries (FAO, 2014).

Potato has been widely described as global food and nutritional security option particularly for the poor people (Singh and Rana, 2013). Farmers consider potato as a transitional crop that helps them survive the severe and prevailing food shortage that occur every year (Semagn*et al*., 2007). Potatoes are among the most widely-grown crop plants in the world giving good yield under various soil and weather conditions (Lisinska and Leszcynski, 1989). Potatoes generally requires high altitude of about 1200 m above sea level, cool temperatures ranging between 15 and 20°C and high rainfall ranging between 1000 and 1500 mm per year (Gusha, 2014), and optimum soil pH ranges from 5.0 and 6.5 (Havlin *et al*., 1999).

Even though, Ethiopia has suitable environmental condition, the average national yield (14.176 t ha^{-1}) productivity of potato during 2018/19 season (CSA, 2019) is very low as compared with world average yield of 20 tha^{-1} (FAOSTAT, 2019) as well as other top

potato producing countries in Africa. On the other hand, the yield potential of the released potato variety in Gudanie ranges between 21 to 29 t ha^{-1} (MoARD, 2009). Moreover, at Bore Agricultural Research Center (2013) an unpublished research progress report clearly indicates that average yield of Gudanie 46.4 t ha^{-1} in the highlands of Guji zone. However, after four years of cultivation, the average yield of Gudanie declined from 46.4 to 29.4 t ha^{-1} in the study area (Dembi*et al*., 2017).The low yields are the result of a number of production constraints mainly involving abiotic and biotic stress factors (Hirut, 2015). Potato, as a high yielding crop, takes up a lot of nutrients from the soil at a given time. The deficiency of any or combinations of high nitrogen (N), phosphorus (P) and potassium (K) can result in retarded growth or complete crop failure under severe cases (Khiari *et al.*, 2001*)*. However, in Ethiopia, N and P fertilizers are used while K application is ignored which causes serious decrease in the status of potassium through depletion in soils of potato growing areas (Pervez, 2013).
Potato requires high amounts of NPK but more K fertilizer for optimum growth, production, and tuber quality (Al-Moshileh and Errebi, 2004), but the ability of this crop to recover P and K is very low. According to Naz*et al*. (2011) response of potato to NPK fertilizers varies depending upon the variety, soil characteristics, and geographical escarpment. The efforts of using N and P containing fertilizers do not satisfy crop nutrient requirements because soil tests through the EthioSIS revealed that Ethiopian soils are deficient in K (EthioSIS, 2013). This is attributed to high soil erosion, removal of nutrients by crops, and continuous cropping with replenishment of nutrients, and inadequate and imbalanced use of organic and inorganic fertilizers (Wassie and Tekalign, 2013). In Ethiopia, low soil fertility is one of the factors limiting the productivity of crops, including potato (Berga*et al*., 1994). This might be caused by land degradation due to up slop cultivation, flooding, soil acidity, low rate of technology adoption by farmers, low inherited soil fertility, limited use of chemical fertilizers is some major negative intervention that slow agricultural productivity in Ethiopia (Tekalign and Hezekeil, 2015).
Lack of adequate nutrient supply, the depletion of organic matter, and soil erosion are the major obstacles to sustained agricultural productivity. Thus, the problem is serious particularly in the high lands of Ethiopia (>1500 meter above sea level) that comprising nearly 44% of the country’s total area and 95% of the cultivated area (Krauer, 1988). On the other hand, soil acidity is also now a serious threat to crop production in most highlands of Ethiopia in general and in Guji zone in particular. Even though soil acidity affects the growth crop because acidic soil contains toxic levels of aluminum and manganese and characterized by deficiency of essential plant nutrients such as P, Ca, K, Mg, and Mo (Tisdale *et al*., 1985).
Productivity of the crop is constrained by multidimensional factors such as lack of disease resistant and high yielding varieties with desirable market qualities, limited knowledge of agronomic and crop protection management technologies, and poor post-harvest handling (Nigussie *et al*., 2012). On the other hand, Wassie and Shiferaw (2011) reported that the highest biological and economical yield of potato was obtained from NPK treatment applied at 110:40:100 kg ha^{-1} in the form of urea, TSP and KCl at both HagereSelam and Chencha locations on farmers' fields. Moreover, Melkamu *et al*. (2018) reported that the soils with low phosphorous content, production of Gudanie variety with application 181.60 kg ha^{-1} NPS fertilizer rates produce the highest marketable tuber yield (46.83 t ha^{-1}) which is also recommended for potato production at Koga Irrigation Scheme. In central highlands of

Ethiopia, Egataet *al*. (2016) reported that Gudanie produced the highest and economical marketable yield (30.53 t ha^{-1}) at the application of 69 kg ha^{-1} potassium and 110 kg ha^{-1} nitrogen.

According to the soil fertility map made over 150 districts, Ethiopian soil lack about seven nutrients N, P, K, S, Cu, Zn, Band a soil fertility inventory conducted in some woreda from 2012-15 also showed that K is deficient in most of the woreda of the country (EthioSIS, 2013). Application of potassium and sulfur fertilizers in increased nitrogen and phosphorus use efficiency by 80 to 100%; N and P fertilizers saved from blanket recommendation alone could be sufficient to pay the extra cost that farmers incurred due to application of S and K (ATA, 2015). In agreement with this, Wassie*et al*. (2011) also reported supplementation of K increased potato tuber yields by 197% over the standard N-P recommendation alone. Even though, nutrient mining due to sub optimal fertilizer use in one hand and unbalanced fertilizer uses on other have favored the emergence of multi nutrient deficiency in Ethiopian soils (Wassie*et al*., 2011).

However, currently in Guji zone no research has so far been conducted in the region to determine the amount of blended NPS and potassium fertilizers for optimum production of potato. Potato growers in the region are recommended to use the blanket rates of only nitrogen and phosphorus fertilizers amounting to 200 kg DAP (92 kg P_2O_5) and 100 kg Urea (82 kg N ha^{-1}) as advised by BoARC(2019). This indicates that the fertilizer recommendation being used to produce the crop in the area is not in accordance with the specific soil and agro-ecological requirements. The recent soil tests through the EthioSIS revealed that Ethiopian soils are deficient in various other nutrients that are not provided by DAP and Urea (ATA, 2013). On the other hand, the blanket application of DAP and Urea does not give due regard to crop need, soil nutrient dynamics, and agro-ecological factor (Tekalign and Hezekeil, 2015). Therefore, this research was conducted with the following objectives:

1. Todetermine the effect of blended NPS and potassium fertilizer rates on potato, and
2. To assess the cost and benefit of different rates of blended NPS and potassium fertilizers on potato

MATERIALS AND METHODS

Description of the Experimental Site:

The experiment was carried out during the 2018 and 2019 over two years during the main cropping season at Bore Agricultural Research Center, Guji Zone of Southern Oromia.. Bore Agricultural Research Center site is located at the distance of about 8 km north of the town of Bore in Songo Bericha '*Kebele'* just on the side of the main road to Addis Ababa via Awassa town. Geographically, the experimental site is situated at the latitude of 06º23'55''N,longitude of 38º35'5''E and at an altitude of 2728 m above sea level. The soil is clay in texture and strongly acidic with pH value of 5.1 (Arega *et al*., 2018). The traditional farming system of the area is characterized by cultivation of Enset as a major crop, maize, potato, head cabbage, barley, wheat and faba bean. As far as fruit and timber crops are concerned, apple and bamboo are the cash crops. Moreover, cattle are an integral part of the farming system (BoARDO, 2015).

Experimental Materials:

An improved potato variety called 'Gudanie' which was released by Holetta Agricultural Research Centre in 2006 (MoARD, 2009), was used as a planting material. The variety was selected on the basis of its high yield, wider adaptation and moderate resistance to late blight in highlands of Guji Zone. Blended NPS (19 % N, 38% P_2O_5, and 7% S), and potassium chloride (KCl) were used as sources of nitrogen, phosphorus, sulfur and potash, respectively. Urea (CO ($[NH_2]_2$) (46% N) was used as a source of nitrogen.

Treatments and Experimental Design:

The treatments consisted of six rates of blended NPS (0, 100, 150, 200, 250 and 300 kg NPS ha^{-1}) and three rates of potassium (0, 100 and 200 kg KCl ha^{-1}), plus 100 kg Urea ha^{-1} applied to all plots equally. The experiment was laid out in Randomized Complete Block Design (RCBD) in 6 x 3 factorial arrangement and replicated three times per treatment. There were 18 treatment combinations, which were assigned to each plot randomly. The total number of plots was 54 and each plot had a gross area of 16.2 m^2 with 3.6 m length and 4.5 m width. Each plot contained six rows of potato plants, with each row accommodating 12 plants with a total population of 72 plants per plot at the spacing of 0.75 m and 0.30 m between rows and plants, respectively. The spacing between plots and adjacent blocks was 1 m and 1.5 m, respectively. For data estimation, tubers were harvested from middle rows, leaving the plants growing in the two border rows as well as those growing at both ends of each row to avoid edge effect (EARO, 2004).

Experimental Procedure and Crop Management:

The blended NPS, urea and potash (KCl) fertilizers at the specified rates were applied by banding the granules of the two fertilizers at the depth of 5 cm below and around the seed tuber at planting. All blended NPS and potash were applied at planting. The urea dose was applied in three splits [¼at planting, ½ at mid-stage of the plant (at about 40 days after planting), and ¼ at the initiation of tubers (at the start of flowering)]. All urea applications were made at time when the soil moisture is not excessively high to avoid leaching of nitrogen.

All the other cultural practices were followed as per the recommendation for raising a successful crop. The first, second and third earthing-up was done 15, 30, and 45 days after planting to prevent exposure of the tubers to direct sunlight, promote tuber bulking and ease of harvesting. Weeds were controlled by hoeing and haulms were also mowed two weeks before harvesting at physiological maturity to toughen the periderm for reducing, skinning and bruising during harvesting and post-harvest handling. Ridomil Gold was sprayed two times at the rate of 2.5 kg ha^{-1} at the interval of 7 days using 400 to 500 liters of water ha^{-1} to control late blight disease.

Soil Sampling and Analysis:

The composite soil samples was collected by using Auger (Soil sampler) from 0-30 cm depth based on the procedure outlined by TayeBekele (2000) and using the zigzag method (Carter and Gregorich, 2008).The surface soil samples collected from the experimental field was air dried and grinded and allowed to pass through 2 mm sieve and for further analysis for total nitrogen and organic carbon allowed to pass through 0.5 mm sieve (FAO, 2008). Pre- planting and immediately after harvesting of cropsoil samples were taken and analyzed for particle size distribution (soil texture), soil pH, Cation exchange capacity (CEC) (Meq/100g soil), organic carbon (%), available potassium

(ppm), phosphorus (ppm), and available sulfur(ppm), boron(ppm), total nitrogen (%), exchangeable magnesium, sodium, and calcium (Cmol (+) kg^{-1}) at Horti coop Ethiopia soil and water analysis laboratory.

The soil reaction (pH) was measured according to FAO (2008) using 1:2.5 (weight/volume) soil sample to H_2O ratio using a glass electrode attached to a digital pH meter. Soil texture was determined by using Bouyoucos Hydrometer Method (Bouyoucos, 1962) following the textural triangle of (USDA, 1987) system as described by Rowell (1994). Soil organic carbon content was determined by using the Walkley and Black method (Walkley and Black, 1934) and soil organic matter content was calculated by multiplying the OC% by a factor 1.724. Total nitrogen of the soil was determined by Kjeldhal Method (Jackson, 1958). Available B will be determined using hot water method (Berger and Truog, 1939). Available S was determined by monocalcium phosphate extraction method or turbidimetric estimation (Johnson and Fixen, 1990) and available phosphorus was determined by Bray II methods (Bray and Kurtz, 1945). Cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc (Chapman, 1965).Exchangeable bases (Aluminum, potassium, magnesium, sodium, and calcium) were determined by Melich-3 methods (Mehlich, 1984).

Data Collection

Phenology of potato

Days to 50% flowering: It was determined by counting the number of days from emergence to the time when 50% of the plants in each plot started to flower through visual observation.

Days to 90% physiological maturity: It was determined by counting the number of days from emergence to the days when more than 90% of the plants in a plot attained physiological maturity, i.e. when plants to reach the stage of growth when 90% of the leaves and stem started to senesce.

Growth of potato crop

Plant height (cm): refers to the height from the base to the apex of the plant. It was determined by measuring the height of 12 randomly taken plants per plot using a meter from the central four rows at flowering (or tuber initiation).

Average number of main stems per hill: was determined by counting the stems that originated from the tuber from 12 plants randomly taken per hills, and taking the average.

Yield components of potato

Average tuber number per hill: This was recorded as the actual number of tubers to be collected from 12 matured plants at harvest.

Average tuber weight (g): was determined at harvest by dividing the weight of all tubers obtained from randomly taken 20 tubers per plot and divided by 20.

Tuber yields

Marketable tuber yield (t ha^{-1}): the weight of tubers which are free from diseases, insect pests, and greater than or equal to 25 g in weight were recorded from 40 plants per hill.

Unmarketable tuber yield (t ha^{-1}): the weight of tubers that are diseased and/or rotting ones and small-sized (less than 25 g in weight) were recorded.

Total tuber yield (t ha^{-1}): the total tuber yield was obtained by adding marketable and unmarketable tuber yields.

Data Analysis:
The data were subjected to analysis of variance (ANOVA) using Gen-Stat release 15th Edition software (Gen-Stat, 2012). The result interpretations were made following the procedure of Gomez and Gomez (1984) and means of significant treatment effects were separated using the Fishers' protected Least Significant Difference (LSD) test at 5% probability level of significance.
Partial Budget 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 Ethiopian Birr. The concepts used in the partial budget analysis were the mean marketable tuber yield of each treatment, the gross benefit (GB) ha^{-1} (the mean marketable tuber yield for each treatment) and the field price of fertilizers (the costs of blended NPS and KCL and the application costs).

Gross average marketable tuber yield (kg ha^{-1}) (AvY): was an average yield of each treatment.
Adjusted yield (AjY): was the average yield adjusted downward by a 10% to reflect the difference between 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).

Adjustable marketable tuber yield = Average yield **-** (Average yield -0.1)
Gross field benefit (GFB): GFB was computed by multiplying field/farm gate price that farmers receive for the potato when they sale it as adjusted marketable tuber yield.
Gross field benefit (GFB) = Adjustable marketable tuber yield*field/farm gate price for potato.

Total variable cost (TVC): Total cost was the cost of fertilizers and application cost of fertilizers as differ dosage for the experiment. The costs of other inputs and production practices such as labor cost, land preparation, planting, Earthingup, weeding, top killing, and harvesting were considered the same or are insignificant among treatments.

Net Income (NI) or Net Benefit (NB): **-** was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the total revenue (TR).
NB = TR – TVC

Marginal rate return (MRR): was the measure of increasing in return by increasing input.

$$MRR = \frac{\text{Change of Net Benefit } (\Delta NB)}{\text{Change of Total Variable Cost } (\Delta TVC)}$$

Marginal rate of return (MRR %): was calculated by dividing change in net benefit by change in total variable cost.

$$MRR\% = \frac{\text{Change of Net Benefit } (\Delta NB)}{\text{Change of Total Varaible Cost } (\Delta TVC)} \times 100$$

Dominance Analysis (identification and elimination of inferior treatments): is also used to eliminate those treatments which involve higher cost but do not generate higher benefits. 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 benefit) is dominated treatment (marked as "D"). Identification of a candidate recommendation was from among the non-dominated treatments. That was the treatment which gives the highest net benefit and a marginal rate of return greater than the minimum considered acceptable to farmers (>1 or 100%).

RESULTS AND DISCUSSION

Physico-Chemical Properties of the Experimental Soil:

The laboratory results of the selected physico-chemical properties of the soil sample taken before planting are presented in (Table1). The results indicate that the soil has 33, 27 and 40% sand, silt and clay, respectively, and could be categorized as clay soil on the basis of USDA (1987) textural soil classificationsystem.According to Murphy (2007), the experimental soil has medium CEC (24.86 Meq/100g soil). The rating made by FAO (2006) indicate that the contents of exchangeable Na is low (0.19 Cmol (+) kg^{-1}), exchangeable potassium is very low (0.16 Cmol (+) kg^{-1}), exchangeable Ca is medium (8.87 Cmol (+) kg^{-1}) and exchangeable Mg is medium (1.45 Cmol (+) kg^{-1})). According to the rating of Tekalign (1991), the organic carbon (OC) content (3.0%) could be categorized as medium.

Furthermore, according to Karltunet al. (2013) and EthioSIS (2014) the soil of the experimental site is strongly acidic in reaction (pH of 5.1), medium in total N (0.25%), very low in available potassium (60.50 ppm) and very low in available S (2.50ppm). The results of the analysis also indicated that the soil has a medium content of available phosphorus (12.10 ppm) in 2018 cropping season according to the rating of Cottenie (1980). The low potassium content may be attributed to the nature of the clay which is kaolinite, having poor retention capacity of potassium ions and hence high susceptibility to leaching of the cation (Mengel and Kirkby, 2001) due to heavy rainfall in the study area. At increased soil acidity (low pH), phosphorus is fixed to surfaces of Fe and Al oxides and hydrous oxide, which are not readily available to plants (Sikoraet al., 1991).

Potatoes can grow under a wide range of soil pH varying from neutral to alkaline reaction (Fageria, 2011). However, the optimum soil pH for potato production ranges from 5.0 – 6.5 (Havlin et al., 1999), which varies from very strongly acidic to slightly acidic reaction (Hazelton and Murphy, 2007). Therefore, the pH of the experimental soil is suitable for potato production.

However, the low content of available potassium and sulfur as well as the medium contents of available phosphorus, organic carbon, and total nitrogen indicate that application of mineral and/organic fertilizers containing these nutrients is important for optimum production of the crops in the study area.

Table 1: Physical and chemical properties of the experimental site before-planting at Bore on-station during 2018 and 2019 main cropping season

Soil properties	2018		2019		References
	Result	Rating	Result	Rating	
1. Physical properties (%)					-
Sand (33%), Silt (27%), and Clay (40%)					-
Textural Class	Clay				(USDA,1987)
2. Chemical Properties					-
pH (1: 2.5 H_2O)	5.1	Strongly Acidic	4.66	Strongly Acidic	(EthioSIS, 2014)
Organic Matter /OM/ (%)	5.17	Medium	4.72	Medium	(EthioSIS, 2014)
Organic Carbon /OC/ (%)	3.0	Medium			(Tekalign,1991)
CEC (meq/100 g soil)	24.86	Medium	23.91	Medium	(Murphy,2007)
Total Nitrogen /TN/ (%)	0.25	Medium	0.29	Medium	(EthioSIS, 2014)
Available Phosphorus /P/ (ppm)	12.10	Medium	8.39	Very low	(Cottenie,1980)
Available Potassium /K/ (ppm)	60.50	Very Low	212.55	Medium	(EthioSIS, 2014)
Available Sulfur /S/ (ppm)	2.50	Very Low	2.14	Very low	(EthioSIS, 2014)
Available Boron /B/ (ppm)	0.84	Medium	0.54	Low	(EthioSIS, 2014)
3.Exchangeable Bases (Cmol(+)kg^{-1})					
Exchangeable Na^+	0.19	Low	0.075	Very low	(FAO, 2006)
Exchangeable K^+	0.16	Very low	0.55	medium	(FAO, 2006)
Exchangeable Ca^{++}	8.87	Medium	7.43	medium	(FAO, 2006)
Exchangeable Mg^{++}	1.45	Medium	1.2	medium	(FAO, 2006)

Table 2: Physical and chemical properties of the experimental site post harvesting at Bore on-station during 2019 main cropping season

Treatments	PH.H20 0-14	Av. P Mg/kg	Av. S Mg/kg	Avail. K Mg/kg	TN %	OM %	CEC Meq/100g soil	Textural class
100NPS +100KCL	4.48	6.57	10.92	164.30	0.32	5.92	22.36	Clay
300NPS+100KCL	4.39	6.89	15.64	190.80	0.32	5.29	26.96	
300NPS +0KCL	4.41	5.30	14.20	201.40	0.30	5.30	19.83	
100NPS+0KCL	4.52	6.53	11.45	171.20	0.20	5.56	27.99	
250NPS+100KCL	4.62	7.42	13.25	201.40	0.31	5.33	29.43	
150NPS +0KCL	4.64	8.35	14.34	165.85	0.31	5.50	26.21	
250NPS+0KCL	4.55	5.46	14.82	144.45	0.31	5.41	27.11	
200NPS + 100KCL	4.52	6.47	13.73	132.50	0.31	5.87	33.89	
300NPS+200KCL	4.82	7.28	16.75	171.20	0.30	5.58	27.64	
200NPS +0KCL	4.48	7.24	14.96	129.60	0.32	5.50	23.43	
0NPS+0KCL	4.44	5.99	12.89	176.55	0.31	5.34	26.04	
0NPS+200KCL	4.85	6.96	17.71	224.70	0.33	5.48	24.37	
150NPS +100KCL	4.39	5.46	10.54	133.75	0.32	5.14	28.17	
150NPS +200KCL	4.50	5.97	9.22	164.80	0.30	5.48	29.22	
100NPS+200KCL	4.48	6.63	15.78	112.35	0.31	5.63	28.74	
0NPS +100KCL	4.52	5.19	8.66	169.60	0.31	5.56	21.94	
200NPS+200KCL	4.46	7.84	14.20	190.80	0.32	5.77	27.69	
250NPS+0KCL	4.34	8.37	17.97	169.60	0.32	5.24	24.79	

Physico-Chemical Properties of the Experimental Soil after Potato Crop Harvest:

The post harvest physiochemical properties of soil as affected by blended NPS and potassium at different fertilizer rates are presented in Table 2. Post-harvest analysis of soil revealed that increasing organic matter (5.92, 5.87 and 5.77%) at the rates of 100,200 kg blended NPS with combined application rates of 100, and 200 kg potassium ha^{-1} respectively. The post-harvest soil analysis results indicated,Control plots, 300,150 kg blended NPS with combined application of 200 kg and nil received plots of potassium fertilizer with some extent increase strongly acidic reaction (pH of 4.85, 4.82, and 4.64) respectively. So, this pH results were in agreement with the suggestion of Havlin *et al.* (1999) who reported that the optimum soil pH for potato production ranges from 5.0 – 6.5.The post-harvest soil analyses indicated that the experimental soil has medium to high CEC (Meq/100g soil) by the application of blended NPS and potassium application of blended NPS and potassium at different fertilizer rates Murphy (2007).

According to EthioSIS (2014) the post-harvest soil analysis showed that very low in available P (Mg/kg), available potassium ranged very low to optimum, available S (Mg/kg) ranged optimum to high, total nitrogen (%) ranged optimum to high by the application of blended NPS and potassium at different fertilizer rates. In particular application of large quantities of phosphorus and potassium fertilizers are important for increasing potato production at the experimental site of the study area.. Therefore, this experimental site indicated thatincludingintegrated application of P and K, and FYM is acceptable for changing nutrient availability and lowering acidity/ increasing pH value of the experimental site.

Table 3: Effect of blended NPS and potassium fertilizer rates on phenology of Gudanie potato variety at Bore during 2018, 2019, and pooled of two years.

Blended NPS (kg ha^{-1})	Phenology					
	2018	2019	Pooled mean of 50% DF	2018	2019	Pooled mean of 90% DM
	50% DF	50% DF		90% DM	90% DM	
0	50.67^{c}	56.67c	52.67c	112.2^{d}	98.2b	105.2c
100	56.00^{b}	57.89abc	56.94b	114.2^{c}	99.9b	107.1bc
150	56.22^{b}	55.89bc	56.06b	114^{cd}	99.4b	106.7bc
200	59.67^{a}	62.22a	60.94a	117.3^{b}	101b	109.2abc
250	60.56^{a}	61.44ab	61a	120.2^{a}	104.9a	112.6ab1
300	60.78^{a}	62.11a	61.44a	120.4^{a}	107a	113.7a
LSD (5%)	2	9.36	2.86	1.86	4.63	5.61
KCl rates (kg ha^{-1})						
0	57.17	57	57.08b	114.1^{c}	100.2b	107.1
100	57.5	61	59.25a	116.7^{b}	101.8ab	109.2
200	57.28	59.11	58.19ab	118.4^{a}	103.3a	110.9
LSD (5%)	NS	NS	2.03	1.32	4.63	3.97
CV (%)	3.7	9.6	7.4	1.7	2.7	7.8

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance;50% DF= days to fifty percent flowering, 90% DM= days to ninety percent physiological maturity, CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Phenology of Potato:

The results from the analysis of variance indicated that application of the blended NPS fertilizer had highly significant ($P < 0.01$) effect on days to 50% flowering and 90% physiologicalmaturity.The interaction effect of blended NPS and potassium fertilizers on da ys to 50% flowering and 90% physiological maturity was non significant (Appendix Table 1). Increasing blended NPS application from 0 to 300 kg ha^{-1} delayed 50% flowering (tuber initiation) by 14.27%. Increasing the blended NPS supply beyond 200 and 300 kg/ ha delayed 50% flowering of the plants by about 8.14% as compared to plants grow n in the control treatment (Table 3).

However, plants grown at the application of 200 and 300 kg ha^{-1} blended NPS fertilizer had statistically similar on days to 50% flowering and 50%days tomaturity. Thus, compared to the plants in plots that did not receive the fertilizer, plots that received the blended NPS at the maximum rate of 300 kg ha^{-1} required about 8.5 days (about 7.48%) to attain 90% physiological maturity. Increasing the rate of potassium application beyond 0 kg KCL ha^{-1} did not affect days to 50% flowering and days to 90% physiological maturity. The delayed maturity of plants in response to the application of the blended NPS fertilizer at higher rates might be due to the effect of nitrogen contained in the fertilizer which may have stimulated plant growth, enlarged leaves and tubers but delayed flowering and maturity. This is in agreement with Tantowijoyo and Van de Fliert (2006) who reported the application of nitrogen fertilizer at higher rates enhances vegetative growth by helping the plant to absorb sunlight and produce carbohydrates but delayed the production of reproductive part and thereby maturity.

Similarly, the results are –in line with Zelalem *et al.* (2009) and Biruk *et al*. (2015) who reported that application of N and P fertilizers delayed flowering and prolonged days required attaining physiological maturity of potato. This result is consistent also with that of Habtam *et al.* (2012) who reported that increasing potassium fertilizer rate prolonged the days required to attain 50% flowering in potato.In contrast with the results of this study, Minwyelet *et al*. (2017) and Getachew *et al.* (2016) reported that there were no significant differences required for days to flowering in potato due to the application of blended fertilizer treatments respectively.

Table 4: Effect of blended NPS and potassium fertilizer rates on Growth of Gudanie potato variety at Bore during 2018, 2019, and pooled of two years.

Blended NPS (kg ha^{-1})	Growth Parameters					
	2018	2019	Pooled	2018	2019	Pooled mean
	PH (cm)	PH (cm)	mean of PH (cm)	SN(no.)	SN(no.)	of SN(no.)
0	53.14^{e}	50.05a	51.59c	5.85^{c}	3.41c	4.57b
100	61.29^{d}	55.72ab	58.5b	6.14^{bc}	3.57bc	4.97ab
150	63.3^{cd}	62.54a	62.92ab	6.42^{abc}	3.53bc	5.03ab
200	65.46^{bc}	62.05a	63.76a	6.8^{ab}	4.16a	5.64ab
250	67.79^{ab}	61.62a	64.7a	6.99^{a}	3.9ab	5.84a
300	69.55^{a}	62.28a	65.92a	7.07^{a}	4.33a	6.14a
LSD (5%)	3.95	11.64	4.56	0.84	0.72	1.07
KCl rates (kg ha^{-1})						
0	56.43^{b}	52.25b	54.34c	6.06^{b}	3.62b	4.88b
100	65.8^{a}	56.77b	61.29b	6.43^{b}	3.64b	5.12b
200	67.78^{a}	68.1a	68.07a	7.15^{a}	4.18a	6.11a
LSD (5%)	1.98	11.64	3.32	1.46	0.72	0.76
CV (%)	6.5	11.9	11.3	13.4	11.3	30.1

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; PH (cm)= plant height in centimeter, Sn= Stem Number,CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Growth of Potato Crop:

The plant height and main stem number per hill of Gudanie potato variety were highly significantly ($P < 0.01$) influenced by application of the blended NPS as well as the potassium fertilizers but not by the interaction of the two factors (Appendix Table 1).

Plant height:

Increasing the rates of both fertilizers increased plant height. Increasing the rate of the blended NPS from nil to 300 kg NPS ha^{-1} increased the height of the potato plants significantly by about 27.78%. However, non-significant increment in potato plant heights was observed in response to increasing the rate of the NPS from 200 to 300 kg ha^{-1} and also 250 to 300. This indicates that application of NPS beyond 200 kg NPS ha^{-1} was not necessary for enhancing the height of the crop plant. On the other hand, increasing application of the potassium fertilizer from nil to 200 kg KCl ha^{-1} increased the height of the plants by about 25.27%. Increment in plant height was observed in response to the rate of fertilizer nill to 200 kg KCl ha^{-1} (Table 4). This showed that application of KClbeyond 100 kg KCL ha^{-1} is important to obtain the optimum height of the plant.

In agreement with this result, Minwyelet *et al*. (2017) and Melkamu *et al.* (2018) reported that the tallest potato plants were observed in response to increasing the rate of NPS application from 272 and 281.75 kg ha^{-1}NPS fertilizer rates. This result is in agreement with the findings of Asmaa and Hafez (2010), Habtam*et al*. (2012) and Egata*et al.* (2016) reported that application of higher rates of potassium resulted in higher plant height of potato.

The increased plant height in response to the application of the fertilizers may be attributed to the influence of the nutrients contained on enhancing plant growth owing to their contribution to enhanced cell division, elongation and vegetative growth of plants (Marschner, 1995).

Main stem number per hill:

Increasing the rates of the two fertilizers, significantly increased stem number per plant. However, increasing the rate of NPS application increased stem number per plant from nil only up to 100 kg NPS ha^{-1}. Thus, the highest stem number of per plant was attained already at the rate of 300 kg NPS ha^{-1}. However, increasing the rate of potassium application from nil to 100 kg KCl ha^{-1} did not increase the number of stems produced per plant. However, increasing the rate of the fertilizer to 200 kg KCl ha^{-1} increased the number of stems significantly by 25.2% (Table 4).

This result is consistent with that of Minwyelet *et al*. (2017) who reported that increasing application of NPS fertilizer rates increased the main stem number of potatoes. Similarly, the result is in agreement with the findings of Khandakhar*et al.* (2004) who reported that stem number per plant increased significantly with increasing the level of lime and potassium application. This result also conforms to that of Niguse (2016) who reported that application of P and K fertilizers significantly increased stem number per hill. In contrast with the findings of Habtam*et al. (*2012) who reported that stem number per plant of potato was not affected by potassium application at Assosa, the soil of which has also low content of available potassium as the soil of this experimental site.

Table 5: Effect of blended NPS and potassium fertilizer rates on average tuber numbers and average tuber weight of Gudanie potato variety at Bore during 2018, 2019, and pooled of two years.

Blended NPS (kg ha^{-1})	Yield component parameters					
	2018	2019	Pooled mean	2018	2019	Pooled mean
	TN(no.)	TN(no.)	of TN(no.)	TW (g)	TW (g)	of TW (g)
0	10.10^{c}	6.63c	7.98b	60.44^{b}	81.59	71.02
100	12.39^{ab}	8.25ab	10.32a	62.45^{b}	91.18	76.82
150	12.62^{ab}	7.61bc	10.11a	62.06^{b}	100.06	81.06
200	11.68^{b}	8.97a	10.32a	77.71^{a}	100.03	88.87
250	12.29^{ab}	8.49ab	10.39a	65.07^{b}	101.9	83.48
300	13.43^{a}	8.1ab	10.77a	67.04^{b}	98.44	82.7
LSD (5%)	1.32	1.89	1.79	9.04	NS	NS
KCl rates (kg ha^{-1})						
0	10.78^{c}	7.66	9.14b	63.68	112.71a	72.19b
100	12.03^{b}	8.11	9.95ab	66.04	93.2b	79.62ab
200	13.45^{a}	8.26	10.85ab	67.65	80.69b	90.18a
LSD (5%)	0.93	NS	1.27	NS	31.95	10.99
CV (%)	11.4	14.2	27.1	14.3	20.2	29.10

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; TN(no.)= Tuber numbers per hill, TW (g) = Tuber weight in gram, CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Yield Components of Potato:

The average tuber numbers per hill were highly significantly ($P < 0.01$) influenced by the application of blended NPS and potassium fertilizers on Gudanie potato variety. Furthermore, application of the potassium fertilizer had a highly significant effect on average tuber weight but not blended NPS fertilizer as well as the interaction of the two factors (Appendix Table 1).

Average tuber numbers:

Increasing the rate of the blended NPS application from nil to 100 kg ha^{-1} significantly increased the average tuber number per hill by about 29.32%. However, increasing the rate of the NPS fertilizer beyond 100 kg ha^{-1} did not affect this parameter (Table 5). This showedthat increasing the rate of NPS did not vigorously affect average tuber numbers of the plant. However, increasing the rate of potassium application from nil to 100 and 200 kg KCl ha^{-1} increased tuber numbers per hill significantly and linearly, by about 18.71% (Table 5). This showed that potassium application had more vigorous effect tuber production than application of the blended NPS fertilizer.

These results are in consistent with that of Daniel *et al*. (2016) who reported that number of tubers per potato plant increased in response to increasing the rate of potassium application. This might be due to the significant role of potassium on photosynthesis, favors high energy status which helps the crop for timely and appropriate nutrients translocation and water absorption by roots.Similarly, Habtam *et al*. (2012) and Niguse (2016) reported that P and K fertilizer application significantly increased the number of tubers produced per plant.In agreement to this there is finding stating , high rates of photosynthesis were found to produce a greater number of tubers per plant (Bergmann, 1992).

Average tuber weight:

Increasing the rate of the blended NPS application from nil to 200 kg ha^{-1} significantly increased the average tuber number per hill by about 25.13%. The highest average tuber weight (88.87g) was observed at blended NPS 200 kg ha^{-1} while the lowest (71.02g) was at the unfertilized plots. Average tuber weight was affected by the application of potassium fertilizer rate (Table 5).

Nitrogen application to potatoes before tuber initiation increases the number of tubers per plant and mean fresh tuber weight (Kanzikwera *et al*., 2001). The increase in average tuber weight of tubers in response to the increased supply of fertilizer nutrients could be due to more luxuriant growth, more foliage and leaf area and higher supply of photosynthesis which may have induced formation of bigger tubers thereby resulting in higher yields (Patricia and Bansal, 1999). Tuber weight or size is not affected by potassium application but by phosphorus application.

This is not consistent with the finding of Zelalem (2009) who reported that the average tuber weight progressively increased with increasing N rate up to 138 kg/ha and tended to decrease at the highest rate of 207 kg/ha. The results of the present study are also not lined with the findings of various researchers (Melkamu*et al*., 2018; Minwyelet*et al*., 2017) who reported that the application of NPS fertilizer increased mean tuber weights of potato. In line with this study result of Israel *et al*. (2012) and Biruk*et al.* (2015) stated that the application of nitrogen and phosphorus not influenced average tuber weight of potato. In consistent with the findings of Niguse*et al*.(2016) who reported that the application of k fertilizer affected average tuber weight, as the K
fertilizer rate increased the average tuber weight increase.

Table 6: Effect of blended NPS and potassium fertilizer rates on tuber yields of Gudanie potato variety at Bore during 2018, 2019, and pooled of two years.

Blended NPS (kg ha^{-1})	Tuber yield parameters								
	2018	2019	Pooled mean of Myld (t ha^{-1})	2018	2019	Pooled mean of UM yld (t ha^{-1})	2018	2019	Pooled mean of Tyld (t ha^{-1})
	Myld (t ha^{-1})	Myld (t ha^{-1})		UM yld (t ha^{-1})	UM yld (t ha^{-1})		Tyld (t ha^{-1})	Tyld (t ha^{-1})	
0	24.96^{d}	22.38ab	23.67c	2.01^{b}	1.99	2.01	26.97^{d}	24.38b	25.68d
100	31.31^{c}	30.41a	30.86b	3.043^{ab}	2.09	2.86	34.35^{c}	33.09a	33.72c
150	31.71^{c}	31.36a	31.54ab	2.71^{ab}	2.77	2.40	34.42^{c}	33.46a	33.94bc
200	36.41^{a}	32.84a	34.63a	3.50^{a}	2.77	3.14	39.91^{a}	35.61a	37.76a

250	34.26^{bc}	35.06a	33.58ab	3.19^{a}	2.6	2.89	37.45^{bc}	37.66a	36.47abc
300	36.06^{ab}	32.34a	34.20ab	3.24^{a}	2.77	2.96	39.30^{b}	35.06a	37.16ab
LSD (5%)	3.44	8.21	3.10	0.93	NS	NS	3.54	7.96	3.09
KCl rates(kg ha^{-1})									
0	27.51^{c}	24.5c	26.01c	2.6	2.9a	2.80	30.11^{c}	27.5c	28.81c
100	32.2^{b}	30.84b	31.54b	2.88	2.26b	2.57	35.08^{b}	33.13b	34.10b
200	36.55^{a}	36.83a	36.39a	3.37	2.15b	2.76	39.92^{a}	38.98a	39.45a
LSD (5%)	2.43	8.21	2.19	0.66	1.44	NS	2.5	7.96	2.19
CV (%)	11.2	16.1	14.9	NS	35.1	38.1	10.2	14.5	13.7

Mean values sharing the same letter in each column for each factor have no-significant difference at 5% probability according to Fisher's protected test at 5% level of significance; Myld (t ha^{-1})= Marketable tuber tone per hectare, UM yld(t ha^{-1})= Unmarketable tuber yield ton per hectare, Tyld (t ha^{-1})=Total tuber yield ton per hectare, CV (%) = Coefficient of variation, LSD (5%) = Least significant difference at 5% probability.

Tuber Yields:

The application of blended NPS and KCL fertilizers had significant ($P < 0.01$) effect on tuber yields (marketable and total tuber yield) of Gudanie potato variety. Furthermore, application of the potassium fertilizer had no significant effect on unmarketable tuber yield. But the two fertilizers did not interact to influence these parameters (Appendix Table 1).

Marketable tuber yield:

Increasing the rate of blended NPS fertilizer from nil to 200 kg ha^{-1} increased marketable tuber yield significantly. This increment amounted to about 46.3%. However, increasing the rate of the fertilizer beyond 200 kg ha^{-1} did not increase the marketable yield. However, further increasing the rate of the fertilizer beyond 200 kg ha^{-1} increased the marketable tuber yield of the crop by about 46.3%, beyond which no increment was recorded (Table 6). In this case, the highest or optimum marketable tuber yield was obtained already at the rate of 200 kg NPS ha^{-1}.

Increasing the rate of potassium fertilizer from nil to 200 kg KCl ha^{-1} increased the marketable tuber yield by about 39.91%. Thus, the response of marketable tuber yield to the application of potassium fertilizer was much more vigorous and continuous at each rate of the fertilizer than the response observed for application of the blended NPS fertilizer (Table 6). The highest marketable tuber yield (36.39 t/ha) was obtained at the highest (200 kg KCl ha^{-1})rate..This is in line with Panique *et al*.(1997) who reported that Potato has a high K demand.

The maximum marketable tuber yield of the crop was obtained in response to the application of 200 kg KCL ha^{-1} (Table6) which indicatedpotassium is an important factor that limitatthe productivity of the crop in the area. On the other hand, reduction in yield due to high rate of N application could be explained by a phenomenon that extra nitrogen application often stimulates shoot growth at the expense of tuber initiation and bulking (Sommerfeld and Knutson, 1965).

Consistent with theseresultsHabtam *et al.* (2012) also reported that the amount of mineral potassium fertilizer that optimized marketable and total tuber yields of potato was 200 kg KCL ha^{-1} in Assosa, which has also low availability of the mineral nutrient. Similarly, Bansal *et al*. (2011) reported that application of 100 kg KCl ha^{-1} as MOP significantly increased marketable yield of potato. This result is also consistent with those of Minwyelet *et al*. (2017) and Melkamu *et al*. (2018) who reported that the application of NPS fertilizer at the rate of 272 kg ha^{-1} resulted in the production of the highest marketable tuber yield (47.02 t ha^{-1}) of potato. The result is also in line with that of Getachew *et al.* (2016) who reported that the maximum marketable yield was obtained in response to the application of 100 kg ha^{-1} blended NPKSZ and the lowest recorded from unfertilized plots. Consistent with the results of this study, Nikardi (2009) reported that application of 200 kg, KCl ha^{-1} resulted in the production of the highest potato tuber yield.

Unmarketable tuber yield:

Increasing the rate of blended NPS fertilizer from nil to 100 kg ha^{-1} significantly increased the unmarketable tuber yield by about 42.29%. However, the unmarketable yield was not affected by the rates of the fertilizers applied above this rate. On the other hand, application of blended NPS and potassium fertilizer did not affect the unmarketable tuber yield of the crop (Table 6).

In general, the response of unmarketable tuber yield of the crop to both fertilizers was not vigorous. This result is consistent with the suggestion of (Berga*et al*. (1994) that unmarketable tuber yield might be controlled more importantly by manipulating other factors such disease incidence, harvesting practice, etc. rather than mineral nutrition.In accordance with this study result, Zelalem*et al*. (2009) and Mulubrhan (2004) observed no significant influence of phosphorus application on unmarketable yield. In agreement with this study result, Habtam*et al*. (2012) reported that further increasing the rate of the nutrient from 100 to 200 kg KCl ha^{-1} further increased unmarketable tuber yield of potato. Moreover, In contrast with this study result, Simret*et al. (*2014) reported that potassium had non- significant effect on unmarketable yield of potato.

Total tuber yield:

Increasing the rate of NPS fertilizer from nil to 200 kg ha^{-1} increased total tuber yield significantly. This increment amounted to about 47.04%. However, increasing the rate of the fertilizer beyond 200 kg ha^{-1} did not showed significant increment of the total tuber yield of potato. However, further increasing the rate of the fertilizer from 100 to 200 kg ha^{-1} increased the marketable tuber yield of the crop by about 12%. Beyond application 200 kg NPS ha^{-1}, total tuber yield rather decreased (Table 6). In this case, the highest or optimum marketable tuber yield was obtained already at the rate of 200 kg NPS ha^{-1}.

Similarly, increasing the rate of potassium fertilizer from control to 100 kg KCl ha^{-1} increased the marketable tuber yield by about 18.36%. Further increasing the rate of the fertilizer to 200 kg KCl ha^{-1} increased the marketable tuber yield by about 36.93%. Thus, the response of total tuber yield to the application of potassium fertilizer was much more vigorous and continuous at each rate of the fertilizer than the response observed for application of the NPS fertilizer (Table6). The highest total tuber yield was obtained at the rate of 200 kg KCl ha^{-1}. The maximum total tuber yield of the crop was obtained in response to the application of 200 kg KCl ha^{-1} (Table 6), which indicates that potassium is an important limiting factor for increasing productivity of the crop.

Consistent with this result, Israel *et al*. (2012) and Zelalem *et al*.(2009) reported that increasing the application rates of nitrogen and phosphorus resulted in increasing total tuber yield. Minwyelet *et al*. (2017) and Melkamu *et al*. (2018) reported that the rate of 272 kg blended NPS ha^{-1} resulted in the production of the highest total tuber yield (47.53 t ha-1) while application of no blended NPS fertilizer produced the lowest total tuber yield (17.32 t ha^{-1}). Getachew *et al.* (2016) also reported that application of 100 kg blended NPKSZ ha^{-1} fertilizer resulted in the highest total tuber yield whereas the lowest tuber yield was obtained in response to nil application of the fertilizer.The results of this study are also consistent with that of Wassie *et al*. (2011) who reported that total tuber yield increased in response to increasing the rate of potassium fertilizer and the highest tuber yield was obtained from K level of 150 kg ha^{-1}.Corroborating the resultsHabtam *et al.* (2012) also reported that further increasing the rate of the nutrient from 100 to 200 KClha^{-1} increased the tuber yield components.

Table 7: Partial budget and marginal rate of return analysis for response of Gudanie potato variety to the application of blended NPS and potassium fertilizer rates at Bore during 2018 and 2019 cropping season

Treatments	Unadjusted Myld(kgha^{-1})	Adjusted Myld(kgha^{-1})	Total VariableCost(ETB)	Gross Return(ETB)	Net Benefit(ETB)	MRR (%)
Blended NPS (kgha^{-1})						
0	23670	21303	0	255636	255636	-
100	30860	27774	2175	333288	331113	3470.21
150	31540	28386	3262.5	340632	337369.5	575.31
200	34630	31167	4350	374004	369654	2968.69
250	33580	30222	5437.5	362664	357226.5	D
300	34200	30780	6525	369360	362835	515.72
Potassium rates (kg ha^{-1})						
0	26010	23409	0	280908	280908	-
100	31540	28386	1875	340632	338757	3085.28
200	36390	32751	3750	393012	389262	2693.60

Where, blended NPS cost = Birr 18 $kg^{-1}$of blended NPS, K_2Ocost = Birr 15 kg^{-1}, blended NPS and K_2O fertilizers application cost=Birr 3.75 $kg^{-1}$of blended NPS and K_2O, Application cost of blended NPS and K_2O fertilizers 5 persons 100 kg ha^{-1}, each 75 ETB day^{-1}, Field price of potato during harvesting = Birr 12 birr kg^{-1}, Myld =Marketable tuber yield, MRR (%) = Marginal rate of return and D= Dominated treatment.

Partial Budget Analysis:

To obtain an excellent economic return, optimum fertilizer application has great importance. The results of the study indicated that blended NPS and KCl fertilizers had given promoting benefit over the control. Partial budget analysis was done based on the view of CIMMYT Economics Program (1988) recommendations, which stated that application of fertilizer with the marginal rate of return above the minimum level (100%) is economical. according to this study, partial budget analysis revealed that the maximum net benefit of Birr 369,654 and 389,262 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2968.69 and 2693.60% was recorded in the treatment that received the application of 200 kg blended NPS ha^{-1} and 200 kg KCl ha^{-1} fertilizer rates, respectively (Table7). However, the lowest net benefit of Birr 255,636 and 280,908 $ha^{-1}$and non- acceptable marginal rates of return (MRR) were obtained in both nil received plots of blended NPS and KCl fertilizers respectively. The application of 200 kg blended NPS ha^{-1} and 200 kg KCl ha^{-1} generated 114,018and 108,354-Birr ha^{-1} more compared to control plots of blended NPS and KCl fertilizers respectively. The application of 200 kg blended NPS and KCl per hectar which gives the highest net benefit and a marginal rate of return greater than the mini mum considered acceptable to farmers (>1or 100%).The identification of a recommendation is based on a change from one treatment to another if the marginal rate of return of that change is greater than the minimum rate of return. Based on this result, 200 kg blended NPS and KCl ha^{-1} were resulted highest adjustable marketable tuber yield (31167 and 32751 kg ha^{-1}) respectively and profitable to the farmers in the study area (Table 7).

Appendix Table 1:.Mean squares of ANOVA for potato parameters response of potato to blended NPS and Potassium fertilizer rates at Bore, Southern Ethiopia in 2018 and 2019 growing season

Variable/Sources	Block	Blended NPS	KCl	Blended NPS x KCl	Error
Degrees of freedom	2	5	2	10	34
Days to 50% flowering	14.05	225.68**	42.26^{NS}	14.59 ^{NS}	18.69
Days to 90% maturity	17.15	209.44**	125.29 ^{NS}	14.06 ^{NS}	71.64
Plant height(cm)	153.03	516.88**	1697.54**	39.75 ^{NS}	47.47
Number of main stem $hill^{-1}$	6.73	6.46**	15.23**	2.80 ^{NS}	2.6
Average tuber number $hill^{-1}$	17.05	18.14**	26.03**	2.39 ^{NS}	7.31
Average tuber weight (g/tuber)	1036.5	675.3^{Ns}	2943.1**	133.8 ^{NS}	550.50
Marketable tuber yield(t ha^{-1})	5.11	3.56*	2056.423**	1456^{NS}	21.90
Unmarketable tuber yield(t ha^{-1})	4.39	3.23NS	0.55 ^{NS}	0.74 ^{NS}	1.07
Total tuber yield(t ha^{-1})	0.10	358.20**	1020.26**	16.05 ^{NS}	21.77

Where, **= highly significant at P ≤ 0.01 probability level, * = significant at P ≤ 0.05 probability level and Ns = non-significant at P > 0.05 probability level.

Conclusions and Recommendation:

Potato is one of the most important food security and cash crop for farmers in highland parts of Ethiopia, particularly in Guji zone where it is grown abundantly. Even though, potatoes serve as a major food source, as well as an inexpensive source of energy and good quality protein as well as very rich in nutrients and can provide nutrition to the growing global population. Twofold digit increasing world population requires producing more food in land which is steadily exhaustion and losing its fertility each year due to over exploitation and poor soil fertility managements. Most highlands of Ethiopian soil including in Guji highlands have limited potential of giving high crop yields due to the diverse and complex but declining soil fertility, increasing soil acidity (low pH).

Even though, potatoes are highly responsive to nitrogen fertilizer because of this the factors to consider when deciding on the rate of N to apply include: potato variety, yield potential or goal, growing season, soil organic matter content, and previous crop. The problem of low soil pH has led to nutrient imbalances that lead to even further decline of potato yields also nutrient imbalance hence reducing potato yields even further. Therefore, this study clearly indicate that the bottleneck problem for crop production severe soil acidity require an urgent need for appropriate use of soil health inputs (nutrients) to reserve the situation for the crops grown in the study area.

This study result, indicate that the main effect of blended NPS and KCL fertilizers influenced (days to 90% maturity, plant height, number of main stem per hill, average tuber number per hill, marketable, total tuber yield and harvest index) had highly significant ($P < 0.01$) while non-significant the main effect of blended NPS and KCL fertilizers on percent of peel content potato. From this result, it can be concluded that the interaction of blended NPS and KCL rates not affected all potato parameters.

The application of 200 kg blended NPS and KCL ha^{-1} fertilizer rates produce the highest adjustable marketable tuber yield (31167 and 36390 kg ha^{-1}) and economic returns (369,654 and 389,262 ETB) respectively. Therefore, partial budget analysisreaveled application of 200 kg KCL ha^{-1} (200 kg KCL and 46 kg N ha^{-1}) or application of 200 kg blended NPS with 46 kg N ha^{-1} (84 kg N ha^{-1} +76 kg P_2O_5 + 14 kg S ha^{-1}) resulted in optimum tuber yield of potato. Therefore, based on this study it can be concluded that combined application of 200 kg KCL ha^{-1} (200 kg KCL and 46 kg N ha^{-1}) or application of 200 kg blended NPS with 46 kg N ha^{-1}(84 kg N ha^{-1} + 76 kg P_2O_5 + 14 kg S ha^{-1}) fertilizer rates led to optimum potato tuber production, economical feasibleand recommended for potato growers in the highland areas of Guji zone.

REFERENCES

Ahmad, N., Khan, M.A., Khan, N.A., Binyamin, R. and Khan, M.A, 2011. Identification of resistance source in potato germplasm against PVX and PVY. *Pakistan Journal of Botany*, 43(6), pp.2745-2749.

Al-Moshileh, A.M. and MA Errebi, 2004. November. Effect of various potassium sulfate rates on growth, yield and quality of potato grown under sandy soil and arid conditions. *In:IPI Regional Workshop on Potassium and Fertigation Development in West Asia and North Africa, Rabat, Morocco* (pp. 24-28).

Arega A, 2018. Response of Potato (*Solanumtuberosum*L.) to Blended NPS and Potassium fertilizers at Bore, Southern Ethiopia. M.Sc. Thesis. Haramaya University, Ethiopia, pp. 20-30.of Agriculture, Haramaya University. 86p.

Asmaa, R.M. and M.M Hafez, 2010. Increasing productivity of potato plants (*Solanumtuberosum* L.) by using potassium fertilizer and humic acid application.*International Academic Research Journal*, 2(2): 83-88.

ATA (Agricultural Transformation Agency), 2013. Transforming the use of fertilizer in Ethiopia: Launching the national fertilizer blending program; February 12, 2013.

ATA (Agricultural Transformation Agency), 2015. Potassium Status and Crop Response to Potash Fertilizer Application on Ethiopian Soils, 24-26 November, 2015 HawassaUnversity, Hawassa, Ethiopia.

Bansal, S.K. and SP Trehan, 2011. Effect of potassium on yield and processing quality attributes of potato. *Karnataka Journal of Agricultural Sciences,* 24(1): 48-54.

BergaLemaga.,GebremedhinWoldegiorgis, TeriessaJalleta and Bereke-TsehaiTuku. 1992. Potato Agronomy Research. The 2nd national horticultural workshop of Ethiopia. Institute of agricultural research, Horticulture research and development in Ethiopia, Addis Ababa, Ethiopia.

Berga Lemaga., GebremedhinWoldegiorgis, TeriessaJalleta and Bereke-TsehaiTuku, 1994. December. Potato agronomy research in Ethiopia. *In*: *Proceedings of the 2nd National Horticultural Workshop,* (pp. 101-109).

Bergmann W, 1992. Nutritional disorders of plants development, visual and analytic diagnosis. *Gustav Fischer,Jena*.

Biruk Masrie, NigussieDechassa, TamadoTana, Yibekal Alemayehu1 and BekeleAbebie, 2015. The Effects of Combined Application of Cattle Manure and NP Fertilizers on Yield and Nutrient Uptake of Potato in North-Eastern Ethiopia.*Journal of Science and Sustainable Development*, 2015, 3(1), 1-23.

BOARC (Bore Agricultural Research Center), 2013. Adaptability study of potato varieties in highlands of Guji zone, southern Oromia. Unpublished progress report of completed research activities by Horticulture and Spice Research team.

BOARC (Bore Agricultural Research Center), 2019. Evaluation of Planting date and different Fertilizer rates for Potato (*Solanumtuberosum*L.*)* production at Bore, GujiZone.published progress report completed activities by Horticultural and Spice research team.

BoARDO (Bore Agriculture and Rural Development Office). 2015. Agriculture Report of Bore District.

Bouyoucos G.J, 1962. Hydrometer Method Improved for Making Particle Size Analyses of Soils 1.*Agronomy journal*, 54(5), pp.464-465.

Bray, R. H. and LT Kurtz, 1945. Determination of total, organic and available forms of phosphorus in soils. *Soil Science*, 59: 39-46.

Chapman HD, 1965. Cation exchange capacity by ammonium saturation. 891-901. *In*: Black, C.A., L.E. Ensminger and F.E. Clark (ed.), Method of soil analysis. *American Society of Agronomy*, Madison Wisconsin, USA. Chaudry, E.H., V. Timmer, A.S. Javed and M.T. Siddique. 2007. Wheat response to micronutrients in rainfed areas of Punjab. *Soil and Environ*, 26: 97-101.

CIMMYT (International Maize and Wheat Improvement Center), 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico. D.F. ISBN 968-61 27-18-6.

Cottenie A, 1980. Soil and plant testing as a basis of fertilizer recommendations.FAO soil bulletin 38/2.Food and Agriculture Organization of the United Nations, Rome.

CSA (Central Statistical Agency), 2019. Report On Area and Production of Major Crops .Agricultural sample survey Addis Ababa Statistical Bulletin Volume 1 pp: 589, 17-58.

Daniel, Z.Z., Sewa, L., Tesfari, T.K. and MG Biniam, 2016.Effect of Potassium Levels on Growth and Productivity of Potato Varieties. *American Journal of Plant Sciences,* 7, 1629-1638.

Dembi Korji and BashaKebede, 2017. On farm demonstration of adapted Potato (*Solanumtuberosum L.*) in Highlands of Guji zone, Oromia Region, Ethiopia.

Devaux, A., Kromann, P. and O Ortiz, 2014. Potatoes for sustainable global food security. Potato Research.doi:10.1007/s11540-014-9265-1.

Egata Shunka, AbebeChindi, Gebremedhin W/giorgis, EbrahimSeid and LemaTessema, 2016. Response of Potato (*Solanumtuberosum* L.) Varieties to Nitrogen and Potassium Fertilizer Rates in Central Highlands of Ethiopia. Advances *In*: Crop Science and Technology 4: 250.

Eskin NA, 1989. Quality and Preservation of Vegetables. pp. 2-11. CRS press, Inc. Bocaraton, Florida.

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

EthioSIS(Ethiopian Soil Information System), 2013. Soil analysis report. Agricultural Transformation Agency.

Fageria VD,2001.Nutrient Interactions in crop plants. *Journal Plant Nutrition,* 24:1269-1290.

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome.

FAO (Food and Agriculture Organization), 2014. Food and Agriculture Organization of the United Nations Statistics Division.

FAO (Food and Agriculture Organization), 2015. Potato World: Production and Consumption.

FAO (Food and Agricultural Organization),2008. Guide to laboratory establishment for plant nutrient analysis, fertilizer and plant nutrition bulletin 19 Rome .

FAOSTAT (Food and Agricultural Organization Statistic),2019. World food and agricultural organization data of statistics. FAO, Bulletin, Italy 10: 275.

Gen-Stat, 2012. Gen Stat Procuduers Library Release. *15th* Edition VSN International Ltd.

Getachew Kahsay, 2016. Response of Potato (*Solanumtuberosum*L.) Varieties to Nitrogen and Blended Fertilizer under Irigation at Maichew, Southern Tigray, Ethiopia. ThesisMaster of Sciences (M.Sc.) in "Agronomy" to the graduate program of College of Agriculture and Environmental Sciences, Haramaya University, Haramaya, pp- 98, 28-59.

Gomez, K.A. and AA Gomez, 1984. Statistical Procedures for Agricultural Research, 2nd edition, John Wiley and Sons, New York, p.680.

Gusha S, 2014. From Potato Fields to Potato Sacks. PastorialResponse.Anglical Diocese of Harare, Zimbabwe.
Habtam Setu, 2012. Response of Potato (*Solanumtuberosum* L.) to the application of Phosphorus and Potassium fertilizers at Assosa, BenishangulGumuz Regional State, Western Ethiopia. ThesisMaster of Sciences (M.Sc.) in "Horticulture" to the graduate program of College of Agriculture and Environmental Sciences, Haramaya University, Haramaya 82, 20-27-52.
Hirut Betaw,2015. Genetic analyses of drought tolerance and resistance to late blight among potato genotypes. A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy (PhD) in Plant Breeding, Republic of South Africa, Pp. 120.
Havlin, J. L., Beaton, J. D., Tisdale, S. L. and W L Nilson, 1999. Soil fertility and Fertilizer: An introduction to nutrient management. 6th ed. Prentice Hail. Upper Saddle River, New Jersey.
Hazelton P and Murphy B, 2007. Interpreting soil test results. What do all the numbers mean? Third Edition, CSIRO Publishing, Victoria.
Israel Zewide, Ali Mohammed and Solomon Tulu, 2012. Effect of Different Rates of Nitrogen and Phosphorus on Yield and Yield Components of Potato (*Solanumtuberosum* L.) at Masha District, Southwestern Ethiopia. *International Journal of Soil Science, 7: 146-156.*
Kumar, C.V., Prakash, S.S., Prashantha, G.M., Mahendra, K.M.B., Lohith, S. and T Chikkaramappa, 2013. Dry matter production and yield of potato as influenced by different sources and time of fertilizer application and soil chemical properties under rainfed conditions. *Research Journal of Agricultural Sciences*, 4(2): 155-159.
Lisińska, G and W. Leszczyński, 1989. Potato Science and Technology. Springer Science & Business Media.
Marschner H, 1995. Mineral nutrition of higher plants.2nd ed. Harcourt science and Technology Company, New York, London, Sydney, Tokyo, Boston. pp 889.
Mehlich A, 1984. Mehlich-3 soil Test Extractant: A Modification of Mehlich-2 Extractant. *Communications in Soil Science and Plant Analysis*, 15(12): 1409-1416.
MelkamuAlemayehu and MinwyeletJemberie, 2018. Optimum rates of NPS fertilizer application for economically profitable production of potato varieties at Koga Irrigation Scheme, Cogent Food & Agriculture, 4pp: 1- 17.
Mengel, K. and E.A. Kirkby, 2001. Principles of Plant Nutrition. Netherlands. Kluwer Academic Publishers. 849 p.
MinwyeletJemberie, 2017. Effects of NPS fertilizer rate and Irrigation frequency determination method on the growth and tuber yield of Potato (*Solanumtuberosum*L.*)*in Koga Irrigation Scheme, West Gojjam, and North Western Ethiopia. ThesisMaster of Sciences (M.Sc.) in "Horticulture" to the graduate program of College of Agriculture and Environmental Sciences, Bahir Dar University, 64, 20-34.
MoA (Ministry of Agriculture and Rural Development), 2009. Crop Variety Register Book, Addis Ababa, Ethiopia.
Mulubrhan Haile, 2004. The effect of Nitrogen, Phosphorus and Potassium fertilization on the yield and yield components of potato (*Solanumtuberosum* L.) grown on vertisols

of Mekele area. M.Sc. Thesis. Haramaya University, Ethiopia, pp. 22-54.of Agriculture, Alemaya University. 82p.
Murphy BW, 2007.Soils their properties and management.' 3rdedn. (Oxford University Press: Melbourne).
Naz, F., Ali, A., Iqbal, Z., Akhtar, N., Asghar, S. and B Ahmad, 2011. Effect of different levels of NPK fertilizers on the proximate composition of potato crop at Abbott bad. *Sarhad Journal Agricultural*, 27(3):353-356.
NiguseAbebe, FasilKebede, and EyasuAbereha, 2016. Effect of Potassium on Tuber Yield and Yield Component of Potato (*Solaniumtubersum* L.) on Loamy Soils of Atsbi-Wenberta, Tigray, Ethiopia. *Journal of Biology, Agriculture and Healthcare*, Vol.6, No.3, 2016.
Niguse, Abebe, 2016. Effect of Phosphorus and Potassium Fertilizer Rates on Yield and Yield Component of Potato (*Solanumtubersum* L,) at K/Awlaelo, Tigray, Ethiopia. Food Science and Quality Management Vol.48.
NigussieDechassa, MengistuKetema, Haile Deressa, Wole, K., TamiruAmanu.,Olkaba, B., Solomon, A. and T Samuel, 2012. Participatory rural appraisal for Gurawa, Haramaya, Kombolcha, and Habro districts of East and West Hararghe zones in Ethiopia.
NikardiGunadi, 2009. Response of Potato to Potassium Fertilizer Sources and Application Methods in Andisols of West Java Response of potato to potassium fertilizer sources .*Indonesian Journal of Agricultural Science*, 10(2), 65-72.
Pandey, N.K., Dhiraj, K. and R.S Kumar, 2014. Summer School on "Current Trends in Quality Potato Production, Processing and Marketing" (8th to 28th July, 2014). Central Potato Research Institute, Shimla, New Delhi.
Panique, E., Kelling, K.A., Schulte, E.E., Hero, D.E., Stevenson, W.R. and RV James, 1997. Potassium Rate and Source Effects on Potato Yield, Quality, and Disease Interaction. *American Potato Journal,* 74(6):379-398.
Panique, E., Kelling, K.A., Schulte, E.E., Hero, D.E., Stevenson, W.R. and RV James, 1997. Potassium Rate and Source Effects on Potato Yield, Quality, and Disease Interaction. *American Potato Journal,* 74(6):379-398.
Patricia, I and SK Bansal, 1999. Potassium and integrated nutrient management in potato. *A paper presented at the Global Conference on Potato*, 6-11 December 1999, New Delhi, India.
Pervez, M. A., Ayyub, M. I. C.M., Shabeen, M. R. and MA Noor, 2013. Determination of Physio-morphological Characteristics of Potato Crop Regulated by Potassium Management. *Pakistan Journal of Agricultural Sciences*, 50(4), 611-615.
Rowell DL, 1994. Soil Science: methods and applications. London. Longman. 350 p.
SemagnAsredie, AbdulwahabAliyi and AbdissaYohannes, 2007. Potato and sweet potato research achievements in North Shewa. *In*: Proceedings of the 1st annual Regional Conference on Completed crop Research Activities. 14-17. August, 2006, ARARI, Bahir Dar.
Somerfeld, T. G., and KW Knutson, 1965. Effects of nitrogen and phosphorus on the growth and development of Russet Burbank potatoes grown in southeastern Idaho. American Potato Journal, 42(12), 351-360.
Singh, B. P. and K Rana Rajesh,2013. Potato for food and nutritional security in the world.

Berger, K.C., and Truog, 1939. Boron determination in soils and plants. Ind. Eng. Anal. Ed. 11: 540 – 545.

Carter, M. R and Gregorich, E. G. (2008). Soil sampling and methods of analysis (2 ed.). Taylor and Francis group

Ethiopian Agricultural Research Organization (EARO),2004.Directory of released crop varieties and their recommended cultural practices. Ethiopian Agricultural Research Organization, Ethiopia, pp. 36.

Johnson, G.V. and P.E. Fixen, 1990. Testing Soils for Sulfur, Boron, Molybedenum and Cholorine. In: Soil Testing and Plant Analysis, Westermann, R.L. (ED.). 3rd Edn., Soil Science Society of America, Madison,USA., pp: 265-273.

MekidesMekashaw ,MelkamuAlemayehu , GetachewShumye& Amare Haileslassie,2020. Effects of blended NPS fertilizer rates on yield and yield components of potato (*Solanumtuberosum*L.) varieties at DessieZuria district, Northeast Ethiopia, Cogent Foodand Agriculture, 6:1, 1779478

Sikora, F. J., Copeland, J. P., Mullins, G. L. and J. M Bartos, 1991. Phosphorus dissolution kinetics and bio-availability of water insoluble fractions from mono-ammonium phosphate fertilizers. *Soil Science Society of America Journal*, 53: 362-368.

Simret Burga, NigussieDechassa and TekalignTsegaw, 2014. Influence of Mineral Nitrogen and Potassium Fertilizers on Ware and Seed Potato Production on Alluvial Soil in Eastern Ethiopia, *EastAfrican Journal of Sciences*, Vol. 8 (2) 155 – 164.

Tantowijoyo, W. and E. Fliert, 2006. All about potatoes: A handbook to the ecology and integrated potato crop management.

Ugent, D., Pozorski, S. and T Pozorski, 1982. Archaeological potato tuber remains from the Casma Valley of Peru. *Economic Botany*, 36(2), pp.182-192.

TayeBekele, Verkuijl, H., Mwangi, W. and D Tanner, 2000. Adoption of Improved Wheat Technologies in Adaba and DodolaWoredas of the Bale Highlands, Ethiopia. Second National Maize and Wheat Workshop.12-16 November 2000; Addis Ababa. International Maize and Wheat Improvement Center) and Ethiopian Agricultural Research Organization (EARO). Addis Ababa, Ethiopia.

TekalignMamo and HezekeilTase, 2015. Series "innovative ideals on effective last mile delivery". Available on www.fertilizers.org/nutrientstewardship. Accessed on July /20/2015.

TekalignTadese, 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13.International Livestock Research Center for Africa, Addis Ababa.

Thompson, H.C. and WC Kelly, 1972.Vegetable crops. Tata McGraw. Hill Publication Co.Ltd., New Dehil, pp: 372-385.

United States Department of Agriculture (USDA), 1987. Forest Service. n.d. Soil resource inventory. Umatilla National Forest, Pacific Northwestern Region.

USDA (United State Department Agriculture**),2014.** National Genetic Resources Program.Germplasm Resources Information Network - (GRIN).

Walkley, A., and IA Black, 1934. An examination of the digestion method for determining soil organic matter and a proposed modification of the chromic and titration method.*Soil Science*, 37:29-38.

WassieHayile and ShiferawBoke, 2011. On-Farm Verification of Lime and NPK Fertilizers Effects on the Tuber Yield of Irish Potato. *Journal of the Drylands*, 4(1), pp. 283-288.

WassieHayileandTekalignMamo, 2013. The effect of potassium on the yields of potato and wheat grown on the acidic soils of Chencha and HagereSelam in Southern Ethiopia. *International Potash Institute Research Findings*, pp.3-8.

Zelalem, A., Tekalign, T. and D Nigussie, 2009. Response of potato (*Solanumtuberosum* L.) to different rates of nitrogen and phosphorus fertilization on vertisols at DebreBerhan, in the central highlands of Ethiopia. *African Journal of Plant Science*, 3(2), pp.016-024.

Response of Head Cabbage (*Brassica olearacea L.)* Yield to Different Rates of Inorganic Nitrogen and Phosphorus Fertilizers at Bore, Southern Ethiopia

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Abstract:

The field trial was conducted during 2017 and 2018 main cropping season at Bore Agricultural Research Centre which is located in Gudji Zone of Southern Ethiopia to determine the effect of different application rates of nitrogen and phosphorus fertilizers on growth, yield and yield components of head cabbage and to identify their economically appropriate rates that maximize yield of head cabbage. The experiment was carried out to study cabbage variety Olsen in response to N and P nutrients in respect to growth, yield and yield related parameters of the crop. The longest head initiation days (90) and longest days (140) to maturity was attained in 294 kg ha^{-1} Nitrogen and 138 kg ha^{-1} phosphorus treatment, while shortest head initiation days (64.33) was obtained in control treatment. The highest plant height (26.4 cm) was recorded for the treatment T3P4 (235and 138 kg ha^{-1}), while the shortest (16.9 cm) plant height was recorded from the T1P1 (control) treatment. Nutrient levels markedly influenced the diameter, height, head mass and yield of head cabbage. The maximum average head diameter (25.44 cm) and average height (27.33 cm) was recorded in treatment receiving 235 kg N and 82 kg P ha^{-1}. Combined application of 235 kg N ha^{-1} with 82 kg ha^{-1} produced the highest (2356.67 g) untrimmed head weight of cabbage followed by second maximum (2133.33 g) untrimmed head weight with the rate of 235 kg N ha^{-1} with 110 kg P_2O_5ha^{-1} while the least (1120.67 g) untrimmed head weight was recorded for the control treatment. Combined application of 235 kg nitrogen and 82 kg phosphorus ha^{-1} (N3P2) recorded maximum (69.00 t) head yield without wrapper ha^{-1} and the lowest (27.66 t ha^{-1}) was recorded by control treatment. The marginal rate of returns, which determines the acceptability of any treatments shows that treatments that received 235 kg N ha^{-1} in combination with 82 kg ha^{-1} of P_2O_5yielded 43498 % marginal revenue. Therefore, this

combined nutrientapplication rates can be recommended in the study area and similar agro-ecologies since it is the most feasible rates for the producersbecause of its low cost of production and higher benefits.

Keywords: Combined, Nitrogen, Nutrient, Olsen, Phosphorus, Treatment

INTRODUCTION

Head cabbage is scientifically known as (*Brassica oleracea* var. *capitata)*. It belongs to the *Cruciferae*family which includes also kale (*Brassica oleracea*var*acephala*), Chinese cabbage (*Brassica pekinensis* (LourRapr.) and Brussels sprouts (*Brassica oleracea* var. *gemmifera* DC). It was introduced initially to China 2000 years ago, where the heading *(Brassica oleoracea*L*)* types were developed (Yamaguchi, 1983).

Cabbage thrives best during cool, moist seasons (Ware and McCollum, 1980; Hemy, 1984; Smith, 1995; Tiwari *et al*., 2003). Even though it requires 500 mm of water for its growing period (Askew, 1999), good drainage is importantas too much water tends to split heads when they are mature (Splittstoesser, 1979; Ware and McCollum,1980). Water should not be deficient from head formation until harvest time, as this willdrastically limit yields (Askew, 1999). According to Hadfield (1995), it can be grownthroughout the year and its optimum soil pH ranges from 6.0 to 7.0. Its growth season is between 80 to 100 days (Lecuona, 1996).

It has long been accepted that applications of nitrogen fertilizer to cabbage increased yields, plant uniformity, and quality (Thomas J. R. *et al.,* 1970). To produce optimum yields of good quality cabbages, often high amounts of nitrogen fertilizer are applied. The recommended total amounts of nitrogen fertilizer for cabbage are 160 to 260 kg ha^{-1}. In reality, the amount of nitrogen fertilizer used is probably higher as farmers may apply more fertilizer than recommended to secure yields. Nitrogen produces reliable and optimal yield and quality of vegetables (Krezel, J. and Koota, E., 2004). However,it isthe most difficult element to manage in a fertilization system in order to ensure an adequate, yet not excessive, amount of available nitrogen within the rhizosphere from planting to harvest (Adler *et al*., 1984).

Nitrogen and phosphorus are one of the nutrients of major importance in the growth of head cabbage. Lack of these major nutrients causes the plant to be stunted and becomes yellow in appearance thereby decreasing yield. An adequate supply of nitrogen is essential for vigorous vegetative growth, head formation and optimum yield of cabbage. However, the response of the crop to nitrogen and phosphorus varies under different soil and agro climatic conditions and thus affecting the optimum level of nitrogen and phosphorus.Achieving and maintaining appropriate levels of soil fertility, especially plant nutrient availability, is very important in agricultural land to remain capable of sustaining crop production at an acceptable level.

In the past, agricultural production was focused on maximizing the quantity of vegetables produced for commercial market (Pavla and Pokluda, 2008) while in the last few decades the organic management of crops has gained great popularity because of increased consumers' awareness of the health problems that come from food grown under conventional and intensive farming. Differences between organic and conventional farming systems, especially in soil fertility management, may affect the nutritive composition of plants.Soils vary in their capacity to provide nutrients to crops and crops differ in their requirements, therefore, most soils cannot supply all essential nutrients to crops. Fertilizers recommendations are therefore, developed to quantify the amount of nutrients for various crops which are to be applied through fertilizers.Therefore the activity was proposed to determine the effect of different application rates of nitrogen and phosphorus fertilizers on growth, yield and yield components of head cabbage and to identify their economically appropriate rates that maximize yield of head cabbage.

LITERATURE REVIEW

Origin, Importance and Ecology

Cabbage originated from a wild non-heading type, 'Cole wart' (*Brassica oleracea var. sylvestris*). The genus *Brassica* includes about 100 species, majorities of which are native to the Mediterranean region. The crop is attributed to Mediterranean centre of origin. It is also considered that the real headed cabbage was evolved in Germany. The Savoy (yellowish green) cabbage originated in Italy and spread to France and Germany in the sixteenth and seventh centuries (Moamogwe, 2005). The cabbage seems to have originated in Europe around 1000BC, after which it was introduced into the Middle East and other areas. Today, cabbages can be found all around the world, making is possible for everyone to experience its benefits (Brandi M., 2019). Today, China is the largest producer of cabbage, followed by India and Russia, which is the biggest consumer of cabbage. Around the world, cabbage is prepared in different ways. While it can be eaten raw, as a salad, cabbage can be steamed, pickled, stewed, sautéed or braised. Sauerkraut and kimchi are the most popular pickled variants while the coleslaw is one of the most popular salads. Cabbage is a leafy vegetable from the wide family of "brassicas". It is grown annually, and we eat its dense green or purple leaves in many different dishes. Head of cabbage, which can grow from 0.5 to 4 kilograms, is rich in vitamins and minerals, has almost no fat and is very rich in fiber which makes it very healthy to eat. Cabbage health benefits includes reducing risk of cancer, improving brain and nervous system health, promoting bone health, maintaining blood pressure, detoxifying the body, promoting bowel regularity, regulating sugar level and promoting weight loss. Other benefits includes improving health of hair, skin and nails, helping prevent or heal acne, healing stomach ulcers, helping care for the heart, promoting healthy pregnancy and boosting immunity(Brandi M., 2019).

It thrives in well-drained, moisture-retentive, loamy soils well supplied with organic matter. It
does not grow well in highly acidic soil. The ideal soil pH ranges from 5.5 to 6.5 and it should
not be allowed to drop below 4.5. Cabbage can be grown easily under a wide range of environmental conditions but cool moist climate is most suitable. The optimum soil temperature for seed germination is 22-26.20C. The optimum temperature for growth is between 25.2 to 34.20C.Whereas, temperature above 43.20C, growth is arrested in most of the cultivars. Cabbage plants that are exposed to temperatures of 10-13 0 C for prolonged periods will produce premature seed stalks instead of heads (Solomon *et al.,* 2018).

Response of Vegetables to Nutrient Application

It's the earth's cultivated cropland that keeps humanity alive and thriving. Plants provide food, fiber, housing and a host of other benefits, and fertilizer plays a key role in this process. As the world population is expected to exceed 9 billion by 2050, fertilizer will be needed more than ever to boost crop production to keep people fed and healthy. All growing

plants need 17 essential elements to grow to their full genetic potential. Of these 17, 14 are absorbed by plants through the soil, while the remaining three come from air and water. Nitrogen, phosphorus and potassium, or NPK, are the "Big 3" primary nutrients in commercial fertilizers. Each of these fundamental nutrients plays a key role in plant nutrition. Nitrogen is considered to be the most important nutrient, and plants absorb more nitrogen than any other element. Nitrogen is essential to in making sure plants are healthy as they develop and nutritious to eat after they're harvested. That's because nitrogen is essential in the formation of protein, and protein makes up much of the tissues of most living things. Below is a picture of corn that is nitrogen deficient (TFI, 2020).
To produce optimum yields of good quality vegetables, often high amounts of nutrients are applied. However, it is usually not feasible to supply sufficient concentrations of essential plant nutrient elements to sustain plant growth for an extended period. The role of nitrogen in vegetable growth has been investigated in a number of vegetable crops. Generally, vigorous growth was attributed to higher nitrogen regimes. Melton and Dufault (1991) studied the effect of various rates of nitrogen, phosphorous and potassium on 'Sunny' tomato transplant growth and transplant quality. It was observed that nitrogen was a major factor affecting tomato transplant growth in both years of research.

Response of Head Cabbage to Nutrient Application

Cabbage has high requirements for all nutrients, especially nitrogen, and cabbage demands for achieving high yields ranged from 130 to 310 kg N/ha (Lešić*et. al.*, 2004, Sanderson and Ivany, 1999). Nitrogen over use in modern agriculture is of major importance with respect to both environmental concerns and the quality of plant products. Cabbage, as other cruciferous vegetables, has high nutritional value and contains specific sulphur compounds glucosinolates that increase its antioxidant activity. Nitrogen and phosphorus are one of the nutrients of major importance in the growth of head cabbage. Lack of these major nutrients causes the plant to be stunted and becomes yellow in appearance thereby decrease yield. An adequate supply of nitrogen is essential for vigorous vegetative growth, head formation and optimum yield of cabbage. However, the response of the crop to nitrogen and phosphorus varies under different soil and agro climatic conditions and thus affecting the optimum level of nitrogen and phosphorus.Achieving and maintaining appropriate levels of soil fertility, especially plant nutrient availability, is of paramount importance in agricultural land to remain capable of sustaining crop production at an acceptable level.
Cabbage has good responsiveness on animal manure application in quantity of 40 t/ha. Organic fertilization enhances soil biological activity, improves nutrient mobilization and soil structure and increases soil water retention. Systems relying on organic fertilizers as plant nutrient sources have different dynamics of nutrient availability than those using mineral fertilizers. Sustainable crop production with integrated use of mineral and organic fertilizer has proved to be highly beneficial. Several studies have shown the positive effect of combined use of mineral and organic fertilizers in fields that continuously for a few years received only N, P and K, without any micronutrient or organic fertilizer (Chand *et al.* 2006; Kaur *et al.* 2005).

MATERIALS AND METHODS

Description of the Study Sites

The field trialwas conducted during 2017 and 2018 main cropping season at Bore Agricultural Research Centre which is located in Gudji Zone of Southern Ethiopia. The climatic condition of the area is most humid and sub humid moisture condition with relatively longer growing season. Bore is found at Latitude of 6^{o}26'52" N,Longitude 38^{o}56'21" E and at an altitude of 2736m.a.s.l. The annual rainfall ranges from1400-1800 mm with a bimodal pattern that extended from April to November. The mean annual minimum and maximum temperature is 10.1 and 20 ^{0}C, respectively(Anonymous, 2014). The type of the soil is red basaltic soil (Nitosols) and Orthic Aerosols. The soil is clay in texture and very strongly acidic with pH around 4.01-5.33 (Horticoop Ethiopia, 2020).

Description of Experimental Materials

Head cabbage variety Olsen was used as experimental material. The seeds of this variety were obtained from open commercial market. The choice of this variety was due to its good adaptability and short vegetative cycle. The seed of variety is normally found in the market at large and this crop is widely cultivated and consumed in different highland parts of the Zone and best variety for midlands of the area.

Description of Experimental Design and Treatments

The experiment was laid out in a Factorial arrangement of Randomized complete Block Design having two factors (nitrogen and phosphorus) with three replications. The treatments consisted four levels of nitrogen and four levels of phosphorus. There were 16 treatment combinations (N_1P_1,N_1P_2,N_1P_3,N_1P_4,N_2P_1,N_2P_2,N_2P_3,N_2P_4,N_3P_1,N_3P_2,N_3P_3,N_3P_4,N_4P_1,N_4P_2,N_4P_3 and N_4P_4).The treatment details were as (i) Levels of nitrogen (N) - N1: control; N2: 176 kg; N3: 235 kg; N4: 294 kg ha^{-1}; (ii) Levels of phosphorus (P_2O_5) P1: control; P2: 82 kg; P3: 110 kg; P4: 138 kg ha^{-1}. Forty five days of old seedlings of head cabbage was transplanted using spacing of 50cm and 40cm between rows and plants,respectively on plotsize of 3.0 m x 2.4 m. The distance between the plot and the block is 0.8 m and 1.0 m, respectively. The plot consisted of six rows and six plant populations per single row,totally 36 plants per plot will be employed. The treatments were applied on permanent plots (3 m by 2.4 m) in a randomized complete block design with three replications. Half dose of nitrogen and full dose of phosphorus was applied to the respected treatment as basal dose and the remaining 50 % nitrogen was given to the treatment at time of head initiation. Urea and NPS fertilizers were used as sources of N, P_2O_5 respectively.Urea (46% N) and DAP (46% P_2O_5+ 18% N) TSP (46%P_2O_5) were used as sources of N and P, respectively.

Soil Sampling and Analysis

Initially a soil sample was collected before land preparation from the depth of 30 cm from different spots of the experimental field using auger. Then a composite soil sample will be made and air dried, crushed and it was passed through 2 mm sieve in the laboratory for analysis of physico-chemical properties of the soil. After harvested the crop, soil samples were also taken from 0-30cm soils depth for each replications and composited treatment wise. Then a composite soil was analyzed for determining the soil textural class, pH, CEC, organic carbon, EC, organic matter, total nitrogen, available P, available K, and Sulphur.The values for each physico-chemical characteristics of the experimental soil were presented in Table 1.

Management of the Experiment

The nursery was prepared by removing plant residues and breaking big soil aggregates. Seedlings of the cabbage were raised in a seed bed. The soil of the seed bed was well ploughed with a spade and prepared in to loose friable dried masses to obtain good tilth that can provide a favorable condition for the vigorous growth of young seedlings. The seed of the cabbage were sown on raised bed and watered once in a day until the seedlings were emerged and ready for transplanting. In the nursery fertilizer was not applied. Five days before transplanting the seedlings were hardened by reducing irrigation frequency. Finally healthy and uniform seedlings were transplanted to the experimental plots after 45 days of sowing. All doses of phosphorus were applied once at time of transplanting and 50% of nitrogen were applied at the time of transplanting and the remaining 50% supplied before head initiation as per treatment dose. Other agronomic practices including weeding, irrigation and cultivation were done uniformly in all plots.

Crop Data Collection

Phenological Data

Days to 50% head initiation: Days to 50% head initiation was recorded when half of the plants in a net plot formed heads.

Days to 90% head maturity: It was recorded from the date of transplanting to when 90% of the heads from the net plot reached maturity. This was determined by the leaf color change, compactness or firmness of the head.

3.6.2. Growth Parameters

Number of expanded leaves per plant: The number of leaves per plant was counted and mean of five plants was recorded before the start of head initiation excluding unfolded and dead leaves.

Plant height: The height of the plant was measured by placing a meter scale from ground level to the tip of the outer longest leaf of an individual plant at the time of 90% days to head maturity. Thus, mean of five selected plants of a single plot was recorded and expressed in centimeter (cm).

Yield and Yield Components

Average fresh weight of untrimmed head per plant: The fresh weight of heads with unfolded leaves per plant was found from the average weight of selected five plants and expressed in gram (g) when yield data was taken.

Average fresh weight of trimmed head per plant: The fresh weight of marketable head per plant was found from the average weight of five plants and was expressed in gram (g) when yield data was taken.

Diameter of head: Five heads were taken randomly. Then sectioning of head was done horizontally with a sharp knife at the middle portion. The diameter of head was measured as the horizontal distance from one side to another side of the selected head and was expressed in centimeter (cm).

Height of head: Head height (cm) was obtained from five representative plants per net plot area and measured by cutting vertically using a ruler at the time of harvesting.

Gross head yield with wrapper: Heads with unfolded leaves of all the plants within a net plot area (harvested area 2 m×2.8 m) were weighed and converted to tons per hectare.

Marketable yield without wrapper per plot: Heads without unfolded leaves of all the plants within a net plot area (harvested area 2 m×2.8 m) were weighed and converted to tons per hectare.

Partial Budget Analysis

Variable cost of N and P fertilizer was largely used for partial budget analysis**.** Price fluctuations during the production season were considered. 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 cabbage due to the application of each rate to the total cost of N and P fertilizer applied at each rate. This enables to identify the most economic rate and source of N and P fertilizer for cabbage production (CIMMYT, 1988).This was achieved by dividing the total variable cost by the net benefit multiplied by 100.

$$\text{MRR}(\%) = \frac{\text{Marginal benefit}}{\text{Marginal Cost}} \times 100$$

Statistical Data Analysis

Analysis of variance procedures was used on every measured parameter to determine the significance of differences between means of treatments using the SAS 9.1.3 systems software for each parameters, and separated by the least significant difference (LSD) using the statistical package. Yield and yield related data was statistically analyzed using the ProcGlm function of SAS and means were compared using LSD at a probability level of 5 % (SAS, 2003).

RESULTS AND DISCUSSION

Soil physicochemical properties

Soil physicochemical properties of site before planting

The analysis results of soil prior to planting indicated that the textural class of the soil was clay which is comfortable for production (Table 1). Accumulation of different organic materials during previous growing seasons might have resulted in high pre-plant organic carbon content (3.02 %), which might have contributed to the high level of total N (0.30%), low level of available phosphorus (4.52 ppm), high level of exchangeable potassium (262.25 mg/kg (ppm)), and medium level of CEC (22.11 Meq/100g) in the soil. Tekalign*et al.*

(1991) and Berhanu (1980) rated 0.12-0.25% total N as high, >3 % OC as high and Olsen *et al.* (1954) rated available phosphorus ranging 5-10 ppm as medium. While Jones, J. Benton (2003) rated available K ranging141-300 as high and Hazelton and Murphy (2007) rated CEC 12-25 cmol (+) kg^{-1} as medium. The soil pH was also very strongly acidic with a value of 4.3 (pH-H2O). Generally, the soil physical and chemical analysis prior to planting indicated that the soils of the experimental fields are potentially productive from the perspectives of chemical properties of soils for cabbage growth except soil acidity of the soil since the ideal soil pH ranges from 5.5 to 6.5 and it should not be allowed to drop below 4.5. Therefore for better fertilizer response the physical nature of the soil should be improved through composted manure and lime to improve moisture retention and raise soil pH.

Table 1. Soil Physiochemical properties of experimental site before planting.

Soil characters	**Values**	**Examination standards**
pH (by 1: 2.5 soil water ratio)	4.30	ES ISO 10390:2014(1:2.5)
Total nitrogen (%)	0.30	ES ISO 11261:2015(Kjeldahl Method)
Organic carbon (%)	3.02	Walkley and Black Method
Available phosphorous (mg/kg (ppm))	4.52	ES ISO 11261:2015(Olsens Method)
Cation exchange capacity (Meq/100g)	22.11	Ammonium Acetate Method
Available potassium (mg/kg (ppm))	262.25	Ammonium Acetate Method
Available sulfur (mg/kg (ppm))	31.19	Turbidometreic
Soil texture:		Bouyoucos Hydrometer Method
Sand	28	
Silt	43	
Clay	31	
Class	Clay	

Source: Tekalign*et al.* (1991), Berhanu (1980), Olsen *et al.* (1954), Jones, J. Benton (2003) and Hazelton and Murphy (2007)

Soil physicochemical properties after crop harvest

The analysis of the experimental soil after harvest for pH, available phosphorus, total nitrogen, sulfur, available potassium, organic carbon, cation exchange capacity and texture is indicated in Table 2. The result revealed that available phosphorus organic carbon, total nitrogen and CEC were increased while available sulfur and available potassium decreased after the application of nitrogen and phosphorus to the experimental plot. However, the range of pH change was only from 4.11 to 5.35 with treatment employed (Table 2) which could be due to the inactivation of nitrogenous fertilizer we used which correspondingly increased the level of soil pH.

The result obtained from composited soil analysis showed that the treatments with 235 kg N $ha^{-1}$and 138 kg ha^{-1} of Phosphorus rate gave an increase of 5.35 % pH, 3.11 % OC and 0.31 % of total nitrogen. However 294 kg N $ha^{-1}$and 138 kg $ha^{-1}$of Phosphorus rate gave an increased available S of 22.05 mg/kg of soil and application of 138 kg $ha^{-1}$of phosphorus gave 30.62 Meq/100 g CEC (Table 2).Similarly, the combined application of the highest rate of 235 kg ha^{-1}and 138 kg ha^{-1}phosphorus increased the P_2O_5level from 4.52 to 16.26mg kg^{-1} after harvest. As the rate of nitrogen and phosphorus application increases, the soil characteristic parameters were increased with increase in nitrogen and phosphorus concentration (Table 2). Maximum pH (5.35) was recovered, when 235 kg ha^{-1} and 138 kg ha^{-1} phosphorus applied with relatively higher rate of phosphorous (Table 3). This increase in pH of the soil increased the availability of cations under acid soils in the study area.

Table 2. Soil Physiochemical properties of experimental site after crop harvest

Trt	PH	P(mg/kg)	S(mg/kg)	K(mg/kg)	CEC	OC (%)	OM (%)	TN (%)	C:N ratio	Texture sand	clay	silt	class
N1P1	4.3	13.4	10.34	105	24.32	2.87	4.94	0.3	9.52	30	44	26	clay
N1P2	4.6	15.0	8.06	106	23.88	3.07	5.29	0.3	9.91	28	44	28	clay
N1P3	4.5	9.81	20.16	136.5	21.33	3.11	5.37	0.3	10.2	26	42	32	clay
N1P4	4.3	6.93	14.68	74.2	30.62	3.03	5.22	0.3	10.2	26	46	28	clay
N2P1	4.1	12.8	13.13	105	20.44	2.89	4.99	0.3	9.61	26	46	28	clay
N2P2	4.1	12.0	15.16	106	28.66	3.06	5.27	0.3	9.77	26	46	28	clay
N2P3	4.0	9.18	6.09	152.25	19.66	2.8	4.82	0.3	9.76	26	46	28	clay
N2P4	5.3	12.7	16.11	127.2	21.43	2.87	4.94	0.3	9.58	30	42	28	clay
N3P1	5.2	16.5	20.16	99.75	20.18	2.92	5.03	0.3	9.51	30	44	26	clay
N3P2	5.3	14.3	14.87	104	21.13	2.89	4.98	0.3	9.61	30	44	26	clay
N3P3	4.9	8.76	12.65	126	18.77	2.8	4.82	0.3	9.8	28	42	30	clay
N3P4	5.4	16.3	14.68	100.7	17.79	3.11	4.87	0.3	9.45	30	42	28	clay
N4P1	5.1	9.48	15.16	111.3	24.04	2.82	5.36	0.3	10.2	30	44	26	clay
N4P2	4.9	12.9	12.77	100.7	19.29	2.78	4.8	0.3	8.86	30	44	26	clay
N4P3	5.3	11.1	11.7	131.25	20.03	2.84	4.89	0.3	9.59	30	44	26	clay
N4P4	5.1	10.4	22.05	105	19.8	2.84	4.89	0.3	10.7	30	42	28	clay

Phenological Parameters of Head Cabbage

Days to 50% Head Initiation

The analysis of variance indicated that interaction effects of Nitrogen and Phosphorushad significant ($p<0.05$) effect on days to 50% heading (Table 3).

Table 3.Interaction effect of N and P on days to 50% head initiation of head cabbage

Phosphorus (kg ha^{-1})	Nitrogen (kg ha^{-1}) 0	176	235	294
0	64.33^{i}	70.66^{f}	72.00^{ef}	71.33^{f}
82	65.33^{hi}	80.66^{b}	79.66^{bc}	78.33^{c}
110	67.00^{gh}	72.33^{ef}	79.66^{bc}	78.66^{bc}
138	68.00^{g}	73.66^{e}	76.00^{d}	90.00^{a}
LSD (0.05) N*P=2.14; CV (%) =1.74				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.01) = Least Significant Difference at 1% level; and CV (%) = coefficient of variation in percent

The shortest head initiation (64.33 days) was obtained in control treatment where the longest (90 days) duration was attained in 294 kg ha^{-1}Nitrogen and 138 kg ha^{-1}phosphorus treatment (Table 3).The control treatment resulted in early finish of heading before attaining of fully required physiological maturity and matured early as compared to those higher doses. This might be due to lower N and P rates not enough to enhance the development of the crop and hastening head formation and maturity.

Days to 90% Maturity

The analysis of variance indicated that interaction effects of Nitrogen and Phosphorushad significant ($p<0.05$) effect on days to maturity (Table 4).Plots treated with lowest (control) combination rates took shorter period to mature which might be because of lower rate of Nitrogen and Phosphorus not enough to enhance the development of the crop and hastening head formation and maturity. While plots treated with maximum 294 kg ha^{-1}Nitrogen and 138 kg ha^{-1}phosphorus combinationrates took longer (140)days to mature (Table 4). The increase in days to maturity due to nutrient application might be related to its role in stimulation of plant growth by the assimilation ofmajor elementsand changes in protein synthesis and finally related to growth and production of the crop.

Table 4.Interaction effect of N and P on days to maturity of head cabbage

Phosphorus (kg ha^{-1})	Nitrogen (kg ha^{-1})			
	0	176	235	294
0	109.66^{j}	117.00^{h}	118.00^{h}	125.00^{f}
82	108.00^{j}	120.00^{g}	132.00^{d}	132.66^{cd}
110	108.00^{j}	127.00^{e}	135.33^{b}	139.00^{a}
138	112.00^{i}	134.33^{bc}	139.66^{a}	140.33^{a}
LSD (0.05) N*P=1.71; CV (%) =0.82				

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. LSD (0.01) = Least Significant Difference at 1% level; and CV (%) = coefficient of variation in percent

Growth Parameters of Head Cabbage

Number of Expanded Leaves

The combined effect of nitrogen and phosphorus was found significant ($P<0.05$) for the characters ofnumber of expanded leaves and Plant height of head cabbage. Combined application of 294 kg nitrogen and 138 kg phosphorus ha^{-1} (N4P4) recorded maximum number of outer leaves (8.33) per plant, while the lowest (5.00) number was recorded from the control (Table 5). The higher nutrient rates, relative to lower rates, increased leaf count regardless of the sampling date. Leaf count increased from plots received of maximum plant nutrient for transplanted treatments, respectively as nitrogen was increased from 176 to 294 kg ha^{-1}.The tendency for the leaf count to increase in response to increasing nitrogen application is in agreement with the results of Melton andDufault (1991). They observed increases in tomato leaf count as nitrogen was increased during both years of their study.

Plant Height

The mean data revealed that plant height was significantly ($P<0.05$) influenced by the combination of Nitrogen and Phosphorus nutrients and it tended to increase with the application of higher amount of nutrients. Plant height is one of the important growth contributing characters for cabbage plant. It depends on several factors like genetic makeup, nutrient availability, climate, soil, etc. Among those nutrient availability is one of the important factors for desirable plant height.

The maximum plant height (26.4 cm) was recorded for the treatment T3P4(235 +138 kg ha^{-1}),while the lowest (16.9 cm) plant height was recorded from the T1P1 (control) treatment (Table5).Sarker*et al.* (1996) noted significant difference in plant height of head cabbage due to different source of nutrients. The increments of plant height in broccoli by the application of 240 kg N, 100 kg P and 80 kg ha^{-1}also reported by Moniruzzaman*et al.* (2006). Nitrogen and Phosphoruswere the mineral nutrient that boosts plant growth and development (Neethu*et al.*, 2015).

Table 5. Mean Interaction effects of Nand P_2O_5 fertilizers onplant height and expanded true leaves of head cabbage at Bore during 2018 and 2019 cropping season

Treatments	ETLV(no)	PH(cm)
N1P1	5.00[d]	16.9[de]
N1P2	6.66[abcd]	19.10[cde]
N1P3	7.00[abcd]	17.9[cde]
N1P4	7.33[abc]	21.06[abcde]
N2P1	8.00[ab]	17.8[cde]
N2P2	5.66[cd]	19.5[cde]
N2P3	6.66[abcd]	20.9[abcde]
N2P4	6.00[bcd]	19.6[cde]
N3P1	7.33[abc]	17.3[cde]
N3P2	7.66[abc]	20.7[abcde]
N3P3	7.00[abcd]	18.9[cde]
N3P4	6.66[abcd]	26.4[a]
N4P1	6.33[abcd]	22.9[abc]
N4P2	7.00[abcd]	25.7[ab]
N4P3	7.66[abc]	20.5[bcde]
N4P4	8.33[a]	22.5[abcd]
Mean	6.95	20.42
LSD (5%)	2.25	5.78
CV (%)	19.45	17.01

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; PH = Plant height (cm), ETLV=No of expanded true leaves, LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

Yield Components and Yield of Head Cabbage
Yield Related Components
4.4.1.1. Head Diameter and Head Height

As shown in Table 6, Effect of N and P levels on growth and yield parameters of cabbage (*Brassica oleracea*L.) under Bore soil conditions was significantly different ($P<0.05$). Diameter of head is an important yield contributing character of cabbage. Nutrient levels markedly influenced the diameter, height, head mass and yield of head cabbage (Table 6). The maximum average diameter (25.44 cm) and average height (27.33 cm) was recorded in treatment receiving 235 kg N and 82 kg P ha^{-1}. The minimum diameter (10.31cm) and minimum (12.33 cm) height was noted by control treatment. It was observed that fertilizer application at different levels result a remarkable change in height and diameter of the head. This result was corroborated with the findings of Singh *et al.*, 2015. Din *et al.*, (2007) reported significantly higher diameter of head cabbage by the application of 120-90-80 NPK ha^{-1}, respectively. That means application of higher nutrient to some level induced maximum diameter and height of cabbage. There was a strong positive correlation between diameter, height and yield without wrapper.

Table 6. Combined Mean Interaction effect of Nand P_2O_5 fertilizers on head height, diameter of head, untrimmed head mass, trimmed head massof Head cabbage at Bore during 2018 and 2019 cropping season.

Treatments	Yield related parameters			
	HH(cm)	DH(cm)	UTHM(gm)	THM(gm)
N1P1	12.33^{j}	10.31^{k}	1120.67^{j}	952.57^{j}
N1P2	16^{i}	14.80^{j}	1403.67^{i}	1193.12^{i}
N1P3	18^{h}	16.10^{i}	1435.0^{i}	1219.75^{i}
N1P4	18^{h}	16.86^{i}	1487.67^{i}	1264.52i
N2P1	19.33^{g}	18.23^{h}	1655.00^{h}	1406.75^{h}
N2P2	22de	19.98^{ef}	1947.33^{efg}	1655.23^{efg}
N2P3	23.33^{c}	22.16^{b}	2005.00^{def}	1704.25^{def}
N2P4	24.66^{b}	21.72^{bcd}	2113.33^{bc}	1796.33^{bc}
N3P1	19.33^{g}	18.56^{gh}	1844.33^{g}	1567.68^{g}
N3P2	27.33^{a}	25.44^{a}	2356.67^{a}	2003.17^{a}
N3P3	24.33^{b}	20.99^{cde}	2133.33^{b}	1813.33^{b}
N3P4	24.33^{b}	22.04^{bc}	2066.67^{bcd}	1756.67^{bcd}
N4P1	20.33^{f}	19.13^{fgh}	1906.67^{fg}	1620.67^{fg}
N4P2	2.33^{de}	20.82^{de}	2002.00^{def}	1701.7^{def}
N4P3	22.66^{cd}	20.14^{ef}	2017.00^{cde}	1714.45^{cde}
N4P4	21.66^{e}	19.66^{fg}	1929.33^{efg}	1639.93^{efg}
Mean	21.00	19.18	1838.98	1563
LSD (5%)	0.92	1.12	103.46	87.94
CV (%)	2.66	3.52	3.38	3.38

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; HH=head height, DH=diameter of head, UTHM=untrimmed *head mass, THM=trimmed head mass, LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation*

Untrimmed and Trimmed weight of head cabbage

The untrimmed and trimmed weight of head cabbage was highly significantly ($P<0.05$) influenced by the main effect of the application of different levels of nitrogen and phosphorus and their interaction (Table 6). Combined application of 235 kg N ha^{-1} with the 82kg $P_2O_5ha^{-1}$ produced the highest (2356.67 g) untrimmed head weight of cabbage followed by second maximum (2133.33 g) untrimmed head weightwith the rate of 235 kg N ha^{-1} with the 110kg$P_2O_5ha^{-1}$ while the least (1120.67 g) untrimmed head weight was recorded from the control treatment (Table 6).The increase in head weight might be attributed to the beneficial effect of nutrient on stimulatingthe meristimic activity for producing more tissues and organs, in addition to its vital contribution in several biochemical processes in the plant, related to growth and yield development (Marschner, 1994).

Yield Components

Yield with wrapper and Yield without wrapper

From the present research it was observed yield with and without wrapper varied significantly ($P<0.05$) among the treatments tested due to application of nutrients(Table 7).

The highest head yield with wrapper (73.83 t ha^{-1}) was found from the treatment combination of N3P2 (dose of 235 kg N ha^{-1}+82kg $P_2O_5ha^{-1}$) followed by 71.69t $ha^{-1}$with dose of 235 kg N ha^{-1}+110kg P ha^{-1}at 5% level of significance, while the lowest yield with wrapper (29.59 t ha^{-1}) was recorded in the treatment T1P1 (zero application). From the above result it was observed that combination of fertilizerswith recommended rate of NP_2O_5 fertilizers is the best for production of highest head yield with wrapper.

Similar to wrapper yield, the yields of cabbage without wrapper was significantly ($P<0.05$) affected both by the main and interaction effect of nitrogen and phosphorus (Table7).The combined effect of nitrogen and phosphorus was found significant for most of the characters of head cabbage. Combined application of 235 kg nitrogen and 82 kg phosphorus ha^{-1} (N3P2) recorded maximum (69.00 t ha^{-1}) head yield without wrapper and the lowest (27.66 t ha^{-1}) was recorded by control treatment. Yield without wrapper or marketable head yield was reduced due to the application of nutrients above 235 kg N and 82 kg P ha^{-1}. It might be due to increase in all the above mention parameters that attribute to increase the final yield ha^{-1} which is due to more vegetative growth, development, photosynthesis, dry matter synthesis and translocation to storage organ.It might be also due to the optimum accumulation of N and translocation of micronutrient such as boron and thus yield from the crops get increases. Similar results were found by Supe and Marbhal (2008); Singh *et al.* (2015). Din *et al.* (2007) also reported that maximum head yield was recorded in treatment receiving 120 kg N, 90 kg P and 80 kg K ha^{-1}.

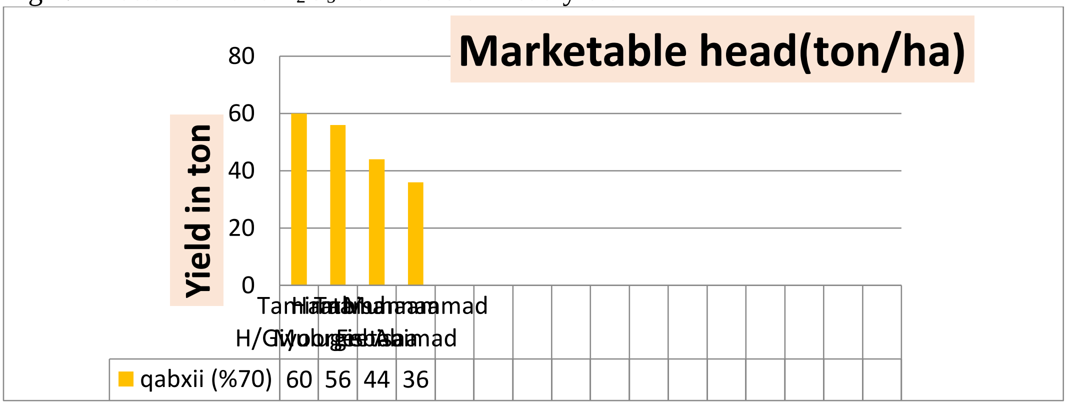
For the current experiment higher yields at higher nitrogen doses could be attributed to great head height, diameter and mass obtained at higher nitrogen and phosphorus doses. Westerveld*et al.* (2003) reported increases in head width (diameter) and height as nitrogen application was increased up to 255 kg·ha^{-1}. Generally excessive application cannot increase economic yield rather plants used for luxury consumption. Solomon *et al.(*2018) reported that Application of optimum N and FYM not only increased crop productivity, but also improved quality of the product as expressed in terms of its highest marketable to unmarketable yield ratio, mainly due to reduced cracking and improved size, particularly for the reduced or balanced application of fertilizer.

Table 7. Mean Interaction effects of Nand P_2O_5 fertilizers on yield with wrapper and without wrapper of Head cabbage at Bore during 2018 and 2019 cropping season.

Treatments	YWR(t ha^{-1})	YWOR(t ha^{-1})
N1P1	29.59^{n}	27.66^{n}
N1P2	32.88^{m}	30.73^{m}
N1P3	36.13^{l}	33.76^{l}
N1P4	38.52^{k}	36.00^{k}
N2P1	42.72^{j}	39.92^{j}
N2P2	51.58^{h}	48.21^{h}
N2P3	59.49^{f}	55.60^{f}
N2P4	66.37^{c}	62.03^{c}
N3P1	43.34^{j}	40.51^{j}
N3P2	73.83^{a}	69.00^{a}
N3P3	71.69^{b}	67.00^{b}
N3P4	63.20^{d}	59.06^{d}
N4P1	48.00^{i}	44.86^{i}
N4P2	60.81^{e}	56.83^{e}
N4P3	53.78^{g}	50.27^{g}
N4P4	51.36^{h}	48.00^{h}
Mean	51.45	48.09
LSD (5%)	1.16	1.09
CV (%)	1.36	1.36

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance;YWR=yield with wrapper and YWOR=without wrapper, LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

Fig 1. Effects of N and P_2O_5 fertilizers on head yield



Economic Analysis

The idea of an economic optimum is based on the wisely appealing notion of doing something only as long as it pays to do it.The marketable head yield was adjusted by 10% adjustment coefficient and the marginal rate of return (MRR) and net benefits are calculated by current Ureaprice was 15 kg^{-1}, NPS 17 kg^{-1}andfield price of cabbage was 4.00 birr kg^{-1}. This marginal principle basically suggests that the producer should apply fertilizer onlyas long as the cost is no more than the additional benefitfrom increased crop yield. In terms of money, the producershould maximize the net returns (revenue minus cost). To illustrate this point, we have performed a simple cost-benefit analysis with the results given in Table 8.Partial budget analysis was done based on the view of CIMMYT Economics Program (1988) recommendations, which stated that the application of nutrients with the marginal rate of return above the minimum level (100%) is economical. The result indicated that the application of nitrogen and phosphorus on Olsen cabbage variety had gave promoting benefit over the control treatment.

In this study, the costs of Nitrogen, Phosphorus fertilizer and labor cost for fertilizer application and weeding varied, while other costs were constant for each treatment. In order to recommend the present result for end users, it is necessary to estimate the minimum rate of return acceptable to farmers in the recommendation domain. Based on partial budget analysis, the net benefit accrued from the experiment ranged from nitrogen application alone is 139127to 153833 birr per hectare compared with non-application of nutrients which is 98376 birr per hectare. For the phosphorus treatments alone net benefit ranged from 107834 to 125654birr per hectare benefit. This is an indication of the level of profitability of the fertilizer application treatments.

The marginal rate of returns, which determines the acceptability of any treatments showed that treatments that received 235 kg N ha^{-1} in combination with 82 kg ha^{-1} of P_2O_5yielded best result with 434.98 marginal revenue. However, the marginal rate of returns for the Nitrogen fertilizer alone was higher than those for the phosphorus fertilizer. Generally, the highest net benefit 241456 birr was obtained from treatment combination of 235 kg N ha^{-1} with 82 kg ha^{-1} of $P_2O_5$with a marginal rate of return 434.98 but the lowest net benefit 98376 birr was obtained from the treatment of nill-application of nutrients in two growing season. Thus, for every 1.00 birr invested for 235 kg N ha^{-1} with 82 kg ha^{-1} of P_2O_5input and its application in the field, farmers can expect to recover 1.00 birr and obtain an additional 4.35Ethiopian birr. In general, the negative value of MRR percentage indicated that the loss on investment, whereas, the positive number indicated that a profit or gain on combined use of nitrogen and phosphorus fertilizer to produce the output. Therefore, treatment combination of 235 kg N ha^{-1} with 82 kg ha^{-1} ofP_2O_5rates are economically feasible to the the farmers around the study areas and with similar agro-ecologies..

Table 8.Cost Benefit Analysis of Cabbage Production

Treatments	Adjusted yield (t ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net Benefit(Birr ha^{-1})	MRR
N1P1	24.894	99576	1200	98376	0
N1P2	27.657	110628	2794	107834	5.9335

N1P3	30.384	121536	3470	118066	15.1361
N1P4	32.4	129600	3946	125654	15.9412
N2P1	35.928	143712	4122	139590	79.1818
N2P2	43.389	173556	4262	169294	212.171
N2P3	50.04	200160	6117	194043	13.3418
N2P4	55.827	223308	6493	216815	60.5638
N3P1	36.459	145836	6708.75	139127	D
N3P2	62.1	248400	6944	241456	434.979
N3P3	60.3	241200	7220	233980	D
N3P4	53.154	212616	7496	205120	D
N4P1	40.374	161496	7663	153833	D
N4P2	51.147	204588	7857	196731	D
N4P3	45.243	180972	8133	172839	D
N4P4	43.2	172800	8609	164191	D

Where,t=tone,ha=hectare and MRR= marginal rate of return

CONCLUSIONSAND RECOMMENDATION

The present study was initiated to assess the effects of different levels of nitrogen and phosphorus on yield and yield components of head cabbage. Accordingly, four levels of N and four levels of phosphorus fertilizer were evaluated at Bore, southern Ethiopia in 4 X 4 factorial arrangements using randomized complete block design with three replications on a plot size of 3.0 m x2.4 m per treatment unit. Cultivation aspects such as nutrient requirements are vital in maximization of cabbage head yields. It is therefore, important for the end user to determine the best combination of optimum nitrogen and phosphorus levels.

The results of the experiment indicated a significant response of nitrogen and phosphoruswith respect to growth and yield characters of head cabbage. Balanced use of nitrogen and phosphorus significantly increased the head mass, diameter and head yield and reduced the percentage of deformed head as well as percentage of unmarketable head compared to lower dose of nitrogen and phosphorus. Hence, the application of 235 kg nitrogen with 82 kg phosphorus ha^{-1} (N3P2) was found sufficient for growth and yield of head cabbage under highland areas of Bore.

Based on cost benefit analysis the highest net benefit 241456 birr was obtained from treatment combinations of 235 kg nitrogen with 82 kg phosphorus $ha^{-1}$with a marginal rate of return of 434.98. Therefore the most attractive rates for the producers with low cost of production and higher benefits on the study areas were the treatment combination of 235 kg nitrogen and 82 kg phosphorus rates ha^{-1}.

REFERENCES

Adler, P. R., Dufault, R. J. and Waters, L. J., 1984. Influence of nitrogen, phosphorous and potassium on asparagus transplant quality. *Horticulture Science* 19, 565-566.

Askew, D., 1999. Cabbage series: Part V: Plant population, transplanting, irrigation and crop rotation. Hygrotech Forum. Newsletter of Hygrotech Seed (Pty) Ltd, Pretoria.

Brandi Marcene, 2019. 14 Amazing Health Benefits of Cabbage. Food and Nutrition. Accessed at <https://www.naturalfoodseries.com/food-nutrition/ march 19, 2020.

Chand, S., Anwar, M. and Patra, D.D., 2006. Influence of long-term application of organic and inorganic fertilizer to build up soil fertility and nutrient uptake in mint-mustard cropping sequence. Communications in Soil Science and Plant Analysis, 37: 63-76.

CIMMYT (The International Maize and Wheat Improvement Center), 1988. *From Agronomic Data to Farmers Recommendations: An Economics Training Manual*. Completely Revised Edition. Mexico, D.F. ISBN 968-61 27-18-6.

Din, M., M.Qasim and M.Alam. 2007. Effect of different levels of n, P and K on the growth and yield of cabbage. J.Agri.Res.45 (2):171-176.

Hadfield, J., 1995. Vegetable gardening in South Africa. Struikh of Publishers, Cape Town, South Africa.

Hemy, C., 1984. Growing vegetables in South Africa. Macmillan, South Africa (Publishers) (Pty) Ltd, Johannesburg, South Africa.

Horticoop Ethiopia PLC, 2020. Bore Agricultural research Center soil analysis certificate. Bishoftu Ethiopia.

Kaur, K., Kapoor, K.K. and Gupta, A.P., 2005. Impact of organic manures with and without mineral fertilizers on soil chemical and biological properties under tropical conditions. Journal Plant Nutrition and Soil Science, 168: 117-122.

Krezel, J. and Koota, E., 2004. The effect of nitrogen fertilization on yield and biological value of Chinese cabbage grown from seed growing for autumn harvest. *FoliaUniversitatisAgriculturaeStetinensisAgricultura*95: 197-200.

Lecuona, A., 1996. The influence of various spacing on yields and head mass of six cabbage cultivars. Roodeplaat Bulletin No. 46.

Lešić, R., Borošić, J., Buturac, I., Herak-Ćustić, M., Poljak, M. and Romić, D., 2004. Povrćarstvo. Zrinskid.d. Čakovec.

Marschner, H. 1994. Mineral Nutrition in Higher Plants. Academic Press. Harcout Brace. JovanovishPuplisher. Pp. 6-74.

Melton, R.R. and Dufault, R.J., 1991. Nitrogen, phosphorus and potassium fertility affect tomato transplant growth. *Horticultural Science*, 26(2): 141 -142.

Moniruzzaman, M.S., M.M. Rahman and M.R.Islam, 2006. Effect of NPK on Growth and yield of Broccoli in southeast hilly areas of Bangladesh. Bangladesh Journal of Agriculture. 31(1and 2): 19-25.

Neethu TM, Tripathi SM, Narwade AV and Sreeganesh S., 2015. Effect of N and P levels on growth and yield parameters of broccoli (*Brassica oleracea*L. var.) under South Gujarat soil conditions, *International Journal of TropicalAgriculture* 33: 913-917. http://www.cabdirect.org/abstracts/20153336357.html.

Pavla, B. and Pokluda, R. 2008. Influence of Alternative Organic Fertilizers on the Antioxidant Capacity in Head Cabbage and Cucumber. NotulaeBotanicaeHortiAgrobotaniciCluj, 36(1), 63-67.

Sanderson, K.R. and Ivany, J.A. 1999. Cole crop yield response to reduced nitrogen rates. Canadian Journal of Plant Science, 79:149-151.

SAS (Statistical Analytical System). 2003. SAS/STAT users Guide for Personal Computers Version (9.1.3: SAS-Institute. Cary, North Carolina.

Singh MK, Chand T, Kumar M, Singh KV, Lodhi SK, Singh VP, Singh SV., 2015. Response of Different Doses of NPK and Boron on Growth and Yield of Broccoli (*Brassica oleracea*L. var. italica), *International Journal of Bio-resource and Stress Management*, **6**(1):108 - 112. DOI:10.5958/0976-4038.2015.00016.0.

Smith, K., 1995. Classic vegetable catalogue. Thomas C. Lothian Pty. Ltd. Victoria, Australia.

Solomon T., Tamado T. and Wassu M., 2018. Response of Head Cabbage (*Brassica oleracea*L.) to Different Rates of Inorganic Nitrogen Fertilizer and Farmyard Manure at Bore, Southern Oromia, Ethiopia. *International Journal ofCurrent Researchand Academic Review*. Vol. 6, No. 12, 2018, pp. 14-36. doi: https://doi.org/10.20546/ijcrar.2018.612.003.

Splittstoesser, W. E., 1979. Vegetable growing handbook. The AVI Publishing Company, Inc., USA.

Supe VS and Marbhal SK., 2008. Effect of organic manure with graded levels of nitrogen on growth and yield of cabbage (Brassica oleracea var. capitata L.). *Asian Journal ofHorticulture* **3**(1):48-50.

The Fertilizer Institute, 2020. Fertilizer 101: The Big 3 - Nitrogen, Phosphorus and Potassium. Accessed at https://www.tfi.org/the-feed/. Washington D.C. 2020

Thomas, J. R., Namken L. N. and Brown R. G., 1970. Yield of cabbage in relation to nitrogen and water supply. Proceeding of American Society Horticultural Science. 95:732-735.

Tiwari, K.N., Singh, P.K. and Mal, P.K., 2003. Effect of drip irrigation on yield of cabbage (*Brassica oleracea* L.*)* under mulch and non-mulch conditions. *Agricultural Water Management.* 58:19-28.

WARE, G.W. and Mccollum, J.P., 1980. Producing vegetable crops. The Interstate Printers and Publishers, Inc. Illinois, USA.

WESTERVELD, S.M., MCDONALD, M.R., MCKEOWN, A.W. and SCOTT-DUPREE, C.D., 2003. Optimum nitrogen fertilization of summer cabbage in Ontario. *ActaHortic.* 627, 211-215.

Yamaguchi, M., 1983. World vegetables. The AVI Publishing Company, Inc. USA.

Influence of Integrated Weed Management Practices on Yield and Yield Components of Chickpea in Southeastern of Ethiopia

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Abstract:
The experiment was conducted on research field of Sinana Agricultural Research center and Goro sub site in the highlands of Bale, south eastern Ethiopia under rain fed conditions during main cropping season of 2018 and 2019 to evaluate the integrated effects of pre-emergence (Dual gold 960 EC), post emergence (Gallant super) herbicides and hand weeding frequencies on yield and yield components of chick pea. The experiment consisted eight weed management options; weedy check, sole dual gold 960 EC, dual gold 960 EC plus one time hand weeding at two weeks after crop emergence,dual gold 960 EC at four weeks after crop emergence, sole gallant super, gallant super with one time hand weeding, one time hand weeding at two weeks after crop emergence and two times hand weeding at two and four weeks after crop emergence along with two varieties (Dhera and Habru) laid out in randomized complete block (RCBD) with three replications. Analysis of variance showed that a significant difference in number of branches per plant, biological yield (kg ha^{-1}), and grain yield (kg ha^{-1}) were observed on different herbicidal treatments and hand weeding at Sinana while at Gorosignificant effects of integrated weed management were observed on dry matter, plant height, biological yield, grain yield and harvest index. The remains parameters studied at both locations were not significant for the treatments studied. The highest net return obtained from the application of 1.5 lit ha^{-1} dual gold 960 EC integrated with hand weeding at four weeks after crop emergenceat Sinana while the highest net return at Goro was obtained from two times hand weeding at two and four weeks after crop emergence and hence can be recommended for the end users.Moreover, similar experiments should be carried out in different cold and warmer regions of chickpea potential areas of the zone to confirm the present findings.

Key words: *Chick pea, Dual gold, Economic benefit, Gallant super, Hand weeding frequency, Yield*

INTRODUCTION

Chickpea is widely grown around the world and serves as a multi-use crop. It plays a significant role in improving soil fertility by fixing the atmospheric nitrogen and can fix up to 140 kg N $ha^{-1}$from air and meet most of its nitrogen requirement.It is also an excellent source of protein, fiber, complex carbohydrates, vitamins, and minerals thus can help alleviating malnutrition and improving human health. Chickpea has been characterized into two main categories primarily on the basisof seed characteristics: the ‘Desi’ types, with relatively small, angular seeds with rough, usually yellow to dark brown testa; and the ‘Kabuli’ types, which have larger more rounded and creamed colored seeds.

Ethiopia is the top producer of chickpea in Africa. **Chickpea has the ability to grow on residual moisture which gives farmers the opportunity to engage in double cropping, where chickpea is sown at the end of the rainy season following the harvest of the main crop. This allows more intensive and productive use of land, particularly in areas where land is scarce.** In Ethiopia, chickpea is the third most important grain legume after faba bean (*Vicia faba*) and common bean (*Phaseolus vulgaris* L.) by volume for small-scale farm production.The national average yield ofchickpea is 1.7 t ha^{-1} (CSA, 2013), which is far below thepotential yield of 4.5 t ha^{-1}.

Chickpea is poorcompetitor to weeds because of slow growth rate andlimited leaf development at early stage of crop growthand establishment, if weed management is neglectedunder these conditions, resulting in yield loss of 40 to87%( ).Weeds are plants which compete with crops for nutrients, space, and light exerting a lot of harmful effects by reducing the quality and quantity of the crop if their populations are left un-controlled (Tepe, 2011). Various methods are used to control weeds in various crops including manual, mechanical, cultural, biological and chemical. Integration of weed control methods is an effective and workable practice that is ecologically and economically viable to the farmers and be the best options for sustainable weed management practices. Generally, for the control of weeds farmers do manual weeding. But with the increase in labour cost and scarcity of labor, manual weed control has become a difficult task in chickpea.Herbicides constitute a new and highly efficient technique for controlling weeds hence increasing yields, improving quality and reducing labor in crop production.When properly used, pre-emergence herbicides accomplish effective and economic weed control, and consequently chickpea seed yields as similar to or only lightly smaller than those of weed free treatments are resulted (Hassan et al., 2003). Efficacy of dual gold herbicidecombined with hand weeding has not yet been evaluated in chickpea growing in mid and lowlands of Bale zone. But, dual gold 960 EC is one of the pre-emergence herbicide which is available to kill both grassy and broadleaf weeds at the early and later stage of the crop growth to reduce yield loss.Hence, the objectives of this study isto evaluate the effect of pre emergence herbicide (dual gold 960 EC)with or without hand weeding, to evaluate the effect of post emergence herbicide (gallant super) on yield and yield components of chick pea and toassess the economic feasibility of the herbicides.

MATERIALS AND METHODS

Chickpea variety ‘Habru and Dhera’ with recommended seed rate of 120 kg per ha was used for the experiment.The experiment consisted eight weed management options: weedy check, one time hand weeding at two weeks after crop emergence, two times hand weeding at two and four weeks after crop emergence, sole dual gold 960 EC, dual gold 960 EC plus one time hand weeding at two weeks after crop emergence, and dual gold 960 EC at four weeks after crop emergence, sole gallant super, gallant super with one time hand weeding laid out in randomized complete block design (RCBD) with three replications. 1.5 lit per hectare of pre-emergence herbicide applied on second date of planting and 1 lit. per hectare gallant super at 2-6 leaf stage of weed growth stage with 200 lit per hectare of water was used.A field layout was prepared and the treatments were assigned randomly to each plot within a block. Both replications and experimental units were separated by 1.5m.Seeds were sown using row planterand each plot consisted of 6 rows with 4 m length and 30cm spaced apart.The outer most two rows on both sides of each plot and 0.25m length on each side of the row served as a border. The remained net plots were used for data collection.

Partial Budget Analysis

The partial budget analysis was done using CIMMYT (1998) to identify the rewarding treatments. Actual yields from experimental plots were adjusted down ward by 10% to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. This is due to optimum plant population density, timely labor availability and better management in weed control and better security under experimental conditions (CIMMYT, 1998). To find out the gross return the price of chick pea (Sale price of 23 Birr kg^{-1}) prevailing in the local market at the time of harvest which is the average of one month was taken into account. Similarly, the variable costs included were the cost of input; the field price of Dual gold and Gallant super herbicides during planting time was 600 and 800 Birr lit^{-1} respectively. The cost of application of herbicides at Sinana and Goro 500 and 650 Birr ha^{-1}were also considered. Cost of labor for hand weeding and spray of herbicides are different at Goro and Sinana and considered accordingly in the analysis.

Data collection

Data were collected on days to maturity, Number of branches per plant, plant height, number of bolls per branch, Biological yield, grain yield, thousand seed weight, and harvest index recorded from net plot area. The net plot area was attained from six rows by leaving one border row at both sides of every plot.

Data analysis

All the collected data were subjected to analysis of variance (ANOVA) using GENSTAT computer software (GenStat, 2012.Version 15.1.0.8035) to identify main effects and interactions in response to integrated weed managements. Differences among means were determined using the least significance difference at the 0.05 level of significance. Treatment effects from the two locations and across years of the experiment followed a similar trend. Thus, the data from the two independent locations and across years were combined in the analysis.

RESULTS AND DISCUSSION

The experiment was conducted at two different locations of south eastern Ethiopia of Bale zone namely, Sinana on-station and Goro sub-site in the two consecutive main cropping seasons of 2018/19 and 2019/20. All the required field data were collected, analyzed and reported below.

Influence of Integrated Weed Management Practices on Yield and Yield Components of Chickpea at Sinana

The analysis of variance showed that days to maturity, number of branches per plant, plant height, number of seeds per boll, thousand seed weight and harvest index were not significantly influenced by weed management methods (dual gold, gallant super and hand weeding frequencies) and the effect due to variety were not significant for days to maturity, branches per plant, bolls per plant, and number of seeds per boll and grain yield. Hence instead of evaluating weed management independently, similar practices can be recommended for both varieties. Furthermore interaction effect revealed that no significant effect was existed among the studied parameters. On the other hand, analysis of variance showed a significant difference on number of branches per plant, biological yield (kg ha^{-1}) and grain yield (kg ha^{-1})due to the main effects of different herbicidal treatments and hand weeding (Table 1).The highest seed yield (2177 kg ha^{-1}) was obtained as a result of dual gold plus one time hand weeding and two times hand weeding, but all are statistically at par. The lowest seed yield was recorded under weedy check, sole use of gallant super and dual gold.This might be herbicides alone or hand weeding control methods were less effective in reducing the number of weeds per unit area; instead of both chemical and hand weeding control methods.These results are in conformity with those reported by Diwash *et al*, (2014), Waktole *et al*.(2013) and Rahmatizadeh *et al*. (2013) and others too. Even though statistically at par sole dual gold application showed higher grain yield than using gallant super alone, this might be due to the herbicides mode of action and time of application, dual gold is applied before weeds and crops are emerged. Whereas gallant super was applied during actively growing weeds and crops. As result weeds emerged with crop can easily compete with crop and cause significant yield reduction.The main effect of variety did not show significant effect on grain yield per hectare and this implies that highest seed yield can be obtained using both varieties keeping them weed free using pre or post emergence herbicides supplemented with hand weeding. Thus, emphasis should be given to control weeds.

Results pertaining biological yield indicated thathighest value was observed using two times hand weeding followed when dual gold was supplemented with one time hand weeding and are statistically significant. This might be crop plants utilized resources more efficiently that resulted in higher final crop stand. In agreement with this result Mizan et al. (2009) reported the increased biomass yield of the crop was highly governed by the length of weed free period. On the other hand the lowest was recorded under sole use of gallant super and weedy check (Table 1).

Table 1. Influence of Integrated Weed Management Practices on Yield and Yield Components of Chickpea in Southeastern Ethiopia at Sinana, 2018 and 2019 (combined)

Treatments	DM	NBrPP	PHT	NBPST	NSB	BYD	GYD	TSW	HI%
Weedy check	162.2	3.4	67.6	12.1^{c}	1.5	2595.5^{c}	630.4^{b}	580	24.6
HW at 14 DAE	160.8	6.3	76.8	21.2^{abc}	1.5	8394.1^{a}	2105.1^{a}	509	22.7
HW at 14 and 28 DAE	162.3	7.3	76.2	27.4^{a}	1.2	9270.8^{a}	2133.4^{a}	473	24
Sole Dual Gold	147.5	5.8	76.2	13.1^{bc}	1.4	3524.3^{c}	687.9^{b}	565	22.1
Dual Gold and HW at 14 DAE	161	6.5	76.2	23.9^{ab}	1.5	8949.7^{a}	1771.6^{a}	550	24
Dual Gold	163.1	5.2	74.7	20.3^{abc}	1.2	6354.2^{b}	2177.6^{a}	551	26.5

and HW at 28 DAE									
Sole Gallant Super	162.1	4.6	75.8	16.9^{abc}	1.5	3168.4^{c}	634.7^{b}	589	22.6
Gallant Super and HW at 7 DAE	162.2	6	72.7	21.5^{abc}	1.5	6414.9^{b}	1637.4^{a}	507	24.7
$LSD_{0.05}$	ns	ns	ns	9.62	ns	1709.59	773.2	Ns	ns
Variety									
Habru	157.6	6	67.5^{a}	20.7	1.4	5221.4^{a}	1536.4	514a	27.4a
Dhera	162.7	5.3	81.5^{b}	18.5	1.4	6946.6^{b}	1408.2	567b	20.4b
$LSD_{0.05}$	ns	Ns	2.37	ns	ns	854.79	ns	40	2.82
CV (%)	11.1	67.2	15.5	60.5	36.2	34.6	64.6	18.2	29.2

Keys: DM=Days to maturity, NBrPP=Number of Branches per plants, PHT=Plant Height, NBPST=Number of Branches per Single Tiller, NSB=Number of Seeds per Boll, BYD=Biological Yield, GYD=Grain yield per hectare, TSW=Thousand Seed Weight, HI%=Harvest Index, LSD=Least Significant difference, and CV=Coefficient of Variation

Influence of Integrated Weed Management Practices on Yield and Yield Components of Chickpea at Goro

The analyzed data results showed significant effects of integrated weed management on dry matter, plant height, biological yield, and grain yield and harvest index.But, significant ($P\leq0.05$) effects were not observed on number of branches per plant, bolls per plant, number of seeds per boll, thousand seed weight. All weed management treatments were boosted yield of chickpea over weedy check treatment (Table2). Increments in yield might be due to successful weed control and efficiency of resource utilizationdue to the decrement of competition by applied treatments against weeds. This is in line with the findings of Waheedullah *et al.* (2008) who reported that weed management suppressed the weeds and increased the grain yield and yield components of maize. The highest grain yield was obtained as a result of gallant super plus hand weeding, two times hand weeding, one time hand weeding and dual gold plus one time hand weeding, but all are statistically at par. However, the lowest seed yield wasrecorded under weedy check, sole dual gold and use of sole gallant super.On the other hand , the effect of variety showed significance difference on days to maturity, number of branches per plant, plant height, biological yield and thousand seed weight whereas varietal differences did not show significant difference on number of bolls per plant, number of seeds per boll, grain yield and harvest index.This implies that the two varieties did not show significant difference to different weed management in different ways. Hence instead of evaluating weed management independently, similar practices can be recommended for both varieties.

The interaction effect of weed management options and variety did not show significance difference ($P\leq0.05$) on the studied parameters.The integration of herbicides and hand weeding produced the highest grain yield than herbicides and hand weeding alone. This finding is in agreement with the work of Singh and Sekhon (2013) who reported that integration of herbicides and hand weeding provided the highest grain yield.

Table 2. Influence of Integrated Weed Management Practices on Yield and Yield Components of Chickpea in Southeastern of Ethiopia, Goro 2018 and 2019.

Treatments	DM	NBrPP	PHT	NBPST	NSB	BYD	GYD	TSW	HI%
Weedy check	102.3^{a}	5.4	72.1^{a}	12	1.8	5486.1^{d}	606.7^{c}	590.8	11.6^{c}
HW at 14 DAE	95.3^{bcd}	8.6	68.3^{ab}	21.8	1.2	7222.2^{bc}	1788.3^{ab}	677.7	25a^{b}
HW at 14 and 28 DAE	96.3^{bc}	8.7	68.5^{ab}	21.8	1.3	8472.2^{a}	1789.8^{ab}	644.2	20.4^{b}
Sole Dual Gold	97^{bc}	5.3	67.4^{ab}	14.8	1.2	6111.1^{cd}	1242.3^{bc}	673.4	20.3^{b}
Dual Gold and HW at 14 DAE	93.2^{d}	8.6	69^{ab}	20.2	1.3	7152.8^{bc}	1467.6^{ab}	671.3	20.3^{b}
Dual Gold and HW at 28 DAE	92.7^{d}	8.1	67.5^{ab}	22.2	1.2	7430.6^{ba}	1734.5^{ab}	652.1	22.8^{ab}
Sole Gallant Super	97.5^{b}	8	66.8^{b}	18.7	1.3	6666.7^{bc}	1422^{ab}	675.8	21^{b}
Gallant Super and HW at 7 DAE	94.5^{cd}	7.9	64.4^{b}	24.1	1.2	7013.9^{bc}	2025^{a}	590.8	29.4^{a}
$LSD_{0.05}$	2.7	ns	4.25	ns	ns	1087.4	651.8	Ns	7.5
Variety									
Habru	96.8^{a}	6.4^{a}	62.8^{a}	17.1	1.3	6458.3^{b}	1358.8	611.7^{a}	20.8
Dhera	95.4^{b}	8.7^{b}	73.2^{b}	21.8	1.4	7430.6^{a}	1660.3	695^{b}	21.8
$LSD_{0.05}$	1.35	1.85	2.13	Ns	ns	543.7	ns	38.74	ns
CV (%)	3.4	60.1	7.7	61.3	33.9	13.3	36.6	14.6	29.6

Partial Budget Analysis

Marginal analysis is an important step in assessing the results of on farm experiments before making recommendations. For this trial variable cost of dual gold, gallant super and hand weeding frequencies were considered since both locations are different in labor cost availabilities. Partial budget analysis of Sinana location indicated that the use of pre-emergence herbicide (Dual gold 960 EC) integrated with hand weeding at different time gave a different economic return as compared to post emergence herbicides (gallant super), weedy check and hand weeding alone. Thus, the highest net benefit was recorded for dual gold integrated with hand weeding at four weeks after crop emergence, one time hand weeding at two weeks after crop emergence and dual gold integrated with one time hand weeding after two weeks after crop emergence respectively while the lowest net benefit was obtained from the control (table 4). Therefore, it can be concluded that the use of dual gold integrated with hand weeding at four weeks after crop emergence could be used as the best weed management options for chick pea production at Sinana areas.

Table 3. Partial and marginal budget analysis for weed management options, Sinana 2018 and 2019

Variety	ManagementOptions	FYD (kg ha^{-1})	AYD (kg ha^{-1})	GB (ETB)	VC (ETB)	NB (ETB)	MRR (%)
Habru	Weedy check	718	646	14853	0	14853	0
Dhera	Weedy check	552	497	11425	0	11425	0
Habru	Gallant super	565	508	11689	1300	10389	
Habru	Dual gold	738	664	15282	1400	13882	3493
Dhera	Gallant super	696	627	14411	1400	13111	
Dhera	Dual gold	638	574	13198	1400	11798	
Dhera	Weeded (1x)	2223	2000	46006	1800	44206	8102
Dhera	Weeded (1x)	1988	1789	41143	1800	39343	
Habru	Weeded (2x)	2233	2010	46230	2000	44230	2443.5
Dhera	Weeded (2x)	2034	1830	42094	2000	40094	
Habru	Dual gold + weeded (1x)	2417	2176	50039	2100	47939	7845
Dhera	Dual gold + weeded (1x)	1938	1744	40115	2100	38015	
Dhera	Gallant super +weeded (1x)	1881	1693	38943	2300	36643	
Habru	Gallant super +weeded (1x)	1394	1254	28847	2300	26547	
Habru	Dual gold + weeded (1x)	2004	1803	41477	2400	39077	12530
Dhera	Dual gold + weeded (1x)	1540	1386	31869	2400	29469	

Keys:- FYD=Field yield, AYD=Adjusted yield, GB=Gross benefit, VC=Variable cost, NB=Net benefit, MRR=Marginal rate of return, 1x=one time, 2x=two times hand weeded

On the other hand, the result of financial analysis (partial budget) at Goro indicated that two times hand weeding at two and four weeks of after crop emergence had highest net benefits (table 4). The pre emergence herbicides tested integrated with hand weeding will be economical only if the price of chick pea raises over 23 birr 100 kg^{-1}. The differences in marginal rate of return in Sinana and Goro could be due to ecological, labor and herbicides costs differences. More cost prevailed at Goro than Sinana.

Table 4. Partial and marginal budget analysis for weed management options, Goro 2018 and 2019

Variety	Management Options	FYD (kg ha^{-1})	AYD (kg ha^{-1})	GB (ETB)	VC (ETB)	NB (ETB)	MRR (%)
Habru	Weedy check	370	333	7651	0	7651	0
Dhera	Weedy check	533	480	11032	0	11032	
Habru	Weeded (1x)	1583	1425	32776	1200	31576	1712
Dhera	Weeded (1x)	1830	1647	37887	1310	36687	4646.4
Habru	Gallant super	862	776	17850	1450	16400	
Dhera	Gallant super	1290	1161	26708	1450	25258	
Habru	Dual gold	845	760	17486	1550	15936	
Dhera	Dual gold	935	841	19347	1550	17797	
Dhera	Gallant super + weeded (1x)	1938	1744	40113	1967	38147	222.2
Habru	Gallant super + weeded (1x)	1906	1716	39463	2150	37313	
Habru	Weeded (2x)	1501	1351	31062	2200	28862	
Dhera	Weeded (2x)	2267	2040	46925	2300	44725	15863
Habru	Dual gold +weeded (1x)	1816	1635	37600	2242	35358	
Habru	Dual gold +weeded (1x)	1603	1443	33192	2350	30842	
Dhera	Dual gold +weeded (1x)	1631	1468	33768	2450	31418	
Dhera	Dual gold +weeded (1x)	1701	1531	35210	2470	32860	

Keys:- FYD=Field yield, AYD=Adjusted yield, GB=Gross benefit, VC=Variable cost, NB=Net benefit, MRR=Marginal rate of return, 1x=one time, 2x=two times

CONCLUSION AND RECOMMENDATIONS

Weed is the major production constraints for chickpea production in Bale highlands. Its management is quite important to increase the production and productivity of the crop. The results of the present study showed that application of 1.5 lit ha^{-1} dual gold 960 ECintegrated with hand weeding at four weeks after crop emergence at Sinana economically shown the maximum net benefit and can be used as the best weed management options for chick pea production at Sinana areas while two times hand weeding at two and four weeks after crop emergence showed economically maximum net benefit at Goro. Moreover, similar experiments should be carried out in different cold and warmer regions of chickpea potential areas of the zone to confirm the present findings.

REFERENCES

Diwash, T., Rajib, N., Kajal, S., 2014. Effect of herbicide application on weed management in green Gram (*vigna radiate*). 3rd International Conference on Agriculture and Horticulture. Conferences, Accelerating Scientific Discovery. October 27-29, 2014, India, 2(4).

Rahmatizadeh, S., Sjedi, N.A., Gomarian, M., 2013. Response of weeds and some characteristics of red bean (*Phaseolus calcaratus* L.) to cultivation time and weeds control methods. Int. J. Farm. Allied Sci., 2(20), 842-850.

Waktole Mosisa, J.J. Sharma and Nigussie Dechassa. 2013. Integrated weed management and itseffect on weeds and yield of haricot bean at Haramaya, Ethiopia. *Ethiopian Journal of WeedManagement*, 6:97-111.

Mizan, A., Sharma, J.J., Gebremedhin, W., 2009. Estimation of critical period of weed-crop competition and yield loss in Sesame (*Sesamum indicum* L.). Ethiop. J. Weed. Manag., 3(1), 39-53.

Waheedullah, M. A. Khan. S. Arifullah and M. Sadiq. 2008. Evaluation of Integrated weed management practices formaize (*Zea mays* L.). *Pak. J. Weed Sci. Res.* 14 (1-2): 19-32.

Singh and Sekhon. 2013. Integrated weed management in pigeonpea [*Cajanuscajan*(L.) Millsp.].*World Journal of Agricultural Sciences* 9 (1): 86-91.

Effects of Nitrogen Rate on Yield,Yield Related Triatsand Grain Quality of Recently Released Durum Wheat Varieties in Bale highlands

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ABSTRACT

Shortage of improved varieties and low soil nitrogen status are some of the major constraints limiting durum wheat yield and grain quality in Bale zone, which is the major wheat producing belt in the country.On-farm experiment was conducted at Sinanaand Gololcha, districts of bale zone for three years(2016-2018), to assess the effect of nitrogen fertilizer rate on yield, yield components and grain quality of durum wheat varieties. Factorial combinations of four durum wheat varieties (Toltu, Dire ,Bekelchaand Ingliz) and five rates of nitrogen (46,92,138,184 and 230 kg N ha^{-1}) were laid out in a randomized complete block design (RCBD) with three replications.The main effects of nitrogen and variety significantly ($P < 0.05$) influenced plant height, spike length,kernels per spike,bio-mass yield,grain yield, harvest index,TKW,HLW and grain protein content.The grain yield for main effects of varietyrangedfrom 3653 to 4650 kg ha^{-1}.Dire recorded the highest grain yield (4650 kg ha^{-1}) in statistical parity with Bekelcha(4563 kg ha$^{-1)}$. Toltuproduced the next highest grain yield (4477kg ha^{-1}) while the lowest yield was obtained from local variety Ingliz(3653 kg ha^{-1}).These results clearly indicated that the improved durum wheat varieties are more productive and responsive to nitrogen fertilizer than the local cultivar.Grain yield for main effectsof N fertilizer rates ranged from 3815 kg ha^{-1} to 4536 kg ha^{-1}.Thehighest N rate (230kg N ha^{-1}) gave the highest grain yield(4536 kg ha^{-1}).The second highest grain yield was obtained from (138 kg N ha^{-1}) in statistical parity with 184and 92 kg N ha^{-1}, *4519,4439 and 4370 kg ha^{-1},respectively.The lowest yield (3815 kg ha^{-1}) was recorded by the lowest N rate (46 kg N ha^{-1}).Bekelcha gave the highest TKW(46.6g) and grain protein content(14.6%). The lowest TKW (42.9g) and grain protein content (12.9g) was recorded from lacal variety Ingliz.The highest grain protein content (15.1%) was obtained from the application of the highest N rate (230kg N ha^{-1}), the lowest (12.8%) was from the lowest N rate (46 kg N ha^{-1}).The economic analysis indicated that optimum grain yield and quality of the improved durum wheat varieties Toltu,Dire and Bekelcha were obtained at the rate of nitrogen application (92 kg N ha^{-1}).Therefore, durum wheat farmers in the study area should use 92 kg N ha^{-1} to realize maximum grain yield and quality of the crop. The results also imply that there is a need to formulate variety-specific N fertilizer recommendation rates for enhancing the productivity and grain quality of durum wheat for pasta/macaroni making.*

Keywords: Durum wheat; Nitrogen rate; Grain protein content; Thousand Kernel Weight; Test Weight; Grain yield

Introduction

Wheat (*Triticum*spp.) is one of the most important cereal crops worldwide in total production and use (Evans, 1998). The crop is grown as bread (*Triticumaestivum*L.) and durum (*Triticumturgidum*L.var. *durum*) wheat. Durum wheat is the second most cultivated wheat species in the world next to bread wheat (Peña and Pfeiffer, 2005). Global wheat production in terms of area coverage in 2009 was estimated at 225,437,694 ha and the grain yield obtained within the same year was estimated at 681,915,838 tons (FAOSTAT, 2011).

In Ethiopia, wheat stands fourth in area coverage and third in production. Eighty-one percent of the total land cultivated to grain crops is covered by cereals out of which wheat accounts for 13.14 % of the area (CSA, 2011).There are ample opportunities in Ethiopia in general and in Bale region in particular in terms of favorable environmental conditions. Arsi and Bale highlands are regarded as highly suitable regions for wheat production in Ethiopia and 30.5% wheat production in the country comes from Arsi and Bale regions (CSA, 2008).

Durum wheat is the most important wheat species grown in the highlands of Ethiopia (Tesfaye, 1987). Ethiopian highlands are regarded as the largest wheat producer in Sub-Saharan Africa (Efrem*et al.*, 2000). Durum wheat is traditionally grown by smallholder farmers on the heavy black clay soils (Vertisols) of the high lands at altitude ranging between 1800 and 2800 m above sea level and rainfall distribution varying from 600 to more than 1200 mm per annum (Hailu, 1991). Despite the long history of durum wheat cultivation and its importance to the Ethiopian agriculture, its average yield is still low, not exceeding 1.5 ton ha^{-1} (Efrem*et al.,* 2000).According to Tesfaye (1986), close to 85 % of the cultivated durum wheat in Ethiopia are landraces. The low yield of durum wheat could be mainly due to the use of low yielding landraces by farmers, weeds, diseases, insect pests, low fertility and moisture stress in the major durum wheat growing areas (Tesfaye, 1988). Soil degradation and depletion of soil nutrients are among the major factors threatening sustainable cereal production in the Ethiopian highlands. Wheat production in the country is adversely affected by low soil fertility and suboptimal use of mineral fertilizers in addition to diseases, weeds, erratic rainfall distribution in lower altitude zonesand water-logging in the Vertisols areas (Amanuel*et al.*, 2002).

The quality of durum wheat is highly dependent on the protein content of the grain, which is largely dependent on genotype and influenced by the environment, especially nitrogen availability of the soil. Nitrogen fertilizers are highly soluble and once applied to the soil may be lost from the soil-plant system or made unavailable to the plants through the processes of leaching, NH_3 volatilization, denitrification, and immobilization (Bock, 1984; Stanford and Legg, 1984).

Nitrogen fertilization management, therefore, offers the opportunity for increasing wheat protein content and other related quality traits. According to Motzo*et al*. (2004), grain protein content is a function of total nitrogen uptake and of the partitioning of nitrogen and dry matter to the grain. Franzen and Goos (1997), also indicated that protein content consistently lower than 12% is an indication that a wheat producer needs to use more nitrogen fertilizer or better manage the nitrogen being applied for improved wheat grain quality for pasta making .

Grain protein content is considered as the main characteristic of durum wheat grain quality (Ottman*et al*., 2000). Protein content was associated mainly to soil nitrogen fertility statusandavailable soil nitrogen is often insufficient and mineral fertilizers should be supplemented. In fact, Metwally and Khamis (1998), indicated that, wheat nitrogen requirements could not be met by the separate application of any organic source. In practice, nitrogen is the most cost efficient and practical factor to manage.

Nowadays durum wheat is considered as potential crop by the government for food industry as import substitution and one means of income diversification for the farmers. With the increasing number of processing industries, the demand for durum wheat grains for pasta processing is growing-up in the country. Due to various reasons, locally produced durum wheat grains are censured to be of poor quality and do not meet the minimum quality standard of pasta production. Hence, in spite of the large volume of local production, some processing industries prefer to import durum wheat grain for pasta production.Information on yield and grain quality under different nitrogen rates for most of the recently released durum wheat varieties in Ethiopia is limited. It is, therefore, necessary to improve durum wheat productivity and grain quality through nitrogen fertilizer management and selection of genotypes with high nitrogen use efficiency to make durum wheat production rewarding to farmers, and to satisfy the demand of the processing industries.

Therefore, the experiment was conducted with the following objectives:

1. To determine the effect of nitrogen fertilizer rates on yield,yield related triats and grain quality of durum wheat varieties.
2. To determine economically optimum nitrogen application rate for higher yield and quality.

Material and Methods:

The experiment was conducted for three years (2016-2018) at three locations (Sinana on-station, Sinana on-farm and Gololcha) in main cropping season. The treatments were consist of combinations of four durum wheat varieties that includes three recently released durum wheat varieties (Toltu, Dire and Bekelcha) released from Sinana Agricultural Research Center and one local check (land race variety Ingliz) and Five rates of nitrogen (46,92,138,184 and 230 kg N ha^{-1}). The experiment was laid out as Randomized Complete Block design (RCBD) in a factorial arrangement with three replications. Treatments were assigned to each plot randomly. The size of each plot was 2.4m x 2.5m=6m^2 and the distance between rows, plots and replications were 0.2, 0.5 and 1.5 m, respectively. Phosphate fertilizer in the form of TSP (46%P_2O_5) at the recommended rate of 46 P_2O_5 $ha^{-1}$was applied uniformly to each plot. Nitrogen was applied as split-application, $^1/_4$ at planting, $^1/_2$ at tillering and $^1/_4$ at anthesis. All the other recommended management practices to the crop were done uniformly to raise the crop.

Statistical data analysis

Analysis of variance (ANOVA) was done using Gen Stat 15th edition and means comparisons for the significantly different variables were made among treatments using least significant differences (LSD) test at 0.05 level of significance.

RESULTS AND DISCUSSION

Effects of Nitrogen Rate on Agronomic Traits and Grain Quality of Durum Wheat Varieties

Soil analysis before planting

Selected physico-chemical properties of the soil were determined for composite surface soil (0-30 cm) samples collected before sowing (Table1). Accordingly, the texture of the soil of the experimental site is dominated by the clay fraction. The clay texture indicates the high degree of weathering that took place in geological times and the high nutrient and water holding capacity of the soil.

Soil pH values for both locations varied from 6.45 to 6.48 for soils of the experimental sites (Table 1).pH status was categorized as slightly acidic soil Jones (2003). Based on these results the pH value is optimum range for most crop production since most plant prefer the pH range 5.5 to 7.0.Soil Organic Matter values for both locations varied from 2.38 to 4.98 for soils of the experimental sites (Table 1). As the rating range established by Tekalign,(1991) soil organic matter content categorized under moderate and low for Sinana on- Station and Sinana on-farm, respectively.Soil Total Nitrogenvalues for both locations varied from 0.22 – 0.33%.As ratings suggested by Landon (1991), the soil total nitrogenof the experimental site were rated into moderate and low for Sinana on- station and Sinanaon-farm, respectively**.** Available Phosphorousvalues for both locations varied from 4.5-20.58 (Table1). According to the rating established by Cottenie (1980) the studied soils have low to high phosphorus content for Sinana on-farm and Sinanaon-station, respectively**.** Adequate phosphorus results in higher grain production, improved crop quality, greater stalk strength, increased root growth, and earlier crop maturity.

Cation exchange capacityvalueswereranged from 24.45 to 38.53for soils of the experimental sites. Based on the rating established by Hazelton (2007)the soil of the study sites were moderate and high for sinanaon-Farm and Sinana on-station, respectively**.**

Table 1. Soil physico-chemical properties of the Sinana on- station and Sinana on-farm

Location	Textural class	pH	OM (%)	TN (%)	Available P (ppm)	CEC (cmol kg^{-1})
Sinana on- station	Clay	6.45	4.98	0.33	20.58	38.53

Plant height

The analysis of variance showed that the varieties differed significantly (P < 0.05) on plant height. The local cultivar Inglizi produced significantly taller plants (122cm) than all the improved varieties. This was followed by the improved variety Bekelcha(88.9cm), which also produced significantly taller plants than Toltu and Dire. Thus, the heights of plants produced by the local cultivar Ingliz exceeded the heights improved varieties Toltu, Dire and Bekelcha by about 31, 27%respectively (Table1).

The shorter suture of the improved varieties compared to the local cultivar may be related to the pattern of modern wheat breeding which always aims at developing dwarf or semi-dwarf wheats for enhanced partitioning of carbohydrate towards the grain.

Table 2: Mean value of plant height and grain yield of durum wheat varieties grown under different N rates

Plant height (cm)							**Grain yield(kg/ha)**					
N kg ha^{-1}	46	92	138	184	230	Mean	46	92	138	184	230	Mean
Variety												
Toltu	81.6	82.8	86.7	84.2	85.7	84.2c	3986	4496	4647	4574	4684	4477b
Dire	81.8	84.1	85.3	84.6	85.5	84.3c	4120	4567	4833	4791	4937	4650a
Bekelcha	86.8	88.3	89.6	89.4	90.3	88.9b	4003	4583	4769	4673	4788	4563ab
Ingliz	121.9	122.3	121.6	122.5	122.2	122.1a	3151	3834	3826	3717	3736	3653c
Mean	93.0	94.3	95.8	95.2	95.9		3815c	4370b	4519ab	4439ab	4536a	
CV (%)			7.4						12.7			
LSD(0.05)												
V			1.77						140			
N			NS						156			
VxN			NS						NS			

Means followed by the same letter I column and row are not significantly different at 5% level of significance; NS=Non significant; N=Nitrogen;V=Variety; CV(%)= Coefficient of variation(%).

Bio-mass yield and harvest index

Analysis of variance indicated significant differences (P < 0.05) among nitrogen rate treatmentsfor biomass yield and nitrogen rate treatments and varieties for harvest index while interaction was not significant for thetwo parameters (Table3).

All fertilizer nitrogen rates averaged over cultivars, gave higher biomass yield than the first twolowest treatments (Table3).Biomass yield increased as rate of nitrogen applied increased

from the lowest to the highest level.Mean biomass yield ranged from 8414 kg ha^{-1} for the lowest treatment(46kg N ha^{-1}) to 11897 kg ha^{-1} forthe highest treatment (230 kg N ha^{-1}) indicating large biomass yield variation under thedifferent nitrogen rate treatments.
Generally,a linear increment in biomass production was observed with an increase in N rates from 46 kg $ha^{-1}$to 230 kg ha-1. This is in agreement with the findings of Amanuel*et al*. (1991) who reported asignificant increase of biomass yield as a result of nitrogen rate increase in wheat.

The ability of a cultivar to partition the dry matter into economic (grain) yield is indicated byits harvest index which was significantly varied among various varieties and nitrogen rate treatments(Table3). The highest nitrogen rate treatments significantly reduced harvest index (40%) as compared to the lowest rate. Thesecond lowest treatment 92 kg ha^{-1}had resulted in the highestharvest index (52%), in statistical parity with the lowest nitrogen rate of 46 kg ha^{-1} with a harvest index value of 51%.There was also highly significant differences ($P < 0.05$) between the local variety and theimproved varieties for harvest index across nitrogen rate treatments. This could be accounted forthe enhanced above ground biomass yield in response to the incremental rates of nitrogen in contrastto grain yield during the growing season. In the case of varieties, statistically all improved varieties were at par for their harvest index ranging from 48-49% suggesting nearly an equal earlyassimilation and utilization of nitrogen nutrients of those varieties while lowest harvest index(42 %) was recorded for varietyIngliz.

Table 3: Mean value of bio-mass yield and harvest index of durum wheat varieties grown under different N rates

	Bio-mass yield (kg ha^{-1})						Harvest index(%)					
N kg ha^{-1}	46	92	138	184	230	Mean	46	92	138	184	230	Mean
Variety												
Toltu	8090	8836	9924	10371	11697	9784	54	55	49	45	41	49a
Dire	8303	9389	9460	10931	11971	10011	53	52	53	45	42	49a
Bekelcha	8300	8649	9887	10782	11676	9859	50	55	50	44	42	48a
Ingliz	8961	9337	10996	11664	12243	10640	45	48	41	37	36	42b
Mean	8414d	9053d	10067c	10937b	11897a		51ab	52a	48b	43c	40c	
CV (%)			25.1						21.4			

LSD (5%)		
V	NS	3
N	717	3
VxN	NS	NS

Means followed by the same letter I column and row are not significantly different at 5% level of significance; NS=Non significant; N=Nitrogen; V=Variety;CV(%)= Coefficient of variation(%).

Grain yield

The ultimate goal in crop production is maximum economic yield, which is a complex function of individual yield components in response to the genetic potential of the cultivars and inputs used.Analysis of variance indicated significant differences ($P < 0.05$) among nitrogen rate treatmentsand varieties for grain yield,while their interaction was not significant (Table2).

Grain yield increased as rate of nitrogen applied increased from the lowest to the highest level. Mean Grain yield ranged from 3815 kg ha^{-1} for the lowest treatment (46 kg N ha^{-1}) to 4536 kg ha^{-1} for the highest treatment (230 kg N ha^{-1}) indicating grain yield variation under the different nitrogen rate treatments. The lowest grain yield (3815 kg ha^{-1}) was recorded by the lowest nitrogen rate (46 kg N ha^{-1}). The highest grain yield (4536 kg ha^{-1}) was recorded by the highest nitrogen rate (230 kg N ha^{-1}).The remaining three nitrogen rates 92,138 and 184 kg N ha^{-1} gave statistically similar grain yield 4370, 4519 and 4439 kg/ha, respectively.

The analysis of variance also revealed that significant differences ($P < 0.05$) among tested varieties. Mean grain yield ranged from 3653 kg/ha for local variety Ingliz to4650 kg/ha for improved variety Dire. Improved variety Bekelcha also produced statistically similar grain yield (4563 kg ha^{-1}) with Dire.Toltu also recorded statistically different grain yield (4477 kg/ha) to local check (3653 kg/ha). The three improved varieties gave statistically much higher grain yield than the Local variety. These results clearly indicated that the improved durum wheat varieties are more productive and responsive to nitrogen fertilizer than the local variety. The results are consistent with the general fact that modern wheat varieties are genetically improved through traits imparting shorter stature and higher potential to partition photo assimilate to the grains.

TKW and HLW

The result showed significant differences ($P < 0.05$) among nitrogen rate treatments andvarieties for TKW and HLW while their interaction was no significant (Table4).

The nitrogen rate treatments caused a slight increase in TKW .The maximum TKW wasobserved for treatments 138 kg N ha^{-1} (45.6 g) which was statistically at par with 184 and 230 kgN ha^{-1} (Table4). This might be attributed to a better nutritional status of the plants whichresulted in good grain filling and development. The minimum TKW (41.3 g) was achieved in the lowest treatment (46 kg N ha^{-1})and significantly different from 92 kg N ha^{-1}. The result also revealed significant differences ($P < 0.05$) among the varieties. Improved variety Bekelcha gave the highest TKW (46.6g) while the lowest was recorded by local variety Ingliz(42.9g).Toltu and Dire were statistically par for TKW.

A significant difference ($P < 0.05$) in the HLW was observed amongthe varieties. The highest HLW was obtained from the variety Toltu (82.3 kg hl^{-1}) in statistical parity with

Dire (81.95 kg hl^{-1}). Dire and Bekelcha were statistically identical for HLW.The lowest HLW was recorded by Local variety Ingliz(81.02 kg hl^{-1}). According to this study all varieties had HLW> 81 kg hl^{-1} which most millers demand as standard for semolina milling (Sission, 2004). In general, HLW was ranged from 81.02-82.3 kg hl^{-1} for the varieties under this study. According toAtwell (2001) hectoliter weight may range from about 57.9 kg hl-1 for a poor wheat to about82.4 kg hl-1 for a sound wheat.

Table4: Mean value of TKW and HLW of durum wheat varieties grown under different N rates

	TKW (g)						HLW (kg hl^{-1})					
N kg ha^{-1}	46	92	138	184	230	Mean	46	92	138	184	230	Mean
Variety												
Toltu	41.0	42.6	45.5	45.0	45.2	43.9b	81.7	82.7	82.5	82.4	82.4	82.3a
Dire	40.5	44.1	45.2	45.5	44.9	44.1b	81.4	82.1	82.2	82.1	82.0	82ab
Bekelcha	43.6	46.3	48.1	47.3	47.6	46.6a	80.8	81.9	82.0	81.8	82.3	81.7b
Ingliz	40.3	42.6	43.5	44.0	44.0	42.9c	80.3	81	81.3	81.3	81.3	81.0c
Mean	41.3c	43.9b	45.6a	45.5a	45.5a		81.1	81.9	82.0	81.9	82.0	
CV (%)			6.9						2.9			
LSD(0.05)												
V			0.78						0.59			
N			0.87						NS			
VxN			NS						NS			

Grain protein content

Results showed significant differences ($P < 0.05$) among nitrogen rate treatments andvarieties for grain protein content while the effect of interaction between various nitrogen rateapplication and varieties was not significant (Table5).

The highest grain protein content (14.6%) was recorded for the highest nitrogen rate (230 kg N ha-1). Thehighest nitrogen rate resulted in 16% more grain protein content than the lowest treatment. Kirrilovand Pavlov (1989) also reported that applied nitrogen increased wheat grain protein content

by 20.29 %. In general this finding was in line with Efrem*etal*. (2000) who reported that protein content of Ethiopian improved durum wheat cultivarsreleased between 1966 and 1996 had ranged between 10.2% to 15.4 % using the whole millflour. The cultivars differed significantly with respect to protein content. Grain protein content of thecultivars ranged from 12.9% (Ingliz) to 14.1% (Bekelchaa) (Table 5).Grain protein contents of improved varieties Bekelcha , Toltu and Dire were significantly higherthan the local cultivar Ingliz. This variation in grain proteincontent of the cultivars may be attributed to their variation in nutrient uptake and translocationcapacities to the sink.

Table 5: Mean value of grain protein content of durum wheat varieties grown under different N rates

			Grain protein content (%)			
N kg ha^{-1}	46	92	138	184	230	Mean

Variety						
Toltu	13.0	13.8	14.5	14.4	15.3	14.2b
Dire	12.9	13.4	14.2	14.7	15.4	14.1b
Bekelcha	13.3	13.6	14.6	15.6	15.8	14.6a
Ingliz	12.1	12.7	12.9	13.5	13.7	12.9c
Mean	12.8e	13.4d	14.1c	14.5b	15.1a	
CV (%)			6.1			
LSD(0.05)						
V		0..22				
N		0.24				
VxN		NS				

Economic analysis

The economic analysis was based on the procedures by CIMMYT (CIMMYT, 1988). Partial budget and marginal analysis were performed for nitrogen fertilizer rate and the decision for selecting the profitable treatment was made based on the highest marginal rate of return (Table6). The Marginal analysis indicated that changing from the first treatment(46 kg N ha^{-1}) to the second treatment (92 kg N ha^{-1}) has resulted the highest marginal rate of return (212%), which means that investing 1 birr in treatment number two acquire a return of 2.12 birr.There for,the best nitrogen rate for durum wheat productivity and profitability in the high lands of bale is 92 kg N ha^{-1}.

Table 6: Partial budget analysis result for nitrogen rate study on durum wheat varieties

Treatments (Nitrogen kg ha^{-1})					
	46	92	138	184	230
Average yield(kg/ha)	3815	4370	4519	4439	4536
Adjusted yield(kg/ha)	3434	3933	4067	3995	4082
Gross field benefits(Birr/ha)	46359	53096	54905	53933	55107
Cost of Nitrogen(Birr/ha)	1500	2999	4499	5998	7498
Cost of labour to apply Nitrogen (Birr/ha)	35	70	105	140	175
Harvesting, packing and transportation (Birr/ha)	3949	4523	4678	4594	4694
Total costs that vary(Birr/ha)	5484	7592	9282	10732	12367
Net benefits (Birr/ha)	40875	45504	45623	43201	42740
MRR%		212	7		

Cost of urea 1500 Birr 100 kg^{-1}or (32.60 Birr kg^{-1} N); urea application of 46 kg N ha^{-1} one person@ 35 Birr/ person/day; 92 kg N ha^{-1} two person@ 35 Birr/ person/day; 138 three person @ 35 Birr / person/day; 184 four person@ 35 Birr / person/day; and 230 kg N ha^{-1} 5 person @ 20 Birr/ person/day; harvesting, packing and transportation 115 Birr per 100 kg; sale price of wheat grain 1350 Birr per 100 kg

Conclusion and recommendations

An experiment was conducted with the objectives of assessing the effect of nitrogen fertilizer rates on grain yield, yield components and grain protein accumulation of durum wheat varieties, in a treatment of factorial combinations of four cultivars (Toltu, Dire, Bekelcha and Ingliz) and and five nitrogen application rates (46,92,138,184 and 230 kg N ha^{-1}) in RCB design with three replications. The results of the experiment revealed that nitrogen fertilizer application significantly influenced durum wheat agronomic traits and grain quality attributes.

Therefore, from the results of three years' data over locations, it was observed that***92 kg N ha***$^{-1}$was the most promising and economically feasible nitrogen rate for recently released durum wheat varieties in the highlands of bale. The results also imply that there is a need to formulate variety-specific fertilizer recommendation rates for enhancing the productivity and grain quality of durum wheat for pasta/macaroni making.

ACKNOWLEDGEMENTS

The authors are grateful to all staff of the Sinana Agricultural Research Centre especially those in the Cereal Crops Technology Generating Team for valuable contributions in data collection.Oromia Agricultural Research Institute is acknowledged for financing the experiment.

References:

AyeleBadebo, Solomon Gelalcha, Ammar, K., Nachit, M. M., &Abdalla, O. 2009. Overview of durum wheat research in Ethiopia: Challenges and prospects. Paper presented at the Proceedings of Basra, and L. S. Randhawa (eds.), Quality Improvement in Field Crops, Food Products Press, Binghampton, NY.

Amanuel Gorfu., Kuhne, R.F., Tanner D.G. and Vlek, P.L.G. 2002. Recovery of 15- N labeled urea applied to wheat in the Ethiopian Highlands as affected by P fertilization. *Journal of Agronomy* and *Crop Science,* 189:.30-38.

Bock, B.R. 1984. Efficient use of nitrogen in cropping systems. *In:* R.D., Hauck (ed.), Nitrogen in crop production, pp.273-293. ASA-CSSA-SSSA, Madison, WI, USA.

CSA (Central Statistical Agency). 2011. Agricultural Sample Survey. Report on Area and Production of Major Crops. Statistical Bulletin, Vol.1, Addis Ababa.

EfremBechere, HirutKebede and Getachew Belay. 2000. Durum wheat in Ethiopia.: An old crop in an ancient land. Institute of Biodiversity Conservation and Research. Addis Ababa, Ethiopia.68p.

Evans, L.T.1998. Feeding the ten billions: Plants and population growth. Cambridge University press.

FAO (Food and Agriculture Organization of the United Nations). 2008. FAO fertilizer and plant nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis. FAO, Rome,Italy. 203p

FAOSTAT (Food and Agriculture Organization of the United Nations), 2011.

Franzen, D.W. and Goos, R.J. 1997. Fertilizing hard red spring wheat, durum, winter and rye. North Dakota State University Extension Service, SF-712.

Haile Deressa , NigussieDechassa, and Amsalu Ayana. 2012. Nitrogen use efficiency of bread wheat: Effects of nitrogen rate and time of application. *Journal of Soil Science and Plant utrition***,** 12 (3): 389-409.

HailuGebre-Mariam, 1991. Wheat production and research in Ethiopia. pp. 1-15. *In*: HailuGebre-Mariam, Tanner, D.G. and MengistuHulluka (eds.), Wheat Research in Ethiopia: A Historical Perspective. IAR/CIMMYT, Addis Ababa, Ethiopia.

Metwally, S.M., Khamis,M.A.1998. Comparative effects of organic and inorganic nitrogen source applied to sandy soil on availability of N and wheat yield. *Egypt Journal of science,* 38 (1-4): 35–54.

Motozo, R., Fosi, S. and Giunta, F. 2004. Relationship between grain yield and quality of durum wheats from different eras of breeding. *Euphytica*, 140: 147-158.

Ottman,M.J., Doerge T.A. and Martin E.C. 2000. Durum Grain Quality as Affected by Nitrogen Fertilization near Anthesis and Irrigation During Grain Filling. *Agronomy Journal*, 92(5): 1035-1041.

Peña, R., and. Pfeiffer W. 2005. Breeding methodologies and strategies for durum wheat quality improvement. *In*: C., Royo, M. Nachit, N. D., Fonzo, J. Araus, W.H., Pfeiffer, and G.A., Slafer (eds.), *Durum Wheat Breeding: Current Approaches and Future Strategies*. New York: Food Product Press. The Haworth Press Inc. pp. 663-772.

Tesfaye Tesemma.1987. Durum wheat breeding in Ethiopia. pp. 18-22. *In*: Van Jankel, M. and D.G.Tanner (eds), Fifth Regional Wheat Workshop for Eastern, Central and Southern Africa and Indian Ocean. CIMMYT, Mexico.

Warraich E.A., Basra S.M.A., Ahmad N., Ahmed R.andAftab ,M.2002. Effect of Nitrogen on Grain Quality and Vigor in Wheat (*Triticumaestivum*L.). Int J AgrBiol, 4 (4): 517-520.

Effects of Seeding and Nitrogen Rate on Yield, Yield Related Traits and Grain Quality of Malt Barley Varieties in the Highlands of Bale

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ABSTRACT

The experiment was conducted at major barley growing districts (Sinana,Goba and Dinsho) of Bale zone for three years from 2016-2018 during the main cropping season with the objective of elucidating the effects of seeding and nitrogen rate on agronomic performance and grain protein content of the improved malt barley varieties.The experimental design in all locations was a split-plot with three replications. Two malt barley varieties (Grace and Traveler) were randomly assigned as main plot factor. On the other hand, factorial combinations of three seeding rates (100,125 and 150 kg ha^{-1}) and four levels of nitrogen fertilizer (0, 23, 46 and 69 kg N ha^{-1}) were arranged in sub-plot factors.The main effects of seeding ratesignificantly influencedBio-mass yield and TKW, while main effects of nitrogen rate significantly ($P < 0.05$) influenced plant height, spike length,kernels per spike,bio-mass yield, harvest index,TKW, HLW and grain protein content. Theinteraction effects of seeding

rate and nitrogen rate significantly influencedgrain yield of malt barley varieties.The grain yieldranged from 1905 kg ha^{-1}to 3957kg ha^{-1}.The lowest grain(1905 kg ha^{-1})d was obtained from the interaction effect of the lowest seeding rate and nil nitrogen rate. The highest (3957kg ha^{-1}) was obtained from the interaction effects of the highest seed(150 kg ha$^{-1)}$ and nitrogen (69 kg ha^{-1})rate. The second highest grain yield was recorded from the interaction effects of the second seed and the highest nitrogenrate which is in statistical parity with the grain yield from the interaction effects of the highest seed rate and the second nitrogen rate.Main effects of nitrogen rate significantly and variably influenced TKW and grain protein contents of malt barley. The highest TKW (40.2g) and grain protein content (12.2%) were obtained from the highest nitrogen rate(69 kg N ha^{-1}).. The lowest TKW (36.1g) and grain protein content (9.2g) was recorded from nil nitrogen rate.According to the result of this study,maximum malt barley grain yield was obtained at seeding rate of 150kg ha^{-1}and economic analysis also indicated that optimum grain yield and quality of the improved malt barley varieties were obtained at the rate of nitrogen application (46 kg N ha^{-1}).Therefore, malt barley farmers in the study area should use seeding rate of 150 kg ha^{-1}and nitrogen rate 46 kg N ha^{-1} to realize maximum grain yield and grain quality of the crop.
Keywords: Malt barley; Seeding rate; Nitrogen rate; Grain yield; Grain protein content; Thousand kernel weight

Introduction

Ethiopia is the only country in tropical Africa, where barley is among the major crop (Onwueme and Sinha,1999). The most important use of Barley is for food and malting,which is mainly used in making alcoholic beverages. For this reason,Barley is considered to be the best of small grains for malting purpose. Barley grain yield and quality are exposed to different factors varying on the large scale. The genotypic traits for a variety and growing climatic conditions are the key factors influencing grain yield and its quality(Leistrumaite and paplauskiene,2005).The first step to success in the growing system of Barley in a given environment is the choice of suitable cultivar. The varietal effect account for 25to 40%of variety performance compared to growing conditions(Dudas, 1994).Stability of grain yield performance is an important characteristics in the selection of new crop varieties (Costa and Bodlero, 2001).

The impact of seeding rate on malt barley quality, including plumpness is an important factor in selecting barley for malt with plump seeds generally having higher starch and lower protein levels.The reason of plumpness is so important that maltsters wanted to produce more extract ,which means more beer. Optimum seeding rate resulted in more uniformity of barley kernals, which improves the modification process and produces higher quality malt(). According to O'Donovan (2008)optimum seeding rate also reduced beta-glucan levels while friability and homogeneity were improved all positive factors for maltsters.

The third most important factor, but the one posing the most challenges and additional questions to researchers,is related to Nitrogen.The major growers' management strategies for producing malt barely is to maximize grain yield and kernel plumpness while maintaining protein content at the acceptable limit(Lauer and Partrigde,1990;Weston *et al*.,1993). High Nitrogen usually increase protein levels,but at protein levels higher than 11.5 percent,the sample will be rejected for malt.High nitrogen rate also increase beta-glucan levels, while other factors such as plumpness, friability and modification are decreased at higher nitrogen rates, all having negative effect on quality.

Higher nitrogen rates, sometimes increase the days to maturity, which can cause problems in years where there is a higher risk of frost or other conditions that will reduce malt barley quality. Research findings show that reducing nitrogen rates will improve malt barley quality()..In principle, processors of malting barley are concerned about the effects of management factors on grain protein and other malting characteristics (Lauer and Partridge, 1990). Often, management strategies that maximize grain yield will not optimize grain protein (Lauer and Partridge,1990, Ayoub*et al*.,1997; Metho*et al*., 1997) and malt quality (Lauer and Partridge,1990).

At present,the level of production in Ethiopia is not sufficient to meet the demands of the malting factories both for quality and quantity. As a result, the factories are continuously importing the grain from foreign countries. However, there are ample opportunities in Ethiopia in general and in Bale in particular in terms of favorable environmental conditions. Inaddition,The rising of market demand for malt barley appears a bright venture for farmers as well as others involved in commercial farming. Development of appropriate agronomic practices like seeding rate and nitrogen management is among the intervention areas where the research centers should play a great role. So far, there was no information generated on varietal differences in response to different seeding and nitrogen fertilizer rates as well as their interaction effects to optimize malt barley quality and quantity of production in bale highlands. Thus, this project isinitiated to fill the information gap with the objective of evaluating effects of nitrogen fertilizer and seed rate with respect to cultivars for the desired malt barley yield and quality.

The favorable environmental condition for production of the crop is another opportunity prevailing in Bale. Despite this, integrated agronomic management practices including seeding and fertilizer rate for the varieties are lacking in the area to optimize malt barley production in terms of yield and grain quality. These calls for an urgent need to determine integrateeffects of seeding and nitrogen fertilizer rates along with improved varieties in order tooptimize yield and grain quality.

Objectives:

- To determine the effects of seed and nitrogen rate on yield, yield related traits and grain quality of improved malt barley varieties
- To determine economically optimum seedand Napplication rate for higher grain yield and quality of Malt barley

Material and methods:

The experiment was conducted for three years (2016-2018) at three locations (Sinana on-station, Goba and Dinsho) in main cropping season. The experimental design in all locations wassplit-plot with three replications. Two malt barley varieties (Grace and Traveler) were randomly assigned as main plot factor and three seeding rates (100,125 and 150 kg ha^{-1}) and four levels of nitrogen fertilizer (0, 23, 46 and 69 kg N ha^{-1}) which combined factoriallywere arranged in sub-plot factors. The entire arrangement of treatments (2x3x4) twenty four treatment combinations were replicated three times. The size of each plot was (1.8 mx2.5m=4.5m^2) and the distance between plots and blocks is kept at 0.5 m and 1.5 m respectively. Field activities such as land preparation and weeding were carried out accordingly. Planting was done using row planting, phosphorous fertilizer in the form of

TSP at the recommended rate of 69 kg P_2O_5 $ha^{-1}$was applied equally for all plots. The highest rates of Nitrogenweresplited to $^1/_3$ at planting and$^2/_3$ attillering.

Statistical data analysis

Analysis of variance (ANOVA) was done using Gen Stat 15th edition and means comparisons for the significantly different variables were made among treatments using least significant differences (LSD) test at 0.05 level of significance.

RESULTS AND DISCUSSION

Effects of Seeding and Nitrogen Rate on Agronomic Traits and Grain Quality of Malt Barley Varieties

4.1.1Soil analysis before planting

Selected physico-chemical properties of the soil were determined for composite surface soil (0-30 cm) samples collected before sowing (Table1). Accordingly, the texture of the soil of the experimental site is dominated by the clay fraction. The clay texture indicates the high degree of weathering that took place in geological times and the high nutrient and water holding capacity of the soil.

Soil pH values for both locations varied from 5.68 to 6.45 for soils of the experimental sites (Table 1).pH status was categorized as moderately to slightlyacidic soil Jones (2003). Based on these results the pH value is optimum range for most crop production since most plant prefer the pH range 5.5 to 7.0.Soil Organic matter values for both locations varied from 2.29 to 4.98 for soils of the experimental sites (Table 1). As the rating range established by Tekalign,(1991) soil organic matter content categorized under low to moderate for Dinsho on-farm and Sinana on- Station, respectively.Soil Total Nitrogenvalues for both locations varied from 0.17 to 0.33.As ratings suggested by Landon (1991) for soil total nitrogen soils of the experimental site were rated into low and moderate for Dinshoon-farm and Sinana on- station, respectively**.** Available Phosphorousvalues for both locations varied from 10.54 to 20.58 (Table1). According to the rating established by Cottenie (1980) the studied soils have moderate to high phosphorus content for Dinsho on-farm andSinanaon-station, respectively**.** Adequate phosphorus results in higher grain production, improved crop quality, greater stalk strength, increased root growth, and earlier crop maturity.

Cation exchange capacityvalueswereranged from 20.45 to 38.53for soils of the experimental sites. Based on the rating established by Hazelton (2007)the soil of the study sites were moderate and high for Dinshoon-Farm and Sinana on-station, respectively**.**

Table 1. Soil physico-chemical properties of the Sinana on- station and Sinana on-farm

Location	Textural class	pH	OM (%)	TN (%)	Available P (ppm)	CEC (cmol kg^{-1})
Sinana on- station	Clay	6.45	4.98	0.33	20.58	38.53
Dinsho on -farm	Clay	5.68	2.29	0.17	10.54	20.45

Plant height

The analysis of variance showed that the main effects of nitrogen rate differed significantly (P <0.05) on plant height. However,the main effect of seeding rate and their interaction effect did not influence plant height (Table1).

The highest nitrogen (69 kg N ha^{-1})rate recorded the highest plant height (67.7cm)even ifstatisticallyparwith 46 kg N ha^{-1}. The lowest was obtained from the control treatment (nill application) but statisticallysimilar with the lowest rate of 23 kg N ha-^{1}.The increased plant height in response to increasing the rate of nitrogen application was probably due to the availability of more nitrogen in the soil, which may have promoted vegetative growth of the barley plants().

Bio-mass yield

Analysis of variance indicated significant differences (P <0.05) for main effects of seeding and nitrogen rate in biomass yield (Table2).

Increasing theseeding rateproportionally increased biomass production. The highest (7993 kg ha^{-1})bio-mass yield was obtained from the highest seeding rate 150 kg ha^{-1}. The lowest (6299 kg ha^{-1})was obtained from the lowest seeding rate 100 kg ha^{-1}. Similarly, nitrogen rate increase proportionally the bio-mass yield. The highest (8614 kg ha^{-1}) was recorded with the highest nitrogen rate (69 kg N ha^{-1}) while the lowest (5671kg ha^{-}1) wasfrom the control(Table2). Increasing N fertilizer rate linearly increase biomass production. The result isin agreement with the findings of Amanuel*et al*. (1991) who reported a significant increase in biomass yield as a result of increasing in the rate of nitrogen application.

Table 2: Seeding and nitrogen rate effect on selected agronomic traits and quality of improved malt barley varieties

Treatments	PH(cm)	SL(cm)	KPS	BM(kg)	HI (%)	TKW(g)	HLW(kg hl^{-1}	GPC (%)
Variety								
Grace	66.4	8.3	28.5	7149	0.41	38.3	68.0	10.7
Traveller	65.3	8.2	28.3	7211	0.43	38.5	67.9	10.6
LSD(P<.05)	NS	NS	NS	NS	NS	NS	NS	NS
Seeding rate(kg/ha)								
100	66.1	8.3	28.6	6299c	0.41	37.1b	67.7	10.7
125	65.1	8.3	28.3	7249b	0.43	38.8a	67.9	10.7
150	66.3	8.1	28.1	7993a	0.41	39.2a	68.3	10.6
LSD(P<.05)	NS	NS	NS	304	NS	0.5	NS	NS
Nitrogen rate (kg N/ha)								
0	63.7c	8.1	27.9	5671d	0.40	36.1d	67.5	9.2d
23	65.2bc	8.1	28.3	6761c	0.43	37.7c	67.8	10.2c
46	66.6ab	8.3	28.4	7674b	0.42	39.5b	68.1	10.9b
69	67.7a	8.4	28.7	8614a	0.41	40.2a	68.4	12.2

								a
LSD(P<.05)	1.6	NS	NS	351	NS	0.58	NS	0.15
Mean	65.8	8.2	28.3	7180	0.42	38.4	67.95	10.0
CV (%)	10.6	15.4	10.3	21.1	27.7	6.6	4.3	6.0

N = Nitrogen; PH = Plant height; SL = Spike length; KPS = Kernels per spike; BM=Biomass; TKW=Thousand kernel weight; HLW=Hectoliter weight; HI = Harvest index; P (%) =Protein in percentage ;Means with the same letter are not significantly different at 5% level of significance; NS = non-significant; LSD = Least significant difference at P <0.05; CV (%) = Coefficient of variation (%)

Grain yield

Analysis of variance indicated that theinteraction effect of seeding and nitrogen rate significantly influenced (P <0.05) the grain yield of improved malt barley varieties (Table3). Increasingseeding rates and nitrogen fertilizerrates significantlyincreasedthe grain yieldsof malt barley.The grain yields also increased across the increased seeding rate for all nitrogen levels. The highest grain yield (3957 kg ha^{-1}) was obtained at the highest seed rate (150 kg ha^{-1}) and nitrogen rate (69kg N ha^{-1}). The second highest grain yield (3702 kg ha^{-1}) was recorded at (125kg ha^{-1}) and (69kg N ha^{-1})which is statisticallyparwith seeding 150kg ha^{-1}) and (46 kg N ha^{-1}) rate. (The lowest grain yield (1905kg ha^{-1}) was produced from the interaction effects of the lowest seed rate (100kg ha^{-1}) and the controltreatment (0 kg N ha^{-1}).

Table 3: Interaction effect of seeding and nitrogen rate on grain yield of improved malt barley varieties

Nitrogen rate(kg N ha^{-1})					
Seeding rate(kg ha^{-1})	0	23	46	69	Mean
100	1905i	2378g	2663f	2878de	2456
125	2165h	2704ef	3365c	3702b	2984
150	2369g	2898d	3597b	3957a	3205
Mean	2146	2660	3208	3512	
LSD= 183.6					
CV(%)=15.9					

Means with the same letter are not significantly different at 5% level of significance; NS= non-significant; LSD=Least Significant Difference at P < 0.05; CV% = Coefficient of variation (%)

Thousand kernel weight and grain protein content

The result showed that significant differences (P <0.05) observed due to the main effects nitrogen and seeding rate treatmentson TKW and nitrogen rate for grain protein content while their interaction was non-significant (Table2).

The seeding rate treatments caused a slight increase in TKW.The maximum(39.2 g) TKW was observed for treatment of 150kg ha^{-1}which was statistically at par with 125kg ha^{-1}.The lowest (37.1g) was recorded with the lowest seeding rate (100kg ha^{-1}).Increasing nitrogen levels proportionally increased thousand kernel weight and grain protein content which was statistically differed and varied from each other (Table 1). The highest TKW (40.2 g) was obtained at the highest nitrogen rate (69kg N ha^{-1}). The lowest (36.1g) was recorded by the control treatment. Similarly, the highest grain protein content (12.2%) was obtained at the highest rate(69kg N ha^{-1}).The lowest (9.2%) was recorded by the control treatment. This might be attributed to a better nutritional status of the plants which resulted in good grain filling and development().

Economic analysis

The economic analysis was based on the procedures by CIMMYT (CIMMYT, 1988). Partial budget and marginal analysis were performed for nitrogen fertilizer and seeding rate and the decision for selecting the profitable treatments were made based on the highest marginal rate of return (Table4&5). The Marginal analysis indicated that for nitrogen rate changing from the second treatment (23 kg N ha^{-1}) to the third treatment (46 kg N ha^{-1}) has resulted the highest marginal rate of return (350%), which means that investing 1 birr in treatment number three acquire a return of 3.50 birr. The marginal analysis for seeding rate also revealed that treatment number two (125kg ha^{-1}) gave the highest marginal rate of return (1713%). There for, the best nitrogen and seeding rate for malt barley productivity and profitability in the high lands of bale are 46 kg N $ha^{-1}$and 125 kg/ha ,respectively.

Table 4: Partial budget analysis result for nitrogen rate study on Malt barley varieties

	Treatments (Nitrogen kg/ha)			
	0	23	46	69
Average yield(kg/ha)	2146	2660	3210	3515
Adjusted yield(kg/ha)	1931	2394	2889	3164
Gross field benefits(Birr/ha)	23172	28728	34668	37968
Cost of Nitrogen(Birr/ha)	0	750	1500	2250
Cost of labour to apply Nitrogen (Birr/ha)	0	35	35	70
Harvesting, packing and transportation (Birr/ha)	2221	2753	3322	3639
Total costs that vary(Birr/ha)	2221	3538	4857	5959
Net benefits (Birr/ha)	20951	25190	29811	32009
MRR%		322	350	199

Cost of urea 1500 Birr 100 kg^{-1}or (32.60 Birr kg^{-1} N); urea application cost of 23,46 kg N ha^{-1}one person@ 35 Birr /day;69kg N ha^{-1}two person@ 35 Birr /day;harvesting, packing and transportation 115 Birr per 100 kg; sale price of malt barley1200 Birr per 100 kg.

Table 5: Partial budget analysis result for seeding rate study on Malt barley varieties

Treatments (Nitrogen kg/ha)			
	100	125	150
Average yield(kg/ha)	2456	2984	3205
Adjusted yield(kg/ha)	2210	2686	2885
Gross field benefits(Birr/ha)	26520	32232	36620
Cost of barley(Birr/ha)	1200	1500	1800

Sowing and transportation (Birr/ha)	50	65	80
Total costs that vary(Birr/ha)	1250	1565	1880
Net benefits (Birr/ha)	25270	30667	34740
MRR%		1713	1293

Sowing and transportation 50 Birr per 100 kg; sale price of malt barley1200 Birr per 100 kg (12 birr/kg).

Conclusion and recommendations

An experiment was conducted with the objectives of assessing the effect of seeding and nitrogen rate on grain yield, yield components and grain protein accumulation of malt barley varieties.The experimental design was a split-plot with three replications. Two malt barley varieties (Grace and Traveler) assigned as main plot factor and factorial combinations of three seeding rates (100,125 and 150 kg ha^{-1}) and four levels of nitrogen(0, 23, 46 and 69 kg N ha^{-1}) were assigned as sub-plotFactors. The results of the experiment revealed that seeding and nitrogen rate significantly influenced some important maltbarley agronomic traits and grain quality attributes.

Therefore, from the results of three years' data over locations, it was observed that the second seeding rate (125kg ha^{-}1) and the second nitrogen rate (46kg N ha^{-1}) were the most promising and economically feasible seeding and nitrogen rate for the two malt barley varieties (Grace and Traveler).Malt barley producing Farmers advised to use 125 kg $ha-^{1}$seed rate and 46 kg N $ha-^{1}$fertilizer rate to realize maximum grain yield and grain quality of the crop.

ACKNOWLEDGEMENTS

The authors are grateful to all staff of the Sinana Agricultural Research Centre especially those in the Cereal Crops Technology Generating Team for valuable contributions in data collection.Oromia Agricultural Research Institute is acknowledged for financing the experiment.

References:

Ayoub,M., Guretin S., Fregeau-Reid J. and Smith D.L. 1997. Nitrogen fertilizer effect on Bread making quality of hard red spring wheat in Eastern Canada. Sci.34;1347-1352

Costa, J.M. ,Bodlero , G.2001. Annals applied biology.139(1):137-143

Dudas, F.1994. Grain quality of barley cv. Perun under different cultivation practices. Actauniv.Agril. Fac.Agron. 42(1/2):149-159

Edney , M. 2008. The effect of agronomic practices on malt quality parameters.

Laure, J. and Partridge J. 1990. Planting date and nitrogen rate effects on spring malting Barley *.Agron.J.82:1083-1088*

Leisrumaite A. and Paplauskiene V. 2005. Genetic resources of malt barley: Screening for yield stability and grain malt quality traits.

Metho, A.L., Hammes P.S. and De.Beer J.M. 1997. Effect of cultivars and soil fertilization on grain yield , yield components and grain protein content in wheat. *Africa Crop Sci. J.3 (2):695-706*

Onwueme, I. C.and Sinha T.D. 1999. Field crop production in tropical Africa:Principle and practice.CTA,Wageningen,Netherlands.

Weston, D., Horsely R., P.Schwarz and Goos R. 1993. Nitrogen and planting date effects on low-protein spring malting barley. *Agron.J.85:1170-1174*.

Effect of NPSZn and Nitrogen Rates on Yield and Yield Components of Maize (*Zea mays* L) in Eastern Hararghe, Oromia

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Abstract

Maize (Zea mays L) cannot produce maximum yields unless sufficient nutrients are available. There are a number of factors which are responsible for the low production and productivity of maize. Among these factors, inappropriate crop nutrition management and poor soil fertility are the most important factors responsible for low yield of maize. When the soil does not supply sufficient nutrients for normal plant growth, application of supplemental nutrients are required. Thus, the activity was done with the objective to determine the optimum application rate of NPSZn and Nitrogen fertilizers for yield and yield components of maize. Three levels of NPSZn (75, 100, and 125kg ha^{-1}) and three level of N (21.2, 28.3, and 35.4kg ha^{-1}) were combined factoriallyafter deducting the amount of N found in NPSZNwere used for the field experiments. Treatments were laid out in RCBD design with three replications. The highest grain yield (4359 kg ha^{-1}) was obtained from combined application of 75 kg NPSZn with 35.4kg ha^{-1}and nearly followed by (4348 kg ha^{-1}) which obtained from combined application of 100 kg NPSZn with 35.4 kg ha^{-1} whereas the lowest grain yield (2475 kg ha^{-1}) was obtained from plots treated without fertilizer. The highest grain yield (4359kg ha^{-1}) and nearly followed (4348 kg ha^{-1}) was obtained from plots fertilized with the higher N application (35.4 kg). The result of partial budget analysis suggested that the higher marginal rate of return (12822.71%) was obtained from the combined application of 100 kgNPSZn with 35.4 kg N ha^{-1}. This combined rate is agronomically optimum and economically affordable levels to increase improved maize production.Therefore, based on this result it can be concluded that the combined application of 100 kg NPSZn with 35.4 kg N ha^{-1}can be recommended on the study areas and for other similar agro-ecologies..

Keywords: NPSZn, Nitrogen, Fertilizer rate, Yield, Yield components, Maize

INTRODUCTION

Maize (*Zea mays L*) is one of the most important cereal crops throughout the world. It is used as feed for animals, food for human and raw material in industries. Maize is the third most important cereal after wheat and rice globally and the most widely distributed (Siwale J. *et al*., 2009). Maize is one of the most important crops grown in Ethiopia (Mosisa*et al*., 2007).It is a major crop in Ethiopia in production, consumption and income generation for both resource constrained men and women. In Ethiopia, maize is first in productivity and second in area coverage after teff (CSA, 2018/19). The national area coverage and average yield of maize is 18.60% (about 2,367,797.39 hectares) and30.08% (94,927,708.34 quintals)respectively(). The area coverage and average yield of maize in Oromia regional state is 1,324,274.98 hectares and 54,383,119.44 Quintals respectively (CSA, 2018/19).

However, there are a number of factors which are responsible for the low production and productivity of maize. Among these factors, inappropriate crop nutrition management and poor soil fertility are the most important factors responsible for low yield of maize (Shah *et al*., 2009). The low productivity of maize is also due to inappropriate cropping systems, mono-cropping, nutrient mining, unbalanced nutrient application, removal of crop residues from the fields and inadequate re-supplies of nutrients (McDonald *et al*., 2005). Low soil fertility is highly affects the growth and development of maize as compared to other crops. As a result, it is often said "maize speaks" implying that maize cannot produce maximum yields unless sufficient nutrients are available (Delorite*et al*., 1967). When the soil does not supply sufficient nutrients for normal plant growth application of supplemental nutrients are required. The proper application rates of plant nutrients are determined by knowledge about the nutrient requirement of the crop and the nutrient supplying power of the soil (Foth*et al*., 1997). However, yield levels obtained by small scale farmers remained stagnant despite the availability of improved varieties (BentiTolessa, 1993). It has been estimated that at least 30 to 50% of crop yield increment is attributable to application of commercial fertilizers (Stewart *et al*., 2005). Like in other developing countries, information on soil fertility status is not adequate to meet the requirement of agricultural development programs, rational fertilizer promotions and recommendations based on actual limiting nutrients for a given crop in Ethiopia. The prevailing blanket fertilizer rate recommendation throughout the country on all soil types and agro ecological zone justifies the existence of little information on the fertility status of Ethiopia's soils.

Nitrogen is a most important and crucial major nutrient and it is very important for maize and other cereal crops. Nitrogen is important for the plant metabolism as it participates of proteins and chlorophyll biosynthesis, being necessary since the early phenological stages of the plant development (Basso *et al*., 2000), and participates in several major metabolic pathways of plants biochemistry (Andrade *et al*., 2003). Under appropriate levels of other nutrients in the soil, nitrogen provides the greatest increment to maize yield (Coelho, 2004). Nitrogen in essential for carbohydrates uses within plants and stimulates root and development as well as the uptake of other nutrients (Khan *et al*., 2014). Deficiency of nitrogen results in low plant growth which reduces the grain yield, leaf area index, leaf area duration and rate of photosynthesis. It imparts dark green color to plants.

Phosphorus has many essential functions in plant life; its role in energy storage and transfer is singly the most important. Large quantity of Phosphorus is found in seed and it is considered essential for seed formation. Phosphorus is essential for grain formation; ripening and reproductive parts of maize plant (Stangel*et al.*, 1994). It needed for growth, nucleus formation, photosynthesis, utilization of sugar and starch, cell division and fat and albumen formation. Phosphorus is readily translocated within the plants and it moves from older tissues to younger tissues (Ali *et al.*, 2002). Phosphorus in adequate amount is necessary for earlier maturity, rapid growth and improves the quality of vegetative growth. Deficiency of phosphorus is responsible for small ears in maize due to crooked and missing rows as (Masood *et al.*, 2011).

Maize also need some micro nutrients for its better growth and higher yield such as zinc (Zn).Zinc applications are reported to increase maize grain yield around world (Harris *et al.*, 2007)

Although zinc required in small quantity for crops but if there is zinc deficiency then it can withhold plant growth.. Zinc plays role in metabolic functions and also it increase protein content in grain because it helps in protein synthesis in grain. Zinc can also increase the plumpness of grain which results in better yield of crop.

To overcome the constraint of low nutrient recovery and optimize fertilizer use, there is need to replace such general and over-simplistic fertilizer recommendations with those that are rationally differentiated according to agro-ecological zones (soils and climate), crop types, nutrient uptake requirements and socio-economic circumstances of farmers..

. Increasing yields through the application of nitrogen and phosphorus alone can deplete other nutrients (FAO, 2000). However, crop productivity can also be limited because of toxicity and/or deficiency of essential plant nutrients. To avert this situation the Ministry of Agriculture of the country has recently introduced a new compound fertilizer NPSZn which containing Nitrogen, Phosphorous, Sulfur and Zinc with the ratio of 17.7% N – 35.3% P2O5 + 6.5%S + 2.5% Zn that can substitutes DAP in Ethiopian agriculture. Nevertheless, little information is available on NPSZn fertilizer requirement including macro and micro plant nutrients. NPSZn was recommended for 18 kebeles of Fadis district of Eastern Hararghe Zone (ATA, 2015). Thus, it became relevant to evaluate the responses of maize to the newly introduced NPSZn fertilizer and nitrogen rates in the study area and to track economic and agronomic optimum rates of its application.Therefore the objective of this study was to determine the optimum application rate of NPSZn and Nitrogen fertilizers for yield and yield components of maize.

MATERIALS AND METHODS

Area description

The experiments were conducted at two sites of Fedis Agricultural Research Center, Boko research station and BalinaArba on farmers' field within the Fedis district of Eastern Hararge of Oromia regional state during the 2018/19 and 2019/20 consecutive cropping season under rain fed condition. Fedis district has latitude between 8°22' and 9°14' North and longitude between 42°02' and 42°19' East, in middle and low land areas: altitude range is from 1200 – 1600m.a.s.l, with a prevalence of low lands. The district receives average annual rainfall of 400 - 804 mm; the minimum and maximum air temperature of 20 – 25^{o}c and 30 – 35^{o}c, respectively.

Experimental design and treatments

The experiments were consisting total of ten treatments including control (without fertilizer). Urea was used as source of N though the amount of N found in NPSZn was considered in order to determining the amount of N required from urea. The three levels of NPSZn (75, 100, and 125) kg ha^{-1} were combined with three level of N (21.2, 28.3, and 35.4) kg ha^{-1} after deducted the amount of N found in NPSZN. The treatment combinations of NPSZn and UREA after deducting the amount of N found in the NPSZn was as the following table.

Table 1: The combinations of NPSZn and UREA after deducting the amount of N found in the NPSZn.

No.	NPSZn (kg ha^{-1})	UREA (kg ha^{-1})
1	0	0
2	75	46.09
3	75	61.52
4	75	76.96
5	100	46.09
6	100	61.52
7	100	76.96
8	125	46.09
9	125	61.52
10	125	76.96

A full dose of NPSZn fertilizer was applied at planting time while N fertilizer was applied at knee height period for the N adjusted. The plot size was 3×3m ($9m^2$) and the net harvested plot area was $9m^2$. The spacing between replications and plots were 1 and 0.5m, respectively. The intra and inter row spacing were 25 cm x 75cm, respectively. Seed of improved Melkasa-2 maize variety was sown for both locations with the recommended seed rate of 25kg ha^{-1} at depth of 10 cm. All recommended cultural practices (plowing, digging and weeding) for the test crop was done as per the recommendation of the area.

Soil sampling and analysis

Soil samples was collected randomly from 0-30 cm depth from the experimental field before planting, the soil samples was collected from the entire area using a zigzag sampling technique. A Disturbed of composite soil sample was taken to laboratory for physico-chemical propertiesanalysis. The sample was analyzed for soil pH, Total Nitrogen (TN), Organic Matter (OM), Available Phosphorus and Electrical Conductivity (EC) atBedele soil research centerfollowing standard analytical procedures.

Crop data collection and Analysis

The plant and plot basis data was recorded from the three central rows out of the five rows per plot. The data collected include plant height (cm), days to 50% (tasseling and silking), days to 90% maturity, number of cobs per plant, cob length (cm), number of kernel rows per cob, hundred grain weight (g) and grain yield per hectare (kg) were collected.

Plant height (cm) of five randomly selected plants per plot was measured from ground level to the point where the tassel started branching and the mean value was taken as plant height. Days to 50% (tasseling and silking) and 90% physiological maturity of the crop was recorded when the plants in the plot reached to their respective phonological stages. The number of cobs of five randomly taken plants was counted from the central three rows of each plotand the average was recorded. Cob length was measured from five randomly selected plants per plot after harvest and the average value was recorded for each plot. The number of kernel rows per cob was counted on five representative ears and the average value was recorded for each plot. Hundred grain weights was determined by counting and weighing from the bulk of shelled grain at 12.5% moisture level and expressed in grams for each plot. Grain yield was determined by harvesting the entire net plot area and converted into kilogram per hectare.

The collected data were subjected to statistical analysis of variance (ANOVA) using Genstat 15th edition. Significant difference between and among treatment means were assessed using the least significant difference (LSD) at 5% level of probability.

RESULTS AND DISCUSSION

Physicochemical Properties of Soil

Soil samples collected and analyzed from the experimental fields before planting for some selected soil properties (Table 2).

Table 2: Physical and chemical properties of soil in the experimental sites before planting

Soil Property	Boko	BalinaArba	Discribtion	Reference
Soil texture (%)	28 Sand 48 clay 24 silt	32 Sand 50 clay 18 silt	Clay	
pH	7.95	7.85	Slightly alkaline	
TN (%)	0.09	0.08	Low	Tekalign, 1991
OM (%)	2.84	3.46	High	Tekalign, 1991
Ava. P (ppm)	1.27	1.2	Very low	Olsen et al., 1954
CEC (meq/100g)	19.08	14.43	Medium	Landon, 1991

Where pH-power of hydrogen, TN=Total nitrogen, OM= Organic matter, Ava. P= Available phosphorus, E.C= Electrical conductivity and CEC= Cation exchange capacity

The soil sample from sites of Boko and BalinaArbaweredominated by clay textural class having an approximately average proportion of sand (28%), clay (48%) and silt contents (24%), and sand (32%), clay (50%) and silt contents (18%), respectively (Table 2). The average pH value of soils of the study sites were 7.95 and 7.85 for Boko and BalinaArba respectively (Table 2). The average pH of sampled soil was fall in the rating of moderately alkaline at both study locations().The surface soil of the study areas exhibited an average Soil electrical conductivity (EC) of 1.19 and 1.37(mmhos/cm) for Boko and BalinaArba, respectively. Soil organic matter (OM) contents of the study sites were 2.84 and 3.46 %, respectively for Boko and BalinaArba (Table 2). The average value of total nitrogen contents of the soils of the study sites of Boko and BalinaArba were 0.09 and 0.08%, respectively (Table 2). The average available phosphorus of soils of the study sites were measured with 1.27 and 1.2 ppm for the sites of Boko and BalinaArba, respectively (Table 2). The Cation exchange capacity (CEC) contents of the study sites were measuredwith values of 19.8 and 14.43 (meq/100g) for Boko and BalinaArba respectively.

Crop Phenology,Growth, Yield and Yield Component Parameters

The combined data analysis of variance(ANOVA) revealed thatsignificance differences (P< 0.05) and non-significance differences (P> 0.05) were observedamong combined fertilizer application of NPSZn with nitrogen.Significance differences were recorded ondays to 50% tasseling,days to 50%Silking,days to 90% physiological maturitywhilenotsignificantly different onplant height (Table 3).The combined data analysis of variance also showed that significance variations were observed on number of cobs per plant,cob length,number of kernel rows per coband grain yield whereassignificantly notdifferent onhundred grain weight (Table 4).

Table 3: Combined mean squares from analysis of variance (ANOVA) of measured phenology and growth parameters

		Mean Square			
Source of variation	d. f.	DT	DS	DM	PH
Rep stratum	2	10.08	2.48	2.03	950.5
Treatment	9	12.60**	42.75**	17.95**	291.30ns
Year	1	728.02**	7631.02**	720.00**	7439.10**
Location	2	598.53**	258.13**	842.70**	4664.60**
treatment*Year	9	4.80*	27.07ns	4.14ns	53.50ns
treatment*Location	18	1.74ns	3.28ns	1.61ns	29.60ns
Residual	48	2.25	15.08	4.24	179
Mean		70.11	86.61	127.2	155.5
LSD		1.42		1.95	12.68
CV (%)		2.1		1.6	8.6

* Significant, ** highly significant at 5% probability level, where, CV-coefficient, ns= none significant, Df= degree of freedom, DT= days to 50% tasseling, DT= days to 50% Silking, DM= days to physiological maturity, PH= plant height

Table 4: Combined mean squares from analysis of variance (ANOVA) of measured yield and yield component parameters

		Mean Square				
Source of variation	d. f.	CPP	CL	KRPC	HSW	GYha-1
Rep stratum	2	0.48	1.17	2.84	63.51	5372192
Treatment	9	1.30**	13.46**	8.30**	16.36ns	1732650**

Year	1	0.67*	16.70**	8.02*	766.05**	24466136**
Location	2	0.01ns	7.42*	0.03ns	104.53**	5808253*
treatment*Year	9	0.40*	1.31ns	1.65ns	4.38ns	1001613ns
treatment*Location	18	0.084ns	1.65ns	0.70ns	1.83ns	454190ns
Residual	48	0.12	1.94	2.1	11.65	1185323
Mean		1.422	16.6	13	23.8	3840
LSD		0.33	1.32	1.4	3.23	984.3
CV (%)		24.3	8.4	11.3	14.4	27

* Significant, ** highly significant at 5% probability level, where, CV-coefficient, ns= none significant, Df= degree of freedom, CPP= number of cobs per plant, CL= cob length, KRPC= number of kernel rows per cob, HGW= hundred grain weight, GY kg ha^{-1}= grain yield (kg/ha)

Plant Height

Analysis of variance showed that there were no significant variations (p >-0.05) among the combined fertilizer rates of NPSZn with N on plant height.Howeverthere was significantly increased plant height as compared to the control (unfertilized plots). The taller combined mean of plant height (161.00 cm) was recorded from plots fertilized with 100 kg NPSZnin combination with35.4 kg Nha^{-1} whereas the shortest plant height was recorded from plots without fertilizer (Table 5). This result implied thateven though there is no significant difference among combined fertilizer rates, plantheightis more responsive to highest N rate.The result showed that plant height increased as N rate increased, this could be attributed to a more fact that higher rates of nitrogen may have caused rapid cell division and elongation. The tallest plant height recorded at highest N rate might be nitrogen has beneficial effect on plant metabolism which affects physiological process of the crop and thereby increases the growth parameters (Jeet*et al*., 2012). Nitrogen helps in maize plant growth & zinc helps in enzymes metabolism and faster cell divisions, cell elongation and ultimately increases plant height. The increment in plant height is due to the nitrogen usage by plants in active cell division to form building blocks for cell expansion (Ullah*et al*., 2015). Similarly, Chimdessa, (2016) also reported that application of blended fertilizer was significantly increased plant height as compared to the recommended NP fertilizers and the control.Similarly more vegetative development by nitrogen resulted in increased mutual shading and intermodal expansion (Asif *et al*., 2013).

Table 5: Combined mean values of days to 50% tasseling, 50% silking, 90% maturity and plant height of Maize

Treatment	PH	DT	DS	DM
0NPSZnX0N	141.80b	73.22c	91.67c	130.80b
75NPSZnX21.2N	160.80a	69.56ab	85.89ab	127.20a
75NPSZnX28.3N	153.40ab	69.89ab	87.44ab	127.40a
75NPSZnX35.4N	157.40a	70.00ab	86.22ab	127.00a
100NPSZnX21.2N	158.30a	68.78a	84.67a	126.00a
100NPSZnX28.3N	154.4ab	70.00ab	86.22ab	125.70a
100NPSZnX35.4N	161.00a	70.11ab	85.33ab	126.80a

125NPSZnX21.2N	158.10a	69.44ab	85.00a	127.40a
125NPSZnX28.3N	158.00a	69.67ab	84.89a	126.20a
125NPSZnX35.4N	151.60ab	70.44b	88.78bc	127.40a
Mean	155.5	70.11	86.61	127.2
LSD	12.68	1.421	3.68	1.95
CV (%)	8.6	2.1	4.5	1.6

Where, means followed by the same letters are not significantly different (P≤0.05), CV-coefficient of variance, NS-non-significance

Days to 50% Tasseling

The results of analysis of variance showed that there was significant difference ($P \leq 0.05$) among combined fertilizers rates ondays to 50% tasseling. Early tasseling (68.78 days) was recorded with plots fertilized with100 kg NPSZnin combination with21.2 kg N ha^{-1} whereas the longest days to 50% tasseling(73.22days) was recorded for unfertilized plots(Table 5).Combined fertilizer application of 100 kg NPSZn with21.2 kg N ha^{-1}hastened days to tasseling by 4.44 days as compared to the control. The result suggested that availability of sufficient nutrient in the soil for plant uptake promoted vigorous vegetative growth and development of the plants. This decrease in days to tasseling with the combined application of NPSZn with N fertilizer might be attributed to the impact of positive interaction with other nutrients. It was observed that NPSZn with different rates of nitrogen might have encouraged early establishment, rapid growth and development of crop thus; shortening the days to tasseling. This may be due to the effect of fertilizers on tasseling of maize. Similarly, Bakala (2018) found that 50% tasseling to be significantly affected by the application of blended fertilizer rates.

Days to 50% Silking

Silking of maize was significantly affected ($P \leq 0.05$) by combined fertilizer application of NPSZn with N. Early silking (84.67days) was recorded with plots fertilized with100 kg NPSZnin combination with21.2 kg N ha^{-1}(Table 5).However, the maximum number of days to attain silking (91.67 days) was observed under control(unfertilized) plots (Table 4).The result showed that combined fertilizer application of 100 kg NPSZnwith 21.2 kg N ha^{-1}hastened days to silking by seven days as compared to control. This implies the combination of NPSZn with N fertilizer might have encouraged early establishment, rapid growth and development of crop thus; shortening the days to silking. The other reason could application of N fertilizer applied at different rate to all treatment of NPSZn fertilizer and thus effect of N was significant. Our result was similar with,Dagne (2016) who found that days to silking were significantly affected by the application of blended fertilizers. Bakala (2018) also found that 50% silking, tasseling and maturity to be significantly affected by the application of blended fertilizer.

Days to 90% Maturity

The result suggested that, days to 90% physiological maturity were significantly affected ($P \leq 0.05$) by combined fertilize rates of NPSZn and N. The combined fertilizer application of NPSZn and N ratehas significantly reduced days to maturity as compared to the control.Early maturity (126 days)was recorded with the plots fertilized with100 kg NPSZnin combination with21.2 kg N ha^{-1}(Table 5). Accordingly, the maximum days to attained 90% physiological maturity (130.8 days) was recorded under unfertilized plots(Table 4). Compared to the control, mean values of days to maturity was decreased by five days due to the rate of 100 kgNPSZnha^{-1} combined with the rate of 21.2kgN$ha^{-1.}$ The result showed that combined fertilizer application of NPSZn with Nwas related with rapid growth and hastened maturity of maize, this might be due to the presence of Zn fertilizer in the NPSZn blended fertilizer. In conformity with the results obtained from this study, Bakala (2018) found that days to 50% maturity to be significantly affected by theapplication of blended fertilizer rates.

Number of Cobs per Plant

The mean values and analysis of combined fertilizer of NPSZn and N on number of cobs per plantrevealed significant difference ($p \leq 0.05$) among fertilizers rates.The maximum combined mean of number of cobs per plant (2.01) was recorded from combined application of 100 kg NPSZn with35.4 kg Nha^{-1}while the lowest number of cobs per plant(1.00) was recorded forcontrol plots (Table 6).The result showed that increasingNPSZn levelfrom 0 to 100kg ha^{-1} and N level from 0 to 35.4kg ha^{-1} significantly increased the number of cobs per plant from 1.00 to 2.00. This implied thatcombined fertilizer of 100 kg NPSZn and 35.4 kg Nha^{-1} increased number of cobs per plant by 50% over the control plots.The result was corroborated by the findings of Matusso, (2014) who reported that increasing nitrogen level from 50 to 300 kg ha^{-1} significantly increased the number of ears per plant from 1.2 to 2.05.

Cob Length

The combined fertilizer rate of NPSZn and N was significantly influenced ($p \leq 0.05$) cob length.The taller combined mean of cob length (18.04cm) was recorded from combined application of100 kg NPSZn with35.4 kg ha^{-1} while, the shortest cob length (13.48cm) was recorded from the control treatment (Table 6). The result showed that as NPSZn increased from 0 to 100 and N increased from 0 to 35.4kg ha^{-1}, cob length increased from 13.48 to 18.04cm.Similarly, combined fertilizer rate of NPSZn and N increased cob length by25.28% over the control treatments. The cob length increment with the combination ofNPSZn and N fertilizer might be attributed to good photo assimilate supply. The maximum assimilate supply should be available during maize grain filling (Arif*et al*., 2010). The two to three week period after 50% silking as critical stage in the development of maize that is highly dependent on assimilate supply; the period when final kernel number is determined (Haney *et al*., 2015).

Number of kernel rows per cob

The combined data analysis of variance showed that there wassignificant difference ($p \leq 0.05$) among fertilizers rates onnumber of kernel rows per cob. The highest combined mean on number of kernel rows per cob (14.00) was recorded from combined application of 100 kg NPSZn with21.2kg N ha^{-1} whereas the lowest number of kernel rows per cob (10.67) was recorded from control (unfertilized treatment) (Table 6). The result showed that as NPSZn increased from 0 to 100 and N increased from 0 to 21.2kg ha^{-1},the number of kernel rows per cob increased from 10.67 to 14. This indicated thatcompared to the control treatment, mean values of number of kernel rows per cob was increased by 23.8% due to thecombined fertilizer application ofNPSZn and N.

Table 6: Combined mean of number of cobs per plant, cob length, number of kernel rows per cob, hundred grain weight and grain yield

Treatment	CPP	CL (cm)	KRPC	HGW (g)	GY (kgha^{-1})
0NPSZnX0N	1.00d	13.48c	10.67c	20.86b	2475a
75NPSZnX21.2N	1.11cd	16.15b	13.78a	23.7ab	3727b
75NPSZnX28.3N	1.11cd	16.89ab	12.22b	24.11a	4240b
75NPSZnX35.4N	1.56b	17.07ab	13.78a	24.87a	4359b
100NPSZnX21.2N	1.01d	16.74ab	14.00a	23.46ab	4061b
100NPSZnX28.3N	1.56b	16.59b	12.89ab	22.8ab	3492ab
100NPSZnX35.4N	2.01a	18.04a	12.89ab	24.08ab	4348b
125NPSZnX21.2N	1.56b	17.28ab	12.67ab	24.97a	3447ab
125NPSZnX28.3N	2.00a	16.81ab	12.89ab	23.2ab	4136b
125NPSZnX35.4N	1.333bc	17.41ab	13.11ab	25.68a	4118b
Mean	1.422	16.6	13	23.8	3840
LSD	0.3269	1.32	1.4	3.23	984.3
CV (%)	24.3	8.4	11.3	14.4	27

Where, Where, means followed by the same letters are not significantly different ($P \leq 0.05$), CV-coefficient of variance, NS-non-significance, CPP- Cop per plant, CL- Cob length, KRPC= kernels row per cob, GY- Grain yield, HGW- Hundred grain weight

Hundred Grain Weight

The result of analysis of variance showed that there was no significant difference (P >- 0.05) among fertilizers rates on hundred grain weight of maize. Howeverthe highest combined mean value of hundred grain weight (25.68g) was obtained from combined application of 125 kg NPSZn with 35.4 kg N ha^{-1} while, the lowest (20.86 g) was obtained from untreated (control)plots (Table 6).The combined mean value of hundred grain weightwas increased by 18.77% as compared to the control. The result showed that hundred grain weight increased from 20.86 to 25.68g as NPSZn increased from 0 to 125 and N increased from 0 to 35.4kg ha^{-1}. Finally the heavier grains and more hundred grains weight were achieved from the highest rate of NPSZn and N.This implied the direct or indirect effects ofnutrients in the NPSZn and N attributed positive interaction on hundred grain weight and other morphological and physiological parameters of maize.The production of more assimilates as a result of the synergistic effect of nitrogen and zinc finally formed heavier grains and more thousand grains weight was achieved.It is the imperative yield dependent parameter. It expresses the magnitude of seed formation and development. Tariq *et al*. (2002) also presented that maize yield factors and yield was positively amplified by zinc application. Sharar*et al*. (2003) had confirmed that on this trait there was influential effect of zinc along with nitrogen as well.

Grain Yield

Analysis of variance showed that there were significant differences ($p \leq 0.05$) among the combined fertilizer rates of NPSZn and N on grain yield.The highest grain yield(4359kg ha^{-1}) was obtained from combined application of75 kg NPSZn with35.4 kg ha^{-1}and nearly followed by (4348 kg ha^{-1}) which obtained fromcombined application of100 kg NPSZn with 35.4 kg ha^{-1} whereasthe lowest grain yield (2475kg ha^{-1}) was obtained from plots treated without fertilizer (Table 6).Combined mean of grain yield had 43.22% yield advantagecompared to the control treatment. The increase in grain yield was probably due to the encouragement in photosynthesis, rapid growth and formation of heavy green foliage by NPSZn and N effectiveness which in turn produced more yield. Application of NPSZn fertilizer increased total grain yield in combination with N doses.Our result was similar with (Coelho, 2004)findings who concluded that under appropriate levels of other nutrients in the soil, nitrogen provides the greatest increment to maize yield. Application of zinc increase total grain yield in combination with high nitrogen doses(Rafiq*et al.*, 2010).Saeed *et al.* (2010)&Mukhtar*et al.* (2011) stated grain total yield got affected by nitrogen.

Partial Budget Analysis

As it were presented in Tables 7, the net farm benefit was calculated taking possible field variable costs and grain yields benefits for the study areas. The maximum farm net benefit was 52748.9ETB ha^{-1} obtained from the combined application of 75 kg NPSZn with 28.3 kg N ha^{-1}. The partial budget analysis revealed that the combined application of 100 kg NPSZn with 35.4 kg N ha^{-1}was resulted in highest marginal rate of return with values of 12822.71%. These values implied that with one ETB cost it was attained 128.23ETB profit. Therefore, the combined application of 100 kg NPSZn with 35.4 kg N ha^{-1}can be recommended for the production of improved maize for the study areas.

Table 7: Partial budget analysis of grain yield of maize under the effect of different combined NPSZn and N fertilizer rates for Boko.

Treatment	**VC**	**YLD**	**GYLD**	**GYGR (ETB)**	**B (ETB)**	**IRR%**
NPSZnX0N		475	227.5	1185	1185	
5NPSZnX21.2N	730.65	727	354.3	6960.2	5229.55	11.52
5NPSZnX28.3N	952.5	240	816	3424	1471.5	813.59
00NPSZnX21.2N	086.65	061	654.9	1168.6	9081.95	[illegible]
5NPSZnX35.4N	174.5	359	923.1	4923.4	2748.9	174.10
00NPSZnX28.3N	308.5	492	142.8	3999.2	1690.7	[illegible]
25NPSZnX21.2N	442.65	447	102.3	3432.2	0989.55	[illegible]
00NPSZnX35.4N	530.5	348	913.2	4784.8	2254.3	[illegible]
25NPSZnX28.3N	664.5	136	722.4	2113.6	9449.1	[illegible]

25NPSZnX35.4N	886.5	118	706.2	1886.8	9000.3	

Where, TVC=total variable cost, GY=grain yield, ADGY=adjusted grain yield, TGYGR=total grain yield gross return, NB=net benefit, MRR=marginal rate of return, ETB=Ethiopian birr, D=dominated. **N.B.** Urea=14.38 ETB/1kg, NPSZn=14.24 ETB/1kg, maize grain=14ETB/1kg.

SUMMARY AND CONCLUSION

According to the combined mean analysis combined fertilizer rates of NPSZn and N revealed significance difference on grain yield. The highest grain yield (4359kg ha^{-1}) and nearly followed (4348 kg ha^{-1}) was obtained from plots fertilized with the higher N application rate (35.4 kg). Combined fertilizer application of 75 NPSZn kg with 35.4 N kg $ha^{-1}$was produced the highest grain yield and closely followed by combined fertilizer application of 100 NPSZn kg with 35.4 N kg ha^{-1}. The result of partial budget analysis suggested that the higher marginal rate of return (12822.71%) was obtained from the combined application of 100 NPSZn kg with 35.4 N kg ha^{-1}. Therefore, based on this result it can be concluded that the combined application of 100 kg NPSZn with 35.4 kg N ha^{-1}can be recommended in the study areas and for other similar agro-ecologies it can beagronomically optimum and economically affordable levels to increase improved maize production.

ACKNOWLEDGEMENT

The author acknowledgesOromia Agricultural Research Institute, Fadis Agricultural Research Center for financing and providing working facility. We would like also to thanks Fadis district bureau of agriculture for their assistance in facilitating our work. Our special thanks also go to BalinaArba village of Fadisdistrict farmers who helped us in giving the farm land and managing our trial work.

REFERENCE

Ali,J., Bakht, J., Shafi, M., Khan, S. and Shah, W.A. (2002) Effect of N and P on Yield Components of Maize. Pakistan Journal of Agronomy, 1, 12-14. http://dx.doi.org/10.3923/ja. 2002.12.14 . http://dx.doi.org/10.3923/ja.2002.12.14

Andrade, A. C., Fonseca, D. M., Queiroz, D. S., Salgado, L. T. and Cecon, P. R. 2003. Elephant grass nitrogen andpotassium fertilization (PennisetumpurpureumSchum. cv. Napier). *Ciência e Agrotecnologia, Lavras*, p. 1643-1651.

Arif, M., I. Amin, M. T. Jan, I. Munir 3, K. Nawab, N. U. Khan, and K. B. Marwat, 2010. Effect of Plant Population And Nitrogen Levels And Methods of Application on Ear Characters and Yield of Maize. *Pakistan Journal of Bot*any, 42 (3): 1959-1967.

Asif, M., M.F. Saleem, S.A. Anjum, M.A. Wahid and M.F. Bilal, 2013. Effect of nitrogen and zinc on growth and yield of maize (*Zea mays* L.). J. Agric. Res., 51(4): 455-464.

ATA (Agricultural Transformation Agency), 2015. Soil Fertility Mapping and Fertilizer Recommendation in Ethiopia: *Update of EthioSIS project and status of fertilizer blending plants 24-26 Hawasa, Ethiopia.*

Bakala A (2018). Soil characterization and response of maize (*Zea mays* L.) to application of blended fertilizer types and rates in Asossadistrict, Western Ethiopia. Unpublished MSc Thesis, HaramayaUniversity, Ethiopia.

Basso, C.J., Ceretta, C.A. 2000. Manejo do nitrogênio no milhoemsucessãoaplantas de cobertura de solo,sobplantiodireto. 2000. *Revistabrasileira de ciência do solo*, 24:905-915.

Basso, C.J., Ceretta, C.A. 2000. Manejo do nitrogênio no milhoemsucessãoaplantas de cobertura de solo,sob

BentiTolessa, 1993. The need an objective of the 1stNational Maize Workshop. In: Proceedings of the 1stNational Maize Workshop of Ethiopia. 5-7 May, 1992, IAR and IMWIC, Addis Ababa, Ethiopia.

Chimdessa, D. (2016). Blended fertilizers effects on maize yield and yield components of Western Oromia, Ethiopia. Agriculture, Forestry and Fisheries, 5(5), 151–162. https://doi.org/10.11648/j.aff.20160505.13

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

DagneChimdessa, 2016. Blended Fertilizers Effects on Maize Yield and Yield Components of Western Oromia, Ethiopia. Agriculture, Forestry and Fisheries. Vol. 5, No. 5, 2016, pp. 151-162.

Delorite, R. J. and H. L. Ahlgren, 1967. Crop Production. (3rded). Prentice Hall,Inc., Englewood Cliffs, New Jersey. Different Phosphorous Level on the Yield and Yield Component of Maize. Sarhad Journal of Agriculture, 27, 167-170.Singh A. K., Singh G. R. and Dixit R. S., 1997. Influence of plant population and moisture regimes on nutrient uptake and quality of winter maize (Zea mays). Indian Journal of Agronomy. 42(1): 107-111.

FAO (Food and Agriculture Organization), 2000. Fertilizers and their use. International Fertilizer Industry Association. Food and Agriculture Organization of the United Nations Rome, Italy.

Foth, H. D. and B. G. Ellis, 1997. Soil Fertility, (2nded). Lewis Publishers, Boca Raton, Florida. 290p.

Haney, R. L., Haney, E. B., Smith, D. R. and White, M. J. (2015) Estimating Potential Nitrogen Mineralization Using the Solvita Soil Respiration System. *Open Journal of Soil Science*, 5, 319-323.

Harris D, Rashid A, Mira G, Arif M, Shah H (2007) ‘On-farm’seed priming with zinc sulphate solutiona cost-effectiveway to increase the maize yields of resource-poor farmers.Field Crops Res 102:119–127

Ho, C. T., 1992. Results of fertilizer trials conducted on major cereal crops by ADD/NFIU. Joint Working Paper No. 43. Addis Ababa, Ethiopia. 83p.

Jeet, S., Singh, J. P., Kumar, R., Prasad, R. K., Kumar, P., Kumari, A., & Prakash, P. (2012). Effect of nitrogen and sulphur levels on yield, economics and quality of QPM hybrids under dry land condition of eastern Uttarpradesh, India. Indian Journal of Agricultural

Khan, F., khan, S., Hussain, S., Fahad, S. and Faisal, S. (2014) Different Strategies for Maintaining Carbon Sequestration in Crop Lands. Scientia Agriculture, 2, 62-76.

Masood, T., Gul, R., Munsif, F., Jalal, F., Hussain, Z., Noreen, N., Khan, H. and Nasiruddin, K.H. (2011) Effect of

Masood., T. Naz, M . Javed, I. Ahmad, H. Ullah and M. Iqbal, 2014. Effect of short term supply of nitrogen and farm yard manure on maize growth and soil parameters. Archives of agronomy and soil science, 60(3): 337-347.

Matusso J (2014). Growth and Yield Response of Maize (*Zea mays* L.) to Different Nitrogen Levels in Acid Soil. Academy Research Journal Agriculture Sciences Research 4(2):35-44.

McDonald AH, Nicol JM (2005) Nematode parasites of cereals. In: Luc M, Sikora RA, Bridge J (eds) Plant parasitic nematodes in subtropical and tropical agriculture. CABI Publishing, Wallingford, pp: 131-191.

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.

Mukhtar, T., M. Arif. S. Hussain, M. Tariq and K. Mehmood, 2011. Effect of different rates of nitrogen and phosphorus fertilizers on growth and yield of maize. J. Agric. Res., 49(3): 333-339. plantiodireto. 2000. *Revistabrasileira de ciência do solo,* 24:905-915.

Rafiq, M.A., A. Ali, M.A. Malik and M. Hussain, 2010. Effect of fertilizer levels and plant densities on yield and protein contents of autumn planted maize. Pak. J. Agri. Sci., 47(3): 201-208.

Saeed, M., A. Khaliq, Z.A. Cheema and A.M. Ranjha, 2010. Effect of nitrogen levels and weed-crop competition durations on yield and yield components of maize. J. Agric. Res., 48(4): 471-481. Sciences, 4(9), 31–38. doi: 5539/jas.v4n9p31

Shah, S., Talat, H., Zamir, M., Shahid, I., Waseem, M., Ali, A., & Khalid, W. B. (2009). Growth and yield response of maize (Zea mays L.) to organic and inorganic sources of nitrogen. Pakistan Journal of Life Society Science, 7(2), 108–111.

Sharar, M.S., M. Ayub, M.A. Nadeem and N. Ahmad, 2003. Effect of different rates of nitrogen and phosphorus on growth and grain yield of maize. Asian J. Pl. Sci., 2(3): 347-349.

Siwale J, Mbata K, Microbert J and Lungu D. 2009. Comparative resistance of improved maize genotypes and landraces to maize weevil. African Crop Sci. J., 17(1):1-16.

Stewart, W. M., D. W. Dibb, A. E. Johnston and T. J. Smyth, 2005. The contribution of commercial fertilizer nutrients to food production. Agron J.97: 1-6.

Tariq, M., M.A. Khan and S. Perveen, 2002. Response of maize to soil applied zinc (Zn). Asian J. Pl. Sci., 1 (4): 476-477.

Ullah, M.I., A.A. Khakwani, M. Sadiq, I. Awan, M. Munir and Ghazanfarullah, 2015. Effects of nitrogen fertization rate on growth, quality and economic return of fodder maize (*Zea mays* L.). Sarhad J. agric., 31(1): 45-52.

Wang, J., H. Mao, H. Zhao, D. Huang and Z. Wanga, 2012. Different increases in maize and wheat grain zinc concentrations caused by soil and foliar applications of zinc in Loess Plateau, China. Elsevier J. Field Crops Research, 135: 89-96.

Effect of Row Spacing on Growth, Yield and Yield Related Components of Early and Medium maturing Sorghum Varieties [*Sorghum bicolor* (L.) Moench] in West Hararghe Zone

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Abstract

Just add some constraints that challenged sorghum production in areas of your study
The objective of this study was to evaluate the agronomic characteristics of early and medium maturing sorghum varieties for row spacing in DaroLebu district West Hararghe zone. Hence, an experiment was carried out on the Experimental Farm at Mechara on station during the main cropping season (2018 and 2019), under rain fedcondition. Two sorghum varieties (Grana-1 and Dagim) cultivated at 45, 55,65, 75, and 85 cm row spacingwere laid out in a randomized block design with three replication with two by five treatment combinations (2 × 5). Grana-1 variety had recorded the highest(4652 kgha^{-1})mean grain yield at 45 cm row spacing whereasDagimrecorded the highest(4874 kg ha^{-1}) grain yield at row spacing of 55cm. Based on the results, it can be concluded that Grana-1 variety is recommended for cultivation at 45cm and Dagim at 55cm rows pacing as they performed better and gave higher yield and showed good agronomic characteristics.

Key words: *Plant density; nitrogen; grain yield; Sorghum.*

Introduction

Sorghum is a particularly essential crop in Africa andsecond to maize, as the staple grain for millions of people. Although it is mainly consumed as a grain, sorghum is also prepared into a wide variety of other food products such as porridges, breads, lactic and alcoholic beverages, and weaning meals(). Sorghum is one of the most important cereal crops planted as food insurance, especially in the moisture deficit lowlands of eastern, northern and north-eastern parts of Ethiopia where the climate is characterized by unpredictable drought and erratic rainfall (Degu*et al*. 2009).

It is also one of the most important cereal crops of the tropics grown extensively over wider areas with altitude ranging from 400 to 3000 meters above sea level m.a.s.l due to its ability to adapt the adverse environmental conditions. 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).In Ethiopia, a total of 5.2 million tons of sorghum is being produced per annum. The mean yield level in the country is estimated at 2.7 t ha^{-1}. Out of the total grain cropped area, sorghum accounts about 14.96% (1,896,389.29) hectares with production of (51,692,525.40 quintals) of the grain crops produced in the 2017/18 post-harvest survey of Meher Season (CSA, 2018). Wortmann*et al*. (2006) reported that drought, low soil fertility (nutrient deficiencies), insect stem borers, insect shoot fly, quelea birds, Striga, poor agronomic management practices and weeds management were recognized as major production constraints affecting sorghum in eastern Africa.

In the lowlands of Ethiopia, the traditional farming practice relies entirely on a rain-fed crop production system, which is characterized by poor crop performance and low yields. The major factors responsible for poor yields include moisture stress, low soil fertility, *Strigahermonthica*, and the limited access to improved seed and efficient production technologies. The national average grain yield of cereals in Ethiopia is relatively low amounting to about 1.7 t $ha^{-1}$for tef 2.1 t $ha^{-1}$for barley, 2.7 t $ha^{-1}$for wheat, 3.8 t $ha^{-1}$for maize, 2.5 t $ha^{-1}$for sorghum, and 2.8 t $ha^{-1}$for rice in 2016 (CSA, 2017). This, amongst others, is due to the widespread use of low yielding varieties coupled with unimproved traditional practices that ultimately contribute to the low national average yield of major cereal in the country. Crop production might be increased without increasing the cultivated area mainly due to the use of cultivars with greater productive potential as well as the appropriate cultivation management. The arrangement of plants can be accomplished by altering the number of plants in the row and the spacing between the planting rows, to increase the yield and to improve the distribution of the plants in the area. This can increase the efficient use of water, solar radiation, and the nutrients available, as well as control weeds. These studies provide information on how to reduce intraspecific competition and maximize the use of environmental resources (Bellaloui*et al*., 2015; Souza *et al*., 2016; Costa *et al*., 2017; Silva et al., 2018). Plant spacing plays an important role on growth, development and yield of cereal crops. Optimum plant spacing ensures that plants grow properly with theaerial and underground parts by utilizing more sunlight, water, soil nutrients and pest control (Miah *et al*., 1990).These relationships are also important for optimal physiological function of the crop. In sorghum, yield is a function of the number of grains per panicle, 1000 grains weigh and harvest index. Optimizing plant density is very important for improving seed yield in a particular environment. As many studies have undertaken by different researchers it showed that grain yield is greatly increased through plant density increase and the yield is fixed in a range of density and through more increase in plant density intense competition between plants decreases the yield (Pandey *et al*., 1999).

In Oromia region, especially HarargheZonewhere this research was conducted, the yield of sorghum is very low (22.05 $quintalsha^{-1}$) as compared toTigray region (24.24 $quintalsha^{-1}$) and national yield average (21.06 $quintalsha^{-1}$)(). In this zone, though more than 23,698 ha of the area are covered with sorghum, there is no recommended plant spacing and farmers have been sown higher plant populations per specific unit of area through broadcasting methods. From different agronomic practices that limit the production of sorghum, lack of optimum plant population (in appropriate spacing) is the main factors that reduces yield of sorghum. Closer spacing hampers intercultural operations and in a densely populated crop, the inter-plant competition for nutrients, air and light is very high, which usually results in mutual shading, lodging and thus favours more straw yield than grain yield(Bhowmik*et al*, 2012).

According to (Lopez-Bellido*et al* 2003) as plant density increases, competition between plants becomes more intense, affecting the growth, development and production of each plant. Therefore the objectives of these studies are to evaluate the effects of spacing on growth of sorghum and to have appropriate plant spacing.

Materials and Methods

Description of the Study Area

DaroLebu is one of the districts found under West Hararghe Zone. The district is situated between 7º52'10" and 8º42'30" N and 4 º023'57" and 41º9 '14" E. at 08º35'.589"North and 40º 19'114"East. The district is characterized mostly by flat and undulating land features

with altitude ranging from 1350 to 2450 m.a.s.l. and ambient temperature of the district ranges from 14to 26^{0}C with average of temperature16^{0}C and an average annual rainfall of 963 mm per year.
The pattern of rain fall is bimodal and its distribution is mostly uneven. Generally, there are two rainy seasons: the short rainy season ‘Belg’ lasts from mid-February to April whereas the long rainy season ‘kiremt’ is from June to September. The rainfall is erratic; onset is unpredictable, its distribution and amount are also quite irregular. Consequently, most kebeles frequently face shortage of rain, hence moisture stress is one of major production constraints in the district (DLDoANRO, 2016). The district has an estimated total population of 239, 222 of whom 122, 386 were males and 116,836 were females; 23,609 of its population were urban dwellers, whereas 215, 613 were rural dwellers (CSA, 2013).

Treatments and Experimental Design
This trial was conducted from 2018 to 2019 cropping season at Mechara on station by using early (Grana-1) and medium maturing sorghum (Dagim) varieties as a test materials for this experiment. The trial was laidout in RCBD design with 3 replications and the sorghum varieties were planted on a gross plot area of 3.75 m x 3m at plant spacing of 25cm as well as 0.75m between plots and 1m among plots were used. Sorghum varieties were randomly assigned to experimental units.Tentreatmentsarranged in factoralcombination with two varities and five spacing (45556575 and 85cm). The necessary trial management practices:land preparation, field layout and leveling,planting, hoeing,weeding as well as Fertilizer application at the rate of 100/100 kg ha^{-1} of N and NPS once at planting and Urea was applied in split application half at planting and the remaining half after 45 days of the seedling growth stages was done.

Table 1Treatments Combination

Treatment Combination	Intra-row spacing(cm)	Treatment Combination
V_1S_1	45	V_2S_1
V_1S_2	55	V_2S_2
V_1S_3	65	V_2S_3
V_1S_4	75	V_2S_4
V_1S_5	85	V_2S_5

V1= Sorghum variety Grana-1 early maturing **V2**=Sorghum variety Dagim medium maturing variety, **S1**= Intra row spacing one (45cm**)** **S2**= Intra row spacing (55cm) **S3**= Intra row spacing (65cm) **S4** = Intra row spacing (75cm) **S5**= Intra row spacing (85cm))

Data Collected

Data was collected from five randomly sampled plants based on the descriptors for sorghum (IBPGR/ICRISAT, 1993). The details of the data collections are as follows:

Days to 50% flowering (days): the number of days from 50% seedling emergence to the date at which 50% of the plants in a plot started flowering.

Days to maturity (days): the number of days from 50% seedling emergence to the date at which 75% of the plants in a plot were physiologically matured.

Plant height (cm): Plant height was measured from five randomly sampled main plants from the two rows at 75% physiological maturity. The mean height from the five plants was then recorded for each plot.

Head weight (g): Head weight was measured from five randomly sampled main plants from the two rows after harvest. The mean head weight from the five plants was then recorded for the plot.

Grain yield (kg ha^{-1}): after harvesting, the panicles from the two rows of each plot were threshed, cleaned and weighed. The plot yield (g/plot) was converted to kg ha^{-1} after the standard moisture was adjusted and converted to ton/hectare.

Data Analysis

The collected data was subjected to the analysis of variance (ANOVA) using the SAS computer package version 9.1 (SAS Institute, 2004). Mean separation was carried out using least significance difference (LSD) test at 5% probability level depending on the ANOVA result as described in Gomez and Gomez (1984).

Results and Discussion

The analysis of variance result revealed that there is a significance difference between varieties and spacing for important parameters determining the main interaction effects. The combined mean results for specific variety and spacing showed a significant difference for days to flowering, maturity, head length for varieties and the other parameters like stand count at harvest, head weight and grain yield were sowed non-significantbreafly

Plant height (cm): The analysis of variance showed that neither the main effect was significant due to main effect of variety or row spacing also (sorghum variety and inter-row spacing) but their interaction was not significantly affected on plant height of sorghum. The tallest plant height was observed 185.5cm for Grana-1 variety at 45cm row spacing and 188.9cm taller plant height recorded for Dagim sorghum Variety at 55cm row spacing (Table9)

Panicle length (cm): Analysis of variance showed that panicle length of sorghum was significantly ($P< 0.05$) affected by the intra row spacing of sorghum variety. However, the interaction effect of variety with row interaction effect had not significant effect on panicle length of sorghum (Table 9). The Panicle length was significantly higher (21.6 cm) for Grana-1 sorghum variety at 85cm row spacing row and (30.1 cm) panicle length was observed for Dagim sorghum variety at 65cm intra row spacing (Table 9). The increment of panicle length could be due to less competition when plant density reduces. Similarly, Undie*et al.* (2012) indicated that cob length of maize was significantly influenced by spatial arrangement. In contrary to the present result, BerhaneSibhatu*et al.* (2015) reported that panicle length of sorghum was no significantly affected by cowpea density

Head weight (gm)
Panicle weight of sorghum was not significantly P>0.05) and highly significantly (P< 0.01)affected by the main effect intra row spacing of sorghum varieties and all interaction effects of variety with row spacing. However Grana-1 and Dagim sorghum varieties were give maximum panicle weight of 568 gm and 603 gm at intra row spacing of 75cm respectively. The lowest panicle weight was recorded for Grana-1 at intra row spacing of 85cm (473gm) and at 45cm intra row spacing for Dagim (482gm). The panicle weight of sorghum was showed an increasing manner for both varieties with row spacing increase this could be resulted from suitable condition wider rows with low nutrient competition that lead to better grain filling on the plant with full physiological growth and increases number of grains per head.

Days to 50% flowering
The statistical analysis of trial reveals that no significance effect was observed for the interaction of row spacing with varieties but row spacing and varieties were showed significance variation alone. The shortest days to flowering was observed for Grana-1 sorghum at 45cm row spacing and Dagim was showed almost similar days for days to flowering. The lateness in days to flowering for Grana-1 sorghum variety was seen at 75cm row spacing, as a whole the Grana-1 sorghum showed lateness with widening of the row space for this trait, but Dagim sorghum variety was not showed much response with increase or decrease of row spacing on days flowering.

Days 75%phsiological maturity
The response of the sorghum varieties to days to maturity statistically was significantly affected on the mean days to flowering with row spacing than interaction. Sorghum Grana-1 variety was showed lateness as the row spacing was increased but Dagim variety of sorghum did not showed an increase decrease in days to maturity.Grana-1 sorghum observed somewhat earliness in day to maturity at row spacing of 45cm and relatively longer days at row spacing of 85cm row spacing however, Dagim sorghum variety was observed minimum days to maturity at 75cm row spacing for this trait and maximum days to maturity at 85cm row spacing (137)

Grain Yield
The analysis of variance result showed significance effect due to row spacing and variety without interaction effect of the treatment for mean grain yield. The observed mean grain yield of the sorghum variety Grana-1 and Dagim was observed better in row spacing of the plant population that yield 4300kgha^{-1}, 4652 kg ha^{-1}, 4304 kg ha^{-1} and 4874 kg ha^{-1} in narrow row spacing of 55cm and 45cm row spacing respectively.

Table 2. Combined mean effect row spacing level on growth, yield and yield related components of early and medium maturing sorghum varieties at Mechara in 2018 to 2019 cropping season

Row Spacing (cm)	Days to Flowering	Plant Height	Stand count at Harvest	Maturity date	Head Weight (gm)	Head Length (cm)	Grain Yield kg ha^{-1}

			Early maturing (Grana-1)				
45	69	180.5	96.5	128.7	535	15.98	4652
55	69.5	177.6	90	130.9	581	20.3	4300
65	69.8	174.3	73.83	136.5	491	20.3	3678
75	74.2	157.1	54.33	128.3	568	14.98	2602
85	70	171.2	57.5	136	473	21.63	3193
Row Spacing			**Medium maturing Sorghum (Dagim)**				
45	85.7	179.5	94.62	134.5	482	29.66	4304
55	85	199	86.32	136.8	529	27.39	4874
65	83	168.2	85.67	136.5	540	30.1	3975
75	84.3	186.6	63.33	128.3	603	25.77	3428
85	84.5	188.9	48.83	137.3	550	29.47	3416
LSD	3.2	14.1	6.9	4.7	94	3.3	626
CV	8.1 **	15.04 Ns	17 NS	6.83 *	15.14 Ns	27.16 **	31.07 Ns

The highest combined mean grain yield of 4652 kg ha^{-1} for Grana-1 at 45cm of row spacing and 4874$kgha^{-1}$ was recorded for at 55cm row spacing for Dagim sorghum. Longer head record of 21.8cm at row spacing of 85cm and shorter 15cm was observed at 45cm for Grana-1.Dagim showed shorter head length at 75cm and relatively long at 65 row spacing.

Conclusion and Recommendation

The result of the experiment showed a promising output for important yield traits like days flowering, maturity and grain yield. The combined mean of varieties were revealed significance effects due to row spacing and better grain yield was recorded for both verities at narrow row spacing of 45cm (4652 kg ha^{-1}) for early maturing and 55cm (4874 kg ha^{-1}).Therefore, planting of early maturing sorghum (Grana-1) at narrow row spacing of 45cm and 55cm for medium (Dagim) sorghum variety was seen as the best yield maximizing option for sorghum producers.

Reference

Miah, M.H.N., M.A. Karim, and M.S. Islam.1990. Performance of Nizersail Mutants under Different Row Spacings. Bangladesh J. Train. Dev. 3(2): 31-34.

Pandey, S. and C.O. 1999. Gardner, Recurrent selection for population.Variety and hybrid improvement in tropical maize.Advances in Agronomy, 48-40.

EARO (Ethiopian Agricultural Research Organization). 2004. Directory of released crop varieties & their recommended cultural practices, Addis Ababa, Ethiopia.

Singh, B.B., O.L. Chamblis and B. Sharma, Advance in Cowpea Research.1997. Copublication of International Institute of Tropical Agriculture and Japan International Research Center for Agricultural Science, Ibadan Nigeria. .

Bhowmik, S. K, M. A. R. Sarkar, and F. Zaman. 2012. Effect of Spacing and Number of Seedlings per Hill on the Performance of *aus*rice cv. NERICA 1 under Dry Direct

Seeded Rice (DDSR) System of Cultivation. J. Bangladesh Agril Univ. 10(2): 191-195.

Reddy, M.S. and KidaneGeorgis. 1994. Overview of the dry land farming research of IAR: objective and focus. In *Development of technologies for the dry land farming area of Ethiopia*, Proceedings of the first national workshop on dry land farming research in Ethiopia. EARO, Addis Ababa, Ethiopia, 3-9. Lopez-Bellido, R. J., L.

Lopez-Bellido, F.J. Lopez-Bellido and J.E. Castillo. 2003. Fababean (Viciafaba L.) response to tillage and soil residual nitrogen in a continuous rotation with wheat (Triticumaestivum L.) under rainfed Mediterranean conditions. Agron. J. 95: 1253–1261.

Silva, T. M., Oliveira, A. B., Moura, J. G., Lessa, B. F. T., & Oliveira, L. S. B. 2018.Potential of sweet sorghum juice as a source of ethanol for semi-arid regions: cultivars and spacing arrangement effects. Sugar Tech, 20, 1-8. https://doi.org/10.1007/s12355-018-0637-8.

Effects of *Rhizobium* Inoculation and NPS rates on Yield and Yield Components of Field Pea (*Pisum sativum* L.) in Western Highlands of Oromia

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Abstract

Low soil fertility is one of the limiting factor for low productivity of field pea in western high lands of Oromia. Thus, a study was conducted to investigate the effects of Rhizobium inoculation and NPS fertilizer rates on nodulation, yield and yield components of field pea and to identify economically profitable treatment/s that can maximize the productivity of field pea in the study area. Factorial combinations of two levels of Rhizobium inoculation (No inoculation and EAL301), two field pea varieties (Jidha and Lammiif) and five levels of NPS fertilizer rates (0, 25, 50, 75, 100 kg NPS ha^{-1}) were laid out in Randomized Complete Block Design (RCBD) with three replications. The results of the study showed that days to 50% flowering, maturity, plant height, hundred seed weight and number of seeds per pod were significantly influenced by the main effects of varieties only. Similarly, harvest index was influenced by the main effect of varieties and NPS fertilizer rates. On the other hand, number of pods per plant and grain yield were significantly influenced by the interaction effects of varieties x Rhizobium inoculation x NPS rates applications. The highest grain yield (2800 kg ha^{-1}) was obtained from application of 100 kg NPS ha^{-1} + Rhizobium inoculation which followed by application of 100 kg NPS ha^{-1} for lammiif variety. The highest net benefit (93490 and 82290 Birr ha^{-1}) and MRR (1596.0 and 1593.3%) were recorded from the application of 100 kg NPS ha^{-1} and 100 kg NPS ha^{-1} + EAL301 strain. Thus, it can be concluded that application of 100 kg NPS ha^{-1} only or application of 100 kg NPS ha^{-1} + EAL301 strain inoculation are recommended for field pea production in western highlands of Oromia and similar agro ecologies.

Keywords: Effectiveness, strain, variety, yield

Introduction

Field pea is the third most important food legume crop among the cool season pulses in Ethiopia (Tilaye *et al*., 1993). It serves as a major source of protein and energy in many developing countries including Ethiopia. Field pea in Ethiopia is produced in mid altitudes range of 1800-3000 m a.s.l and with an annual rainfall of 600-700 mm (Tilaye, 1979). It is one of legume crop serve as a rotation crop with cereals (barley and bread wheat) to restore soil N content and minimize weeds, insect pests and disease in cereals (Assefa, 2001). The area allocated and total production of field pea in 2015/16 cropping season in Ethiopia has been 221,415.67 ha and 323,390.13 ton, respectively (CSA, 2016). Despite its ecologic as well as economic importance, the productivity of the crop is only 1.46 ton ha^{-1} (CSA, 2016), which is far below the potential yield as recorded at research plot yield of 2.5-3.5 ton ha^{-1} (Anteneh and Abere, 2017). The major yield limiting problems in the country are degraded soil fertility, recurrent droughts, and inadequate traditional agronomic practices. Low soil fertility is the major constraint for field pea production in Ethiopia (Tsige, 1994). Several research reports revealed an improvement of field pea yield up to 61% by N and P inorganic fertilizer application (Tsige, 1994).

On the other hand, field peas have the inherent ability to obtain much of its nitrogen (N) requirement from the atmosphere by forming a symbiotic relationship with *Rhizobium* bacteria in the soil (Anteneh and Abere, 2017). Field pea is nodulated by *Rhizobium leguminosarum bv. Viciae*. This *Rhizobium* species can also form nodules with other legumes, including faba bean (*Vicia faba* L.), vetch (*Vicia sativa* L.), lentil (*Lens culinaris Medik*.) and grass pea (*Lathyrus sativus* L.) (Ruiz-Díez *et al*., 2012). Under the favorable condition, field pea can derive 65-70% of accumulated N from biological N fixation (Jensen, 1997). Hailmariam and Tsigie (2006) revealed that Rhizobium *leguminosarum bv. viciae* inoculation increased the yield of major cools season pulses including field pea up to 38% as compared to the uninoculated treatment.

Field pea crop production has been practiced in western high lands of Oromia but the average yield is below the potential yield of the crop. Among the major yield reduction factors for field pea production in western Oromia, low soil fertility is the measure factor. Currently, the government introduced the blended fertilizers for the farmers in the study areas. Therefore, response of field pea to *Rhizobium* inoculation and blended NPS rates applications have not been evaluated in the study areas. Thus, basing on the fact that inoculation of rhizobia and supplementation of blended NPS fertilizers increases nitrogen and phosphorus levels in the soil, their application may play a key role on yield and economic benefits of field pea grown in highly depleted acidic soils of Western Oromia. Therefore, the objectives of this study were to investigate the effects of *Rhizobium* inoculation and NPS fertilizer rates on nodulation, growth, yield and yield components of field pea and to identify economically profitable treatment/s that can maximize the productivity of field pea in the study area.

Materials and Methods

Description of the Study Area

The field experiment was conducted at Shambu and Gedo during main cropping season of 2018 and 2019. Shambu lies between 9°34'N latitude and 37°06'E longitude at an altitude of 2400 meter above sea level. Mean annual rainfall of 1,695 mm (Abera and Abebe, 2018). It has a cool humid climate with the mean minimum, mean maximum, and average air temperatures of 8.15, 15.72 and 11.94°C, respectively. Gedo lies between 9°03'N latitude and 37°26'E longitude at an altitude of 2500 meter above sea level receiving mean annual rainfall of 1,026 mm [26]. It has a cool humid climate with the mean minimum, mean maximum, and average air temperatures of 8.51, 18.48 and 13.49°C, respectively. The soil in both sites is Nitisols (Mesfin, 1998) and the properties are indicated in Table 1.

Experimental Materials

Improved field pea varieties (Jidha and Lammiif) were used as a test crop. The varieties were released by Bako Agricultural Research Center (BARC) in 2017. Jidha and Lammiif varieties are characterized by kik and shiro types, respectively. Jidha and Lammiif varieties takes 110-140 and 105-130 days to maturity having white and brown seed colors and a yield potential of 2.7-3.6 and 2.8-3.5 ton ha^{-1} at research station, respectively (MARD, 2017). They are highly adaptable to high land areas of western Oromia. NPS fertilizer containing 19% N, 38% P_2O_5 and 7% S was applied in the row as per the treatment and mixed with soil just at the time of field pea planting. Carrier based *Rhizobium* strain *leguminosarum bv. Viciae*, EAL301 was obtained from Managasha Biotechnology Private Limited Company, Addis Ababa, Ethiopia.

Soil Sampling and Analysis

A representative soil sample was taken using auger at a depth of 0-20 cm randomly in zigzag pattern from the whole experimental field prior to planting from 10 spots. Finally composite sample was prepared for analysis to determine physico-chemical properties of the soil of experimental site. The collected soil samples were air dried, ground and sieved using a 2 mm mesh size sieve for analysis of total N, soil pH, organic carbon and available phosphorus. The selected soil physico-chemical properties were analyzed at Bako Agricultural Research Center Soil Laboratory. Soil pH was determined potentiometrically using pH meter with combined glass electrode in a 1:2.5 soil to water supernatant suspension (Van Reeuwijk, 1992). Walkely and Black (1994) method was used to determine the organic carbon content. The base titration method which involves saturation of the soil sample with 1M KCl solution and titrating with sodium hydroxide was employed to determine exchangeable acidity. Soil total nitrogen was determined by the Kjeldahl method using micro- Kjeldahl distillation unit and Kjeldahl digestion stand as described by Jackson (1962). Available soil phosphorus was extracted by the Bray II procedure (Bray and Kurtz, 1945) and determined colorimetrically by spectrophotometer.

Treatments and Experimental Design

The treatment comprised three factors namely; NPS fertilizer rates (0, 25, 50, 75 and 100 NPS kg ha^{-1}), two levels of *Rhizobium* inoculation (Un-inoculated and EAL301) and two field pea varieties (Jidha and Lammiif). The treatment was arranged as 5×2×2 in factorial combinations in RCBD with three replications. Each plot comprised of seven rows of 3 m length (7 × 0.2 m × 3 m = 4.2 m^2) and used for data collection as net plot.

Experimental Procedure

The land was ploughed by tractor, disked and harrowed. The seeds were planted at spacing of 20 cm and 10 cm between rows and within rows, respectively. The spacing between blocks and plots were 1.5 m and 0.8 m, respectively. Two seeds were sown per hill and then thinned to one plant after seedling establishment. All other management practices were done as per the recommendations. Carrier based inoculants of each strain was applied at the rate of 10 g inoculants per kg of seed (Rice *et al*., 2001). The inoculants were mixed by sugar with the addition of some water in order to facilitate the adhesion of the strain on the seed. To ensure that the applied inoculants stick to the seed, the required quantities of inoculants were suspended in 1:1 ratio in 10% sugar solution. The thick slurry of the inoculants was gently mixed with the dry seeds so that all the seeds received a thin coating of the inoculants. To maintain the viability of the cells, inoculation was done under the shade and allowed to air dry for 30 minutes and sown at the recommended spacing. Seeds were immediately covered with soil after sowing to avoid death of cells due to the sun's radiation. A plot with un-inoculated seeds was planted first to avoid contamination.

Data Collected

Days to 50% flowering: Number of days from sowing to the date on which 50% of plants on the net plot produced at least their first flower.

Days to physiological maturity: Days to physiological maturity was recorded as the number of days from sowing to the stage when 90% of the plants in a plot have reached physiological maturity, *i.e.* the stage at which pods lost their pigmentation and begin to dry.

Plant height: The height of ten randomly taken plants from each of the four middle rows was measured in centimeter (cm) from the ground level to the tip of the plant at harvest maturity and expressed as an average of ten plants per plot.

Number of primary branches: Number of primary branches was counted at physiological maturity by taking ten randomly taken plants from four central rows and expressed as an average of ten plants.

Total number of nodules per plant: Five plants were sampled randomly from the destructive rows of each plot at mid flowering. The whole plant was carefully uprooted using a fork so as to obtain intact roots and nodules for nodulation parameters. Uprooting was done by exposing the whole root system to avoid loss of nodules. The adhering soil was removed by soaking the ball of soil and root in barrel filled with water and thoroughly rinsed in separate water filled. From the same uprooted plants, number of nodules per plant was recorded by counting the number of nodules from five plants and averaged as per plant.

Number of pods per plant: The number of pods per plant was counted from five randomly selected plants from four middle rows at harvest maturity and expressed as an average of each plant.

Number of seeds per pod: Number of seeds per pod was counted from the randomly taken 5 pods from the net plot and was expressed as an average of ten pods.

Hundred seed weight: weight of 100 seeds that were sampled from each plot was weighed using sensitive balance and the weight was adjusted at 10% standard moisture content.

Above ground biomass yield: the above ground dry biomass from each plot was measured at harvesting time and converted in to kg ha^{-1}. This was used to calculate the harvest index.

Grain yield: Grain yield was measured by harvesting the crop from the net plot area. The harvested produce was sun dried for seven days and threshed by hitting with sticks and winnowing was done. The moisture content of the grain was adjusted to 10%. Then the weight was converted to kg ha^{-1}.

Harvest index (HI): Harvest index was calculated by dividing grain yield per plot by the total above ground dry biomass yield per plot after the yield obtained from ten plants were converted to plot bases.

Data Analysis
All collected parameters were subjected to analysis of variance using of Gen Stat 18th edition (GenStat, 2016). Whenever the effects of the treatments were found to be significant, the means were compared using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

Partial Budget Analysis
The economically acceptable treatment(s) were determined by partial budget analysis to estimate the gross value of the grain yield by using the adjusted yield (CIMMYT, 1988) at the market value of the grain and inputs during the cropping period. Only total costs that varied (TCV) were used to compute costs. Current prices of field pea, inoculant, NPS fertilizer and application cost of inoculants and NPS were considered as variable with their cost. Cost of land preparation, field management, harvest, transportation and storage were not included in the analysis as they were not variable. To equate the field pea grain yield with what a farmer would get, the obtained yield was adjusted downward by 10%. Both the costs and benefits were converted to monetary values in Ethiopian Birr (ETB) and reported per hectare. Treatments net benefits (NB) and TCV were compared using dominance analysis.
The first step was calculation of the NB as shown in the formula below as suggested by CIMMYT (1988)
NB = (GY x P) – TCV, Where GY x P = Gross Field Benefit (GFB), GY = Adjusted Grain yield per hectare and P = Field price per unit of the crop.
Secondly, treatments TCV were listed in increasing order in accordance with dominance analysis. All treatments which had NB less than or equal to treatment with lower TCV were

marked with a letter "D" since they were dominated and eliminated from any further analysis. Un-dominated treatments were subjected to Marginal Rate of Return (MRR) analysis (CIMMYT, 1988) in stepwise manner, moving from lower TCV to the next as shown below:

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

Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCV_b = the next highest TCV.

Results and Discussion

Soil properties of the experimental site before planting

Laboratory analysis results of selected properties of soil of experimental site before planting are presented in Table 1. The results showed that the soil pH of the experimental sites are 5.07 at Shambu and 5.02 at Gedo. Thus, according to rating done by Tekalign (1991) the chemical reaction of the experimental soil are strongly acidic (Table 1). The organic carbon content of the experimental soil are medium (1.06% and 1.59%) according to rating done by Hazelton and Murphy, (2007). Organic carbon in soils influence physical, chemical and biological properties of soils, such as soil structure, water retention, nutrient contents and retention and micro-biological life and activities in the soils.

The analysis further indicated that the total N content of the experimental sites are 0.09% at Shambu and 0.14 at Gedo which rated as low according to Hazelton and Murphy (2007). The low total nitrogen might have been caused by soil acidity that tend to reduce microbial mediate processed that results in poor organic matter decomposition, mineralization of nitrogen, N uptake by plants and denitrification (Massawe *et al.,* 2016). Phosphorus levels in the soil can be used as a guide to indicate whether phosphate fertilizer is required for plant growth. The available P in the experimental soil were 8.58 mg/kg of soil at Shambu and 8.23 mg/kg of soil at Gedo (Table 1). According to Takelign (1991) rating, the available soil P are rated as low.

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

Soil characters	**Value**		**Rating**	**Reference**
	Shambu	**Gedo**		
Textural class	Clay	Clay		
Soil pH (1:2.5 (H_2O) suspension	5.07	5.02	Strongly acidic	Takelign (1991)
Organic carbon (%)	1.06	1.59	Medium	Hazelton and Murphy (2007)
Organic matter (%)	1.83	2.74	Medium	Takelign (1991)
Total nitrogen (%)	0.09	0.14	Low	Hazelton and Murphy (2007)
Available P (mg/kg) soil	8.58	8.23	Low	Takelign (1991)

Phenological parameters

Days to 50% flowering and physiological maturity

The main effect of *Rhizobium* strain and NPS rates and two or three way interaction effect of varieties, *Bradyrhizobium* strain and NPS rates did not significantly influence days to 50% flowering and days to physiological maturity. On the other hand, the main effect of field pea varieties revealed significant difference on days to 50% flowering and days to physiological maturity (Table 2). Days to 50% flowering and days to physiological maturity were influenced by the main effect of varieties only. Jidha variety having indeterminate growth habit took considerably longer period of time (77 and 136 days) to reach 50% flowering and physiological maturity while variety Lammif took 76.4 and 133.8 days to reach 50% flowering and physiological maturity indicating that Lammif matured earlier than Jidha variety. This might be due to the fact that indeterminate varieties produce additional nodes after initial flowering as a result, the physiological maturity become longer.

Table 2: The main effect of varieties, *Rhizobium* inoculation and NPS fertilizer application on days to 50% flowering and days to physiological maturity

Treatment	**Parameters**	
	Days to 50% flowering	**Days to physiological maturity**
Variety		
Lemmif	76.37	133.8
Jidha	77.03	136.1
LSD (0.05)	0.56	2.93
Inoculation		
Un-inoculated	76.79	138.3
EAL301	76.6	135.6
LSD (0.05)	NS	NS
NPS rate (kg ha^{-1})		
0	76.81	135.3
25	76.94	135.5
50	76.65	143
75	76.67	135.6
100	76.42	135.5
LSD (0.05)	NS	NS
CV (%)	2.9	17

Yield and yield components

Plant height, number of seeds per pod and hundred seed weight were significantly influenced by the main effect of field pea varieties only (Table 3).

The difference in plant height, number of seeds per pod and hundred seed weight between field pea varieties were might be due to difference in genetic potential of the varieties. Non-significant main and interaction effect of variety by *Rhizobium* inoculation and NPS rates in number of seeds per pod indicated that the varietal seed per pod responses were similar under different *Rhizobium* inoculation and NPS rates. Non-significant effects of studied treatments on number of seeds per pod might be due to more effects of genetic factors in controlling of this trait than environmental and management factors. This result was in line with the finding of Ali and Raouf (2011) in which nitrogen fertilizer had not significantly influence on the number of seeds per pod. Lammiif variety produced significantly heavier seed weight which was about 21.32g compared with the Jidha variety (19.63 g) (Table 3). The result might indicate that seed weight was less likely to be affected by the external application of fertilizers compared to the genetic effect. Among various NPS fertilizer levels, the maximum harvest index was recorded at the rate of 75 and 100 kg NPS ha^{-1} while the lowest harvest index was recorded at 0 kg NPS ha^{-1} (Table 3). The increased mean harvest index with the increase of NPS fertilizer rate might be due to the influence P for greater fruit and seed setting than above ground biomass yield. In line with this result, Masresha and Kibebew (2017) obtained the maximum mean harvest index of soybean from application of 46 kg P_2O_5 ha^{-1}, which resulted in 19.1% increase over the control.

Table 3. Main effects of field pea variety, *Rhizobium* strains and NPS fertilizer rates on plant height

Treatment	**Parameters**			
	Plant height (cm)	**No of seeds/pod**	**HSW (g)**	**Harvest index (%)**
Variety				
Lammiif	133.1	4.27	21.32	37.64
Jidha	146.9	4.04	19.63	33.77
LSD (0.05)	4.07	0.04	0.41	3.2
Inoculation				
Uninoculated	139.3	4.1	20.56	34.3
EAL301	140.7	4.1	20.38	37.11
LSD (0.05)	NS	NS	NS	NS
NPS fertilizer rate				
0	135.1	4.117	20.75	31.0
25	139.7	4.154	20.23	35.1
50	140.7	4.208	20.31	36.0
75	140.7	4.162	20.88	38.4
100	143.8	4.121	20.19	38.2
LSD (0.05)	NS	NS	NS	4.5
CV (%)	11.4	12.3	7.9	13.5

Where, HSW: Hundred seed weight, CV: Coefficient of variation, LSD: Least significant difference.

Number of pods per plant was significantly influenced by the interaction effects of variety x *Rhizobium* x NPS rates. More number of pods per plant was recorded from application of NPS fertilizer supplied with Rhizobium inoculant (Table 4). The positive effects of the inoculants might be due to better amount of nitrogen rendered through nitrogen fixation which promoted vegetative growth and plant height and thus improving number of pods per plant. This could again be attributed to the availability of phosphorus that would have increased the intensity of photosynthesis, nitrogen fixation, root development, flowering, seed formation and fruiting. Increased number of pods per plant of soybean due to combined application phosphorus up to 100 kg P_2O_5 ha^{-1} and inoculation was reported by Shahid *et al*. (2009).

Table 4: Interaction effects of Variety x *Rhizobium* x NPS rates on number of pods per plant

		Rhizobium Inoculation	
NPS rate (Kg ha^{-1})	Variety	Uninoculated (-R)	Inoculated (+R)
0	Jidha	10.3^{abc}	10.4^{abc}
	Lemmif	7.6^{c}	8.1^{c}
25	Jidha	11.9^{ab}	10.5^{abc}
	Lemmif	8.7^{c}	8.5^{c}
50	Jidha	9.7^{abc}	11.9^{ab}
	Lemmif	7.6^{c}	9.6^{abc}
75	Jidha	10.8^{abc}	12.5^{a}
	Lemmif	9.87^{abc}	9.6^{abc}
100	Jidha	10.1^{abc}	10.8^{abc}
	Lemmif	8.7^{bc}	8.7c
LSD (0.05)		1.7	
CV (%)		16	

Grain yield was significantly influenced by the interaction effects of variety x *Rhizobium* x NPS rates. Results in Figure 1 revealed the performance of field pea varieties with application of different rates of NPS fertilizer with and without *Rhizobium* strain. Both varieties (Jidha and Lammiif) were showed positive yield increment with increasing rates of NPS fertilizer both under *Rhizobium* inoculation and uninoculated plots but the performance of the varieties were better under *Rhizobium* inoculation compared to uninoculated conditions (Figure 1). The highest grain yield (2800 kg ha^{-1}) was obtained from application of 100 kg NPS ha^{-1} + Rhizobium inoculation which followed by application of 100 kg NPS ha^{-1} for lammiif variety.

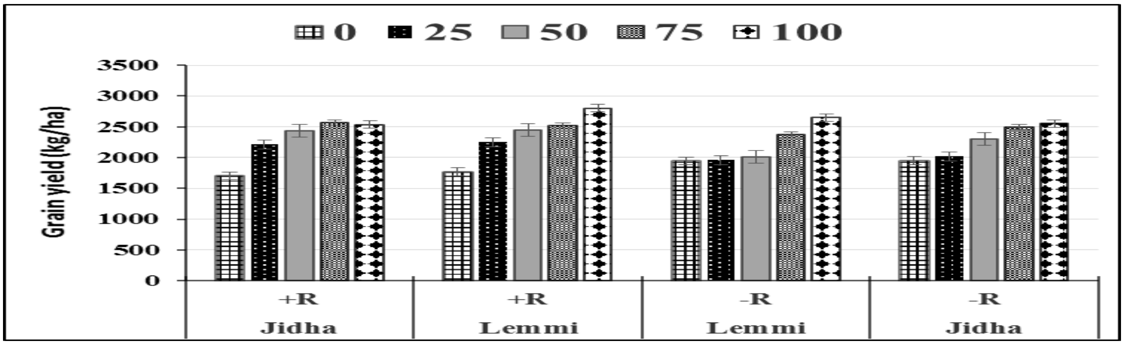

Fig 1: The interaction effects of variety x *Rhizobium* x NPS rates on grain yield of field pea.

Partial Budget Analysis

Analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 5. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation by farmers. The study assessed the economic benefits of the treatments to help develop recommendation from the agronomic data. This enhances selection of the right combination of resources by farmers in the study area. The partial budget analysis was done on the basis of cost of NPS, inoculant and **application cost of fertilizer and cost of mixing inoculant with seeds were considered.**

The partial budget analysis showed that the application of 100 kg NPS ha^{-1} inoculated with EAL301 produced the highest net benefits of 93490 Birr ha^{-1} with highest marginal rate of return of (1596.0%). Similarly, application of 100 kg NPS ha^{-1} and 50 kg NPS ha^{-1} + EAL301 gave the highest net benefit and marginal rate of return (Table 5). This implies that farmers would be better of inoculating their field pea in combination with application of 50 kg NPS ha^{-1} or the farmers can use 100 kg NPS ha^{-1} only if the inoculants are not available. These can increase fieldpea yields and thus increase farmer's income. Thus, application of 100 kg NPS ha^{-1} or 50 kg NPS ha^{-1} + EAL301 is profitable and recommended for the farmers in the study areas and other areas with similar agro-ecological conditions.

Table 5. Partial budget analysis of the effects of *Rhizobium* strain and NPS rates on the productivities of field pea varieties

Variety	Inoculation	NPS (kg ha)	Yield	TVC	Gross benefit	Net benefit	MRR (%)
Jidha	-R	0	1949	0	66266	66266	0
Lemmi	-R	0	1947	0	66198	66198	0
Jidha	EAL301	0	1700	235	57800	57565	-3673.6
Lemmi	EAL301	0	1769	235	60146	59911	-2675.3
Jidha	-R	25	2018	425	68612	68187	468.0
Lemmi	-R	25	1958	425	66572	66147	D
Lemmi	EAL301	25	2248	660	76432	75772	1450.6
Jidha	EAL301	25	2216	660	75344	74684	D
Jidha	-R	50	2300	775	78200	77425	1448.6
Lemmi	-R	50	2013	775	68442	67667	D
Lemmi	**EAL301**	**50**	**2450**	**1010**	**83300**	**82290**	**1593.3**

Jidha	EAL301	50	2434	1010	82756	81746	D
Jidha	-R	75	2500	1125	85000	83875	1571.3
Lemmi	-R	75	2376	1125	80784	79659	D
Jidha	EAL301	75	2570	1360	87380	86020	1457.5
Lemmi	EAL301	75	2522	1360	85748	84388	D
Jidha	-R	100	2553	1475	86802	85327	D
Lemmi	**-R**	**100**	**2650**	**1475**	**90100**	**88625**	**1520.5**
Lemmi	**EAL301**	**100**	**2800**	**1710**	**95200**	**93490**	**1596.0**
Jidha	EAL301	100	2534	1710	86156	84446	D

Key: -R= without inoculation, 14 birr= cost of NPS/kg, 1kg of field pea = 34 Birr, one sachets of inoculant= 40 birr, TCV= Total costs that vary, MRR= Marginal rate of return, D = Dominated

Conclusion

Low soil fertility is one the major constraints of field pea production in western high lands of Oromia. The highest grain yield (2800 kg ha^{-1}) was obtained from application of 100 kg NPS ha^{-1} + *Rhizobium* inoculation which followed by application of 100 kg NPS ha^{-1} for Lammiif variety. The highest net benefit (93490 Birr ha^{-1}) and MRR (1596.0%) were recorded from the application of 100 kg NPS ha^{-1} which followed by 50 kg NPS ha^{-1} supplied with EAL301 strain. From this study, it can be concluded that application of 100 kg NPS ha^{-1} only or 50 kg NPS ha^{-1} supplied with EAL301 inoculation had resulted in higher net benefit and it is recommended for use in the study areas. However, as this study was done under acidic soil (problematic soil), the experiment has to be repeated under reclaimed soil in the study area to reach at a conclusive recommendation.

Acknowledgement

The authors want to thank Oromia Agricultural Research Institute for funding of the experiment. The authors also thank Bako Agricultural Research Center, Pulse and Oils Research Team members for conducting the experiment and data collection.

References

Abera, T. and Abebe, Z., 2018. Effects of Fertilizer, Rhizobium Inoculation and Lime Rate on Growth and Yields Field Pea in Horro and Gedo Highlands. *Adv Crop Sci Tech*, *6*, p.397.

Ali, N. and S. S. Raouf, 2011. Phenological and morphological response of chickpea (*Cicer artienium* L.) to symbiotic and mineral nitrogen fertilization. *Zemdiryste = Agri.*2 (98): 121-130.

Anteneh Argaw and Abere Mnalku, 2017. Symbiotic effectiveness of *Rhizobium leguminosarum bv. Vicieae* isolated from major highland pulses on field pea (*Pisum sativum* L.) in soil with abundant rhizobial population, *Annals of Agrarian Science*: 1-10.

CSA (Central Statistical Agency). 2016. Agricultural Sample Survey Report on Area and Production of Major Crops, 1: 21-22.

Hazelton, P. and B. Murphy, 2007. *Interpreting soil test results: What do all the numbers mean? 2nd Edition*. CSIRO Publishing. pp. 152.

Kumar, A .and Dwakar, P. 2015. Response of Pea (*Pisum sativum* L.) to Rhizobium Inoculation and Nitrogen Application in soils of North East alluvial plains of Bihar. Asian Journal of Soil Science, 10(2): 252-258.

Masresha Abitew and Kibebew Kibret. 2017. Effects of *Rhizobium*, Nitrogen and Phosphorus Fertilizers on Growth, Nodulation, Yield and Yield Attributes of Soybean at Pawe Northwestern Ethiopia. *World Scientific News*, 67(2): 201-218.

Massawe, P.I., Mtei, K.M., Munishi, L.K. and Ndakidemi, P.A. 2016. Effect of *Rhizobium* and Intercropping Systems on Soil Nutrients and Biological Nitrogen Fixation as Influenced by Legumes (*Phaseolus vulgaris* and *Dolichos lablab*). *International Journal of Current Microbiology and Applied Sciences*, 5(10): 135-149.

Mesfin, A. 1998. Nature and management of Ethiopian soils. Alemaya University of Agriculture, Ethiopia, p: 272.

Ruiz-Díez, B., Fajardo, S. and Fernandez-Pascual, M. 2012. Selection of rhizobia from agronomic legumes grown in semiarid soils to be employed as bioinoculants, *Agron. J.* 104:550-559.

Shahid, M.Q., Saleem, M.F., Khan, H.Z and Anjum, S.A. 2009. Performance of soybean (*Glycine max* L.) under different phosphorus levels and inoculation. *Pakistan Journal of Agricultural Sciences*, 46(4): 237-241.

Tekalign Tadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

Tilaye, A, Demtsu, B. and Getachew, T. 1993. Genetics and Breeding of Field pea. In: Telaye A, Bejiga G, Saxena MC, Solh MB (Eds) Cool-season food legumes of Ethiopia. Proceeding of the first cool-season food legumes review conference, 16-20 December, Addis Ababa, Ethiopia, pp 122-137.

Tilaye, A. Broad beans (*Vicia faba* L.) and dry peas (*Pisum sativum* L.) in Ethiopia, in: G.C. Hawtin, G.J. Chancellor (Eds.), Food Legume Improvement and Development, IDRC, Ottawa, Ontario, 1979, pp. 80e84. Proc. Workshop Held at the University of Alleppo, Syria, 2-7 May 1978.

Mishra, N. 2014. Growth and yield response of pea *(pisum sativum* l.) to Integrated Nutrient Management. A Review, *Journal of Plant and Pest Science*, 1 (2): 87-95.

Ta'a, A. Effect of Stable Management, Tillage and Cropping Sequence on Sustainable Wheat Production in Southeastern Highlands of Ethiopia, PhD Thesis, University of the Free State, Boemfontein, South Africa, 2001, p. 283.

Tsigie, A. and Woldeab, A. Fertilizer response trials on highlands food legumes, in: A. Telaye (Ed.), Cool-season Food Legumes of Ethiopia, ICARDA, Alepo, Syria, 1994, pp. 279-292.

Effects of *Rhizobium* strains and Common bean varieties on Nodulation, Yield and Yield Components in Bako areas, Western Oromia

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Abstract

Effectiveness of Rhizobium *strain is influenced by varieties and environments. Thus, study was conducted to select the most efficient rhizobia strains on common bean that can be used for inoculant production in Ethiopia and to observe the possibilities of common bean varietal and strains interactions. Factorial combinations of four* Rhizobium *strains (uninoculated, HB-429 (check), HB-A-15 and CB-NAK-91), three common bean varieties (Akos keyo, Hawasa Dume and Nasir) and one nitrogen rate (23 kg N ha^{-1}) were laid out in Randomized Complete Block Design (RCBD) with three replications. The results showed that Rhizobium inoculation, the genotypes, environment and their interaction significantly (P ≤ 0.01) affected days to 50% flowering, days to maturity, nodule number and seed yield. The highest yield and yield related traits of common bean were recorded from Hawassa dume variety in all inoculation treatments. The* Rhizobium *strains (HB-429 and HB-A-15) inoculated with Hawassa dume variety gave better yields compared to other variety. According to the average environment coordination (AEC) views of the genotype-rhizobium-location interaction biplot, common bean variety Hawassa dume inoculated with HB-429 and HB-A-15 strains which followed by Nasir variety inoculated with CB-NAK-91 strain and supplied with nitrogen fertilizer were identified as the most stable and high yielding treatments. Thus, it can be concluded that Hawassa dume and Nasir varieties with HB-429 and HB-A-15 strains were recommended for further production in most common bean growing areas of western Ethiopia.*

Keywords: Effectiveness, Genotypes, inoculation, nitrogen fixation, yield stability

Introduction

The common bean (*Phaseolus vulgaris* L.) is the most important pulse crop in the world. It is an important source of calories, proteins, dietary fibers, minerals, and vitamins for millions of people in both developing and developed countries worldwide (Myers et al., 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 (Argaw et al., 2015). Its area of production is increasing and according to CSA (2016) report common bean was produced on about 244,049.94 ha of land and 3,804,994.53 quintals produced in 2015/16 main cropping season with the productivity of 1.5 t ha^{-1}.

Organic and chemical fertilizers are the two main agricultural inputs applied to crops by large scale farmers in Africa. Nitrogen is the major plant nutrient that limits common bean production in Ethiopia (Argaw et al., 2015). N_2-fixing legumes are a cheaper and more sustainable alternative to chemical N fertilizers for small-scale farmers in Africa. Nodulated legumes are known to contribute substantial amounts of symbiotic N to cropping systems (Nyemba and Dakora 2010; Pule-Meulenberg et al. 2010; Mohale et al. 2014). The inclusion of nodulated grain legumes like common bean in cropping systems can improve crop yields and thus replenish soil N (Maina et al. 2011). N_2 fixation in legumes is the second most important biological process after photosynthesis (Hayat et al. 2008; Unkovichetal. 2008), improve soil fertility (Kawaka et al., 2018) and contributes N to meet the legume's N demand, as well as for succeeding crops (Peoples et al. 2009). However, N_2 fixation by the common bean symbiosis with soil rhizobia is hardly adequate to meet plant growth and grain yield (Pastor-Bueis et al., 2019). This is due, in part, to susceptibility of the crop to nutritional and environmental constraints, its short maturity period, and the ineffectiveness of indigenous soil rhizobia (Kabahuma 2013). Pre-inoculation of seeds with elite rhizobial strains was shown to increase symbiotic performance and grain yield of common bean planted in farmers' fields (Argaw and Muleta, 2018).

Nitrogen is the most important nutrient for crop production and deficient in most tropical regions (Fageria and Baligar, 2001). The main reasons for N deficiency include losses by leaching, volatilization, and denitrification, lower rates of N applied compared to rates of N removed in the harvested portion of the crop, low N use efficiency and soil degradation with successive crop cultivation (Abebe, 2017). Therefore, the efficient use of mineral fertilizers to the infertile soil is recognized to be a quick and direct way of boosting crop production. However, most of the smallholder farmers in tropical Africa, including Ethiopia, are resource limited and use an insufficient amount of inorganic fertilizers. Common beans are generally regarded as low N2 fixer compared to other legume crops (Giller, 2001), but their symbiotic performance effectiveness is known to vary with legume genotypes and rhizobium strains (Mandri et al., 2012; Argaw and Muleta, 2018), biotic and abiotic factors (Alemayehu et al., 2018) and their interactions (Gunnabo et al., 2019). Inoculation of *Rhizobium* strains certainly improved growth and nitrogen fixation, which can help in enhancing the yield potential of legumes.

Recently, some studies were conducted on response of common bean to *Rhizobium* inoculation in Ethiopia. However, response of common bean is vary from farmers to farmer's fields as well as from location to location due to low soil fertility and soil acidity in western Ethiopia. Therefore, studies on the combination of different *Rhizobium* strains with common bean varieties interaction across environments have not been evaluated in western Ethiopia. The improvement of common bean production requires the selection of effective rhizobia strains and common bean genotypes adapted to available soil phosphorus limitations (Mandri et al., 2012). Therefore, there is a need to find effective rhizobia starins in high rainfall areas of western Ethiopia, where the soil is acidic. In Ethiopia, rhizobia strains response differently for different varieties under diverse agro ecologies, indicating a need to develop cultivar and site specific rhizobial strain. Thus, basing on the fact that rhizobia-common bean varietal-environment interaction may increase the opportunities to select best elite *Rhizobium* strains and common bean varieties in common bean growing areas of western Ethiopia. Therefore, the objectives of this study were to select the most efficient rhizobia strains on field that can be used for inoculant production in Ethiopia and to observe the possibilities of common bean varietal and strains interactions.

Materials and Methods

Description of the Study Area

The experiments were carried out during the main rainy season (June to November) at Bako areas (Sheboka, Sadan Kite and Gute) during 2017 and 2018 main cropping season. Figure 1 present climatic data of rain fall and temperature during 2017 and 2018 growing season. The area has a warm humid climate with annual mean minimum and maximum temperature of 10.6 and 34.6°C, respectively. The area receives an annual rainfall of 1317 mm mainly from May to October with maximum precipitation in the month of May to September (Meteorological station of the center, 2017 and 2018). The predominant soil type of the area is *Nitosols* which is characteristically reddish brown and clay in texture with a pH that falls in the range of very strongly acidic to strongly acidic according to rating done by Jones

(2003). The area is known for its mixed crop-livestock farming system in which cultivation of maize, niger seed, hot pepper, soybean, common bean, mango, banana are the major cropping activities.

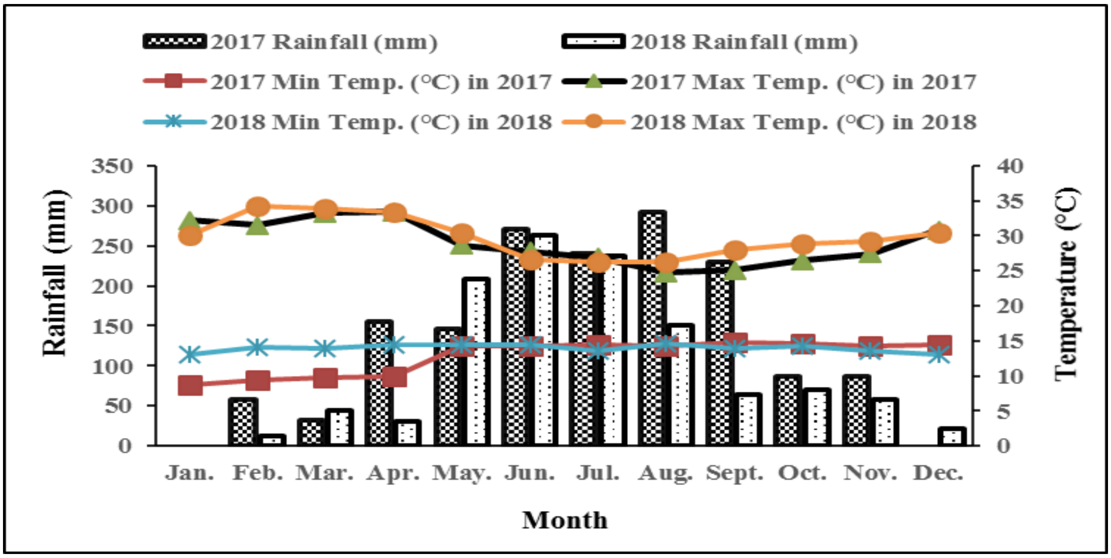


Figure 1. Monthly total rainfall (mm), mean minimum and maximum temperatures (°C) of the study areas in 2017 and 2018

Experimental Materials

Improved common bean varieties (Nasir, Acos keyo and Hawasa Dume) were used as a test crop. The Nasir and Hawassa Dume varieties were released by Melkassa Agricultural Research Center and Hawassa Agricultural Research Center, respectively. Nasir and Hawasa Dume grows as an indeterminate semi-bush, takes about 85-110 days to physiological maturity, and has dark-red seed coat pigmentation. Carrier based *Rhizobium* strains namely, HB-429 (check), HB-A-15 and CB-NAK-91 were obtained from Holleta Agricultural Research Center Soil Laboratory, Ethiopia.

Soil Sampling and Analysis

A representative soil sample was taken using a cylindrical auger at a depth of 0-20 cm randomly in zigzag pattern from the whole experimental field prior to lime application from 15 spots. Finally composite sample was prepared for analysis to determine physico-chemical properties of the soil of experimental site. The collected soil samples were air dried, ground and sieved using a 2 mm mesh size sieve for analysis of total N, soil pH, organic carbon and available phosphorus. The selected soil physico-chemical properties were analyzed at Bako Agricultural Research Center Soil Laboratory. Soil pH was determined potentiometrically using pH meter with combined glass electrode in a 1:2.5 soil to water supernatant suspension (Van Reeuwijk, 1992). Walkely and Black (1994) method was used to determine the organic carbon content. Soil total nitrogen was determined by the Kjeldahl method using micro- Kjeldahl distillation unit and Kjeldahl digestion stand as described by Jackson (1962). Available soil phosphorus was extracted by the Bray II procedure (Bray and Kurtz, 1945) and determined colorimetrically by spectrophotometer.

Treatments and Experimental Design

The treatment comprised three factors namely; three common bean varieties (Nasir, Acos Keyo and Hawasa Dume), four levels of inoculation (Un-inoculated, HB-429 (check), HB-A-15 and CB-NAK-91) and N rate (28 kg ha^{-1}) as urea. The treatment was arranged as 3×5 factorial combinations in Randomized Complete Block Design (RCBD) with three replications. The gross plot comprised of seven rows of 4 m length (4 × 0.4 m × 4 m = 6.4 m^2) and one row each from both sides of the plot was left as a border row. Thus, the central four rows (2 × 0.4 m × 4 m = 3.2 m^2) were used for data collection as net plot.

Experimental Procedure and Field Management

The land was ploughed three times by oxen and levelled by human power. The seeds were planted at spacing of 40 cm and 10 cm between rows and within rows, respectively. NPS fertilizer containing (19% N, 38% P_2O_5 and 7% S) was applied uniformly to all plots during planting time at the rate of 50 kg NPS ha^{-1}. The cropping history of the experimental plot was identified at each locations and the common bean was planted on plots previously not planted with legumes. The spacing between blocks and plots were 1.5 m and 0.8 m, respectively. Two seeds were sown per hill and then thinned to one plant after seedling establishment. All other management practices were done as per the recommendations.

Carrier based inoculants of each strain was applied at the rate of 10 g inoculants per kg of seed (Rice *et al*., 2001). The inoculants were mixed by sugar with the addition of some water in order to facilitate the adhesion of the strain on the seed. To ensure that the applied inoculants stick to the seed, the required quantities of inoculants were suspended in 1:1 ratio in 10% sugar solution. The thick slurry of the inoculants was gently mixed with the dry seeds so that all the seeds received a thin coating of the inoculants. To maintain the viability of the cells, inoculation was done under the shade and allowed to air dry for 30 minutes and sown at the recommended spacing. Seeds were immediately covered with soil after sowing to avoid death of cells due to the sun’s radiation. A plot with un-inoculated seeds was planted first to avoid contamination.

Data Collected

Days to 50% flowering: Number of days from sowing to the date on which 50% of plants on the net plot produced at least their first flower.

Days to physiological maturity: Days to physiological maturity was recorded as the number of days from sowing to the stage when 90% of the plants in a plot have reached physiological maturity, *i.e.* the stage at which pods lost their pigmentation and begin to dry.

Number of nodules per plant: Five plants were sampled randomly from each plot at mid flowering. The whole plant was carefully uprooted using a fork so as to obtain intact roots and nodules for nodulation parameters. Uprooting was done by exposing the whole root system to avoid loss of nodules. The adhering soil was removed by soaking the ball of soil and root in barrel filled with water and thoroughly rinsed in separate water filled. From the same uprooted plants, number of nodules per plant was recorded by counting the number of nodules from five plants and averaged as per plant.

Nodule dry weight: The nodules collected from five plant samples from each plot were pooled and their dry weight was measured by oven drying at 70˚C for 24 hours. The dry weight was reported as 'g' per plant.

Grain yield: Grain yield was measured by harvesting the crop from the net plot area. The harvested produce was sun dried for seven days and threshed by hitting with sticks and winnowing was done. The moisture content of the grain was adjusted to 10%. Then the weight was converted to kg ha^{-1}.

Data Analysis

All collected parameters were subjected to analysis of variance using of SAS software 9.3 version. Whenever the effects of the treatments were found to be significant, the means were compared using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance. AMMI analysis and GGE bi- plots were performed using Gen Stat 18^{th} edition statistical package (GenStat, 2016). Figures were prepared using sigma plot software version 10.0.

Results and Discussion

Selected soil chemical properties before planting

Laboratory analysis results of selected properties of soil of experimental site before planting are presented in Table 1. The results showed that the soil pH of the experimental sites are 5.13 at Sheboka, 5.41 at Sadan Kite (2017), 4.58 at Sadan Kite (2018) and 4.9 at Gute. Thus, according to rating done by Tekalign (1991) the chemical reaction of the experimental soil are fall in the ranges of very strongly acidic to strongly acidic (Table 1). Common bean has been found to do well in pH values of 5.5 - 7 and any pH below these values will affect its growth and needs amendment (Ferguson *et al.*, 2006). The organic carbon content of the experimental soil are medium (1.74%, 1.8%, 2.0% and 1.49%) according to rating done by Hazelton and Murphy, (2007). Organic carbon in soils influence physical, chemical and biological properties of soils, such as soil structure, water retention, nutrient contents and retention and micro-biological life and activities in the soils.

The analysis further indicated that the total N content of the experimental sites are 0.12% at Sheboka, 0.16 at Sadan Kite (2017), 0.17 at Sadan Kite (2018) and 0.13 at Gute (0.12%) which rated as low to medium according to Hazelton and Murphy (2007). The low total nitrogen might have been caused by soil acidity that tend to reduce microbial mediate processed that results in poor organic matter decomposition, mineralization of nitrogen, N uptake by plants and denitrification (Massawe *et al.*, 2016). Phosphorus levels in the soil can be used as a guide to indicate whether phosphate fertilizer is required for plant growth. The available P in the experimental soil were 9.1 mg/kg of soil at Sheboka, 15.05 mg/kg of soil at Sadan Kite (2017), 7.34 mg/kg of soil at Sadan Kite (2018) and 8.8 mg/kg of soil at Gute (Table 1). According to Takelign (1991) rating, the available soil P are rated as low to medium.

Table 1. Soil chemical properties of the experimental sites before planting

Soil parameter	Test location			Rating	Reference
	Sheboka (2017)	Sadan kite (2017 & 2018)	Gute (2017 & 2018)		
PH-H_2O	5.4	5.07	4.54	Very strongly acidic to strongly acidic	Takelign (1991)
Ca2+	12.5	11.72	5.7	Medium to high	FAO (2006)
Mg2+	2.98	3.85	3.1	Medium	FAO (2006)
K+	1.86	0.79	0.31	Medium to high	FAO (2006)
Na+	0.1	0.09	0.08	Very low to low	FAO (2006)
Ava. p	11.75	2.56	1.81	Very low to medium	Cotteine (1980)
CEC	30.81	30.67	27.93	High	Hazelton & Murphy (2007)
S	14.74	15.4	23.85		
B	0.57	0.32	0.2	Low to medium	Takelign (1991)
Fe	107.25	66.2	116.94	Medium	Takelign (1991)
Mn	113.15	81.11	199.77	Medium to high	Takelign (1991)
Cu	4.35	4.61	7.61	Medium	Berger and Truog (1939)
Zn	3.04	1.51	1.29	Medium	Takelign (1991)
OC	2.87	2.87	2.73	Medium	Berhanu(1990)
OM	4.94	4.96	4.72	Medium	Takelign (1991)
TN	0.2	0.18	0.21	Medium	Takelign (1991)
C:N Ratio	14.44	16.02	13.24	Low to medium	Hazelton & Murphy (2007)

Combined ANOVA

There were statistically significant differences ($P < 0.01$) among the treatments, test locations and their interaction for days to 50% flowering, days to physiological maturity, number of nodules per plant and seed yield of common bean varieties (Table 2). On the other hand, nodule dry weight was significantly influenced by the main effect of location, variety and *Rhizobium* strain only (Table 2). This suggests the existence of genetic variation among the common bean varieties and possibility to select effective *Rhizobium* strains, the test locations are variable and the differential response of evaluated treatments across the testing environments.

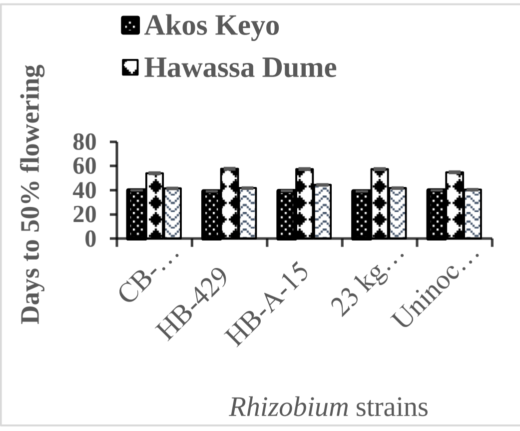
Table 2. Combined Analysis of variance for yield and yield related traits of common bean varieties evaluated across environments in western Ethiopia.

Source of variation	**DF**	**Mean squares**				
		FD	DM	SY	NNP	NDW
Block within locations	2	36.3	303.3	759737	87.9	0.0009
Location	4	9	1416.8**	22253044**	135.9**	0.061**
Variety	2	6204.3**	345.3**	4959065**	3189.3**	0.030**
Strains	4	34.3**	118.8	553126**	1885.7**	0.018**
Loc x Variety	8	0	71.1	1908153**	591.2**	0.018
Loc x Strains	16	0	56.9	195393**	461.2**	0.003
Variety x Strains	8	22.5**	158.3**	330043**	288.5**	0.005
Loc x Variety x Strains	32	0	64.7	169654*	120.4	0.005
Error	148	4.0	57.3	88702	49.6	0.0028
LSD (0.05)		3.2	12.2	480.5	11.5	0.087
CV (%)		4.4	9.5	22.1	26.0	6.2

Where, DF= Degree of freedom, FD= Days to 50% flowering, DM= Days to maturity, SY= Seed yield, LSD=Least Significant Differences, CV= Coefficient of variation, **= significant at P = 0.01, ns = non-significant

Days to 50% flowering and physiological maturity

Days to 50% flowering and physiological maturity were significantly influenced by the interaction effect of common bean varieties and *rhizobium* strains (Table 2). The longest days to 50% flowering was recorded from Hawassa Dume variety treated with different treatments while the shortest days 50% flowering was recorded from Akos keyo variety (Figure 2). Similarly, the longest days to physiological maturity was recorded from Hawassa Dume and Nasir varieties supplied with different treatments. The delayed maturity with Hawasa Dume and Nasir might be due to an indeterminate growth habits of the varieties and nitrogen produced by N_2 fixation
through inoculation promoted vegetative growth which in turn extended days to maturity.



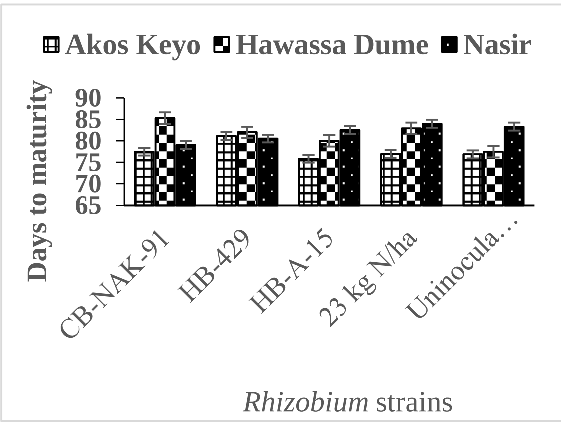


Figure 2. Interaction effect of common bean varieties and *rhizobium* strains on days to 50% flowering and physiological maturity.

Nodule number

The analysis of variance showed that total number of nodules per plant was significantly influenced by the interaction effect of *Rhizobium* × common bean varieties (Table 1). The result in Figure 3 showed significant interaction between *Rhizobium* and common bean varieties on number of nodules per plant. The highest number of nodules per plant (56.9) was recorded from Nasir variety inoculated with *Rhizobium* strain (CA-NAK-91), while the lowest number of nodules per plant (9.6 and 11.6) were recorded from Akos Keyo and Hawassa Dume varieties supplied with nitrogen fertilizer (Figure 3). The results of this study also revealed that few nodules were observed on uninoculated plots which is an indicator of the presence of common bean nodulating indigenous rhizobia bacteria in the experimental soil (Figure 3). In line with this results, Workneh and Asfaw (2012); Argaw and Muleta (2018) reported the presence of few nodules on uninoculated plots for soybean and common bean, respectively.

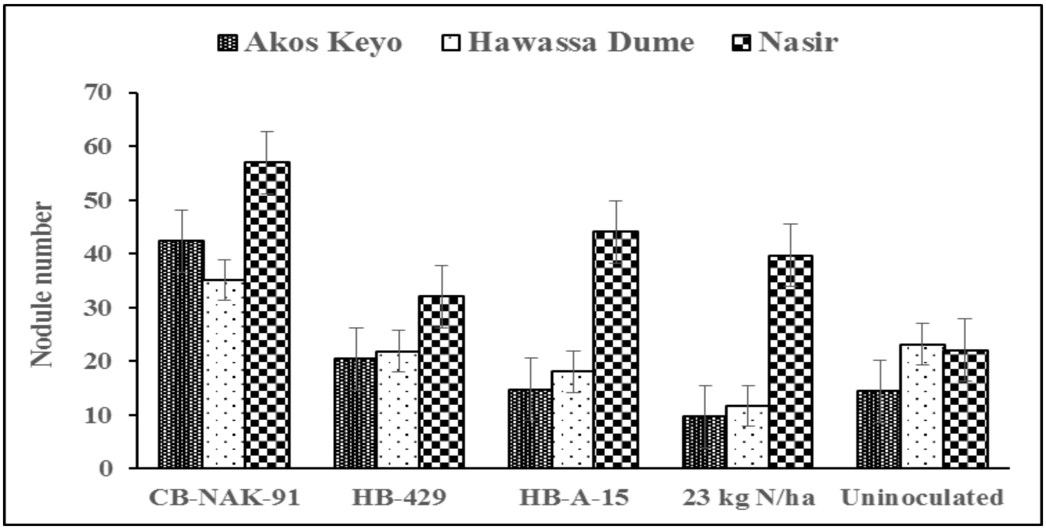


Figure 3. Interaction effect of common bean varieties and *rhizobium* strains on number of nodules per plant.

Nodule dry weight

There were positive significant effects of the variety, *Rhizobium* strains and locations on nodule dry weight (Table 1). The highest nodule dry weight (0.91 g/plant) was recorded from plots treated with CA-NAK-91 strain followed by plots inoculated with HB-429 strain (0.87 g/plant), whereas the lowest nodule dry weight (0.83 g/plant) was obtained from plots supplied with nitrogen fertilizer (Table 2). Similarly, nodule dry weight was significantly influenced by the main effect of common bean varieties. The highest nodule dry weight (0.89 g/plant) was obtained from Nasir common bean variety while the lowest nodule weight (0.83 g/plant) was recorded from Akos Keyo variety (Table 2).

***Table 2**. Main effects of common bean variety and* Rhizobium *strains on nodule dry weight*

Treatment	Nodule dry weight (g/plant)
Variety	
Akos Keyo	0.19(0.83)
Hawassa Dume	0.24(0.86)
Nasir	0.30(0.89)
LSD (0.05)	0.03
Inoculation	
Uninoculated	0.23(0.85)
CA-NAK-91	0.33(0.91)
HB-429	0.25(0.87)
HB-A-15	0.21(0.84)
N (28 kg ha-1)	0.19(0.83)
LSD (0.05)	0.04
CV (%)	6.2

Where, CV: Coefficient of variation, LSD: Least significant difference. Numbers in parentheses are square root transformed ($\sqrt{X+0.5}$).

Performance of the treatments across the environments

In the first four AMMI selection of treatments, Hawassa Dume + HB-429 strain took the first position at Sadan Kite and Gute while Hawassa Dume + CB-NAK-91 took the first best position at Sheboka (Table 2). Accordingly, Hawassa dume inoculated with HB-429 and HB-A-15 strains which followed by Nasir variety inoculated with CB-NAK-91 revealed static stability as compared to other treatments, which is desirable for common bean production in western Ethiopia. Nasir + HB-A-15 also took the first position at Sadan Kite in 2017 cropping season showing uniform yield performance in the particular environment (Table 2). The relative static performance of Hawassa dume inoculated with HB-429 and HB-A-15 strains and Nasir variety inoculated with CB-NAK-91 common bean varieties in different environment is an indication of general adaptability of these varieties.

Table-2: First four AMMI selections per environment

Environment	Mean seed yield (kg ha^{-1})	Genotype/Treatment rank			
		1	**2**	**3**	**4**
Sheboka	1159	G7	G15	G1	G5
Sadan Kite-2018	1204	G8	G6	G7	G9
Gute-2017	751	G8	G6	G7	G5
Gute-2018	1068	G6	G8	G3	G2
Sadan Kite-2017	2567	G1	G2	G3	G5

Keys: G1= Nasir + HB-A-15, G2= Nasir + CB-NAK-91, G3= Nasir + HB-429, G5= Nasir + N (28 kg ha^{-1}) as urea, G6= Hawassa Dume + HB-A-15, G7= Hawassa Dume + CB-NAK-91, G8= Hawassa Dume + HB-429, G9= Hawassa Dume + No strain and G15= Akos Keyo + N (28 kg ha^{-1}) as urea.

Seed yield

Analysis of variance showed significant interaction of common bean varieties x *Rhizobium* strain on seed yield of common bean (Table 1). Results in Figure 3 revealed the performance of common bean varieties under different *Rhizobium* strains. Varieties Hawassa Dume and Nasir were showed positive yield response to *Rhizobium* strains inoculation while variety Akos keyo gave lower yield compared to other varieties (Figure 3). The highest seed yield was recorded from Hawassa Dume variety inoculated with HB-429 and HB-A-15 strains while the lowest seed yield was obtained from Akos keyo variety inoculated with HB-A-15 strain (Figure 3). Hawassa Dume variety was revealed more static performance across the treatments in comparison to other common bean varieties. Generally, Hawassa Dume and Nasir varieties showed good seed yield performance across treatments. Common bean genotype-rhizobium- environment interaction revealed that yield and yield related traits of common bean varieties were significantly influenced by the interaction effect of variety, Rhizobium strains and locations (Table 1). This indicates the need for specific *Rhizobium* strain development for each of common bean genotypes when growing in different environments. Similar findings were previously reported on common bean genotypes (Abebe, 2017; Argaw and Muleta, 2018; Gunnabo et al., 2019).

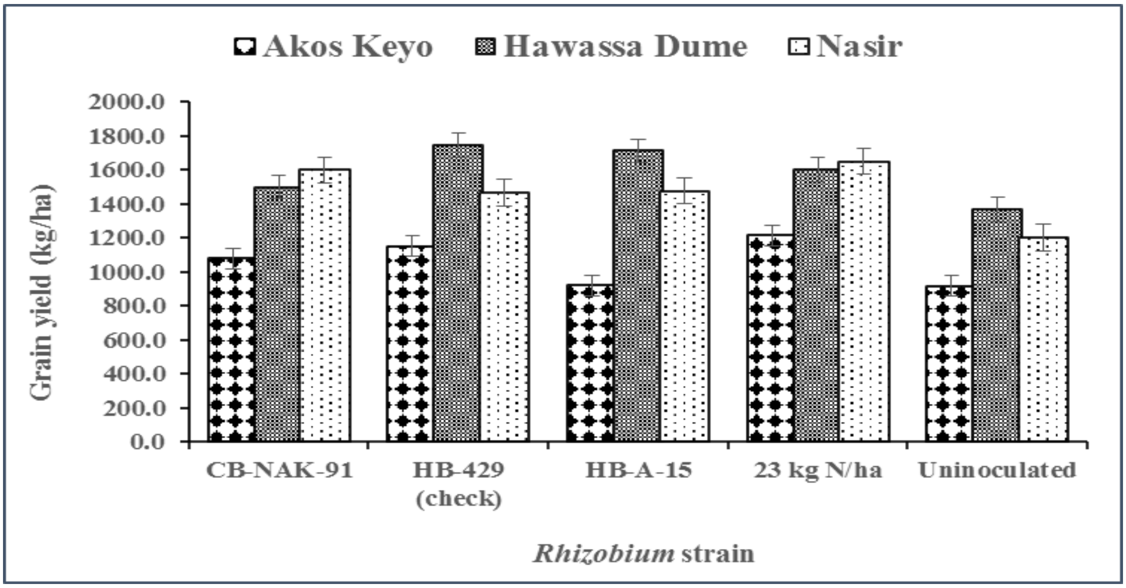


Figure 3. Interaction effect of common bean varieties and *Rhizobium* strains on seed yield.

Yield stability of the treatments across the test environments

In genotype by environment interaction biplot (Fig 3), $IPCA_1$ and $IPCA_2$ explained 62.0 and 21.78%, respectively, of common bean varieties-*Rhizobium* by environment interaction and made a total of 83.57%. An ideal genotype is defined as genotype which having the greatest IPCA1 score (mean performance) and with zero genotype by environment interaction (GEI), as represented by an arrow pointing to it (Figure 4). A genotype or treatment is more desirable if it is located closer to the ideal genotype. Thus, using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype. Therefore, the ranking based on the treatment-focused scaling assumes that stability and mean yield are equally important. In this study, Hawassa dume inoculated with HB-429 and HB-A-15 Rhizobium strains which followed by Nasir variety inoculated with CB-NAK-91 Rhizobium strain and supplied with nitrogen fertilizer fell closest to the ideal genotype were identified as the most desirable treatments as compared to the rest of the tested treatments in western Ethiopia for furthher production of common bean (Figure 4). In genotype x *Rhizobium* x environment interaction biplot (Figure 5), $IPCA_1$ and $IPCA_2$ explained 62.0 and 21.78%, respectively, of common bean varieties x *Rhizobium* x environment interaction and made a total of 83.57%. The other studies conducted on common bean genotypes by Gunnabo et al., 2019, explained an interaction of 77.4 and 17.1% respectively, extracted from $IPCA_1$ and $IPCA_2$ for relative shoot dry weight and 83.1 IPCA1 and 13% IPCA2 extracted for relative N2 derived from atmosphere in pots experiment.

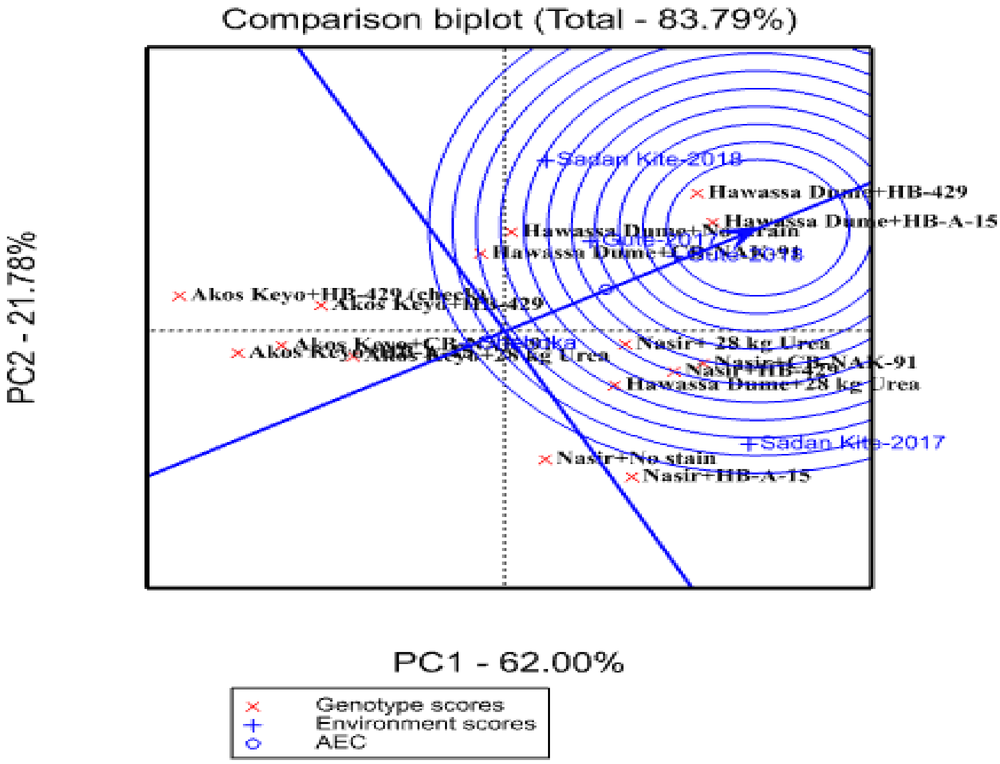


Figure 4. GGE bi-plot based on treatment-focused scaling for comparison of *Rhizobium* x common bean varieties interaction for their seed yield potential and stability.

Conclusion

Utilizing *Rhizobium* strains for pulse crop production is a recent practice in Ethiopian agriculture Effectiveness of *Rhizobium* strain is depend on the genotypes and environmental factors like essential plant nutrients, soil reaction (acidity and salinity), soil moisture, soil temperature. Varieties Hawassa Dume and Nasir were showed positive yield response to *Rhizobium* strains inoculation while variety Akos keyo gave lower yield compared to other varieties. The results showed that *Rhizobium* inoculation, the genotypes, environment and their interaction significantly affected yield and yield related traits of common bean varieties. The Hawassa Dume and Nasir varieties inoculated with *Rhizobium* strains (HB-429 and HB-A-15) and application of nitrogen fertilizer to Hawassa Dume and Nasir varieties gave the highest yields, compared to other treatments. According to the average environment coordination (AEC) views of the genotype-*rhizobium*-location interaction biplot, Hawassa dume variety inoculated with HB-429 and HB-A-15 strains which followed by Nasir variety inoculated with CB-NAK-91 strain and supplied with nitrogen fertilizer were identified as the most stable and high yielding varieties. Thus, it can be concluded that Hawassa dume and Nasir varieties with HB-429 and HB-A-15 strains were recommended for further production in most common bean growing areas of western Ethiopia.

Acknowledgement

Special gratitude goes to the N2 Africa project, which was funded by the Bill and Melinda Gates Foundation. The authors also thank Bako Agricultural Research Center, Pulse and Oils Research Team members for conducting the experiment and data collection.

References

Abebe, Z., 2017. On-farm yield variability and responses of common bean (Phaseolus vulgaris L.) varieties to rhizobium inoculation with inorganic fertilizer rates. *J Anim Plant Sci*, *32*(2), pp.5120-5133.

Akter, Z, Pageni, B.B., Lupwayi, N.Z., Balasubramanian, P.M., 2014. Biological nitrogen fixation and nifH gene expression in dry beans (Phaseolus vulgaris L.) Can J Plant Sci 94(2):203–212. https://doi. org/10.4141/cjps2013-200

Argaw, A., Mekonnen, E., Muleta, D., 2015. Agronomic efficiency of N of common bean (Phaseolus vulgaris L.) in some representative soils of Eastern Ethiopia. *Cogent Food & Agriculture*, *1*(1), p.1074790.

Argaw, A., Muleta, D., 2018. Effect of genotypes-Rhizobium-environment interaction on nodulation and productivity of common bean (Phaseolus vulgaris L.) in eastern Ethiopia. *Environmental Systems Research*, *6*(1), p.14.

Bambara, S., Ndakidemi, P., 2010(a). Phaseolus vulgaris response to Rhizobium inoculation, lime and molybdenum in selected low pH soil in Western Cape, South Africa. Afr J Agric Res 5:1804–1811

Bambara, S., Ndakidemi, P.A., 2010(b). Effects of Rhizobium inoculation, lime and molybdenum on nitrogen fixation of nodulated Phaseolus vulgaris L. Afr JMicrobiol Res 4:682–696.

Ferguson, R.B., Shapiro, C.A., Dobermann, A.R., Wortmann, C.S., 2006. Fertilizer Recommendation for soybeans. Neb Guide G859. 6 pp.

Fukuda, M., Nagumo, F., Nakamura, S., Tobita, S., 2012. Alternative fertilizer utilizing methods for sustaining low input agriculture. In: Soil fertility. InTech, Rijeka.

Gunnabo, A.H., Geurts, R., Wolde-meskel, E., Degefu, T., Giller, K.E., van Heerwaarden, J., 2019. Genetic interaction studies reveal superior performance of Rhizobium tropici CIAT899 on a range of diverse East African common bean (*Phaseolus vulgaris* L.) genotypes. Appl Environ Microbiol 85:e01763-19. https://doi.org/10..1128/AEM.01763-19.

Hayat, R., Ali, S., Siddique, M.T., Chatha, T.H., 2008. Biological nitrogen fixation of summer legumes and their residual effects on subsequent rainfed wheat yield. Pak J Bot 40:711–722.

Hazelton, P. and B. Murphy, 2007. *Interpreting soil test results: What do all the numbers mean? 2nd Edition*. CSIRO Publishing. pp. 152.
Kabahuma, M.K., 2013. Enhancing biological nitrogen fixation in common bean (Phaseolus vulgaris L). MSc Thesis, Iowa State University, Ames
Kawaka, F., Makonde, H., Dida, M., Opala, P., Ombori, O., Maingi, J. and Muoma, J., 2018. Genetic diversity of symbiotic bacteria nodulating common bean (Phaseolus vulgaris) in western Kenya. *PloS one*, *13*(11), p.e0207403.
Maina, F., Kihara, J., Mokwunye, U., 2011. Fighting poverty in sub-Saharan Africa: the multiple roles of legumes in integrated soil fertility management.
Mandri, B., Drevon, J.J., Bargaz, A., Oufdou, K., Faghire, M., Plassard, C., Payre, H., Ghoulam, C., 2012. Interactions between common bean genotypes and rhizobia strains isolated from Moroccan soils for growth, phosphatase and phytase activities under phosphorus deficiency conditions. *Journal of plant nutrition*, *35*(10), pp.1477-1490.
Massawe, P.I., Mtei, K.M., Munishi, L.K., Ndakidemi, P.A., 2016. Effect of *Rhizobium* and Intercropping Systems on Soil Nutrients and Biological Nitrogen Fixation as Influenced by Legumes (*Phaseolus vulgaris* and *Dolichos lablab*). *International Journal of Current Microbiology and Applied Sciences*, 5(10): 135-149.
Mohale, K.C., Belane, A.K., Dakora, F.D., 2014. Symbiotic N nutrition, C assimilation, and plant water use efficiency in Bambara groundnut (Vigna subterranea L. Verdc) grown in farmers' fields in South Africa, measured using 15N and 13C natural abundance. Biol Fertil Soils 50:307–319
Myers, J.R., Kmiecik, K., 2017. Common Bean: Economic importance and relevance to biological science research. In *The Common Bean Genome* (pp. 1-20). Springer, Cham.
Ngetich, F.K., Shisanya, C.A., Mugwe, J., Mucheru-Muna, M., Mugendi, D., 2012. The potential of organic and inorganic nutrient sources in Sub-Saharan African crop farming systems. In: Soil fertility im- provement and integrated nutrient management-a global perspective. InTech, Rijeka.
Nyemba, R.C., Dakora, F.D., 2010. Evaluating N2 fixation by food grain legumes in farmers' fields in three agro-ecological zones of Zambia, using 15N natural abundance. Biol Fertil Soils 46(5):461–470. https://doi.org/10.1007/s00374-010-0451-2.
Pastor-Bueis, R., Sánchez-Cañizares, C., James, E.K., González-Andrés, F., 2019. Formulation of a Highly Effective Inoculant for Common Bean based on an Autochthonous Elite Strain of Rhizobium leguminosarum bv. phaseoli, and Genomic-based Insights into its Agronomic Performance. *Frontiers in Microbiology*, *10*, p.2724.
Peoples, M., BrockwelL, P., Herridge, D., Rochester, I., Alves, B., Urquiaga, S., Boddey, R., Dakora, F., Bhattarai, S., Maskey, S., 2009. The contributions of nitrogen-fixing crop legumes to the productivity of agricultural systems. Symbiosis 48(1-3):1–17. https://doi.org/10.1007/BF03179980.
Pule-Meulenberg, F., Belane, A.K., Krasova-Wade, T., Dakora, F.D., 2010. Symbiotic functioning and bradyrhizobial biodiversity of cowpea (*Vigna unguiculata* L. Walp.) in Africa. BMC Microbiol 10(1):89. https://doi.org/10.1186/1471-2180-10-89.

Rice, W.A., Clayton, G.W., Lupwayi, N.Z. and Olsen, P.E. 2001. Evaluation of coated seeds as a *Rhizobium* delivery system for field pea. Lacombe, Alberta. *Canadian Journal of Plant Science*, 81(1): 248-249.

Tabaro, A., 2014. Evaluation of effectiveness of rhizobia isolates from Rwandan soils on common bean (Phaseolus vulgaris L.). MSc. Dissertation, University of Nairobi

Tekalign Tadese. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

Unkovich, M., Herridge, D., Peoples, M., Cadisch, G., Boddey, B., Giller, K., Alves, B., Chalk, P., 2008. Measuring plant-associated nitrogen fixation in agricultural systems. ACIAR.Monograph no 136, Canbberra.

Workneh Bekere and Asfaw Hailemariam. 2012. Influence of Inoculation Methods and Phosphorus Levels on Nitrogen Fixation Attributes and Yield of Soybean (*Glycine max* L.) at Haru, Western Ethiopia. *American Journal of Plant Nutrition and Fertilization Technology*, 2(2): 45-55.

Effect of Inter and Intra row Spacing on Yield and Yield Components of Different Maturity Groups of Soybean Varieties in western Oromia, Ethiopia

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Abstract
Crop geometry is an essential agronomic practice and affects the productivity of crops. Hence, the study was conducted to determine the effect of inter and intra row spacing on yield and yield components of soybean varieties and to determine appropriate plant density for each maturity groups of soybean varieties to achieve high yield of soybean in the study area. Two soybean varieties from each maturity groups, four inter row spacing (30, 40, 50 and 60 cm) and two intra row spacing (5 and 10 cm) were arranged in factorial combinations in RCBD with three replications. The results showed that days to flowering, days to maturity, plant height, number of seeds/pod, number of pods/plant and hundred seed weight were significantly influenced by the main effect of varieties, inter and intra row spacing for each maturity groups of soybean varieties. The highest grain yield was recorded from narrow inter-row spacing for early and medium maturity groups regardless of intra-row spacing while the highest grain yield was obtained from 50 cm inter-row spacing for late maturing groups. Thus, it can be concluded that, 40 cm inter-row spacing is recommended for early and medium soybean varieties while 50 cm inter-row spacing recommended for late maturing soybean varieties for western parts of Oromia and similar agro-ecologies.
Keywords: Crop geometry, maturity groups, plant density

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. Soybean is a promising pulse crop proposed for alleviation of acute shortage of protein and oil worldwide (Mahamood *et al.*, 2009).

Soybean is one of the main pulse crops that can be widely grown in sub-tropical area. It has different maturity group in terms of their maturity periods, morphological characters and other growth characteristics. Their agronomic managements may also differ in terms of nutrient requirements, plant population per ha and other agronomic traits. Plant density is one of an important agronomic aspect which may influences crop growth and productivity. Some research finding revealed that maximum yield can be obtained when the plant community produces enough leaf area to provide maximum interception of light during reproductive growth (Gazahagn *et al*., 2017). Plant density is an essential agronomic practice and affects the productivity of crops. Hence, the optimum plant density to achieve the maximum productivity may vary from crop to crop, genotype to genotype and location to location (Gulluoglu *et al*., 2017).

Soybean varieties in Ethiopia are categorized into three maturity groups early-, medium- and late-maturing varieties, are recommended for different agro-ecological zones of Ethiopia. Growers traditionally use either 40 or 60 cm row spacing and 5 cm plant spacing, regardless of the maturity groups of the varieties and agronomic conditions of the location (Ali *et al.*, 2003). However, a recent study on the responses of early and late maturing varieties to planting density in south-western Ethiopia showed less weed growth and greater yield and yield components per m^2 as row spacing decreased from 70 to 50 cm and plant spacing

from 10 to 2.5 cm or as plant density increased from 14 m^2 to 80 m^2.

Soybean production in different agro-ecologies of Ethiopia including hot-humid regions is steadily growing to meet the ever-increasing market demand. In Ethiopia, soybean growers traditionally use either 40 or 60 cm row by 5 cm plant spacing regardless of the agronomic conditions of the location. However, as no study was conducted to determine the effect of plant density on the growth and yield of soya bean for various varieties in western Oromia, this study was initiated with the objectives to determine the effect of inter and intra row spacing on yield and yield components for each maturity groups of soybean varieties and to determine appropriate plant density for early, medium and late maturity groups of soybean varieties to achieve high yield of the cop in the study area.

Materials and Methods

Description of the study areas

The experiment was carried out during the main rainy season (June to November) during 2018 and 2019 at Bako, Gute and Billo, western Oromia. Table 1 present climatic data of rain fall, GPS reading and soil type of the test locations. The predominant soil type of the area is *Nitosols* which is characteristically reddish brown and clay in texture with a pH that falls in the range of very strongly acidic to strongly acidic according to rating done by Jones (2003).

Table 1: Test locatons used in the study and their main characteristics

Location	Longitude	Latitude	Altitude (m.a.s.l)	RF (mm)	Soil type
Bako	37°09'E	09°06'N	1650	1431	Sandy-clay
Gute	E:036^{0}38.196’	N:09^{0}01.061’	1915	NI	Clay
Billo	E:037^{0}00.165’	N:09^{0}54.097’	1645	1500	Clay

NI = Not indicated

Experimental Materials

Two soybean varieties from each maturity groups were used for the study. These varieties were released by Bako Agricultural Research Center and selected based on their maturity group and better performance in the study area.

Table 2. Information of soybean varieties used for the study

Variety	Maturity class	Days to maturity	Yield potential (Qt ha^{-1})		Year of release
			On farm	On research field	
Boshe	Early set	100-120	14-28	16-30	2008
Jalale	Early set	100-120	15	22	2003
Cheri	Medium set	100-120	15	22	2003
Dhidhessa	Medium set	120-150	14-28	20-33	2008
Keta	Late set	120-150	13-28	14-32	2011
Korme	Late set	120-150	12-32	12-38	2011

Treatments and Experimental Design

Three sets of experiments were conducted separately for each maturity groups of soybean varieties. Each set of experiment was comprised three factors, namely two soybean varieties, four inter row spacing (30, 40, 50 and 60 cm) and two intra row spacing (5 and 10 cm). The first set was consists of two early maturing soybean varieties (Boshe and Jalale), four inter row spacing (30, 40, 50 and 60 cm) and two intra row spacing (5 and 10 cm). The second set of experiment was comprised of two medium maturing soybean varieties (Cheri and Dhidhessa), four inter row spacing (30, 40, 50 and 60 cm) and two intra row spacing (5 and 10 cm). The third set of experiment was comprised of two late maturing soybean varieties (Ketta and Korme), four inter row spacing (30, 40, 50 and 60 cm) and two intra row spacing (5 and 10 cm). The treatments of each set was arranged as 2x4x2 factorial combinations in RCBD with three replications for each set of experiment. The gross plot was 3m x 3m area and one row each from both sides of the plot was left as a border row.

Field managements

The experimental field was ploughed with tractor to a fine tilth. The plots were leveled manually, and the sowing was done in mid- June, 2018-2019. The seeds were planted by hand at a specified spacing by placing two seeds per hill and thinning was done to one plant at each specific intra row spacing two weeks after seedling emergence to achieve the desired plant density in each row. Uniform dose of recommended NPS fertilizer containing (18% N, 38% P_2O_5 and 7% S) was applied to all treatments during planting. All the other agronomic practices were followed as per the recommendation for the crop.

Data collected

Phenological and growth parameters

Days to 50% flowering: Number of days from planting to the date on which 50% of plants on the net plot produce at least their first flower.

Days to physiological maturity: The number of days from planting to the stage when 90% of the plants in a plot have reached physiological maturity, *i.e.* the stage at which pods lose their pigmentation and begin to dry.

Plant height: the height of ten randomly taken plants from each of the four middle rows was measured from the ground level to the tip of the plant at maturity and expressed as an average of ten plants per plot.

Number of primary branches: Number of primary branches was counted at physiological maturity by taking ten randomly taken soybean plants from four central rows.

Yield and yield components

Number of pods per plant: The number of pods per plant was counted from five randomly selected plants from the four middle rows at harvest maturity and expressed as an average for each plot.

Number of seeds per pod: Number of seeds was counted from the randomly taken pods from the net plot and will be expressed as an average of five pods.

Hundred seed weight: weight of 100 seeds that was sampled from each plot was weighed using sensitive balance and the weight was adjusted at 10% standard moisture content.

Grain yield: Grain yield was measured by harvesting the crop from the net plot area. The moisture content of the grain will be adjusted to 10%. Then the weight will be converted to kg ha^{-1}.

Data Analysis

All collected parameters will be subjected to analysis of variance using of GenStat 18th edition (GenStat, 2016). Whenever the effects of the treatments was found to be significant, the means was compared using Least Significance Difference (LSD) test at 5% level of significant.

Results and Discussion

Set I: Response of early maturing soybean varieties to inter and intra row spacing

Analysis of variance

Plant height was showed significant difference among seasons only. Number of pods per plant was significantly influenced by the main effect of variety, inter and intra-row spacing while hundred seed weight was influenced by variety only. The grain yield was significantly influenced by the main effect of inter row spacing. Narrow inter row spacing gave the highest grain yield regardless of intra row spacing compared to wider inter row spacing.

Table 3: Anova table for early maturing soybean varieties

Source of variation	Mean squares							
	DF	FD	DM	PH	NPB	NPP	HSW	GY
Block	2	4.823	1.792	42.87	3.3904	408.7	3.049	447728
Year (Yr)	1	536.76**	527.344**	338.5**	2.94**	138.2	5.617	124185
Variety (V)	1	10.01	61.76**	6.9	0.1667	2262**	861.349**	104996
Inter-row spacing	3	5.649	5.538*	59.36	0.4583	1719.6**	3.682	976186**
Intra-row spacing	1	3.76	10.01*	128.65	9.8817**	4521**	7.421	536100
Year x Variety	1	25.01**	82.51**	68.46	0.0017	462.9	9.263	230391
Year x Inter-RS	3	3.455	2.399	35.01	0.1744	388	4.27	486998
Variety x Inter-RS	3	7.483	1.594	55.11	0.73	325.6	5.596	142458
Year x Intra-RS	1	19.26*	3.01	10.36	0.4267	495	2.711	347579
Variety x Intra-RS	1	21.094*	3.01	46.76	1.9267*	220.8	0.918	1498
Inter-RS x Intra-RS	3	0.955	1.122	13.96	0.7161	141.9	4.707	206952
Yr x V x Inter-RS	3	5.76	1.177	11.9	0.1339	122.2	0.521	69069
Yr x V x Intra-RS	1	3.01	0.51	46.76	2.535**	726	0.009	1569376**
Yr x Inter-RS x Intra-RS	3	1.399	0.622	25.68	0.2567	44	5.569	756514
V x Inter-RS x Intra-RS	3	4.899	0.733	14.92	0.1033	172.8	1.927	11621
Yr xVxInter-RS x Intra-RS	3	2.094	1.177	5.95	0.0761	22.3	7.471	107300
Error	62	3.554	1.878	38.33	0.4231	142	2.621	230998

Key: DF= Degree of freedom, FD= Days to 50% flowering, DM= Days to maturity, PH= Plant height, NBP=Number of primary branches per plant, NPP= Number of pods per plant, HSW= Hundred seed weight and GY= Grain yield.

Days to flowering and number of branches

Days to 50% flowering and number of primary branches per plant were significantly influenced by the interaction effect of variety and intra-row spacing. Soybean planted with smaller intra row (5 cm) produced smaller branches compared to wider intra row (10 cm)

(Figure 1). The increased primary branches that carry more pod numbers at wider intra row spacing might be due to the low completion of light, space and nutrients among plants.

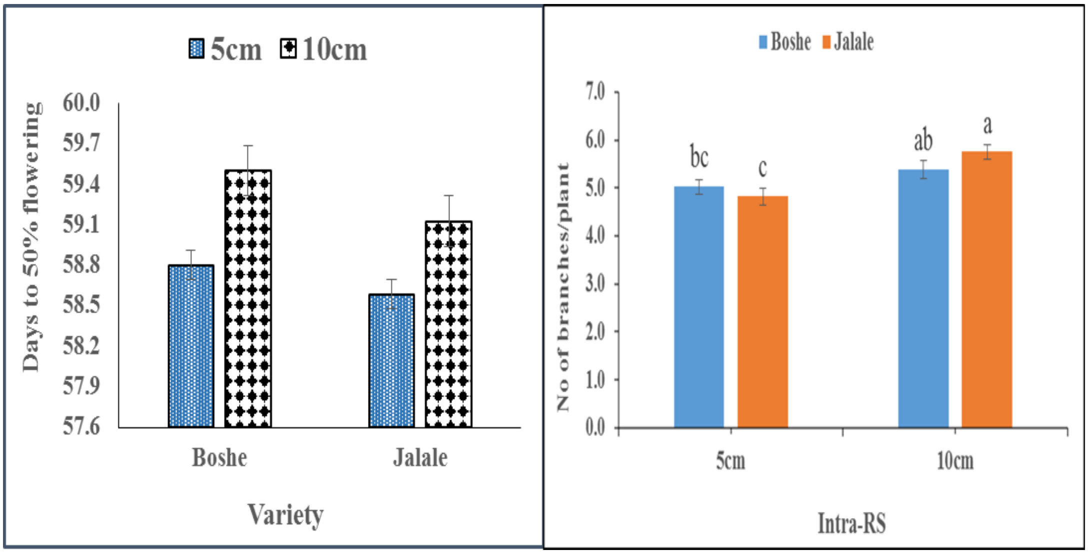

Figure 1: Interaction effect of variety by intra-row spacing on days to 50% flowering and number of primary branches per plant

Yield and yield components

Plant height did not respond to inter and intra row spacing. Number of pods per plant was significantly influenced by the main effect of variety, inter and intra-row spacing. Soybean produced more number of pods per pant at wider inter and intra row spacing (Table 4). Compensation in more number of pods per plant at lower plant density, mainly on the branches is the secondary yield components most responsible for soybean yield compensation to increased space either within or between rows. In line with results, Cox and Cherney (2011) recorded the more number of pods per plant at lower plant density.

The grain yield was significantly influenced by the main effect of inter row spacing. Narrow inter row spacing gave the highest grain yield regardless of intra row spacing compared to wider inter row spacing (Table 4). Similarly, Cox and Cherney (2011) recorded 7% more soybean yield at 19 cm compared with 38 cm and 17% more soybean yield with 76 cm rows. In western and southern Canada a row spacing of less than 76 cm gave consistently higher yields than a row spacing of more than 76 cm (De Bruin and Pedersen, 2008), whereas under hot sub-moist tropical conditions in south western of Ethiopia, a row spacing of 40 cm gave higher yields than a wider row spacing (Worku and Astatkie, 2015).

Table 4: The main effect of variety, inter and intra-row spacing on days to 50% flowering, plant height, number of pods per plant and hundred seed weight and grain yield of early maturing soybean varieties.

Treatment	Days to maturity	Plant height (cm)	Pods/plant	Hundred seed weight (g)	Grain yield (kg/ha)
Variety					
Boshe	117.0	61.7	64.6a	14.66b	2782
Jalale	115.4	62.3	54.9b	20.65a	2865
LSD (0.05)	0.56	NS	4.9	0.7	NS
Inter-row spacing					
30 cm	115.7	63.9	51.9c	17.6	3187
40 cm	116.0	62.0	54.4bc	17.7	2664
50 cm	116.3	62.1	62.1b	17.2	2838
60 cm	116.8	60.1	70.6a	18.2	2605
LSD (0.05)	0.79	NS	6.9	NS	347.2
Intra-row spacing					
5 cm	115.8	63.2	52.9	17.4	2914
10 cm	116.5	60.9	66.6	17.9	2733
LSD (0.05)	0.56	NS	4.9	NS	NS
CV (%)	1.2	10	20	9.2	17

Set II: Response of medium maturing soybean varieties to inter and intra row spacing
Phenological periods in medium maturity groups

Days to 50% flowering was significantly influenced by the interaction effect of test location x soybean variety whereas days to reach physiological maturity was influenced by the interaction effect of variety x inter row spacing (Figure 32A-B). Soybean varieties took the longest days to reach days to 50% flowering at Bako, compared to Billo (Figure 2A). Five days interval were observed to reach days to 50% flowering between locations.

Narrow inter row spacing matured earlier compared to wider spacing. As inter row spacing becomes wider, days to reach physiological maturity extended significantly (Figure 2B). The delayed maturity under wider inter row spacing for Dhidhessa variety compared to Cheri variety might be due to the indeterminate growth habit of the variety under low nutrient completion under wider inter row spacing. Varieties respond vary to inter-row spacing to reach days to physiological maturity.

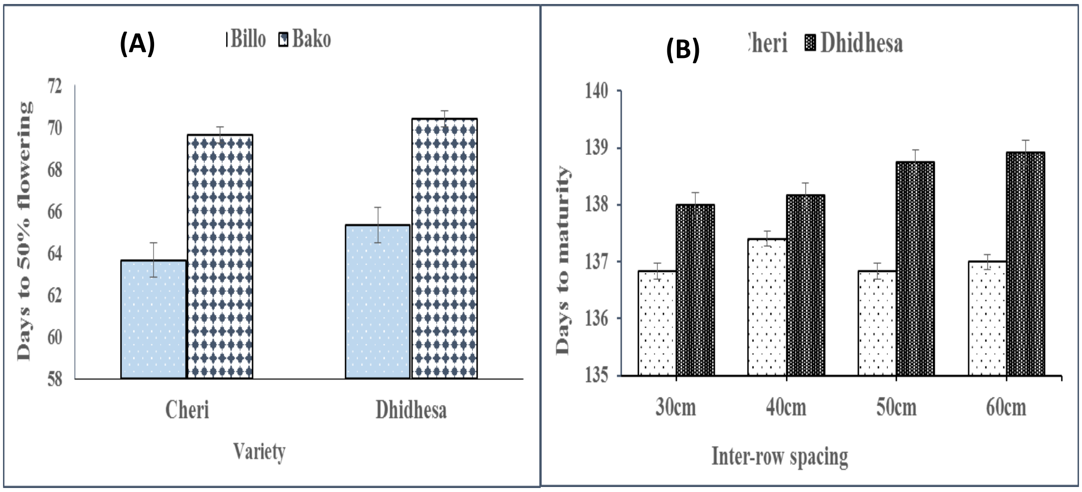

Figure 2: (A) Interaction effect of test location x variety on days to 50% flowering and (B) Interaction effect of variety x inter-row spacing on days to reach physiological maturity**.**

Growth parameters

Plant height (cm)

Plant height was significantly affected by the main effects of variety x inter row spacing x locations (Figure 3). The highest plant height was observed for variety Cheri and Dhidhessa at 60 cm and 30 cm, respectively at Bako and Billo. In agreement with this result, Kena (2018) reported significant differences among the varieties of soybean for plant height and found that medium maturing soybean varieties were longer than early maturing soybean varieties.

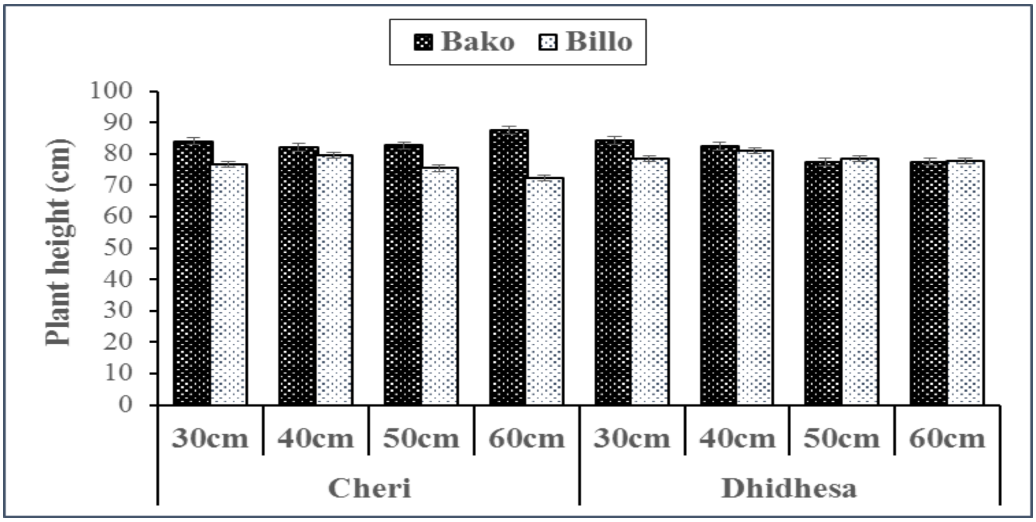

Figure 3: Interaction effect of test location x variety x inter-row spacing on plant height of medium maturity groups

Primary branches

Analysis of variance revealed that number of primary branches was significantly influenced by the main effects of inter and intra row spacing (P<0.01), while the main effect of variety and the interaction effect of variety, inter and intra row spacing showed non-significant effect on the number of primary branches per plant. The highest number of primary branches was recorded from wider inter and intra row spacing (Table 4). Thus, the presence of significant effect of inter and intra row spacing on the number of primary branches indicated the differential response of the soybean to inter and intra row spacing.

Yield and yield components

Number of pods per plant was significantly influenced by the main effect of variety, inter and intra row spacing. Soybean produced more number of pods per pant at wider inter and intra row spacing (Table 5). Compensation in more number of pods per plant at lower plant density, mainly on the branches is the secondary yield components most responsible for soybean yield compensation to increased space either within or between rows. In line with results, Cox and Cherney (2011) recorded the more number of pods per plant at lower plant density.

The grain yield was significantly influenced by the main effect of inter row spacing. Narrow inter row spacing gave the highest grain yield regardless of intra row spacing compared to wider inter row spacing. Similarly, Cox and Cherney (2011) recorded 7% more soybean yield at 19 cm compared with 38 cm and 17% more soybean yield with 76 cm rows. In western and southern Canada a row spacing of less than 76 cm gave consistently higher yields than a row spacing of more than 76 cm (De Bruin and Pedersen, 2008), whereas under hot sub-moist tropical conditions in south western of Ethiopia, a row spacing of 40 cm gave higher yields than a wider row spacing (Worku and Astatkie, 2015).

Table 5: The main effect of variety, inter and intra-row spacing on grain yield of medium maturing soybean varieties.

Treatment	Number of branches/plant	Number of pods/plant	Hundred seed weight (g)	Grain yield (kg/ha)
Variety				
Cheri	6.5	52.35	14.61	2197
Dhidhessa	6.3	58.14	15.62	2425
LSD (0.05)	NS	2.9	0.34	155.5
Inter-row spacing				
30 cm	5.9	48.46	15.19	2264
40 cm	6.5	57.24	15.23	2547
50 cm	6.5	56.35	14.94	2251
60 cm	6.6	58.93	15.13	2182
LSD (0.05)	0.39	4.2	NS	220.0
Intra-row spacing				
5 cm	6.1	50.91	15.15	2302
10 cm	6.7	59.58	15.09	2320
LSD (0.05)	0.28	2.9	NS	NS
CV (%)	15.3	18.7	8.0	19.6

Set III: Response of late maturing soybean varieties to inter and intra row spacingHundred seed weight: Hundred seed weight was influenced by interaction effect of variety by test locations (Table 6). Significantly higher hundred seed weight (19.7g) was recorded for variety Keta than variety Ethio-yougslavia (18.5g) (Table 6). The significant difference on hundred seed weight might be due to seed size of different varieties; because final crop yield is a function of the number and size of seeds. This result was in conformity with the study by Kena (2018), who reported that the number of 100 grains weight was significantly affected by main effect of varieties.

Table 6: Interaction effect of location by variety on plant height and hundred seed weight

Location	Plant height (cm)		Hundred seed weight (g)	
	Variety		Variety	
	Ethio-yugslavia	Keta	Ethio-yugslavia	Keta
Bako	89.5[a]	78.1[b]	16.7[c]	19.7[a]
Gute	69.7[c]	65.3[d]	16.7[c]	18.5[b]
LSD (0.05)	3.01		0.6	
CV (%)	9.9		8.4	

Number primary branches per plant and number of pods per plant were significantly influenced by the main effect of inter and intra row spacing. Medium maturing soybean varieties produced more number of primary branches and number of pods per pant at wider inter and intra row spacing (Table 7). Compensation in more number of pods per plant at lower plant density, mainly on the branches is the secondary yield components most responsible for soybean yield compensation to increased space either within or between rows. In line with results, Cox and Cherney (2011) recorded the more number of pods per plant at lower plant density.

Table 7: The main effects of variety, inter and intra-row spacing on number of primary branches and pods per plant

Treatment	**Parameters**	
Variety	No of primary branches/plant	No of Pods/plant
Keta	5.8	48.0
Ethio-yugslavia	6.1	47.5
LSD (0.05)	NS	NS
Inter-row spacing		
30 cm	5.5	39.5
40 cm	5.9	46.7
50 cm	6.3	52.6
60 cm	6.1	52.4
LSD (0.05)	0.44	4.2
Intra-row spacing		
5 cm	5.8	43.8
10 cm	6.2	51.8
LSD (0.05)	0.3	2.9
CV (%)	18.4	17

Grain yield: Grain yield was significantly influenced by interaction effect of inter row spacing and test location. The highest grain yield (3500 kg ha^{-1}) was recorded from 50 cm inter row spacing for late maturing soybean varieties (Figure 4). The main difference of grain yield of the interaction effect might be due to response of different varieties of the same crop to different plant spacing because of their growth habit, number of branches per plant and plant height affected by inter row spacing. This result was in line with Dereje (2014), who reported that narrow spacing for early mature variety and wider spacing for medium and late maturing group soybean varieties. This implies that row spacing recommendations for optimizing soybean production in the hot submoist agro ecological zone of southwest Ethiopia need not be as variety specific as plant spacing recommendations made previously (Worku and Astatkie, 2011). Genotypes with different growth habits also responded with different total biomass and seed yield to increased plant density (Gan *et al.*, 2002).

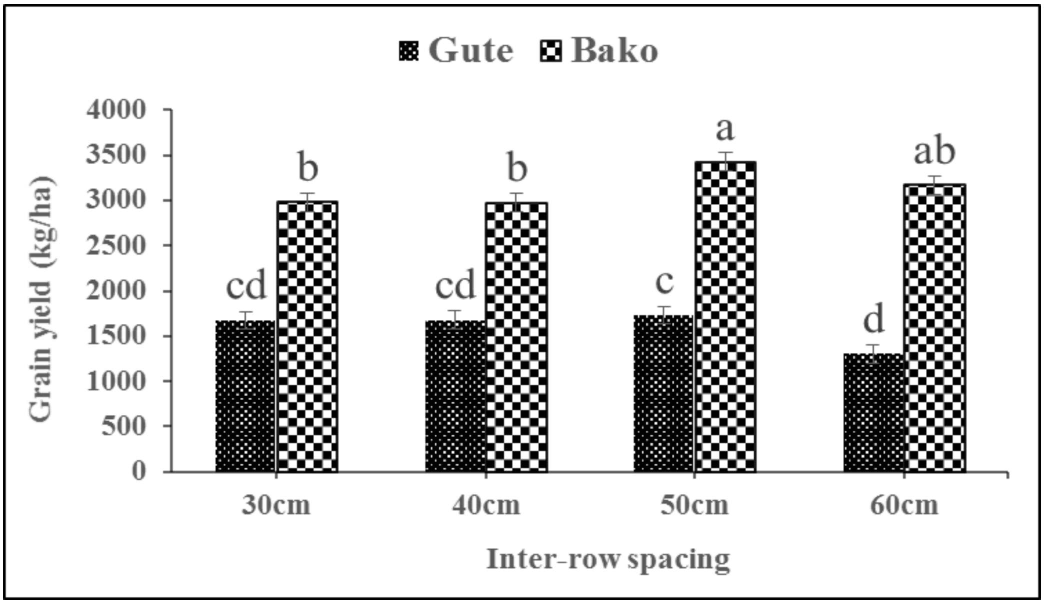

Figure 4: Interaction effect of location by inter-row spacing on grain yield of late maturity groups of soybean varieties

Conclusion

Plant density is an essential agronomic practice and affects the productivity of crops. Hence, the optimum plant density to achieve the maximum productivity may vary from crop to crop, genotype to genotype and location to location. The results showed that, the highest grain yield was recorded from narrow inter row spacing (40 cm) for early and medium maturing soybean varieties while the highest grain yield was obtained from wider inter row spacing (50 cm) for late maturing soybean varieties. Therefore, it can be concluded that, 40 cm inter-row spacing is recommended for early and medium soybean varieties while 50 cm inter-row spacing recommended for late maturing soybean varieties for western parts of Oromia and similar agro-ecologies.

References

Bradley, K.W., 2006. A review of the effects of row spacing on weed management in corn and soybean. *Crop Management*, *5*(1).

Chauhan, B.S. and Opeña, J.L., 2013. Effect of plant spacing on growth and grain yield of soybean. *American Journal of Plant Sciences*, *4*(10), p.2011.

Cox, W.J. and Cherney, J.H., 2011. Growth and yield responses of soybean to row spacing and seeding rate. *Agronomy Journal*, *103*(1), pp.123-128.

De Bruin, J.L. and Pedersen, P., 2008. Effect of row spacing and seeding rate on soybean yield. *Agronomy journal*, *100*(3), pp.704-710.

Dereje, Yigezu, 2014. Response of Soybean [*Glycine max* (L.) Merrill] Varieties to Plant Spacing in Guliso District, Western Ethiopia. MSc. Thesis in Agronomy, Haramaya University, 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.

Gulluoglu, L., Bakal, H., Sabagh, A.E. and Arioglu, H., 2017. Soybean Managing For Maximize Production: Plant Population Density Effects On Seed Yield And Some Agronomical Traits in Main Cropped Soybean Production. *Journal of Experimental Biology*, *5*, pp: 1.

Jones, J.B. 2003. Agronomic Handbook: Management of Crops, Soils, and Their Fertility CRC Press LLC, Boca Raton, FL, USA. 482p.

Kena, K., 2018. Effect of inter row spacing on yield components and yield of soybean (Glycine Max (L.) Merrill) varieties in Dale Sedi District. Western Ethiopia. *Agri Res & Tech: Open Access J*, *18*(4), p.556068.

Kumagai, E., 2020. Agronomic responses of soybean cultivars to narrow intra-row spacing in a cool region of northern Japan. *Plant Production Science*, pp.1-12.

Mahamood, J., Abayomi, Y.A. and Aduloju, M.O. 2009. Comparative growth and grain yield responses of soybean genotypes to phosphorous fertilizer application. *African Journal of Biotechnology*, 8(6):1030-1036.

Moreira, A., Moraes, L.A., Schroth, G. and Mandarino, J.M., 2015. Effect of nitrogen, row spacing, and plant density on yield, yield components, and plant physiology in soybean–wheat intercropping. *Agronomy Journal*, *107*(6), pp.2162-2170.

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.

Worku, M. and Astatkie, T., 2015. Effects of row spacing on productivity and nodulation of two soybean varieties under hot sub-moist tropical conditions in south-western Ethiopia. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS)*, *116*(2), pp.99-106.

Determination of nitrogen and NPS fertilizer rates on Hot pepper(*Capsicum annuum* L.) of yield and yield component at western wollega, oromia, Ethiopia.

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Abstract
Hot Pepper (Capsicum annum L.) is the world's most important vegetable after tomato and used as fresh, dried or processed products, as vegetables and as spices or condiments.A new blended fertilizer (NPS) containing nitrogen (19% N), phosphorous (38% P_2O_5) and sulfur (7% S) is recently introduced aiming at substituting DAP in Ethiopian agriculture. However, the productivity is low due to nitrogen, phosphorus and other micronutrient as S, B, Zn deficiencies are the main constraints for vegetable and other crop production. Recently acquired soil inventory data from Ethio SIS.Therefore the field experiment was conducted at western –Wollega zone of oromia to determine the effect of nitrogen and NPS rates on growth and yield parameters of hot pepper variety and to investigate the effect of N and NPS rates on yield and economic of hot pepper variety during the main cropping season of 2018 and 2019 at Bako Agricultural Research center. The treatment consist of factorial combination of one variety BakoLocal withfour N rates level (0kg N ha^{-1}), (46 kg N ha^{-1}), (69 kg N ha^{-1}), (92 kg N ha^{-1}) and four NPS rates level (0kg, 50kg, 75kg and 100kg NPS ha^{-1}) and the experiment was laid out as a Randomized Complete Block Design (RCBD) and replicated three times. The analysis result show that main effect was significant ($P<0.05$) influenced due the combined application of Nitrogen and NPS blended fertilizer rates on the growth parameter of plant height, number pod per plant and canopy diameter per plant, but the non-significant on stand count at harvesting, number of main branch, pod length and pod diameter.The analysis variance revealed that main effect was significant ($P<0.05$) influenced dueto the combined application of Nitrogen and NPS blended fertilizer rates on the yield component parameter of marketable dry pods yield, unmarketable dry pods yield and Total dry pods yield. In general the combined applications of 69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$or 150 kg/ha urea and 75kg/ha NPS produced the highest total dry pod yield (1.12 t ha^{-1}) and the most economically feasible for hot pepper production which provided the net benefit of (113227.5 ETB ha^{-1}) and also recommended forwestern Oromia and similar agroecology.

Keywords: *Hot pepper and NPS*

Introduction

Hot Pepper (*Capsicum annum L.)* is the world's most important vegetable after tomato and used as fresh, dried or processed products, as vegetables and as spices or condiments (Acquaah, 2004). Hot Peppers are third importance in tropics among cultivated vegetables, primarily grown for their pungency, as good sources of vitamins A and C especially in fresh state (Abu *et al*., 2011). It is the main parts of the daily diet of most Ethiopian (Dennis, 2013). The average daily consumption of hot pepper by Ethiopian adult is estimated 15g, which is higher than tomatoes and most other vegetables (MARC, 2004).

Pepper is an important spice and vegetable crop in Ethiopia covering 64.93% of the area covered under vegetables and accounts 28.59% of vegetable production (CSA, 2010). Correspondingly, CSA (2010) reported that peasants produced 61,463.7 tons of
green pepper and 159,327.5 tons of red pepper on 7,850 ha and 89,862 ha of land, respectively. According to FAO (2007) report, world production of pepper was 28.4 million tons in both dry and green fruits from 3.3 million hectare of land, with annual growth rate of 0.5 percent.
Pepper is an economically and traditionally important crop in Ethiopia. It is a major spice and
vegetable crop produced by the majority of farmers in SNNPRS, Oromia, and Amhara regions
(EEPA, 2003). In addition to its export value, the powder from the dried pod is the main component in the daily diet of Ethiopians. The nutritional value of hot pepper merits special attention. It is a rich source of vitamin A and E. Both hot and sweet peppers contain more vitamin C than any other vegetable crop (Bosland and Votava, 2000).
Despite much effort to increase productivity of pepper, average output per hectare of farm land has not shown significant increase (EEA, 2002). According to CSA (2006), the productivity of dry and green hot pepper was 2.2 t ha-1 and 6.42 t ha-1, respectively. World average green pepper productivity on the other hand, stood at 14.05 t ha-1 (FAO, 2004). Therefore it can be concluded that Ethiopia's *Capsicum* productivity is far below the world average that strongly demands immediate improvement, aiming at increasing productivity.
Many factors have contributed to the low yield of the crop in the country. Low production inputs including old varieties, fertilizers, lack of appropriate crop protection, poor pre and post-harvest practices, lack of appropriate cultural practices etc. Among these, soil fertility management is considered to be the most yield limiting problem for hot pepper production in Ethiopia (Alemu & Ermias, 2000). One of the major problems affecting food production in Africa including Ethiopia is the rapid depletion of nutrients in small holder farms (Achieng *et al.,* 2010). Application of the fertilizer especially nitrogen has been shown to increase the number and size of marketable fruits, overall yield and fruit pungency of pepper (Johnson and Decoteau, 1996). The overall effect would depend on the available N in the soil, especially to the amount of nitrogen that is applied (Payero and Bhangoo, 1990).

The application of balanced fertilizers is the basis to produce more crop output from existing land under cultivation (Amalfitano *et al.,* 2017; Caruso *et al*., 2019). It enhances sustainable production and provides nutrient needs to crops according to their physiological requirements and expected yields (Ryan, 2008). Previous fertilizer research work in Ethiopia has been focused on nitrogen (N) and phosphorous (P) fertilizer sources under different soil types and various climatic conditions, while very limited work has been reported with other essential macro- and micro-nutrients (S, Fe, Zn, B, etc). FAO (2009) report indicated that the estimated production of pepper in Ethiopia was 220,791tons from 97,712 ha in green form and 118,514 tons of dry pepper from an area of 300,000 ha. Mineral fertilizers are used to supplement the natural soil nutrient supply in order to satisfy the demand of crops with a high yield potential, compensate for the nutrients lost by the removal of plant products and by leaching. Mineral fertilizers have the merit of being readily soluble in soil solution, less bulky and easy to manipulate but their constitution in most cases does not include the much needed essential minor elements as compared to organic manures which meet this requirement (Bekunda *et al*., 2010).

STATEMENT OF THE PROBLEM

Recently, the Ethiopia ministry of agriculture has introduced NPS as newly blended fertilizer for improved crop production (Tegbarum, 2015). Hintsa *et al.*, (2015) have conducted the demonstration on the variety (melka shote) to the district. However, the productivity is low due to nitrogen, phosphorus and other micronutrient as S, B, Zn deficiencies are the main constraints for vegetable and other crop production. Recently acquired soil inventory data from Ethio SIS (Ethiopian Soil Information System) also revealed that in addition to N and P, nutrients such as S, B, and Zn are deficient in Ethiopian soils (ATA, 2015).Available information regarding soil fertility studies with regard to hot pepper production islimited in western oromia. Fertilizers have been used in the area mainly based on blanket recommendationand fertilizer recommendation not timely update for hot pepper production of country. This, therefore, makes it impossible to determine whether hot pepper is deficient in nutrients in the absence of defined standards or threshold levels in the region mentioned.

Objective

- To investigate nitrogen and NPS fertilizers and their interaction effect on growth, yield and yield components of hot pepper.
- To investigate the effect of N and NPS rates on yieldand economic of Hot pepper variety.

Materialsand Methods

A field experiment was conducted at western –Wollega zone of oromiato determine the effect of nitrogen and NPS rates on growth and yield parameters of hot pepper variety and to investigate the effect of N and NPS rates on yield and economic of hot pepper variety during the main cropping season of 2018 and 2019 at Bako Agricultural Research Center (BARC) on-station and Bilo sub-site

Experimental materials

Hot pepper variety (Bako Local), which adapted to the agro- ecology of the area, was used for the study. Bako local is the most successful variety released by Bako Agricultural Research Center in 2005. Variety has wider adaptability and grows well at altitude ranging from 1400 and 1900 meters above sea level. The variety yield obtained about 30quantal from per hectare on research station and 20quintal on farmer fieldand NPS blended mineral fertilizer containing 19%N, 38%P and 7%S was used as inorganic fertilizer.

Experimental Design and procedure

Raising and transplanting seedlings

Land preparation for the nursery bed and main field was done in March 2018/2019. The seed of the varietywas drilled by hand onto the nursery beds of 1 m width and 5 m length at the inter-row spacing of 15 cm on mid-April, 2018/2019. In the nursery 25% NPS $ha^{-1}$was applied at seedbed.The beds were covered with dry grass mulch until emergence and watered using watering can as needed.

A week before transplanting, water supply to the nursery was reduced in order to harden the seedlings and reduce transplanting shock. The seedlings were watered on the bed to enhance easy uprooting and prevent too much root damage. Well established seedlings (standard seedlings) at a height of 20-25 cm was selected and transplanted on June, 2010 to the experimental field on ridges at the spacing of 70 x30 cm

Thenitrogen fertilizer wasapplied by drilling in two splits, first half of the amountat plantingdays after transplanting and the remaining half before flowering along the rows of each plot to ensure that N is evenly distributed and the remaining 75% NPS was applied at transplanting. The treatment consist of factorial combination of one variety Bako Local with four N rates level (0kgNha^{-1}), (46 kg N ha^{-1}), (69 kg N ha^{-1}), (92 kg N ha^{-1}) and four NPS rates level (0kg, 50kg, 75kg and 100kg NPS ha^{-1}).The treatments were arranged in randomized complete block design with three replications. Each plot was 3 m long and 3.5 m wide (5 rows). The inside three rows were set aside for data collection to eliminate any border effects. All the rest agronomic management of the crop was applied according to the recommended methods. Finally,hot pepper plants in the central net plot area (6.3m^2)was harvested atnormal physiological maturity. The pods hot pepperwas harvested manually using by hand picking.

Soil sampling and analysis

Soil sample wastaken prior to planting at a depth of 0-30cm in a zigzag pattern randomly from the experimental field using auger. Composite samples were prepared for analysis to determine the soil physico-chemical properties of the experimental site atBako Soil Laboratory. The composited soil sample was air-dried, ground and sieved to pass through a 2 mm sieve. Total nitrogen wasdetermined following kjeldahl procedure (Cottenie, 1980), the soil pH (in water suspension) by a digital pH meter (Page, 1982)organic carbonby wet digestion method (Walkley and Black, 1935) and the available phosphorous by Olson methods (Olsen *et al.,* 1954), cation exchange capacity (CEC) by ammonium acetate method (Cottenie, 1980) and soil texture by Bouyoucons Hydrometer method (Bouyoucos,1962).

Economics analysis

Net return (NR ha–1) and benefit: cost ratio (B: C) was calculated by considering the sale prices of hot pepper (1kg =120ETH Birr) and cost of fertilizers (100kg UREA =1354ETH Birr and 100kg NPS = 1522ETH Birr) and labor market for all field activities done. Thus, the economic gains of the different treatments was calculated to estimate the net returns and the cost of cultivation, after considering the cost of fertilizer N, NPS, and the income from marketable hot pepper fruit for economic analysis. Hence, following the CIMMYT partial budget analysis methodology, total variable costs (TVC), gross benefits (GB) and net benefits (NB) were calculated (CIMMYT, 1988).

Data to be collected

Phenological Data:

Plant height (cm): This was measured in cm from the soil surface to the top most growth point of six pre-tagged plants from the central rows of each plot. Measurements were taken at harvest from base of the plant to the tip of the growing point using a measuring tape.

Number of branches per plant: This refers to the average number of primary branches per plant in the pre-tagged six plants at last picking

Number of pods per plant: This refers to the number of physiologically matured pods. The pod number (both marketable and unmarketable pods) were counted from the six randomly pre-tagged plants at each harvest and averaged after the final stage of harvesting.
Canopy diameter per plant:

Yield and Yield Components:
Number of pods plant^{-1}: The mean number of mature pods and red ripe of randomly sampled five plants from central rows for each plot were counted during harvest.

Pod Length (cm): The length of five randomly selected pods from each sampled plots during harvest was measured using a centimeter and mean values are taken.

Pod Width (cm): The pod body width at the base of each pods were measured from marketable pods of sampled plants from each plot using caliper and the mean values of them were recorded.

Marketable dry pod yield (t ha^{-1}): During harvest, the marketable yields from the net plot area of each plot were weighed. The color of the pods (red), absence of unacceptable defects from insects, free of disease or physiological disorder (including sun scald) and pod size (pods > 1 cm^3) were considered as marketable yield (Tsedal, 2004).

Unmarketable dry pod yield (t ha^{-1}): This was determined also during harvest. Unmarketable pod yield from the net plot area of each plot was measured. Pods that were undersized < 1cm^3 in size (Tsedal, 2004), damaged by birds, shriveled and discolored due to sun-scald were considered as unmarketable and weighed.

Total dry pod yield (t ha^{-1}): This refers to the cumulative pod yields obtained at harvesting and includes both marketable and unmarketable yields.

Data Analysis

All the yield and yield component data will be subjected to analysis of variance (ANOVA) using general linear model (GLM) procedure of SAS statistical version 9.3 software. The least significant difference (LSD) will be used to separate differences in treatment means of main factor effects where significant variation was observed at 5% probability level. Lsmeans for significantly different interaction effects will be separated by SAS model *PLGLM800* (P=0.05) using Duncan multiple Rang test (DMRT).

RESULTS AND DISCUSSION

Selected Physico -Chemical Properties of the Soil of the Experimental Site

The laboratory results of the selected physico- chemical properties of the soil sample taken before planting are presented in (Table.1). The results indicated both Bako and Bilo Boshe that the soil has 39% ,5% and 56% sand, silt and clay and 28%, 6% and 66% sand , silt and clay respectively, and could be categorized as clay soil for both location based on USDA

(1987) textural soil classification system. Soils for growing pepper should be well drained, rich in organic matter with a pH range of 6.0 to 6.5. However, pepper can also tolerate a wider soil pH range of 4.5 (acidic) to 8.0 (slightly alkaline). Light sands, clay sandy and sandy loams are also suitable for growing pepper (Dennis, 2013). Similarly, Anonymous, (2014) reported that the quality and quantity of pepper fruits are of crucial importance and are greatly influenced by the fertility and nutrient levels of the soil. Pepper prefers sandy to loam soils. However, the plant can grow moderately well over a wide range of soil types.

The total N, available P, available OC, C: N ratio and CEC of the soil before planting for Bako site were 0.26%, 14ppm, 3.06 %, 11.33 and 10.16Meq/100g soil respectively (Table. 1) The total N, available P, available OC, C: N ratio and CEC of the soil before planting for Bilo Boshe site were 0.24%, 17ppm, 2.81 %, 12.24and 18.44Meq/100g soil respectively.

According to (Havlin *et al.*, 1999) soils are classified depending on their total N content in percentage (%), as very low (<0.1), low (0.1-0.15), medium (0.16-0.25), and high (>0.25). Thus, the soil of the Bakoand Bilo Boshe site has high and medium total N content respectively. Olsen (1954)classified available P content of the range < 5 as very low, 5 – 10 as low, 11 – 17 as moderate, 18-25 as high and > 25 mg kg^{-1} as very high. Thus, the soil of the both study site has moderate available P content. At increased soil acidity (low pH) phosphorus is fixed to surface of Fe and Al oxides and hydrous oxide, which are not readily available to plants. Charman and Roper (2007) classified organic carbon content of the range <0.40% as extremely low, 0.4-0.6% as very low, 0.6-1% as low, 1-1.8% as moderate, 1.8-3% as high, and >3% as very high, respectively. Based on these ratings organic carbon Bako and Bilo Boshe site were ranged in very high and moderate respectively. Charman and Roper (2007) further classified Organic matter (5.27%) as very high range. Organic matter in soils influence physical, chemical and biological properties of soils, such as soil structure, water retention, nutrient contents and retention and micro-biological life and activities in the soils.

According Newey (2006) classified C: N ratio ranges of <10.0 as very low, 10.0−15.0 as low, 15.0-25.0 as medium, 25.0- 70.0 as high, 70-100 as very high, and > 100 extremely very high. Based on these ratings the ratio of carbon to nitrogen revealed Bako (11.33) and Bilo Boshe (12.24) site before planting of the experimental field was in the low range both study site. Hazelton and Murphy (2007)classified CEC ranges of < 6 as very low, 6-12 as low, 12-25 as moderate, 25-40 as high and > 40 cmol kg^{-1} as very high. Based on these ratings the cation exchange capacity of Bako site is (10.16 Meq/ 100g soil) and Bilo Boshe (18.44Meq/ 100g soil) of the experimental field were in the low and moderate range respectively.

Generally, the soil analysis result indicated that the area is deficient in NPS fertilizer to support the potential crop production. This may be associated with poor agronomic management practices including continuous cropping with little or no fertilizers input which resulted in a decline in soil fertility. Therefore, the low content of total nitrogen, available phosphorus, available sulfur, organic carbon indicate that application of mineral and/organic fertilizers containing these nutrients is important for optimum production of the crops in the study area.

Table .1. Physical and chemical properties of the experimental site before planting at Bako during 2019 main cropping season

Properties	Result		Rating		References
	Bako	Bilo Boshe	Bako	Bilo Boshe	
1. Physical properties (%)					
Sand (%)	39	28	Medium	Medium	Hazelton and Murphy(2007)
Silt (%)	5	6	low	low	”
Clay (%)	56	66	High	High	”
Textural class	clay	clay			USDA (1987)
2. Chemical properties					
pH (1: 2.5 H_2O)	5.15	5.06	----		Karltun *et al.* (2013)
Organic carbon (%)	3.06	2.81	Very high	Moderate	Charman and Roper (2007)
Organic matter (%)	5.27	6.76	”		”
C:N ratio	11.33	12.24	Low	low	Newey (2006)
Total Nitrogen (%)	0.26	0.24	high	Medium	Havlin *et al.* (1999)
Available Phosphorus (ppm)	14	17	low	Moderate	Olsen (1954) Singh and Trehan (1998)
CEC (meq/100 g soil)	10.16	18.44	Medium	Moderate	Hazelton and Murphy (2007)
Ex. Ca (meq/100g soil)	15.2	11.9	Medium		FAO (2006)
Ex. Mg (meq/100g soil)	11.6	7.9	Medium		”

Growth parameter of hot pepper

Plant height (cm)andStand count at harvesting

The analysis result show that main effect was significant (P<0.05) influenced due the combined application of Nitrogen and NPS blended fertilizer rates on plant height parameter (Table .2).The tallest (54.48cm) and shortest (42.83cm) plants were observed in plots that received 69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$ and control plot 0NKg ha^{-1} X 0 NPS Kg ha $^{-1}$ respectivel

The shortest plant height from unfertilized plot (11.65 cm) was lower than the longest plant height obtained. This could be due to better nutrient supply might in turn better plant height. But the no significantly different plant height shown across location.

Similarly, El-Tohamy *et al.,* (2006) reported that the increase in plant height could be initiated due to better availability of soil nutrients in the growing areas, especially nitrogen and phosphorus, which have enhancing effect on the vegetative growth of plants by increasing cell division and elongation. It is concurrent with the result of Hassaneen (1992) who found that sulfur application plays important roles in the soil that it is used as a soil amendment to improve the availability of nutrients such as P, K, Zn, Mn and Cu. The author also found that sulfur element reduced soil pH and converted the unavailable phosphorus to available form for plant tissues. The not Significant ($P<0.05$) differences were observed in stand count at harvesting due to the influence of main effects of nitrogen and NPS fertilizer rates application. But numerical difference indicated that the maximum (26.25) and minimum (22.25) stand count at harvesting was observed in plots that received 69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$ and control plot 0 N Kg ha^{-1} X 0 NPS Kg ha $^{-1}$ respectively. The stand count at harvesting significantly different across both location were observed. (Table .2)

Table.2. Main effect of growth parameter of Stand count at harvesting and plant height

Treatment	Stand count at harvesting	Plant Height cm
0NKg ha^{-1} X 0 NPS Kg ha $^{-1}$	22.25c	42.83c
46 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$	24.5abc	48.62abc
46 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$	24.42abc	51.37ab
46 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$	23.08bc	48.1bc
69 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$	23.17bc	48.07bc
69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$	26.25a	54.48a
69 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$	25.92ab	51.76ab
92 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$	23.92abc	52.38ab
92 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$	24.92abc	53.13ab
92 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$	24.83abc	50.7ab
Mean	24.33	50.14
CV%	10.68	10.2
LSD (0.05)	3.036	5.99
Location		
Bako	25.42a	51.14a
Bilo Boshe	23.23b	49.15a
LSD (0.05)	1.36	2.68

Clue:CV: coefficient of variation, LSD: Least of significant different

Canopy diameter per plant and Number of Main branch per plant

The combined application of Nitrogen and NPS blended fertilizer rates were showed significant ($P<0.05$) difference on canopy diameter across location (Table.3).

The widest canopy diameter (38.28cm) in plants was recorded from the application of 69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$treatment (Table .3). The narrowest canopy diameter (26.18cm) was observed from unfertilized plot.

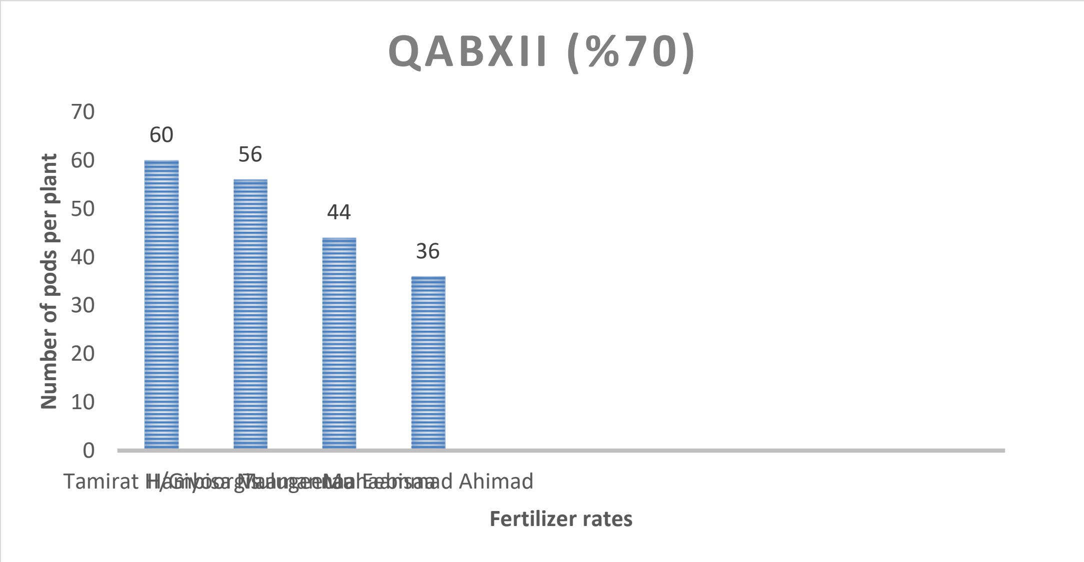
This might indicate that optimum application of fertilizers could result better canopy diameter rather than excess or lower application of fertilizers. El-Tohamy *et al.,* (2006) noted that nitrogen has positive effect on branching of pepper plants. Accordingly, the wider the canopy diameter might be resulted due to higher branch number of Marako Fana variety. The analysis of variance indicate that the main effect of nitrogen and NPS fertilizer rates were not significant (P<0.05) differences on the number main branch but the significantly difference were observed across location. The results were contradict with (Uchid, 2000) the increase in the number of branches in response to the increases in the rates of fertilizer up to optimum could be attributed to the positive effect of nitrogen and other nutrients on promotion of vegetative growth due to its simulative effect on protein synthesis and meristematic tissues through hormonal synthesis leading to more number of buds which may have resulted in the production of more number of branches per plant.

Table.3. Main effect of growth parameter of Canopy diameter per plant and Number of Main branch per plant

Treatment	Canopy diameter per plant	Number of Main branch per plant
0NKg ha^{-1} X 0 NPS Kg ha^{-1}	26.18d	1.98a
46 N Kg ha^{-1} x 50 NPS Kg ha^{-1}	33.03bc	2.03a
46 N Kg ha^{-1} x 75 NPS Kg ha^{-1}	33.77abc	2.34a
46 N Kg ha^{-1} x 100 NPS Kg ha^{-1}	32.67bc	2.12a
69 N Kg ha^{-1} x 50 NPS Kg ha^{-1}	31.85c	2.15a
69 N Kg ha^{-1} x 75 NPS Kg ha^{-1}	38.28a	2.5a
69 N Kg ha^{-1} x 100 NPS Kg ha^{-1}	32.87bc	2.15a
92 N Kg ha^{-1} x 50 NPS Kg ha^{-1}	35.34abc	2.4a
92 N Kg ha^{-1} x 75 NPS Kg ha^{-1}	37.23ab	2.22a
92 N Kg ha^{-1} x 100 NPS Kg ha^{-1}	33.23bc	2.02a
Mean	33.44	2.19
CV%	12.43	23.77
LSD (0.05)	4.86	0.61
Location		
Bako	35.50a	2.39a
Bilo Boshe	31.39b	1.99b
LSD (0.05)	2.17	0.27

Effect of Nitrogen and NPS Fertilizers on Yield of Hot Pepper
Number of Pods per Plant

The analysis of variation revealed the main effect of Nitrogen and NPS fertilizers showed that significantly ($p < 0.05$) difference across location were recorded the maximum number of pods per plant (23.49) obtained from the plot treated with supply of 69 N Kg ha^{-1} x 75 NPS Kg ha^{-1} treatment combinations (Graph 1). On the contrary, the minimum number of pods per plant (12.13) was counted from unfertilized plot (0NKg ha^{-1} X 0 NPS Kg ha $^{-1}$). Pepper benefits from some nitrogen, but too much nitrogen can over-stimulate growth resulting in large plants with few early pods. It is in line with Lunin *et al.*, (1963) who demonstrated the age of pepper on susceptibility of salinity and found the leaf production dropped sharply when saline conditions were imposed at the early five germination stages and as a result yield reduction.



Graph--. Effect nitrogen and NPS blended fertilizer on number of pods per plant across location

Pod length and pod diameter

The analysis of variance revealed that a combined application of nitrogen and NPS fertilizer was not significant (P<0.05) influenced by average diameter and length of pods across location (Table 4). The highest length of marketable red pods (16.93cm) was obtained in plots that received 92 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$ combinations. Plants in unfertilized plot produced pods significantly the shortest (10.13cm) in length.

The highest width of pods (1.93 cm) was recorded from plots treated with 92 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$ combinations and lowest width (1.77cm) of pods treated with (46 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$) .

The reason that supply of blended inorganic fertilizer had no significant difference with that of the highest pods width obtained from combined inorganic and organic fertilizers applications produced higher pods width might be attributed due to the presence of sulfur. It is in conformity with Randle and Bussard (1993) who reported that sulfur often ranked immediately behind nitrogen, phosphorus, and potassium in terms of importance to crop productivity.

Table.4. Main effect of nitrogen and NPS blended fertilizer rates application on Pod length and pod diameter

Treatment	Pod Length	Pod Diameter
0NKg ha^{-1} X 0 NPS Kg ha $^{-1}$	10.13b	1.84ab
46 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$	10.48b	1.88ab
46 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$	10.3b	1.86ab
46 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$	10.07b	1.77b
69 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$	10.59b	1.84ab
69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$	10.54b	1.81ab
69 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$	10.24b	1.88ab
92 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$	16.93a	1.83ab
92 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$	10.37b	1.93a
92 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$	10.83b	1.82ab
Mean	11.05	1.84
CV%	44.67	6.29
LSD (0.05)	5.77	0.14
Location		
Bako	11.55a	1.83a
Bilo Boshe	10.55a	1.86a
LSD (0.05)	2.58	0.06

Clue: CV: coefficient of variation, LSD: Least of significant different

Marketable, Unmarketable Dry pod Yield ($kgha^{-1}$) and Total Dry Pod Yield (t ha^{-1})

The combined main effect of analysis result indicated that there was significantly ($p < 0.05$) different across location and the maximum marketable dry pod yield (1025.9kg ha^{-1}) was obtained from plots fertilized 69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$treatment (Table.5).The maximum unmarketable dry pods(108.54 kg ha-1) and minimum (38.89kg ha^{-1}) on plots 46 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$ and 0 N Kg ha^{-1} x 0 NPS Kg ha $^{-1}$ respectively. This in turn had resulted in development of pods which are relatively healthy, attractive and acceptable in markets. Similarly Matta and Cotter (1994) pointed out that marketable pod yield increase in response to addition of plant growth.The minimum marketable dry pod yield (355.3 kg ha^{-1}) was obtained from the unfertilized plot (0 N Kg ha-1 x 0 NPS Kg ha -1). Production of lower marketable yield from higher rate combination of inorganic fertilizers could be due to toxic effect of over fertilization. Harmful effects to the young plants leading to retarded growth or death have been observed.

Bosland and Votava (2000) reported that high salt in the soil could result pinching off young leaves at the soil line and young seedling can die when light rain moves the salt to the younger tender roots. The authors also pointed out that high nitrogen fertilizer is unable to translocate adequate calcium to the pod and as the result the yield could be low.

Total dry fruit yield was significantly ($P < 0.05$) affected by the combined applications of nitrogen and NPS blended fertilizer rates across location. The combined applications of 69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$ produced the highest total dry pod yield (1.12 t ha^{-1}) as compared to the control (0N Kg ha^{-1} x 0 NPS Kg ha $^{-1}$) (0.394 t ha^{-1}) (Table .5).

The highest total dry pod yield might be due to the higher mean pod length, width, weight, seed number and relatively larger number of marketable pod obtained at this level of fertilizer supply. However, there was a yield decline at the highest rate of fertilizers supply, implying that hot pepper yield increase occurs up to a certain optimum level of fertilizer supply and then decrease afterwards (Roy *et al*., 2011).

Table.5. Main effect Nitrogen and NPS fertilizer on Marketable, Unmarketable Dry pod Yield (kgha^{-1}) and Total Dry Pod Yield (t ha^{-1})

Treatment	Marketable dry pod yieldha^{-1} Kg	Unmarketable dry pod yield ha -1 Kg	Total dry pod yieldt ha^{-1}
0NKg ha^{-1} x 0 NPS Kg ha $^{-1}$	355.3c	38.89d	0.394c
46 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$	612.4b	108.54a	0.721b
46 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$	742.9b	86.79abc	0.829b
46 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$	611.4b	48.15cd	0.659b
69 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$	663.1b	61.12bcd	0.724b
69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$	1025.9a	94.43ab	1.120a
69 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$	711.2b	101.72ab	0.813b
92 N Kg ha^{-1} x 50 NPS Kg ha $^{-1}$	722.4b	83.78abc	0.806b
92 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$	755.0b	90.93abc	0.846b
92 N Kg ha^{-1} x 100 NPS Kg ha $^{-1}$	673.3b	76.72abcd	0.75b
Mean	687.29	79.11	766.40
CV%	28.73	46.27	28.09
LSD (0.05)	230.75	42.78	251.63
Location			
Bako	896.88a	58.91b	955.80a
Bilo Boshe	477.70b	99.3a	577.01b
LSD (0.05)	103.2	19.13	112.53

Economic analysis

Cost benefit analysis was undertaken with the combination of Urea fertilizer and NPS rates to determine the highest net benefit with acceptable rate of net return. The results revealed that the maximum net benefit was obtained from 69 N Kg ha-1 x 75 NPS Kg ha $^{-1}$ or 150 kg urea and 75 NPS kg ha $^{-1}$ (Table.6). An excess usage of fertilizer was increased cost and decreased marketable yield. This implies that the profitability of hot pepper production is partly related with the right type and rate of input (fertilizers) usage and the cost incurred for these inputs (Amare, 2010). Thus, on the basis of marketable yield, net income and cost benefit ratio, it can be concluded that among the fertilizer rates tested 69 N Kg ha-1 x 75 NPS Kg ha $^{-1}$ or 150 kg urea and 75 NPS kg ha $^{-1}$ was the most economically feasible for hot pepper production which provided the net benefit of (113227.5 ETB ha^{-1}) and more profitable than the rest of treatment combinations.

Table6. The results of Economic Analysis for the Combination of Urea and NPS fertilizer

Treatment	Tuber yield tone/ ha	Gross return in Birr -1	Cost of production (Birr-1) or total cost vary birr/ha	Net benefit birr/ha or Net return (GR-PC)(Birr-1)	Benefit: cost ratio (GR/PC ETH Birr)	Return/Birr investment (NR/PC ETB	Net return (ETHBha-1)
0 N Kg ha-1 x 0 NPS Kg ha -1	0.394	46800	18000	28800	2.6	1.6	
46 N Kg ha-1 x 50 NPS Kg ha -1	0.721	86520	20115	66405	4.301267711	3.301267711	
46 N Kg ha-1 x 75 NPS Kg ha -1	0.829	99480	20495.5	78984.5	4.853748384	3.853748384	78984.5
46 N Kg ha-1 x 100 NPS Kg ha -1	0.659	79080	20876	58204	3.788082008	2.788082008	
69 N Kg ha-1 x 50 NPS Kg ha -1	0.724	86880	20792	66088	4.178530204	3.178530204	
69 N Kg ha-1 x 75 NPS Kg ha -1	1.120	134400	21172.5	113227.5	6.34785689	5.34785689	113227.5
69 N Kg ha-1 x 100 NPS Kg ha -1	0.813	97560	21553	76007	4.52651603	3.52651603	
92 N Kg ha-1 x 50 NPS Kg ha -1	0.806	96720	21469	75251	4.505100377	3.505100377	

92 N Kg ha-1 x 75 NPS Kg ha -1	0.846	101520	21849.5	79670.5	4.64633058	3.64633058	79670.5
92 N Kg ha-1 x 100 NPS Kg ha -1	0.75	90000	22230	67770	4.048582996	3.048582996	

CONCLUSIONS AND RECOMMENDATION

A field experiment was conducted at western –Wollega zone of oromiato determine of nitrogen and NPS fertilizer rates onhot pepper variety during the main cropping season of 2018 and 2019 at Bako Agricultural Research Center (BARC) on-station and Bilo sub-site.

The analysis result show that main effect were significant ($P<0.05$) influenced due the combined application of Nitrogen and NPS blended fertilizer rates on parameter of plant height parameter,Canopy diameter per plant, Number of Main branch per plant,number of Pods per Plant,Pod length, pod diameter, Marketable, Unmarketable Dry pod Yield (kgha^{-1}) and Total Dry Pod Yield (t ha^{-1}). The combined applications of 69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$ produced the highest total dry pod yield (1.12 t ha^{-1}) as compared to the control (0N Kg ha^{-1} x 0 NPS Kg ha $^{-1}$) (0.394 t ha^{-1})

Generally, the present study indicated that the combined application of Nitrogen fertilizer and NPS blended improved growth and yield component of hot pepper. Accordingly, the optimum marketable dry pod yield was obtained from combined application of 69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$ and in terms of the economic point of view, it can be concluded that among the fertilizer rates tested 69 N Kg ha^{-1} x 75 NPS Kg ha $^{-1}$ or 150 kg urea and 75 NPS kg ha $^{-1}$ was the most economically feasible for hot pepper production which provided the net benefit of (113227.5 ETB ha^{-1}) and recommended for hot pepper growing areas of western Oromia and similar agro ecology.

Reference

Abu, N.E., Uguru, M.I. and Obi, I.U. 2011. Genotype by trait relations of yield and yield components in aromatic peppers (*Capsicum annum L.*) based on GT bi plot. Journal of Plant Breeding and Crop Science, 3(14): 382-390.

Acquaah, G. 2004. Horticulture Principles and Practices. 2nd edition, Prentice Hall of India Private Ltd. New Delhi, India

Alemu, H. and A. Ermias, 2000. Horticultural crops production and associated constraints in North-west Ethiopia. Working paper. Agricultural Economics Research Division, Agricultural Research Centre, Adet. 18p.

Amalfitano C, Del Vacchio L, Somma S, Cuciniello A, Caruso G (2017). Effects of cultural cycle and nutrient solution electrical conductivity on plant growth, yield and fruit quality of “Friariello” pepper grown in hydroponics. Horticultural Science 44:91-98.

ATA, 2015. Soil fertility mapping and fertilizer Recommendation in Ethiopia: Update of Ethio SIS project and status of fertilizer blending Agricultural Transformation Agency. Ethiopia 108 p.

Bekunda, B; Sanginga, N. and Woomer, P. L. 2010. Restoring soil fertility in sub-Sahara Africa. *Advances in Agronomy*, 108: 184-236.

Bosland, P.W. and E.J. Votava, 2000. Peppers: Vegetables and spice *Capsicums*. CAIB publishing. New York.198p.

Bosland, P.W. and Votava E. J. 2000. Peppers: Vegetables and Spice Capsicums. In: Crop production science in horticulture, series No 12, CBI Publishing, UK, 96-98p.

Bouyoucos, G. J. (1962). Hydrometer Method Improved for Making Particle Size Analyses of Soils. *Agronomy Journal,54*(5), 464–465.

Brady, N.C. and Weil, R. R. (2002). *The nature and properties of soils. Thirteenth edition. Prentice Hall, New Jersey.*

Charman, P. E. V. and Roper, M. M. (2007). *Soil organic matter. In 'Soils – their properties and management'. 3rd edn. (Eds P. E. V. Charman and B. W. Murphy.) pp. 276–285. (Oxford University Press: Melbourne.*

CIMMYT, 1998. From agronomic data to farmer recommendations. An economics-training manual.Completely revised edition.D.F,Mexico 51p.

Cottenie, A. (1980). *Soil testing and plant testing as a basis of fertilizer recommendation. FAO Soils Bull.38*, 70–73.

CSA (Central Statistical Agency), 2010. Area and production of crops. Country level, volume

IV, Addis Ababa. 60p.

CSA, 2006. Agricultural Sample Survey. report on area and productivity of crops. Statstical Bulletin, Volume, I. Adds Ababa.361p.

Dennis S (2013) Learn How to Grow Peppers.Nairobi, Kenya. ISBN 978-9966-47-838-2.

EEA (Ethiopian Economic Association), 2002. *Land tenure and agricultural development in Ethiopia.* Addis Ababa.

EEPA (Ethiopian Export Promotion Agency), 2003. Spice potential and market study, Addis

Ababa. 103p.

El-Tohamy WA, Ghoname AA and Abou-Hussein SD (2006). Improvement of pepper growth and productivity in sandy soil by different fertilization treatments under protected cultivation. *Journal of applied Science Research,* 2: 8-12.

FAO (Food and Agricultural Organization of the United Nations), 2007. Production year book, Rome.

FAO (Food and Agriculture Organization of the United Nations). 2009. FAO STAT Database for production of peppers. Rome, Italy.

FAO, 2004. FAOSTAT database result for chillies and peppers. http:// apps.fao.org/

FAO. (2006). *Food and Agricultura Organization. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome*.

for plant growth: Nutrient functions and deficiency symptoms; Plant

Hassaneen MN (1992). Effect of sulfur application to calcareous soil on growth and certain metabolic changes in some crops. *Journal of Agriculture Science,* 17(10): 3184-3195.

Havlin, J. L., Beaton, J.D., Nelson, W.L. and Tisdale, S. L. (1999). *Soil fertility and fertilizers: An introduction to nutrient management (pp. 499). Upper Saddle River, NJ: Pearson Prentice Hall*.

Hazelton, P. and Murphy, B. (2007). Interpreting soil test results: What do all the numbers mean? 2nd Edition. *CSIRO Publishing.*, 152.

Hintsa M; Fantay B; Atsbaha G; and Kassa M; 2019. Evaluation of NPS Fertilizer on Yield and Economic Performance of New Variety of Hot Pepper (*Capsicum annum L.*) inTanqua Abergelle, Central Tigray, Ethiopia, Int. J. of. Life Science, Volume 7(2): 181-186.

Johnson, C.D. and D.R. Decoteau, 1996. Nitrogen and potassium fertility affects jalapeno pepper plant growth, pod yield and pungency. *Journal of Horticultural Science*, 31(7):1119-1123.

Karltun, E., Tekalign Mamo, Taye Bekele, S. G. and S. K. 2013. (2013). *Towards improved fertilizer recommendations in Ethiopia Nutrient indices for categorization of fertilizer blends from EthioSIS woreda soil inventory data: A Discussion paper. Ethiopian Agricultural Transformation Agency (ATA)/Ethiopian Soil Information Sy*.

Lunin J, Gallatin MH and Bachelder AR (1963) Saline irrigation of several vegetable crops at various growth stages effect on yields. *Agronomy journal*, 55: 107-114.

MARC (Melkasa Agricultural Research Center). 2004. Progress report, Addis Ababa, Ethiopia

Matta F.R. and Cotter D.J. 1994.Chile production in North-Central New Mexico.NMCooperative Extension Circular.

Newey, A. (2006). *Litter carbon turnover with depth. Ph.D. Thesis, Australian National University, Canberra.*

nutrient management in Hawaii's soils

Olsen, S. R. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate United States Department of Agriculture; Washington.*

Payero, J.O. and M.S. Bhangoo, 1990. Nitrogen fertilizer management practices to enhance seed production by 'Anaheim Chili' peppers. *Journal of the American Society for Horticultural Science*, 115 (2): 245-254.

R **Uchid** - Approaches for Tropical and Subtropical Agriculture, **2000**. Essential nutrients

Randle, W.M. and Bussard, M.L. 1993. Pungency and sugars of short day onion as affected by sulfur nutrition. Journal of American Society of Horticulture Science, 118(6): 766-770

Roy SS, Khan MS and Pall KK (2011) Nitrogen and Phosphorus Efficiency on the Fruit Size and Yield of Capsicum. *Journal of Experimental Sciences*, 2(1): 32-37.

Singh, J.P. and Trehan, S. P. (1998). *Balanced fertilization to increase the yield of potato. Paper presented at the IPI-PRII-PAU Workshop on Balanced Fertilization in Punjab Agriculture, Punjab Agricultural University, Ludhiana, India,*. (15-16 December 1997), 129–139.

Tegbaru B. (2015). Soil fertility mapping and fertilizer recommendation in Ethiopia: update of Ethio SIS project and status of fertilizer blending plants Hawassa university joint symposium.

Tsedal, T; 2004.Yield and quality response of tomato and hot pepper to pruning.MSc Thesis Presented to the School of Graduate Studies of Pretoria University, pp.1-132.nutrition.

USDA. (1987). *United States Department of Agriculture Forest Service n.d. Soil resource inventory. Umatilla National Forest, Pacific Northwestern Region.*

Walkley, AC, and Black, T. (1935). Estimation of soil organic carbon by chromic acid titration method. *Soil Sci*, *47*, 29–38.

Sensor based Validation of Nitrogen Fertilizer rates for Maize Using a Handheld Normalized Difference Vegetative Index (NDVI) Sensor at Bako, Western Ethiopia

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Abstract
Maize is the most important crops in the national diet of Ethiopia because of its various benefits as food and feed for animals, which is produced in a number of agro-ecologies of the country. However, its productivity is limited by blanket application of nitrogen (N) fertilizer without considering field to field variability of soil N supply. Site-specific fertilizer recommendations using precision agricultural tools are among the recent technologies developed to assess the actual crop N status in the field. In this view, a field experiment was conducted on three farmers' field in Gobu-Sayo district, Ethiopia in 2018 and 2019 to determine the best N rate for side-dressing and validate the N application using crop sensor. The treatment consisted of three N levels (0, 25 and 50 kg ha^{-1}) all applied during planting and four N rates (19, 38, 56, and 75 kg ha^{-1}) side-dressed. The experiment was arranged in a factorial randomized complete block design with three replications. Significant differences were observed between applied N rate on grain yield and yield components of maize. Correlation coefficients of 0.24 and 0.60 were observed between Normalized Difference vegetative Index (NDVI) value and grain yield at leaf four (V4) and eight (V8) growth stages of maize. The highest grain yield (8.6 t ha^{-1}) was obtained at 50 and 75 kg N ha^{-1} applied during planting and side-dressed at 35 days after emergence, respectively. On the contrary, the lowest grain yield was obtained when 19 kg N ha^{-1} appliedat planting.Maximum net benefit (ETB 65343.36 ha^{-1}) and acceptable marginal rate of return were obtained when 50 and 75 kg N ha^{-1} was used atplanting and side-dressed, respectively. In conclusion, 50 kg N ha^{-1} during planting and 75 kg N ha^{-1} for side-dressing is the best N rate and economically feasible for maize production in the study area.

Keywords: Maize, NDVI, Nitrogen, Yield

Introduction

In Ethiopia, more than 80% of the population is reliant on agriculture, which is the engine of economic development and contribute for more than80% of the country's export earnings (Lulseged *et al*. 2017).The country is endowed with huge potential for agricultural development and cereal crops like maize are cultivated in various ranges of agro-ecologies of the country (Woktole *et al*. 2011). Even though the agricultural sector is among the strategies in securing food for the current fastgrowing population, it is still constrained by low use of agricultural inputs, low productivity and inadequate utilization of improved crop production (CSA 2018). The limited response of crops to applied fertilizer could also another challenge, which is largely explained by the blanket nutrient applications without considering field-field soil nutrient variation, crop types and environmental conditions.

Recently various national and international research institutions have been started various initiatives in developing improved crop varieties as well as testing crop response to fertilizers to develop site and crop specific fertilizer recommendations.To this, maize is one of the strategic and main popular cereal crops to feed the ever increasing population of the country due to its high value as food for human beings and as feed for animals and even for fuel purposes (Hailu Feyisa and Tolera Abera 2020; Zerihun Abebe and Hailu Feyisa 2016). According to FAO (2012) reports, Ethiopia is the forth in Africa and first in the east Africa region in producing maize. It is also the main crops leading all other cereal crops in terms of production and productivity, while second in area coverage next to *tef*(CSA 2018). The total land areas of 10,232, 582 ha (81%) were under cereals of which maize covered about 17% (2,128,949 ha) and 27% (83,958,872 quintals) grain yields (CSA 2018). Because of its various benefits, about 88% of maize produced is consumed at home as food, in green cobs and grain, and it is one of the high priority crops to feed the fast growing Ethiopian population (Mandefro *et al*. 2001; Zerihun *et al*. 2016).

In spite of significant contribution for food and huge area under maize cultivation, its current national yield is only 3.9 t ha^{-1}, which is far below the yield potential of the crop.For instance, the late-maturing hybrid maize, BH661 can produce up to 9.5 to 12, and 6 to 8.5 t ha^{-1} at research field and farmers' field, respectively (Variety registration 2012). Even though, many factors can contribute to this big yield gaps, declining of soil fertility and poor plant nutrient management are among the major factors to low productivity of maize (CIMMYT 2004; Mourice *et al*. 2015; Achalu*et al*. 2012).

Nitrogen (N) fertilizer in maize farming system is one of the mainconcern since the productivity of maize is more limited over N than any other element, as it is the primary nutrient for growth and development of the crop (Blumenthal et al., 2008). Nevertheless, the majorities of the farmers in the western Oromia specifically in Gobu Seyodistrict and the surrounding area fertilize their maize crop following blanket recommendations. This blanket recommendation consists of applying 92-150 kg N ha^{-1} (equivalent to 200-350 kg urea ha^{-1}). Furthermore, appropriate N application rates have not been devised with the newly recommended NPS fertilizer rates to improve productivity of hybrid maize and fertilizer use efficiency in the study area. Moreover, many farmers refine from applying sufficient amount fertilizer due to the sky rocket price of inorganic fertilizers, or lack of knowledge as to which type and rates are appropriate (Hopkins *et al*. 2008). On the contrary, excessive application is wasteful, worsen the environmental contamination and potent to the crop (Westermann and Kleinkopf 1985). About 30 to 70% of the applied N may be lost as ammonia within 7-10 days after application and may lead to an elevated level of NO_3 in the soil (Canfield *et al*. 2010; Xue *et al*. 2010; Hailu and Tolera Abera2020). Another reports by Jamal et al. (2006) showed that more than 50% of applied N fertilizers remain unavailable to a crop due to losses through runoff or leaching.

Improving fertilizer application methods and amendments of the previous fertilizer type used are among the methods used to increasing crop productivity as well as the efficiency of applied fertilizers, which is minimizing the losses of applied fertilizer. Recent advances in N management are focusing on a convenient and rapid method to measure plant N status to match the requirement of N by crop within the growing season as per crop demand. To this, precision agriculture is among the practice that has a set of tools that allows researchers to quantify and manage the spatial variability in farm field. It aims at doing the right thing, at the right place and at the right time.

Crop canopy sensors are among the recent technologies developed to help researchers as well as growers to assess the actual crop N status. This is non-sampling, not requiring laboratory analysis, and safe time, energy and inexpensive method used for large-area estimation of crop N status within a limited time. It is designed to measure crop spectral reflectance at specific wavelength and generate vegetation indices such as Normalized Difference Vegetation Index (NDVI).Various studies have been conducted with respect to remote sensing and its application in N determination for sustainable maize production. Sripada *et al*. (2005) and Chang *et al*. (2003) stated that remotely sensed imagery can give valuable information of in-field N variability in maize. Active sensors have their own source of light energy and allow for the determination of reflectance measurements at specific times and locations throughout the growing season (Trimble 2012). They are placed about 0.60cm above the crop canopy and collect data as the sensor moves through the maize crop and allows the sensors to cover a lot of ground in a short period, thus recommendations for supplemental N fertilizer can be made on a field scale. The NDVI value correlates with many variables such as, crop N content (deficiency/excess), final grain yield, crop disease and weed species, and long-term water stress (Hailu and Tolera 2020; Tolera et al. 2020; Adis *et al*. 2015; Ngie 2014). Similarly, Lukina *et al*. (2001) stated that there is a high correlation (0.80-0.97) between vegetation cover and NDVI value. Another authors, Getinet and Getachew (2019) showed that greater leaf area and green plant biomass levels result in higher subsequent sensor readings as these variables are directly related to the N content of the plant. Higher NDVI value indicates higher plant N content. These properties allow sensors to be a valuable tool in determining the relative plant N status by comparing the plants with sufficient N to plants with a N deficiency.Unlike in maize, there were also evidences that prediction of wheat response to N applications guided by an optical sensor which was positively correlated to measured N response and resulted in increased NUE (Raun *et al*. 2002; Li *et al*. 2009). Raun *et al*. (2001) reported that expected yield, as determined from NDVI obtained with the Green-Seeker optical sensor, was closely related to the actual grain yield of wheat. Likewise, Chang *et al*. (2003) found high coefficients (r^2) of determination between NDVI and maize grain yield.

This technology is the latest addition to the list of crops sensors in African agriculture. Our preliminary observations of 2014/15 and the results of one year with single location using NDVI sensor in relation to crop N content and final grain yield in hybrid of quality protein maize (Hailu and Toler, 2020) are very encouraging and envisage a potential scope of sensors for monitoring crop growth in order to predicting the dose of N application for maximizing maize production and productivity maize. There was also an effort by researchers on in-season N fertilizer calibration using hand held Green-seeker sensors, which will be used by validating the results (Tolera et al. 2015; Adis *et al*. 2015).

Thus, hybrid maize, BHQPY545 is among the recently released quality protein maize for humid mid-altitudes (Adefris*et al*. 2015).Much of the effort making fertilizer recommendation with modern approach has not been investigated yet the potential of using crop sensors to upturn economic and environmental wellbeing in the study area rather than blanket recommendation used as national level. Therefore, the objective was tostudy the relationships of NDVI value measured by sensor with crop growth and final yield in maize, and to determine the best N rate for maize in the study area.

Materials and Methods

The studywasconducted in a sub-humid agro-ecology of Western Ethiopia, Ethiopia.Field experiment was executed on three farmers' fieldaroundGobu Sayo district in 2018 and 2019 rainy season. The area is lies between 8’59'31"N to 9'01'16 ‘’N latitude and 37'13'29 E to 37°21''’E longitude and at an altitude rangedfrom 1727 to 1778 meter above sea level. The ten years, 2010 to 2019, weather information data at nearby study area (Bako Agricultural research center) indicated a unimodal rainfall pattern a mean annual rainfall of 1240.5 with maximum precipitation being received in months of June to begging of September (MBARC 2014). The experimental area is characterized by warm and humid climate with minimum, maximum and mean air temperatures of 14, 28.5 and 21.2ºc to 13.4, 28.49 and 20.95°c, correspondingly(WWW.IQQO.ORG). The soil type is brown clay loam Nitisols and Alfiso (Mesfin 1998; Tolera *et al*. 2016). The farming system of the surroundings area is a mixed farming and is one of the major maize growing belts in Ethiopia, and finger millet, soybean and hot pepper commonly cultivated there.

The experiment was laid out in a randomized complete block design with factorial arrangement in three replications and the plot size was 5.1m length with 4.5m width. Three levels of N (0, 25, and 50 kg N ha^{-1}) which is all applied at the time of planting, and four N levels(19, 38, 56 and 75 kg N ha^{-1})for side dressing were used as a treatments. For this experiment, medium maturing hybrid maize, BHQPY545 was used as a test crop. The cultivar is well adapted to altitude areas of 1000-1800 meter above sea level and it requires an annual rainfall of 500-1000 mm with uniform distribution in its growing periods, and has yield potential ranges from 8.0-9.5 t ha^{-1} at research field and 5.5-6.5t ha^{-1} at farmers field (Adefris *et al*. 2015).The hybrid was planted in rows spaced at 75 cm between rows and 30 cm intra-row spacing. Recommended phosphorus (20 kg P ha^{-1}) in the form of triple super phosphate was uniformly and equally applied to all experimental plots at the time of planting. Urea was used for the source of N fertilizer which was applied at different rates as constituted in the treatments. All other non-treatment management practices were carried outuniformly for all plots as per recommendation for the cultivar.

NDVI values were recorded using Green Seeker sensor at vegetative at vegetativegrowth stage of leaf four (V4),six (V6) and eight (V8) of maize. The value of NDVI readings can range from 0.00 to 0.99; the higher reading, the healthier the plant, healthier crop canopy has a higher NDVI value.

Harvesting wasdone from central rows by excluding two border rows from each side. A net plot size for each plot was 2.25 m x 5.1 m (11.475 m^2). Phonological, yield traits and grain data on leaf area, leaf area index, plant height, biomass yield, grain yield, harvest index, thousand kernel weight and other relevant agronomic traits of maize were collected. Finally, all the collected data wereanalyzed using Gen Stat software. Mean separation was done using Duncan’s multiple range tests at $P< 0.05$ (Duncan 1955).Regression analysis was also done to see relationship between different variables as affected by different levels of N applications.

Results and Discussion

The combined analysis of variance reveled that applied N fertilizer at planting and side dressed significantly (P<0.01) affected grain yield, dry biomass and harvest index (Table 1). There was also significant (P<0.05) difference between the applied N fertilizer on plant height, NDVI-V4 and NDVI-V6 (Table 1 and Table 2).In addition, applied N at planting showed a highly significant (P<0.01) variation on NDVI at V4. In contrary, the response of thousand kernel weight and NDVI at V6 to N rate did not show significant variations. On the other hand, grain yield and all yield parameters of maize were significantly differed among farmers field, indicating soil fertility variation in farmers field.

Table 1. Analysis of variance for yield and yield traits as influenced by nitrogen rates and interaction effects in 2018 and 2019season at Gobu-Seyo district, Ethiopia.

		MS				
Source of variation	D.f.	GY	DB	HI	TKW	PH
Nitrogen at planting (N)	2	42.38^{**}	298.47^{**}	14.85^{ns}	361.5^{ns}	0.298^{**}
Nitrogen for side dressing (SD)	3	20.03^{**}	94.85^{**}	60.70^{*}	688.2^{ns}	0.117^{**}
Location (Loc)	2	20.60^{**}	333.79^{**}	602.80^{**}	6295.3^{**}	0.324^{**}
Year (Yr)	1	45.31^{**}	3345.82^{**}	2841.65^{**}	103889.3^{**}	12.06^{**}
N* SD	6	1.81^{**}	29.54^{**}	104.41^{**}	422.5^{ns}	0.020^{*}
N* SD*Loc	12	1.90^{**}	27.00^{**}	67.82^{**}	848.9^{*}	0.013^{ns}
N* SD*Yr	6	1.31^{*}	11.88^{ns}	65.85^{**}	638.1^{ns}	0.004^{ns}
N* SD*Loc*Yr	12	1.42^{**}	18.55^{*}	58.35^{**}	1015.7^{**}	0.006^{ns}
Replication	2	1.15^{*}	2.71^{ns}	11.72^{ns}	1488.8^{*}	0.026^{ns}
Residual	142	0.42	7.15	11.42	296.3	0.009
Total	215	–	–	–	–	–

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

Table 2. Analysis of variance for NDVI value as influenced to different levels of N fertilizer in 2018 and 2019 at Gobu-Seyo district, Ethiopia.

MS				
Source of variation	D.f.	NDVI at node		
		V4	V6	V8
Nitrogen at planting (N)	2	0.00826**	0.01587**	0.01767**
Nitrogen for side dressing (SD)	3	0.00047ns	0.00208ns	0.00269*
Location (Loc)	2	0.028107**	0.01667**	0.04162**
Year (Yr)	1	0.232395**	0.24911**	0.10701**
N* SD	6	0.00173*	0.00095ns	0.00179*
N* SD*Loc	12	0.00082ns	0.00093ns	0.00089ns
N* SD*Yr	6	0.00097ns	0.00044ns	0.00065ns
N* SD*Loc*Yr	12	0.00123*	0.00095ns	0.00089ns
Replication	2	0.00332*	0.01428**	0.00518*
Residual	142	0.00060	0.00106	0.00073
Total	215	–	–	–

* and ** =significant difference at 5% and 1% probability level, ns = non-significant difference at 5% and 1%, MS Mean square, d.f .= degree freedom, V4, V6 and V8 = vegetative growth stages at leaf four, six and eight, correspondingly.

Crop phenology, growth and yield traits of maize

All yield parameters, except for plant height, were significantly affected by applied N rates in each farmer's field and year. The yield components and growth parameters were showed significant increase up to 56 kg N ha^{-1} and then minimum increment after that (Table 3 and 4). This might be someamount of applied N was not used by the crop due to losses through different process. Teboh *et al*. (2012) stated that recommendations of fertilizers in Sub-Saharan Africa are mainly inefficient since application rates are neither specific to crop demand nor current with related yields, which reduce the influence of temporal changes that affect final yields. Hence, the result magnifies the significance of crop sensor-based N management for maize production.

As indicated in table 3, higher dry biomass (25.7 t ha^{-1}) was recorded from the combined use of 50 kg N at planting and 56 kg N ha^{-1}as side dressed at 35 days after planting. Whereas, maximum harvest index(35 %) was attained from the treatmentreceiving 50 and 75 kg N ha^{-1} at planting and side dressing, correspondingly. On the contrary, minimum dry biomass (17.9 t ha^{-1}) and harvest index (28%) were attained from plots receiving only 19 kg N ha^{-1} as side dressing compared to other treatment combinations. On the other hand, the highest NDVI value at V4 (0.37) was recorded at 25/38 kg N and 50/19 kg N ha^{-1} application rates and it shows a decrease in NDVI value as N level increased (Table 4). The maximum NDVI value at V8 (0.71) was, however, recorded from the application of 50/19 and 50/56 kg N ha.

Table 3. Effects of N fertilizer rate on Grain yield, dry biomass, harvest index and thousand kernel weight of quality protein maize at Gobu-Seyo district, Ethiopia.

Nitrogen levelsat planting (kg ha-¹)	Nitrogen rate for side dressing (kg ha-¹)	Dry biomass (t ha^{-1})	Harvest index (%)	Thousand kernel weight (g)
0	19	17.9a	28a	273a
0	38	20.1b	34e	288bc
0	56	21.5bc	33de	290c
0	75	22.6cd	30ab	286abc
25	19	21.3bc	31bcd	282abc
25	38	24.3def	29ab	281abc
25	56	23.4de	33cde	277abc
25	75	25.1ef	33cde	283abc
50	19	23.8def	31bcd	274ab
50	38	22.8cd	32cde	284abc
50	56	25.7f	31abc	2823abc
50	75	25.3ef	35 e	279abc
LSD (5%)		1.76	2.2	NS
CV (%)		11.7	10.7	6.1

Table 4. Plant height and NDVI reading of QPM in 2018 and 2019 at Gobu-Seyo district, Ethiopia.

Nrates at planting (kg ha-¹)	Side dressing N rates (kg ha-¹)	Plant height (m)	NDVI at		
			V4	V6	V8
0	19	2.3a	0.33ab	0.40abc	0.67ab
0	38	2.3ab	0.34a	0.41a	0.67a
0	56	2.4defg	0.35abcde	0.42bcde	0.68bcd
0	75	2.4bc	0.34abc	0.41ab	0.67ab

25	19	2.4cd	0.35abcde	0.44de	0.69bcde
25	38	2.4cde	0.37e	0.44de	0.70cdef
25	56	2.5efgh	0.36 de	0.44de	0.70cdef
25	75	2.5gh	0.36 e	0.45 e	0.70cdef
50	19	2.5efgh	0.37e	0.44de	0.71 f
50	38	2.4cdef	0.35bcde	0.42abcd	0.68bc
50	56	2.5fgh	0.36cde	0.43cde	0.71ef
50	75	2.5h	0.34abcd	0.42abcde	0.70def
LSD (5%)		0.06	0.016	NS	0.018
CV (%)		3.9	7.0	7.6	3.9

Conversely, the lowest NDVI at V4 and V6 were recorded from the use minimum 19 kg N ha^{-1} rates than other treatments. In general, the NDVI values were very low at the beginning of the growth stages (Figure 1 and Table 4). However, it becomes higher after V4 as the growth progressed and reaching a maximum.This was might be due to the initial growth stage of maize or it possibly the failure of the maize canopy cover over the space between plants and

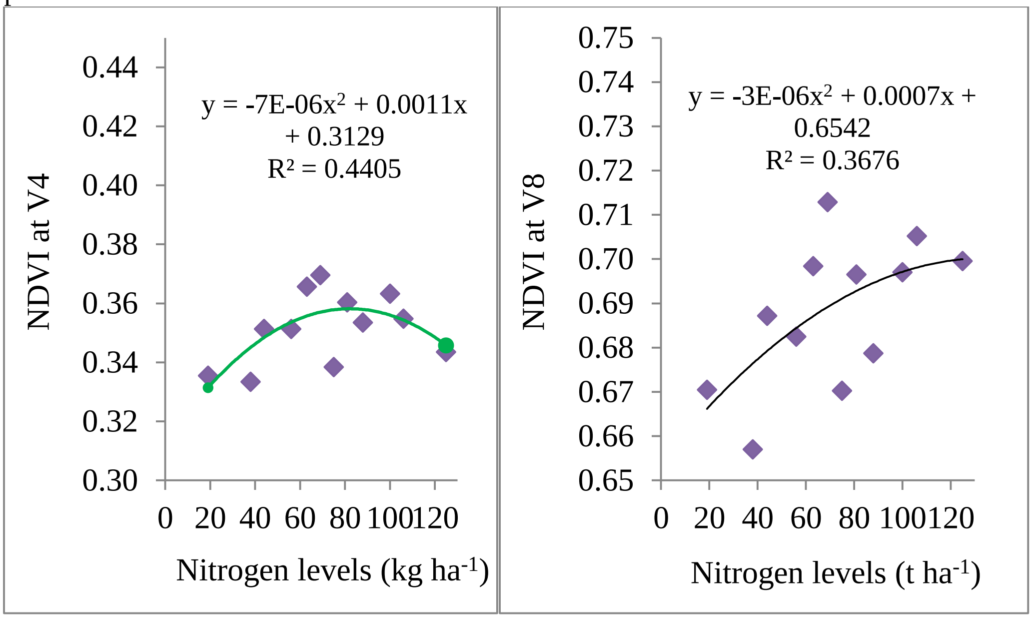

Figure 1. Nitrogen level Vs. NDVI at V4 (left) and V8 (right) in 2018 and 2019 at Gobu-Seyo district, Ethiopia.

lack of N stress at early stage. At later growth stages, however, the reading value gradually increasing probably due to a more canopy cover of maize over the space. A similar result was reported by Hailu and Toler (2020) and Tolera *et al*. (2020) on quality protein maize.

Another author, Govaerts (2007) reported that the NDVI value at the beginning of the season is very low, but gradually enhanced as the growth progressed and reaching a maximum and decreasing gradually as the grain starts to ripening. There was evidence that increase in N rates improved spectral vegetation indices which is helpful in indirectly obtaining information plant nutrient status such as potential yield and photosynthetic efficiency of target crop (Tolera *et al*., 2015; Ngie *et al*, 2014).
There was a correlation between applied N and NDVI observed in 2018 and 2019 cropping season. Higher correlation between NDVI reading and applied N observed with 0.44 and 0.37 at V4 and V8 growth stages, correspondingly (Figure 1). This indicates that the NDVI value at different growth stages correlated to plant physiological parameters.

Grain yield of maize

As depicted in figure 2, applied N rates also showed significant effects to grain yield of maize crop. The highest significant grain yields (8.6 t ha^{-1}) were attained at 50/75 kg N ha^{-1} (50 kg at planting and 75 kg N ha^{-1} as side dressed) application rates followed by 25/75 kg N ha^{-1} (Figure3). In addition, comparable yield was recorded when 50/56 kg N ha^{-1} practiced. Minimum yield (5.5 t ha^{-1}) was, however, obtained from treatments receiving 19 kg N ha^{-1} which applied as side dressed as compared to other treatment combinations. The mean grain yield obtained at the three farmers' field was less to the yield recorded at research fields (8-9.5 t ha^{-1})for the variety used as a test crop. This is most likely due to better soil fertility management and fertilizer application over time in research stations. Various reports indicated research stations are mainly characterized by relatively high level nutrient replenishment, or sometimes accumulation and better agronomic practices (Tittonell *et al*., 2008). Similarly, Zingore *et al*. (2008) and Rusinamhodzi (2011) reported that Smallholder farming areas characterized by poor soil fertility and low level agronomic practices. The response of maize grain yield to N application depends on various factors such as history of soil fertility management, soil type, amount and distribution of rainfall and form of the N fertilizer (Gotosa *et al*., 2019).
In addition, the yield of maize response to application of N rates was significantly varied among farms (Table 5). This might be due to variability's among farmers field in soil fertility status and the different levels of land use intensity and the ability of farmers to apply inputs (crop residues, manure, refuse, fertilizer) to some fields over time (Tittonel, *et al*., 2012). Similarly, Tolera *et al.* (2020) reported the heterogeneity of farmers' field was contributed to a great extent in yield variations of maize with similar nutrient rate application in the soil during planting. Likewise, Vanlauwe *et al*. (2014) indicated that long term interplay of geological and landscape conditions and plot-specific management have generated variations within farm soil fertility gradients. Another author, Schmid *et al*. (2002) indicated that a highly variable amount of nutrient was required to bring any given subplot of maize within a farmer's field to highest yield. A wide range of farm-field management practices and long-term production history at each site subsequently affects the response of applied treatments to on-farm research (Mack, 2006).
This indicates the call for site based fertilizer management for maize production. The highest grain yield was attained at use of 125 kg N ha^{-1} (50 kg N ha^{-1} at planting and 75 kg N ha-1 side dressed at 35 days after planting) (Table 5) for maize around Bako, Western Ethiopia.

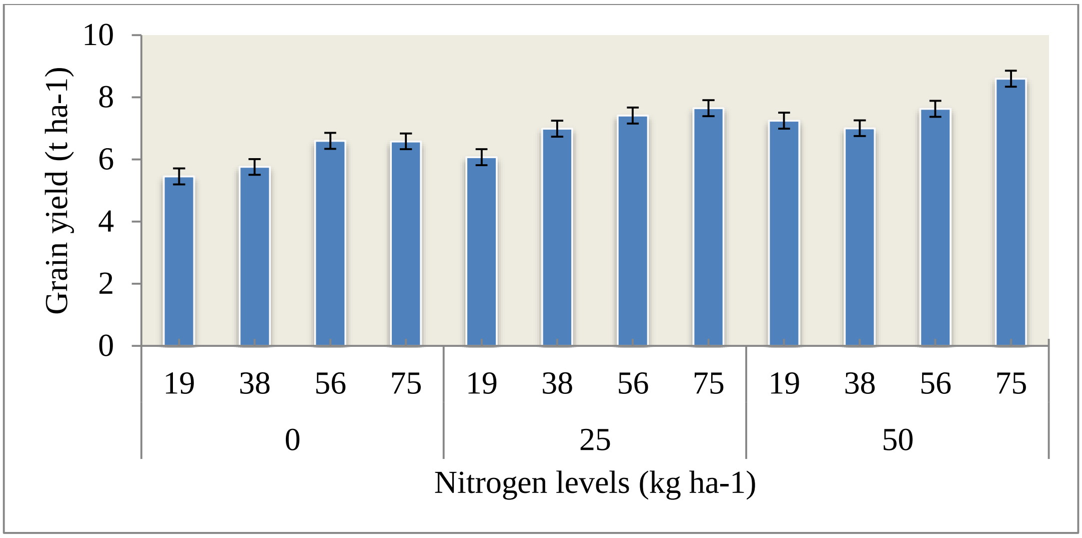

Figure 2.Effects of N fertilizer rate on Grain yield of quality protein maize in 2018 and 2019 at Gobu-Seyo district,, Ethiopia.

Table 5. Effects of nitrogen rates on mean grain yield of maize conducted on farmers' field in 2018 and 2019 cropping season around Gobu-Seyo district,district, Western Ethiopia.

		Grain yield (t ha^{-1})			
Nitrogen levelsat planting (kg ha-^{1})	Nitrogen rate for side dressing (kg ha-^{1})	Farmer-1	Farmer-2	Farmer-3	Mean
0	19	4.7	5.6	6.0	**5.4**
0	38	5.7	5.5	6.1	**5.8**
0	56	5.7	6.7	7.4	**6.6**
0	75	5.4	6.7	7.6	**6.6**
25	19	5.4	5.7	7.1	**6.1**
25	38	6.8	6.5	7.7	**7.0**
25	56	7.3	6.9	8.1	**7.4**
25	75	7.9	7.0	8.0	**7.6**
50	19	6.9	7.2	7.6	**7.2**
50	38	6.4	7.2	7.4	**7.0**
50	56	8.5	6.2	8.2	**7.6**
50	75	8.9	7.7	9.2	**8.6**
Mean		**6.6**	**6.6**	**7.5**	**6.9**
LSD (5%)					

There was also a correlation between applied N and yield of maize observed with 0.44 and 0.37 at V4 and V8 growth stages, correspondingly (Figure 3). This shows the NDVI value at different growth stages correlated to plant physiological parameters and crop yields. Similarly, Tolera *et al*. (2020) reported that NDVI value correlated to crop yield, plant growth and biomass production. Likewise, Moges (2004) found that NDVI values were positively correlated with final grain yield. Govaerts (2007) also reported that measured NDVI value

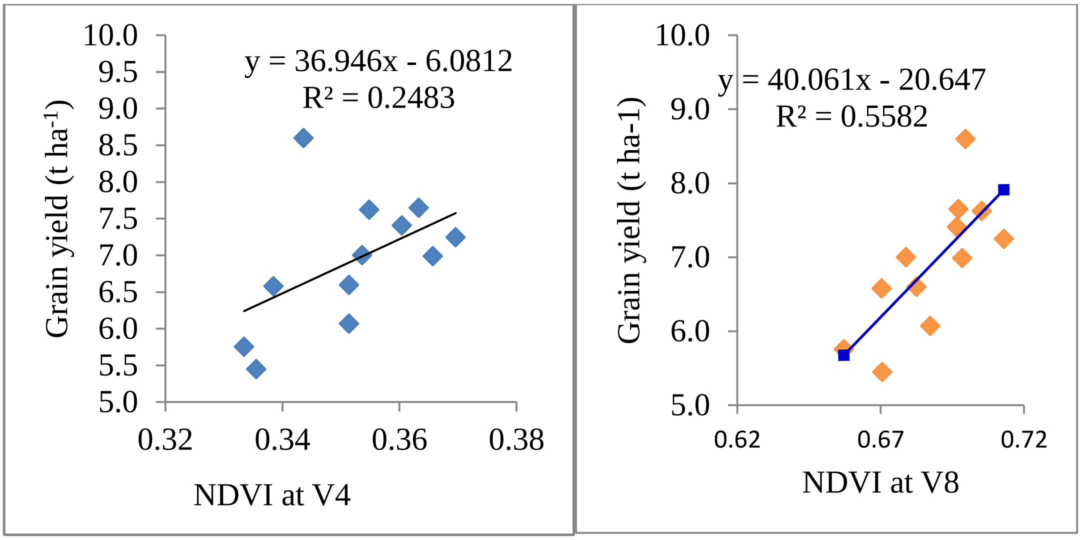

Figure3. Grain yield Vs. NDVI at V4 (left) and V8 (right) in 2018 and 2019 at Gobu-Seyo district, Ethiopia.

using handheld crop sensor correlated well with final grain yield of maize. Hence, the sensor-based N management is one of the best tools in optimum N fertilizer application for maize production. Mamo et al. (2003) showed that optical sensor-based N application according to spatial variability can minimize the overall N rate applied and enhance productivity when compared with a uniform N application. Further. Lie *et al*. (2009) reported that Green-Seeker sensor as N management tool which can improve nitrogen use efficiency with significant increase in net profits for cereal and grain crops. Thus, the hand-held green seeker sensor is a very crucial instrument in monitoring the real time maize growth under different levels of N application, and detecting crop health and lack of stress which intern shows maximum yield and reduce environmental contamination due to over application of N.

Economic feasibility of nitrogen fertilizer application rate on maize

Economic feasibility for means of treatments was also assessed. The result of the partial analysis showed that the responses of grain yield to applied nitrogen rates were varied. As depicted in table 6, the highest net benefit ETB 65,343.36 ha^{-1}and value to cost ratio of ETB 15.10 per unit of investment were obtained, when 50 and 75 kg N ha^{-1} were used during planting and side-dressing at 35 days after emergence, correspondingly, followed by 50 kg N ha^{-1} at planting with side-dressed of 56 kg N ha^{-1} which gave the next maximum net benefit (ETB 58,767.96 ha^{-1}). In contrary, minimum net benefit (ETB 43,445.38) was achieved from using 19 kg N ha^{-1} asside-dressed only. The value to cost ratio ranged from ETB 15.10 to 39.30 per unit investment of nitrogen fertilizer used. However, the acceptable marginal rate of

Table 6. Partial budget analysis as affected by the application of N rates on maize in the 2018 and 2019rainy season.

Treatments NL (Kg ha^{-1})	GY	Adj. GY	TC	GB	NB	CR	MRR
0/19	5.5	5.0	1104.62	44550.0	43445.38	39.30	
0/38	5.8	5.2	1769.56	46980.0	45210.44	25.50	265.4
25/19	6.1	5.5	1828.40	49410.0	47581.60	26.60	4029.8
0/56	6.6	5.9	2384.04	53460.0	51075.96	21.40	628.9
25/38	7.0	6.3	2465.94	56700.0	54234.06	22.00	3856.0
50/19	7.2	6.5	2667.00	58320.0	55653.00	20.90	705.73
0/75	6.6	5.9	2986.16	53460.0	50473.84	16.90	
25/56	7.4	6.7	3025.12	59940.0	56914.88	18.80	352.4
50/38	7.0	6.3	3225.64	56700.0	53474.36	16.60	
25/75	7.7	6.9	3602.04	62370.0	58767.96	16.30	321.2
50/56	7.6	6.8	3713.22	61560.0	57846.78	15.60	
50/75	8.6	7.7	4316.64	69660.0	65343.36	15.10	920.2

NL= Nitrogen Levels (kg ha^{-1}), GY = Grain yield of maize (t ha^{-1}), Adj.GY = Adjusted yield (t ha^{-1}), TC = Total cost that varied among treatments (ETB ha^{-1}), GB = Gross benefit (ETB ha^{-1}), NB = Net benefit (ETB ha^{-1}), CR = Value to cost ratio, MRR = Marginal rate of return (%), D = Dominated, and 1 USD = 25.0 ETB

return920.2% with maximum net benefit (ETB 65,343.40) was attained when 50 kg N ha^{-1} applied during planting and side-dressed with 75 kg N ha^{-1}.Hence, 50 kg N at planting and 75 kg N ha^{-1} during side-dressing is economically feasible rate for maize production in the study area.

Conclusion

Crop sensor technology such as Green-seeker sensor is one of the new approach ways of N management for maize producing farmers in western Oromia. Significant differences were observed between applied N rates onphonological growth, grain yield and yield traits of maize. Higher relationship of 0.25 and 0.56 were observed between grain yield and applied N fertilizer at V4 and V8 respectively. Significantly higher mean grain yield of 8.6 tha^{-1}was obtained when 125 kg N ha^{-1} (50 kg N ha^{-1} at planting and side dressing with 75 kg N ha^{-1}) was used followed by100 kg N ha^{-1}.The value to cost ratio ranged from ETB 15.10 to 39.30 per unit investment of nitrogen fertilizer used. However, N application rates of 50 and 75 kg ha^{-1} during planting and side dressing at 35 days after emergence gave the maximum yield, and net benefit of ETB 65343.36 ha^{-1} with acceptable marginal rate of return.Therefore, N application rate at 50 kg N ha^{-1} during planting and 75 kg N ha^{-1} for side-dressing is the best N rate and economically feasible for maize production in the study area.

Acknowledgment

Of all, the authors greatly acknowledge Bako Agricultural Research Center for the financial support as well as a great role in administrative support and incredibly appreciated. Lastly, we would like to extend our gratitude to all staff members of Cereal crops Technology Generation team for their assistance in setting up, planting, collecting all required data and maintaining the field experiments since the start of the project in 2018.

References

Achalu Chimdi, Heluf Gebrekidan, Kibebew Kibret and Abi Tadasse. 2012. Status of selected physio-chemical properties of soils under different land use systems of Western Oromia, Ethiopia. *Biodiversity and Environmental Science*, 2, 57-71.

Addis Teshome, HaeKoo Kim, Adugna Debala. 2015. Calibration of Nitrogen Fertilizer for Quality Protein Maize based on In-season estimated yield using a hand-held NDVI Sensor in the Central Rift Valley of Ethiopia. *Asia Pacific Journal of Energy and Environment*, 2, 25-32.

Adefris Teklewold, Dagne wegary, Abraham Tadesse, Birhanu Tadesse, Kassahun Bantte, Dennis Friesen and PrasannaBM. 2015. Quality Protein Maize: A Guide to the Technology and its Promotion in Ethiopia. CIMMYT: Addis Ababa, Ethiopia.

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

Canfield DE, Glazer AN and FalkowskiPG. 2010. *The Evolution and future of earth's nitrogen cycle Science*, 330, 192-196.

Central Statistical Agency (CSA). 2018. Agricultural Sample survey: report on area and production of major crops (private peasant holdings, Meher season). *Statistical Bulletin* 586, Addis Ababa, Ethiopia.

Chang J, Clay D E, Dalsted K, Clay S and O'Neill M. 2003. Corn (*Zea Mays* L.) yield prediction using multispectral and multi-date reflectance. *Journal of Agronomy*, 95, 1447-1453.

CIMMYT. 2004. CIMMYT's work for Maize systems and farmers in Sub-Saharan Africa report. CIMMYT, Mexico. Available at: http://hdl.handle.net/10883/3716.

Duncan D B. 1955. Multiple range and multiple F tests. *Biometrics*,11:1-42.

Gotosa J, Kodzwa J, Nyamangara J and Gwenzi G. 2019. Effect of nitrogen fertilizer application on maize yield across agro-ecological regions and soil types in Zimbabwe. *International Journal of Plant Production*, https://doi.org/10.1007/s42106-019-00045-9.

Govaerts D B. 2007. Conservation agriculture, a sustainable production alternative for the (sub) tropical highlands: Toward an integrated evaluation of the system. PhD thesis, katholieke universiteit Leuven.

Hailu Feyisa 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*, 14,289-296.

Hopkins B G, Rosen C J, Shuffler A K and TaysomT W. 2008. Enhanced efficiency fertilizers for improved nutrient management of potato. United States Department of Agriculture, National Agriculture Library. *Crop management*, 7(1): 0. 10.1094/CM-2008-0317-01-RV

LiF, Miao Y, Zhang F, Cui Z, Li R, Chen X, Zhang H, Schroder J, Raun WRand JiaL.2009. In-season optical sensing improves Nitrogen Use Efficiency for winter wheat. *America Soil Science Society*, 73, 1566-1574.

Lukina EV, Freeman KW, Wynn KJ, Thomason WE, Mullen RW, Klatt AR, Johnson, GV, Elliott RL, Stone ML, Solie JB and RaunWR.2001. Nitrogen fertilization optimization algorithm based on in-season estimates of yield and plant nitrogen uptake. *Plant Nutrition*, 24, 885-898.

Lulseged Temene, Tilahun Amede, Job Kihara, Degefie Tibebe, Steffen Schulz. 2017. A review of soil fertility management and crop response to fertilizer application in Ethiopia. *International Center for Tropical Agriculture* (CIAT) Publication, 443, 2-6.

MBARC, 2014. Meteorological data of Bako area for 1960-2014. Bako, Oromia, Ethiopia.

Mack C J. 2006. Validation of nitrogen calibration strip technology for prescribing accurate top dress nitrogen fertilizer. M.Sc. Thesis, Oklahoma State University, United States.

Madefro Nigssie, Tanner D, and Twumasi-Afriyi S. 2001. Enhancing the contribution of maize to food security in Ethiopia: *Proceedings of the second national maize workshop of Ethiopia, pp. 12-16 Addis Ababa, Ethiopia.*

Mamo M, Malzer G L, Mulla D J, Huggins D R and Strock J. 2003. Spatial and temporal variation in economically optimum nitrogen rate for corn. *Agronomy Journal*, 95, 958-964.

Mesfin Abebe. 1998. Nature and Management of Ethiopian Soils. Haramaya University of Agriculture, Ethiopia.

Moges SM. 2004. Evaluation of Green, Red and Near Infrared bands for predicting winter wheat biomass, Nitrogen uptake and final grain yield. *Plant Nutrition*, 27, 1431-1441.

Mourice S K, Tumbo S D, Nyambilila A and RweyemamuC L. 2015. Modeling potential rain-fed maize productivity and yield gaps in the Wami River Sub-basin, Tanzania. *Soil and Plant Science*, 65, 132-140.

NgieA,Ahmed F and AbutalebK. 2014. Remote sensing potential for investigation of maize production: review of literature. *South African Journal of Geomatics*, 3, 163-184.

Raun WR, Johnson GV, Stone ML, SollieJB, Lukina EV, Thomason WE and SchepersJS. 2001. In-Season prediction of potential grain yield in winter wheat using canopy reflectance. *Agronomy Journal*, 93, 131-138.

Raun WR, Solie J B, Johnson G V, Stone M L , Mullen R W, Freeman K W, Thomsan W E and LukinaE V. 2002. Improving nitrogen use efficiency in ceral grain production with optical sensing and variable rate application. Agronomy journal, 94, 815-820.

Rusinamhodzi L, Corbeels M, Van Wiik M T, Rufino M C, Nyamangara J and GillerK E. 2011. A met-analysis of long-term effects of conservation agriculture on maize grain yield under rain-fed conditions. *Agronomy for sustainable development*, 31, 657-673.

Schmidt J P, DeJoia A J, Ferguson R B, Taylor R K, Young R K and HavlinJ L. 2002. Corn yield response to nitrogen at multiple in-field locations. *Agronomy Journal*, 94, 798-806.

Sripada R P, Heiniger R W, White JG and WeiszR. 2005. Aerial color infrared photography for determining late-season nitrogen requirements in corn. *Agronomy journal*, 97, 1443-1451.
Teboh J M, Tubana B S, Udeigwe T K, Emendack Y Y and LoftonJ. 2012. Applicability of ground-based remote sensors for crop management in sub-sharan Africa. *Journal of Agricultural Science*, 4, 175-188.
Tittonell P, Muriuki A, Klapwijk C J, Shepherd K D, Coe R and VanlauweB. 2012. Soil heterogeneity and soil fertility gradients in smallholder farmers of the east African highlands. *American Soil Science Society*, 77, 525-538.
Tittonell P, Vanlauwe B and CorbeelsM. 2008. Yield gaps, nutrient use efficiencies and response to fertilizers by maize across heterogeneous smallholder farms of western Kenya. *Journal of Plant and Soil*, 313, 19-37.
Tolera Abera, Dagne wegary and HaeKoo Kim. 2020. In-season nitrogen determination for quality protein maize using Normalized difference vegetation index on-farmers field around Toke Kutaye, Oromia region, Western Ethiopia. *World journal of Agricultural Science,* 16, 180-194.
Tolera Abera, Dagne wegary, Tolessa Debele, Ernest Semu and HaeKoo Kim. 2016. Pedological characterization, fertility status and classification of some typical soils of Bako-Tibe and Toke Kutaye districts of western Showa, Ethiopia. *Ethiopian journal of Applied Science,* 7, 49-67.
Tolera Abera, Ernest Semu, Tolessa Debele, Dagne wegary and HaeKoo Kim. 2015. Sensor based in-season nitrogen prediction for quality protein maize varieties on farmers' field around Bako-Tibe, Western Ethiopia. *America-Eurasian Journal of Agriculture and Environmental Science*, 15, 1556-1567.
Trimble Navigation Limited (2012). Trimble and the Globe & Triangle logo are trademarks of Trimble Navigation Limited, registered in the United States and other Countries. Version 1.00. PN 022503-1124-1 (01/14).
Vanlauwe B, Coyne D, Gochkowski J, Hauser S, Huising J, Masso C, Nziguheba G, Schut, M and van AstenP. 2014. Sustainable intensification and African smallholder farmer. *Current opinion in environment sustainability*, 8, 15-22.
Variety Register for crops. 2012. Crop variety registration, in CVR, Addis Ababa, 2012.
Westermann D T and KleinkopfG E. 1985. Nitrogen requirement of potatoes. *Agronomy Journal*, 77, 616-671.
Woktole Mosisa, Legesse Wolde, Berhanu Tadesse, Girma Demissie, Wonde Abera, Tolera Keno, Gezahegn Bogale, Dagne Wegary, Solomon Admassu, Zelalem Habtamu, KassaY, Temesgen Chibsa, Habte Jifa, Demoz Nuguse and Getachew Biru. 2011. Status and future direction of maize research and production in Ethiopia. In *Proceedings of the third National maize workshop In Meeting the challenges of global climate change and food security through innovative maize research of Ethiopia*, pp. 17-2011, Addis Ababa, Ethiopia.
Xue LH, Qin X, Li GH and YangLZ.2010.Effect of basal and tiller nitrogen rates on population dynamics, nitrogen uptake and utilization, and yield formation of direct seeded early rice. *Journal of Soil*, 42, 681-688.
Zerihun Abebe, Chela Dabala and Tadesse Birhanu. 2016. System productivity as influenced by varieties and temporal arrangement of bean in maize-climbing bean intercropping. *Agronomy Journal*, 16, 1-11.

Zerihun Abebe and Hailu Feyisa. 2017. Effects of Nitrogen rates and time of application on the yield of maize: Rainfall variability influenced time of N application. *International Journal of Agronomy*, 2017. Available at: https://doi.org/10.1155/2017/1545280.

Zingore S, Delve R J, Nyamangara J and GillerK E. 2008. Multiple benefits of manure: The key to maintenance of soil fertility and restoration of depleted sandy soils on African smallholder farms. *Journal ofNutrition Cycling Agro-ecosystem*, 80, 267-282.

Determination of optimum Nitrogen and NPS fertilizer rates for yieldand yield component of Potato (*Solanum tuberosum* L.) at Western Oromia, Bako.

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Abstract

Potato (Solanum tuberosum L.) is one of the most important food crops in many countries of the world. In volume of production, it is the fourth most important crop in the world after wheat, maize, and rice with annual production of 314.1 million tons cultivated on about 18.1 million hectares of land (Adane et al., 2010). A new blended fertilizer (NPS) containing nitrogen (19% N), phosphorous (38% P_2O_5) and sulfur (7% S) is recently introduced aiming to substitute DAP in Ethiopian agriculture. Therefore thisfield experiment was conducted at Western Oromia to determine the effect of nitrogen and NPS rates on growth, yield parameters and to investigate the interaction effect of N and NPS rates on yield and economic of potato variety as well . The treatments consisted of factorial combination of one variety Horo with four N rates level (0kg N ha^{-1}), (46 kg N ha^{-1}), (92 kg N ha^{-1}), (138 kg N ha^{-1}) and four NPS rates level (0kg, 50kg, 75kg and 100kg NPS ha^{-1}). The experiment was laid out in a Randomized Complete Block Design (RCBD) replicated three times. Results showed that main effect was significantly ($P<0.05$) influenced due to the combined application of Nitrogen and NPS blended fertilizer rates on the growth parameter of plant height, plant canopy and number of main branch per plant,but non-significant on stand count at harvesting . The analysis variance revealed that main effect was significantly ($P<0.05$) influenced due to the combined application of Nitrogen and NPS blended fertilizer rates on the yield component parameter of number of tuber per plant, marketable number of tuber per plant, number tuber per plot, number marketable tuber per plot and number unmarketable tuber per plot. In general the combined applications of 92 N Kg $ha^{-1}$with 100 NPS Kg ha $^{-1}$ or 200 kg/ha urea and 100kg/ha NPS produced the highest total marketable tuber (15.383t ha^{-1}) and most economically feasible option for potato production that also provided the net benefit of (208515 ETB ha^{-1}) and as a result was recommended for Western Oromia and other similar agro-ecologies.

Keywords: *Potato, N and NPS*

Introduction

Potato (*Solanum tuberosum* L.) is one of the most important food crops in many countries of the world. In volume of production, it is the fourth most important crop in the world after wheat, maize, and rice with annual production of 314.1 million tons cultivated on about 18.1 million hectares of land (Adane *et al*., 2010). In 2007 the potato production reached a record of 325 million metric tons becoming the first non-grain commodity for humanity (FAO, 2009). However demand for both food and energy is rising and it is expected to keep the same trends with increases in global population and average income (Lobell *et al*., 2009). Asia and Europe are the world's major potato producing regions, accounting for more than 80% of world production, while Africa produces the least, accounting for about 5% (FAO, 2008). North America is the leader in productivity at more than 40% t ha^{-1}, followed by Europe at 17.4 t ha^{-1}, while Africa lags at about 10 t ha^{-1} (FAO, 2008). The average yield of potato in Ethiopia ranges only between 8 to 10 t ha^{-1} ,which in much lower than the yields obtained even in Sudan (17 t ha^{-1}) and Egypt (26 t ha^{-1}) (Haverkort *et al*., 2012). The major contributing factors to the low yields of potato have been the use of poorly adapted varieties, high prevalence of diseases and pests, poor soils, unfavorable weather conditions, un-scientific cultural practices including tuber planting depth (Snapp and Kravchenko, 2010)

Nutrient losses due to low rate of return of biomass to crop fields, inadequate fertilizer application (Gebrekidan, 2003; Zelleke et al., 2010), and escalating fertilizer prices (Morris et al., 2007; Bekunda et al., 2010; Walsh et al., 2012) are identified as major constraints to agricultural production and food security in the Ethiopian farming system (Amede and Takele, 2001). Thus, external supply of inorganic and organic fertilizer inputs is necessary to increase crop productivity of major food crops in Ethiopia (Wakene et al., 2005)

On the other hand, potatoes demand high levels of soil nutrients due to a relatively poorly developed, coarse, and shallow root system (Dechassa *etal*., 2003). The crop produces much more dry matter in a shorter cycle that results in large amounts of nutrients removed per unit time, which generally most of the soils are not able to supply (Islam *et al*., 2013). For example, it removes approximately 3-5 kg nitrogen (N), 0.4-0.8 kg phosphorus (P) and 4-6 kg potassium (K) t-1 of tubers (Perrenoud, 1983). Potatoes farmers apply DAP and urea at low rates as well as some amounts of manure at small and varied rates (Gildemacher *et al*., 2009; Haverkort, 2012). Therefore, nutrient deficiencies are a common cause of low yields of the crop.

Nutrient mining due to sub optimal fertilizer use in one hand and unbalanced fertilizer uses on other have favored the emergence of multi nutrient deficiency in Ethiopia soils (Abyie et al., 2003, Beyene, 1984; Wassie et al., 2011) that in part my contributed to fertilizer factor productivity decline experienced over recent past. Different research reports indicate that nutrients like K, S, Ca, Mg and all micro-nutrients except Fe are becoming depleted and deficiency symptoms are being observed on major crops in different areas of the country (Wassie et al., 2011; Wassie et al., 2010; Asgelil et al.; 2007; Abyie et al., 2003; Abyie et al., 2001). The national soil of Ethiopia inventory data also revealed that in addition to nitrogen and phosphorus, sulfur, born and zinic deferiencies are widespread in Ethiopia soils.

In addition, nutrient management can decrease the severity of a number of important potato diseases. Proper N nutrition normally suppresses disease. Adequate N uptake is essential to the formation of various structures, proteins and enzymes needed both in growth and disease resistance. One of the most commonly assumed relationships of N to disease is that high N rates lead to more disease. Conversely, it has been observed that in some plants as the N content is increased beyond sufficient levels, the amount of antifungal compounds decreases. Potatoes deficient in either N or P are more susceptible to early blight (*Alternaria solani*) (Barclay et al 1973; Soltanpour and Harrison 1974).

A complete NPK fertilizer applied at planting, but not at later times, influenced the resistance of potato leaves to infection by *Phytophthora infestans* and the subsequent growth of lesions. Lesion size and lesion growth rate increased linearly with increasing fertilizer rates. Increasing rates of phosphate or potash, applied separately, did *not* significantly affect the development of blight lesions but a linear increase in lesion size was associated with increasing application rates of nitrogen (Carnegie and Colhoun 1983). To solve these problems the Ministry of Agriculture (MoA) currently popularize the implementation of soil test based fertilizer application system, using soil fertility information (MoA, 2013) and thus introduced a new fertilizer (NPS) which contains 19% N, 38% P_20_5 and 07% S in the country's farming system to increase productivity of crops. According to ATA, (2015) soils around Bako were deficient of Nitrogen, Phosphorus and Sulfur.

As the need for blended fertilizer become essential, ATA and its partners determined to provide local capacity to blend individual compound fertilizer to address the issue of nutrient deficiency of the country, but fertilizer recommendation for crop varieties by name and types not updated timelyfor crop species accordingly and majority ofwestern part of oromia deficiency in NPS nutrient. Therefore this project was initiated to test the right fertilizer rate recommendation of potato varieties for yieldin western Oromia.

Objective

- To determine the effect of nitrogen and NPS rates on growth and yield parameters of potato variety.
- To investigate theinteraction effect of N and NPS rates on yield and economic of potato variety.

Materials and method

A field experiment was conducted at Western Oromia to determine the effect of nitrogen and NPS rates on growth, yield parameters and toinvestigate theinteraction effect of N and NPS rates on yield and economic of potato variety during the main cropping season of 2018 and 2019 at Bako Agricultural Research Center (BARC) subsite of Shambu and Gedo.

Plant materials

Potato variety Horo, which is adapted to the agro-ecology of the area,NPS and Urea fertilizerwas used for the study. Variety Horo is the most successful variety released by Bako Agricultural Research Centre in 2015.

Experimental Design and plot management

The experimental field was ploughed and harrowed by a tractor to get a fine seedbed and leveled manually before the field layout was made. Planting was done onEarly Aprilin 2018 and seeds sown at a spacing of 75 cm between rows and 30 cm between plants.

The nitrogen fertilizer source used urea (46% N) which was applied by drilling in two splits, half of the amount at planting and the remaining half two weeks after full emergence along the rows of each plot to ensure that N is evenly distributed and NPSwas applied at planting. The treatment consist of factorial combination of one variety (Horo) with four N rates level (0kg N ha^{-1}), (46 kg N ha^{-1}), (92 kg N ha^{-1}), (138 kg N ha^{-1}) and four NPS rates level (0kg, 50kg, 75kg and 100kg NPS ha^{-1}). The treatments was arranged in randomized complete block design (RCBD) with three replications. Each plot was 3 m long and 3.75 m wide (5 rows). The inside three rows were set aside for data collection to eliminate any border effects. All the rest agronomic management of the crop were applied according to the recommended methods. Finally, potato plants in the central net plot area (6.75 m^2) were harvested at normal physiological maturity. The tubers were harvested manually using by hoeing and hand picking.

Soil sampling and analysis

Soil sample was taken prior to planting at a depth of 0-30 cm in a zigzag pattern randomly from the experimental field using auger. Composite samples were prepared for analysis to determine the soil physico-chemical properties of the experimental site atBako Soil Laboratory. The composited soil sample was air-dried, ground and sieved to pass through a 2 mm sieve. Total nitrogen was determined following kjeldahl procedure (Cottenie, 1980), the soil pH (in water suspension) by a digital pH meter (Page, 1982) organic carbon by wet digestion method (Walkley and Black, 1934) and the available phosphorous by Olson methods (Olsen *et al.*, 1954), cation exchange capacity (CEC) by ammonium acetate method (Cottenie, 1980) and soil texture by Bouyoucons Hydrometer method (Bouyoucos, 1962).

Economics analysis

Net return (NR ha–1) and benefit: cost ratio (B: C) was calculated by considering the sale prices of potato (1kg =15 ETH Birr) and cost of fertilizers (100kg UREA =1354ETH Birr and 100kg NPS = 1522ETH Birr) and labor market for all field activities done. Thus, the economic gains of the different treatments was calculated to estimate the net returns and the cost of cultivation, after considering the cost of fertilizer N, NPS, and the income from marketable potatotuber for economic analysis. Hence, following the CIMMYT partial budget analysis methodology, total variable costs (TVC), gross benefits (GB) and net benefits (NB) were calculated (CIMMYT, 1988).

Data to be collected

Growth and yield related parameters were collected from the net plot area of each plot to avoid
border effects using the standard procedures described below. Growth parameters considered were plant height, number of stem shoots per hill, Number of main branch and canopy diameter, while yield parameters were fresh weight, and dry matter content of tubers, marketable, unmarketable, and total tuber yields.

Plant height (cm): It was collected by measuring the plant heights from the soil surface to the tip of the main stem of five per tagged randomly selected plants using ruler at physiological maturity of thecrop and the mean values in cm were computed for further analysis.

Tuber weights: Fresh weight of a tuber was recorded by measuring the weights of five randomly selected tubers in each plot using sensitive balance and the average fresh weight was computed and used for further analysis.

Tuber yield (t ha−1): Tubers which were free of mechanical, disease and insect pest damages
and medium to large in size were considered as marketable. On the other hand, tubers which were damaged, small in size were considered as unmarketable as described by Tesfaye, Shermari and Thunya (2013). The weights of such tubers obtained from the net plot area of each plot was measured in kilogram using scaled balance and expressed in t ha−1 and considered as marketable yield as well as unmarketable tuber yield. Finally the total tuber yield was obtained from the sum of marketable and unmarketable yields.

Data Analysis

All the disease, yield and yield component data was subjected to analysis of variance (ANOVA) using general linear model (GLM) procedure of SAS statistical version 9.3 software. The Ls means for significantly different interaction effects was separated by SAS model *PLGLM800* (P=0.05) using Duncan multiple Rang test (DMRT). Proc corr. procedure was used to correlate potato diseases and fertilizer rates.

Results and Discussion

Physico -Chemical Properties of the Soil of the Experimental Site

The laboratory results of the selected physico- chemical properties of the soil sample taken before planting are presented in (Table. 1). The results indicated that both Shambu and Gedo soil has 37% ,7% and 54% sand, silt and clay and 38%, 11% and 51% sand , silt and clay respectively, and could be categorized as clay soil for both locations based on USDA (1987) textural soil classification system. Potato is largely grown; in this region soils have low organic matter content and a pH < 5. Plant nutrients are most available at soil pH levels near 6.5; Potatoes grown in soils near pH 6.5 produce higher yields with less fertilizer (Rosemary, 1991). The ideal pH for Potato ranges from 5.2 to 6.5(Adams, 1984). However, the plant can grow moderately well over a wide range of soil types.
The total N, available P, available OC, C: N ratio and CEC of the soil before planting for Shambu site were 0.13%, 16 ppm, 1.06 %, 11.33 and 19.4 Meq/100g soil, respectively (Table. 1) The total N, available P, available OC, C: N ratio and CEC of the soil before planting for Gedo site were 0.16%, 12ppm, 1.86 %, 12.24 and 20.3 Meq/100g soil, respectively.
According to (Havlin *et al.,* 1999) soils are classified depending on their total N content in percentage (%), as very low (<0.1), low (0.1-0.15), medium (0.16-0.25), and high (>0.25). Thus, the soil of Shambu and Gedo site has low and medium total N content, respectively. Olsen (1954)classified available P content of the range < 5 as very low, 5 – 10 as low, 11 – 17 as moderate, 18-25 as high and > 25 mg kg^{-1} as very high. Thus, the soil of both study site has moderate available P content. At increased soil acidity (low pH) phosphorus is fixed to surface of Fe and Al oxides and hydrous oxide, which are not readily available to plants.

Charman and Roper (2007) classified organic carbon content of the range <0.40% as extremely low, 0.4-0.6% as very low, 0.6-1% as low, 1-1.8% as moderate, 1.8-3% as high, and >3% as very high, respectively. Based on these ratings organic carbon of Shambu and Gedo site were ranged in moderate and high, respectively. Charman and Roper (2007) further classified Organic matter (5.27%) as very high range. Organic matter in soils influence physical, chemical and biological properties of soils, such as soil structure, water retention, nutrient contents and retention and micro-biological life and activities in the soils.
Newey (2006) classifies C: N ratio ranges of <10.0 as very low, 10.0−15.0 as low, 15.0-25.0 as medium, 25.0- 70.0 as high, 70-100 as very high, and > 100 extremely very high. Based on this rating the ratio of carbon to nitrogen revealed at Shambu (11.33) and Gedo (12.24) sites taken before planting of the experimental field was in the low range at both study sites. Hazelton and Murphy (2007)classified CEC ranges of < 6 as very low, 6-12 as low, 12-25 as moderate, 25-40 as high and > 40 cmol kg^{-1} as very high. Based on these ratings the cation exchange capacity of Shambu site is (19.4 Meq/ 100g soil) and Gedo (20.3 Meq/ 100 g soil) of experimental field were in the moderate and moderate ranges, respectively.
Generally, the soil analysis result indicated that the area is deficient in NPS fertilizer to support the potential crop production. This may be associated with poor agronomic management practices including continuous cropping with little or no fertilizers input which resulted in a decline in soil fertility. Therefore, the low content of total nitrogen, available phosphorus, available sulfur, organic carbon indicate that application of mineral and/organic fertilizers containing these nutrients is important for optimum production of the crops in the study area.

Table .1. Physical and chemical properties of the experimental site before planting at Bako during 2019 main cropping season

Properties	Result		Rating		References
	Shambu	Gedo	Shambu	Gedo	
1. Physical properties (%)					
Sand (%)	37	38	Medium	medium	Hazelton and Murphy(2007)
Silt (%)	9	11	low	low	”
Clay (%)	54	51	High	high	”
Textural class	Clay	clay			USDA (1987)
2. Chemical properties					
pH (1: 2.5 H_2O)	5.08	5.0	---- moderate	high	Karltun *et al.* (2013)
Organic carbon (%)	1.06	1.86	”		Charman and Roper (2007)
Organic matter (%)	2.58	3.21	low	low	”
C:N ratio	11.33	12.24	low	medium	Newey (2006)
Total Nitrogen (%)	0.13	0.16	Moderate	Moderat	Havlin *et al.* (1999)
Available Phosphorus (ppm)	16	12			Olsen (1954)
					Singh and Trehan (1998)
CEC (meq/100 g soil)	19.4	20.3	moderate	moderate	Hazelton and Murphy (2007)
Ex. Ca (meq/100g soil)	12.7	11.7			FAO (2006)
Ex. Mg (meq/100g soil)	6.3	9.9	Medium		”

Effect of nitrogen and NPS fertilizer on growth parameter of potato Horo variety
Stand count at harvest, Plant height, plant canopy and number of main branch per plant

The Analysis of Variance showed that main effect were significantly ($P<0.05$) influenced due to the combined application of Nitrogen and NPS blended fertilizer rates on plant height, plant canopy and number of main branch per plant parameter across years and locations of potato Horo variety. But there was non-significant across years and locationson standcount at harvesting parameter. The maximum plant height (47.9cm) was produced in the 2019 growing season while a minimum plant height (44.9cm) was produced in 2018. The maximum plant height was attained at application of 138Nx100NPS kg/ha rates while the minimum value of plant height was produced at application of 0Nx0NPS kg/ha (Table 2).Sulfur plays an essential role in chlorophyll formation and many reactions of living cells Tisdale et al. (1995). The results of the present study are in line with the findings of various researchers where potato plant heights and stem shoot numbers were increased with the application of sulfur containing fertilizers (Chettri, Mondal, & Roy, 2002; Choudhary, 2013;

Sharma, 2015). The higher plant canopy and number of main branch per plant (38.71 cm) and (4.34 cm) were obtained in 2018 respectively and the lower
Plant canopy and number of main branch per plant (32.26cm) and (4.12cm) wereproduced in 2019 respectively.

Table.2 Main effect of nitrogen and NPS fertilizer on growth parameter ofStand count at harvest, Plant height, plant canopy and number of main branch per plant

`Treatment	Stand Count	Plant height in cm	Plant Canopy in cm	Number main branch of Plant
0Nx0NPS kg/ha	26.75a	38.65e	30.06d	3.5c
46Nx50NPS kg/ha	27.42a	42.48d	33.93c	4bc
46Nx75NPS kg/ha	27.33a	43.35d	35.35abc	4.17ab
46Nx100NPS kg/ha	27.33a	45.63cd	34.39bc	4.17ab
92Nx50NPS kg/ha	27.58a	46.82bc	35.65abc	4.12ab
92Nx75NPS kg/ha	27.92a	47.48abc	36.03abc	4.08bc
92Nx100NPS kg/ha	27.58a	50.23ab	38.88a	4.27ab
138Nx50NPS kg/ha	27.33a	49.23ab	38.15ab	4.4ab
138Nx75NPS kg/ha	27.58a	50.12ab	35.56abc	4.37ab
138Nx100NPS kg/ha	27.17a	50.4a	36.8abc	4.683a
mean	27.4	46.4	35.48	4.18
Cv%	8.2	9.1	13.18	17.24
years				
2018	26.37b	44.98b	38.71a	4.23a
2019	28.43a	47.9a	32.26b	4.12a
Location				
Shambu	28.15a	45.57b	36.33a	4.34a
Gedo	26.65b	47.31a	34.63b	4.01b
Trt	ns	**	**	*
Yr	**	**	**	ns
Loc	**	*	*	*
Rep	ns	*	Ns	ns
Trt*yr	ns	ns	Ns	ns
Trt*Loc	ns	ns	Ns	ns
yr*Loc	ns	**	Ns	ns
Trt*yr*Loc	ns	ns	Ns	ns

`Treatment	Number of tuber Per plant	Marketable number per Plant	Un marketable number per plant	Tuber number per plot	Marketable number per plot	Un marketable number per plot
0Nx0NPS kg/ha	6.5e	4.87c	1.68bc	132.33c	90.67c	41.67cd
46Nx50NPS kg/ha	9.27bcd	7.18b	2.22ab	215b	157.17b	57.83ab
46Nx75NPS kg/ha	10.58ab	8.12ab	2.45a	228.75ab	170.08ab	58.67ab
46Nx100NPS kg/ha	10.13abc	7.72ab	2.43a	244.33a	180.75a	63.58a
92Nx50NPS kg/ha	9.43bcd	7.25b	2.15ab	219.67ab	172.33ab	47.3bcd
92Nx75NPS kg/ha	9.43bcd	7.42b	1.88abc	224.33ab	171.58ab	52.75abc
92Nx100NPS kg/ha	10.28abc	8.07ab	2.17ab	233.92ab	181.58a	52.3abcd
138Nx50NPS kg/ha	8.9cd	7.35b	1.72abc	224.25ab	183.50	40.75d
138Nx75NPS kg/ha	8.52d	7.12b	1.4c	235.83ab	193.08a	42.75cd
138Nx100NPS kg/ha	11.12a	8.7a	2.43a	241.08ab	186a	55.08ab
Mean	9.42	7.38	2.05	219.95	168.68	51.28
Cv%	18.68	19.76	44.9	15.75	17.08	27.86
Years						
2018	9.36a	7.55a	1.78b	223.4a	178.85a	44.55b
2019	9.47a	7.21a	2.32a	216.5a	158.5b	58a
Location						
Shambu	10.73a	8.4a	2.4a	246.1a	183.95a	62.12a
Gedo	8.1b	6.4b	1.74b	193.8b	153.4b	40.43b
Trt	**	**	ns	**	**	**
Yr	ns	ns	*	ns	**	**
Loc	**	**	*	**	**	**
Rep	ns	*	ns	**	**	**
Trt*yr	ns	ns	ns	ns	ns	Ns
Trt*Loc	ns	ns	ns	ns	ns	Ns
yr*Loc	**	**	*	**	**	**
Trt*yr*Loc	ns	ns	ns	ns	ns	Ns

Effect of nitrogen and NPS fertilizers on tuber yield component of potato Horo variety
Number of tuber per plant, marketable number of tuber per plant, number tuber per plot, number marketable tuber per plot and number unmarketable tuber per plot
The Analysis of Variance revealed that main effect were significantly ($P<0.05$) influenced due to the combined application of Nitrogen and NPS blended fertilizer rates on number of

tuber per plant ,numbermarketable tuber per plant, tuber number per plot, number of marketable tuber per plot and number of un marketable tuber per plot parameter across years and locations.The maximum tuber number per plot (223.4) and number of marketable tuber per plot (178.85) were produced in the 2018growing season while a minimumtuber number per plot (216.5) and number of marketable tuber per plot (158.5) were recorded in 2019. The maximum value obtainedon number of tuber per plant ,numbermarketable tuber per plant, tuber number per plot, number of marketable tuber per plot and number of un marketable tuber per plot were attained at location ofShambu while the minimum valueof were produced at location of Gedo (Table 3). Similarly, the increased S application contributes to increasing the dry matter contents of the tubers might be due to its role in the growth and physiological functioning of plants (Sanchez, 2007).

Effect of nitrogen and NPS fertilizer on tuber weight per plant, marketable weight per plant and unmarketable weight per plant in kilo gram

The combined main effect of analysis indicated that there were significant ($p < 0.05$) difference across locationsand yearsthe maximum tuber weight per plant in kilo gram (0.56 kg) andmarketable tuber weight per plant (0.54) obtained from plots fertilized 138Nx100NPS kg/ha^{1}treatment (Table.4).But, the main effect of nitrogen and NPS was non-significantly ($P<0.05$) affectedon parameter of unmarketable weight per plant (Table 4). The current result is in conformity with the work of Israel et al. (2012) who reported an increase in phosphorous fertilizer revealed significant contribution to increase in total tuber yield and advanced to get larger average tuber weight and size. Similarly, sulfur fertilizer contributed to a significant increment of potato tuber yield through enlarging tuber weight per plant (Barczak et al., 2013; Sharma et al., 2011, 2015). The higher N rate triggers the vegetative growth for more photo-assimilate production while phosphorous enhanced the development of roots for nutrient uptake (Fantaw et al., 2019). In this study, when the NPS rate was maximum the average tuber weight was lower, this could be due to luxury consumption of N and S elements (Gómez et al., 2018) that could be due to their role in the vegetative growth (Sanchez, 2007) that led to a lower growth of tubers resulting from the low transport of assimilates to organs including tuber (Gómez et al., 2018) resulted with lower tuber weight.

Table 4. Main effect of nitrogen and NPS fertilizer on tuber weight per plant, marketable weight per plant and unmarketable weight per plant in kilo gram

Treatment	Tuber Weight per plant in Kg	Marketable weight per plant in kg	Un marketable weight per plant in Kg
0Nx0NPS kg/ha	0.27d	0.25d	0.021ab
46Nx50NPS kg/ha	0.44c	0.41c	0.03a
46Nx75NPS kg/ha	0.45c	0.43c	0.024ab
46Nx100NPS kg/ha	0.45c	0.41c	0.028ab
92Nx50NPS kg/ha	0.458c	0.44bc	0.023ab
92Nx75NPS kg/ha	0.46c	0.45bc	0.026ab
92Nx100NPS kg/ha	0.52ab	0.49ab	0.03a
138Nx50NPS kg/ha	0.44c	0.42c	0.02ab
138Nx75NPS kg/ha	0.47bc	0.46bc	0.012b
138Nx100NPS kg/ha	0.56a	0.54a	0.025ab
mean	0.45	0.43	0.024
Cv%	16.43	18.42	94.1
years			
2018	0.5a	0.49a	0.017b
2019	0.398b	0.37b	0.03a
Location			
Shambu	0.59a	0.56a	0.035a
Gedo	0.31b	0.30b	0.012b
Trt	**	**	Ns
Yr	**	**	*
Loc	**	**	**
Rep	*	ns	Ns
Trt*yr	ns	ns	Ns
Trt*Loc	*	ns	Ns
yr*Loc	**	**	*
Trt*yr*Loc	ns	ns	Ns

Clue: CV: coefficient of variation, LSD: Least of significant different, Trt: treatment, Yr: year, Loc: Location

Table 5. Main effect of nitrogen and NPS fertilizer on tuber weight per plot, marketable weight per plot, unmarketable tuber weight per plot and marketable tuber weight per hectare in kilo gram

Treatment	Tuber weight per plot in Kg	Marketable tuber weight per plot in Kg	Un marketable tuber weight per plot in Kg	Marketable tuber weight per plot Ha/Kg
0Nx0NPS kg/ha	5.31d	4.83e	0.48e	7154e
46Nx50NPS kg/ha	9.1c	8.23d	0.82abc	12193d
46Nx75NPS kg/ha	9.73bc	8.88bcd	0.85abc	13151bcd
46Nx100NPS kg/ha	9.72bc	8.76cd	0.96a	12980cd
92Nx50NPS kg/ha	10.87ab	10.2abc	0.67bcde	15117abc
92Nx75NPS kg/ha	10.98ab	10.07abc	0.91ab	14920abc
92Nx100NPS kg/ha	11.21ab	10.38ab	0.83abc	15383ab
138Nx50NPS kg/ha	10.88ab	10.34ab	0.54de	15321ab
138Nx75NPS kg/ha	9.97bc	9.35bcd	0.62cde	13848bcd
138Nx100NPS kg/ha	11.83a	11.06a	0.77abcd	16389a
mean	9.95	9.21	0.74	13645.62
Cv%	19.11	20.95	40.69	20.95
years				
2018	10.62a	10.1a	0.52b	14964.9a
2019	9.29b	8.32b	0.97a	12326.3b
Location				
Shambu	13.1a	12a	1.1a	17792.1a
Gedo	6.81b	6.4b	0.4b	9499.1b
Trt	**	**	**	**
yr	**	**	**	**
Loc	**	**	**	**
Rep	*	*	Ns	*
Trt*yr	Ns	ns	*	ns
Trt*Loc	*	ns	*	ns
yr*Loc	**	**	**	**
Trt*yr*Loc	Ns	ns	Ns	ns

Tuber weight per plot, marketable weight per plot, unmarketable tuber weight per plot and marketable tuber weight per hectare in kilo gram

The combined main effect of analysis indicated that there were significant ($p < 0.05$) difference on tuber weight per plot in kilo gram, marketable tuber weight per plot, un marketable tuber weight per plot and marketable tuber weight per hectare in kilo gram across locations and years. Higher tuber weight per plot (13.1kg) marketable tuber weight per plot (12kg),un marketable tuber weight per plot (1.1kg) and marketable tuber weight per hectare (17792.1kg)were produced from Shambu while tuber weight per plot (6.81kg) marketable tuber weight per plot (6.4kg),un marketable tuber weight per plot (0.4kg) and marketable tuber weight per hectare (9499.1kg)were recorded from the Gedo location. Similarly, sulfur fertilizer contributed to a significant increment of potato tuber yield through enlarging tuber weight per plant (Barczak et al., 2013; Sharma et al., 2011, 2015).

Effect of nitrogen and NPS on parameter of totaltuber weight per hectare in tone

The combination of main effect of nitrogen and NPS on growing location and years were highly significant (<1%) in affecting total tuber weight ton/ha. Higher growing location average mean of total tuber weight t/ha (19.4141) whereas the lower average mean of total tuber weight t/ha (10.082) were obtained from Shambu and Gedo respectively and also higher growing year average mean of total tuber weight in 2018 and lower growing year average mean of total tuber weight in 2019 (figure 1.)

According to Bansal and Trehan (2011) there is a significant yield variability in relation to variety and growing location which makes it consistent with the present experiment as growingyear and location were highly significant in affecting yield and yield component of the potato. Potato yield and yield component varied with variety, soil characteristics and geographical escarpment (Naz et al. 2011).

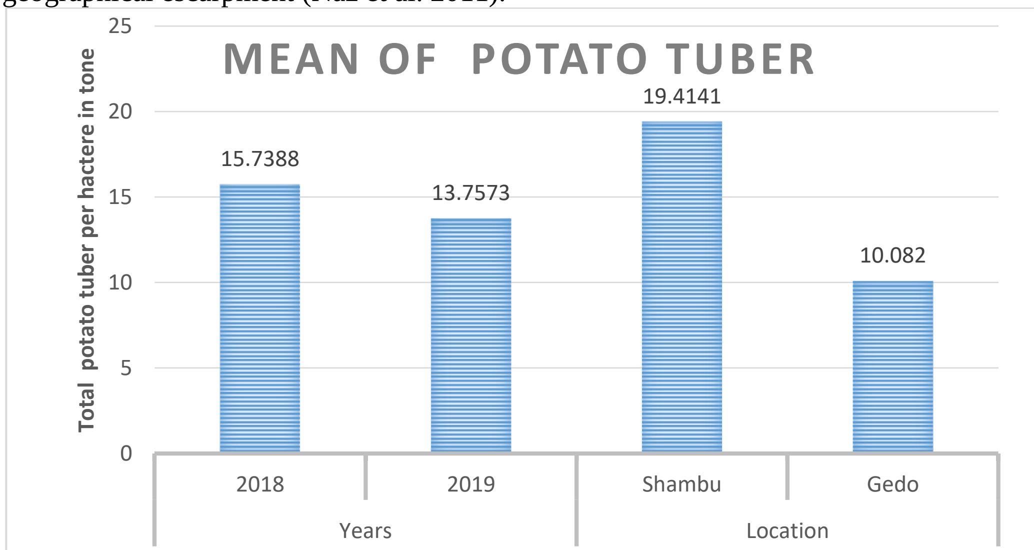

Figure 1: Effect of nitrogen and NPS on total potato tuber per hectare across locations and years

Economic Analysis

Cost benefit analysis was undertaken with the combination of Urea fertilizer and NPS rates to determine the highest net benefit with acceptable rate of net return. The results revealed that the maximum net benefit was obtained from 92N with 100NPS Kg ha $^{-1}$ or 200 kg urea and 100 NPS kg ha $^{-1}$ (Table. 6). An excess usage of fertilizer increased cost and decreased marketable yield. This implies that the profitability of Potato production is partly related with the right type and rate of input (fertilizers) usage and the cost incurred for these inputs (Amare, 2010). Thus, on the basis of marketable yield, net income and cost benefit ratio, it can be concluded that among the fertilizer rates tested 92Nx100NPS Kg ha $^{-1}$ or 200 kg urea and 100 NPS kg ha $^{-1}$ was the most economically feasible for Potato production which provided the net benefit of (208515ETB ha^{-1}) and more profitable than the rest of treatment combinations.

Table. 6. The results of Economic Analysis for the Combination of Urea and NPS fertilizer

Treatment	Tuber yield tone/ ha	Gross return in Birr -1	Cost of production(Birr-1) or total cost vary birr/ha	Net benefit birr/ha or Net return (GR-PC)(Birr-1)	Benefit: cost ratio (GR/PC ETH Birr)	Return/Birr investment (NR/PC ETB	Net return (ETHB ha-1)
0Nx0NPS kg/ha	7.154	107310	18000	89310	5.961666667	4.961666667	
46Nx50NPS kg/ha	12.193	182895	20115	162780	9.092468307	8.092468307	
46Nx75NPS kg/ha	13.151	197265	20495.5	176769.5	9.624795687	8.624795687	
46Nx100NPS kg/ha	12.980	194700	20876	173824	9.326499329	8.326499329	
92Nx50NPS kg/ha	15.117	226755	21469	205286	10.56197308	9.561973077	205286
92Nx75NPS kg/ha	14.920	223800	21849.5	201950.5	10.24279732	9.242797318	
92Nx100NPS kg/ha	15.383	230745	22230	208515	10.37989204	9.379892038	208515
138Nx50NPS kg/ha	15.321	229815	26892	202923	8.545850067	7.545850067	
138Nx75NPS kg/ha	13.848	207720	33172.5	174547.5	6.261813249	5.261813249	
138Nx100NPS kg/ha	16.389	245835	43553	202282	5.644502101	4.644502101	

Conclusion and Recommendation

A field experiment was conducted at Western Oromia to determine the effect of nitrogen and NPS rates on growth, yield parameters and toinvestigate theinteraction effect of N and NPS rates on yield and economic of potato variety during the main cropping season of 2018 and 2019 at Bako Agricultural Research Center (BARC) subsite of Shambu and Gedo.

The Analysis of Variance showed that main effect were significantly ($P<0.05$) influenced due to the combined application of Nitrogen and NPS blended fertilizer rates on plant height, plant canopy and number of main branch per plant parameter across years and locations of potato Horo variety.Higher growing location average mean of total tuber weight t/ha (19.4141) whereas the lower average mean of total tuber weight t/ha (10.082) were obtained from Shambu and Gedo respectively and also higher growing year average mean of total tuber weight in 2018 and lower growing year average mean of total tuber weight in 2019.

Generally, the present study indicated that the combined application of Nitrogen fertilizer and NPS blended improved growth and yield component of Potato. Accordingly, the optimum marketable tuber was obtained from combined application of 92 N Kg ha^{-1} with 100 NPS Kg ha^{-1} and in terms of the economic point of view, it can be concluded that among the fertilizer rates tested 92 N Kg ha^{-1} with 100 NPS Kg ha^{-1} or 200 kg urea and 100 NPS kg ha^{-1} was the most economically feasible for potato production which provided the net benefit of (208515ETB ha^{-1}) and recommended for potato growing areas of western Oromia and similar agro ecology.

Reference

Adams, F. (1984). Soil acidity and liming, crop response on soil in tropics. Wisconsin, USA

Adane, H., Miranda, P., Meuwissen, M., Agajie, [3] Willemien, J., Lommen, M., Alfons, O.L.,Admasu, T. and St ruik, P.C. (2010). Analysis of Seed Potato Systems in Ethiopia, *American Journal of Potato Research*, 87:537–552.

Barczak, B., Nowak, K., & Knapowski, T. (2013). Potato yield is affected by sulphur form and rate. *Agrochimica*, *57*(4), 363–372. https://www.research gate.net/publication/261710220.

Bouyoucos, G. J. (1962). Hydrometer Method Improved for Making Particle Size Analyses of Soils. *Agronomy Journal,54*(5), 464–465.

Brady, N.C. and Weil, R. R. (2002). *The nature and properties of soils. Thirteenth edition. Prentice Hall, New Jersey.*

Charman, P. E. V. and Roper, M. M. (2007). *Soil organic matter. In 'Soils – their properties and management'. 3rd edn. (Eds P. E. V. Charman and B. W. Murphy.) pp. 276–285. (Oxford University Press: Melbourne.*

Chettri, M., Mondal, S., & Roy, B. (2002). Influence of potassium and sulphur with and without FYM on growth, productivity and diseases index of potato in soil of West Bangal. *Journal of Indian Potato Association, 29*(3), 61–69.

Choudhary, R. (2013). Impact of nitrogen and sulfur fertilization on yield, quality and uptake of nutrient by Maize in Southern Rajasthan. *Annals of Plant and Soil Research, 15*(2), 118–121.

CIMMYT, 1998. From agronomic data to farmer recommendations. An economics-training manual.Completely revised edition.D.F,Mexico 51p.

Cottenie, A. (1980). *Soil testing and plant testing as a basis of fertilizer recommendation. FAO Soils Bull.38*, 70–73.

Fantaw, S., Derajew, A., & Aleminew, T. (2019). Effect of blended chemical fertilizer (sulfur, nitrogen and phosphorus) on yield and yield components of potato (*Solanum tuberosum* L.) in the rainy season. *Journalof Horticulture and Forestry*, *11*(3), 54–61. https://doi. org/10.5897/JHF2019.0574

FAO (2008). Strengthening potato value chains: The Internat ional Year of the Potato. Rome, Italy.

FAO. (2006). *Food and Agricultura Organization. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16, Rome*.

Gebremedhin, W., Endale, G. and Lemaga, B. (2008). Potato Agronomy. In: Gebremedhin, W,Endale, G. and Lemaga, B.(eds), Root and tuber crops: The untapped resources, pp.33– 36 Addis Abeba:Ethiopian Inst itute of Agricultural Research.

Gómez, M. I., Magnitskiy, S., & Rodríguez, L. E. (2018). Potential yield and efficiency of N and K uptake in tubers of cvs. Capiro and Suprema (Solanum tuberosum Group Andigenum). *Agronomía Colombiana*, *36* (2), 126–134. https://doi.org/10.15446/agron.colomb. v36n2.72766

Havlin, J. L., Beaton, J.D., Nelson, W.L. and Tisdale, S. L. (1999). *Soil fertility and fertilizers: An introduction to nutrient management (pp. 499). Upper Saddle River, NJ: Pearson Prentice Hall*.

Hazelton, P. and Murphy, B. (2007). Interpreting soil test results: What do all the numbers mean? 2nd Edition. *CSIRO Publishing.*, 152.

Israel, Z., Ali, M., & Solomon, T. (2012). Effect of different rates of nitrogen and phosphorus on yield and yield components of potato (*Solanum tuberosum* L.) at Masha district, Southwestern Ethiopia. *InternationalJournal of Soil Science*, *7*(4), 146–156. https://doi.org/ 10.3923/ijss.2012.146.156

Karltun, E., Tekalign Mamo, Taye Bekele, S. G. and S. K. 2013. (2013). *Towards improved fertilizer recommendations in Ethiopia Nutrient indices for categorization of fertilizer blends from EthioSIS woreda soil inventory data: A Discussion paper. Ethiopian Agricultural Transformation Agency (ATA)/Ethiopian Soil Information Sy*.

Naz F., Ali A., Iqbal Z., Akhtar N., Asghar S., Ahmad B., Effect of different levels of NPK fertilizers on the proximate composition of potato crop at Abbottabad.Sarhad J. Agric., 2011, 27(3), 353-356

Newey, A. (2006). *Litter carbon turnover with depth. Ph.D. Thesis, Australian National University, Canberra.*

nutrient management in Hawaii's soils

Olsen, S. R. (1954). *Estimation of available phosphorus in soils by extraction with sodium bicarbonate United States Department of Agriculture; Washington.*

Rosemary, L. (1991). Vegetable crops. New York, USA: Department of plant pathology, Cornell University.

SAS Institute Inc. (2008). *SAS/STAT. 9.2 User's Guide*. Cary, NC: SAS Institute Inc. USA.

Sharma, D. (2015). Effect of sulfur on growth, yield and economic of potato cultivar. *Annals of Plant and SoilResearch*, *17*(1), 45–49.

Sharma, D. K., Kushwah, S. S., Nema, P. K., & Rathore, S. S. (2011). Effect of sulphur on yield and quality of potato (*Solanium tubersoum* L.). *International Journal of Agricultural Research*, *6*(2), 143–148. https://doi. org/10.3923/ijar.2011.143.148
Singh, J.P. and Trehan, S. P. (1998). *Balanced fertilization to increase the yield of potato. Paper presented at the IPI-PRII-PAU Workshop on Balanced Fertilization in Punjab Agriculture, Punjab Agricultural University, Ludhiana, India,*. (15-16 December 1997), 129–139.
Tesfaye, A., Shermari, W., & Thunya, T. (2013). Evaluation of specific gravity of potato varieties in Ethiopia as criterion for determining processing quality. *Kasetsart Journal(Natural Science)*, *47*(1), 30–41.
Tisdale, S. L., Nolson, L. W., Beaton, J. D., & John, H. L. (1995). *Soil fertility and fertilizers* (5th ed.). New York: Macmillan Publishing Company.
Trehan S.P., Efficiency of potassium utilization from soil as influenced by different potato cultivars in the absence and presence of green manure (Sesbania aculeata). Advances. Horti. Sci., 2007, 21(3), 156-164

The Effect of Sowing Date and Inter-row Spacing on Growth, Yield and Yield Components of Mung Bean (*Vigna radiate* L.)in western Oromia, Ethiopia.

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Abstract
The experiment was conducted at Bako and Chawaka locations during 2018 and 2019 main cropping season with the objective of to determine an appropriate sowing date and inter row spacing. The experiment consisted of two factors (Late June, Early July and Late July sowing date) and (20cm, 30cm and 40cm inter row spacing). A total of 9 treatments were laid out in Randomized Complete Block Design with three replications in 3x3 factorial arrangement.The result revealed that sowing date and inter row spacing showed highly significant differences for primary branch, number pod per plant, seed per pod, hundred seed weight and grain yield.The lowest number ofprimary branch, number pod per plant, seed per pod and hundred seed weight were obtained from Late July sowing date and 20cm inter row spacing.Inter row spacing was positively correlated with yield per unit area but negatively correlated with yield per plant. Early July sowing date gave the highest grain yields (827.78 kg ha^{-1}) at Bako and (1081.07 kg ha^{-1}) at Chawaka. Inter row spacing of 20cm was given the highest grain yield of 812.94 kg ha^{-1} at Bako and 910.18 kgha^{-1} at Chawaka. Therefore inter row spacing of 20cm and early July sowing date was recommended for mung bean production in the study area and similar agroecology

Key words: *Grain yield, inter row spacing, mung bean,sowing date*

Introduction

Mung bean (*Vignaradiata* L. Wilczek) belongs to the family Leguminoseae and sub family Papilionaceae.It can be best on fertile, sandy loam soils with good internal drainage and slightly acidic soil, which is an ideal for production (Fanuel and Walelign, 2013). Root growth can be restricted on heavy clays. It is an important pulse crop grown in most of the tropical and sub-tropical parts of the world. Mung bean can be grown at low to medium elevations in the tropics as a rain fed crop. It is a warm season crop requiring 90–120 days of frost- free conditions from planting to maturity (depending on the variety).

According central statistical agency(2019) report, the total area occupied by mung bean in Ethiopia in 2018/19 was 48,074.52 hectares with production of 576,204.64 quintals and the productivity of 11.93 quintal ha^{-1}. In Ethiopia one of the six Ethiopia Commodity Exchange (ECX) trading crops. Beyond its export demands, Mung bean is highly required for local consumption since it has high in protein sources. It can be used as roasted grains or in different items of recipes in combinations with other cereal and/or legume crops.

Among the various agronomic practices, sowing time is the most important factor influencing the yield of mung bean (Malik M.A*et al*., 2006). Optimum sowing time of mung bean may vary from one variety to another and also from one region to another due to variation of agro-ecological conditions (Sarkar *et al*., 2004). Patel *et al*. (1992) reported that the grain yield of two varieties of mung bean was considerably more at the first date of sowing as compared to second date of sowing. Late sowing which result in flowering during the high temperature to low moisture periods will reduce yield. Early sowing date in humid and sub-humid areas of may lead to high disease pressures and maximum yield loss may be observed (Itefa, 2016).

Row spacing affects plant growth and yield due to increased competition with increased plant population. Moreover, the optimum plant population differs with the availability of soil moisture, relative humidity and nutrients. Higher plant population reduced plant growth and yield components but increased yield per unit area (Wans M.N. J. *et al*., 1986)

However, an appropriate agronomic management including sowing date and row spacing of mung bean are unavailable for Western Ethiopia. On the other hand, many local investors are demanding adaptable varieties of mung bean with appropriate twing date, row spacing and fertilizer requirements. Even though, adaptation trials for different varieties of the crops is currently conducting, no specific recommendation of optimum time of sowing date; plant spacing and fertilizer requirements were available for the end users. Therefore, this activity was initiated with the following objectives:

- To determine an appropriate sowing date of mung bean for Sub-humid areas of western Oromia
- To determine an appropriate inter-row spacing to recommend optimum plant density

Materials and Methods

Description of the Study Area

The study was conducted at Bako agricultural research center and Chawakasitefor two consecutive years (2018 and 2019). Bako agriculture research center is found between 37°1’00”E to 37°3’40”E and 9°4’20’’N to 9°7’20”N and its altitude1650m and Chawaka is located between 35°57’00’’E to 36°21’00’’E and 8°44’00’’N to 9°3’30’’N, and its altitude

1237m (Fig.1). Both locations receive a mono modal pattern of rainfall distribution that receives from May to September cropping season, which is the main rain season and the soil of the areas is reddish. Maize, sorghum, finger millet, common bean, soybean, ground nut and sesame are major crops that are commonly grown in the area.

Figure 1. Map of the study area

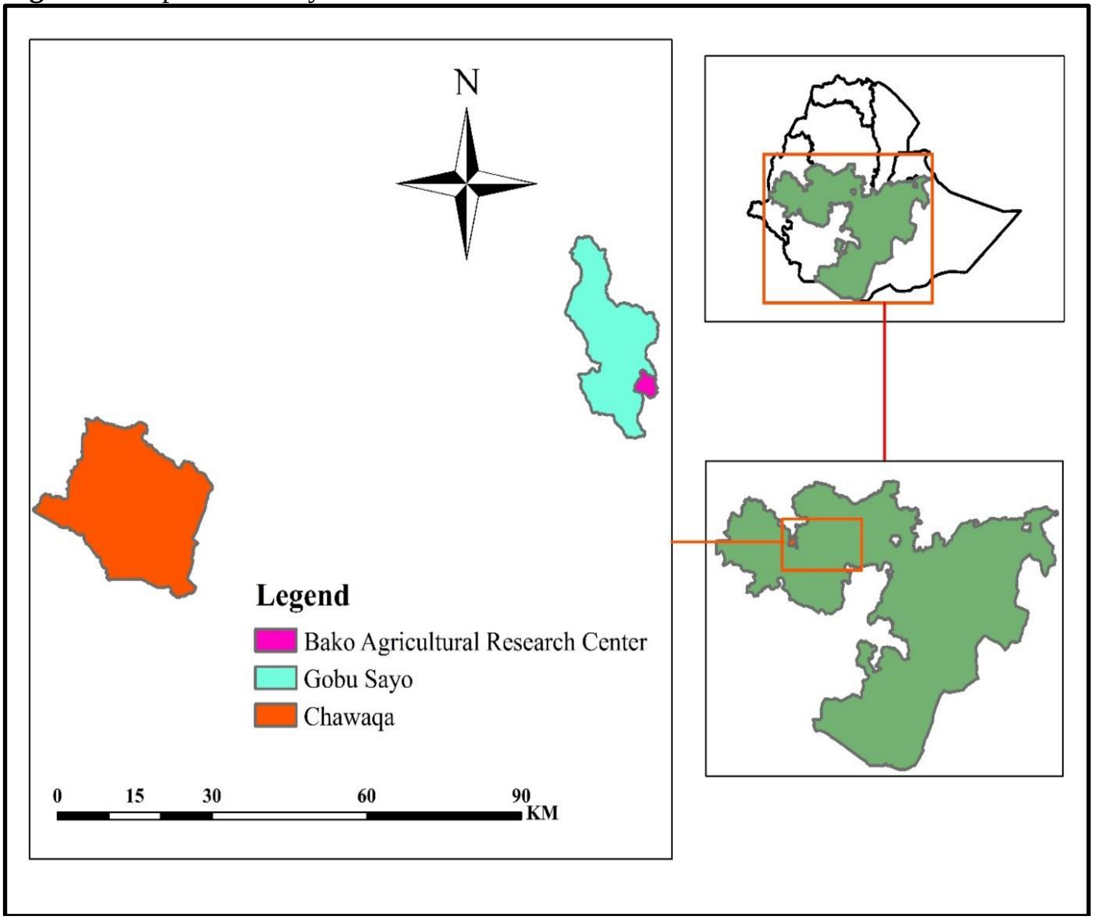

Table 1: Physico-chemical properties of experimental soil before planting

Soil characteristic	**Value**		
	Bako	**Chawaka**	**Description**
Textural class	Clay loam	Clay loam	
pH (1:2.5 H2O)	5.03	5.22	Acidic
Organic matter (%)	1.55	1.99	low according to Berhanu (1980)
Organic carbon	0.90	3.43	
Total nitrogen (%)	0.14	0.17	moderate according to Tekalign*et al.* (1991)
Available phosphorous (ppm)	9.84	5.91	low According to Tekalign*et al.* (1991)

Table 2: Weather data of the experimental sites (2018 and 2019)

Month	Rain fall(mm)	Temperature(C^0)			Relative humidity (%)
		Min	Max	Mean	
January	0	13.65	30.6	22.125	48.00
February	13.25	14.10	32.95	23.525	45.05
March	56.95	13.75	32.00	22.875	46.00
April	73.35	12.55	32.75	22.65	48.85
May	147.85	14.40	30.75	22.575	50.65
June	324.35	14.55	27.00	20.775	54.50
July	165.4	14.15	26.00	20.075	53.85
August	187.3	14.50	25.35	19.925	54.50
September	127.9	14.30	26.75	20.525	53.00
October	65.4	14.25	27.65	20.95	52.80
November	37.45	13.55	29.25	21.40	53.65
December	11.55	13.80	29.80	21.80	52.00

(Source: Bako weather station)

Treatments and Experimental Design

The experiment consisted of two factors. Three Sowing date (Late June, Early July and Late July) and three inter row spacing (20cm, 30cm and 40cm). Recently adapted mung bean variety to the study areas (Chinese) was used as a test crop. A total of 20 treatments were laid out in randomized complete block design with three replications in factorial arrangement. The space between plants was 10cm and population of plants according to inter row spacing were 500,000, 333,333 and 250,000 plants ha^{-1} for 20cm, 30cm and 40cm respectively. 100 kg ha^{-1} NPS fertilizer was used.

Experimental Procedures and Field Managements

The experimental plotwereplowed by oxen three times andfine seed beds were prepared before planting. The seeds were sowed at spacing of 10 cm between plants on the experimental plot. All NPS fertilizer was applied in the row and mixed with soil at the time of planting.

Soil Sampling and Analysis

Soil samples were taken at a depth of 0-30 cm in a zigzag pattern randomly from the experimental field before planting from both locations. Composite samples were prepared separately for both locations to determine the physico-chemical properties of the soil of the experimental site. The composited soil sample was air-dried, ground and sieved to pass through a 2 mm sieve. Total nitrogen was determined following the kjeldahl procedure as described by (Cottenie, 1980); the soil pH was determined by using a digital pH meter (Page, 1982). Organic carbon was determined following wet digestion method as described by (Walkley and Black, 1934); and the available phosphorus was measured using Olson II methods (Olsen *et al.,* 1954).

Data Collection and Measurements

Crop Phenology and growth: Days to flowering, Days to maturity, Plant height (cm) and Number of primary branches per plant.

Yield and Yield Components: pod per plant, seed per pod, hundred seed weight, above ground biomass (kg ha^{-1}) and yield (kg ha^{-1})

Statistical Data Analysis: Analysis of variance was carried using General Linear Model of ANOVA using SAS software. Mean separation was carried out using Least Significance Difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION

Crop Phenology and Growth

Days to Flowering and Physiological maturity

The analysis of variance over locations and years showed that 50% flower initiation and days to physiological maturity were not significantly affected by the main effect of inter row spacing and interaction effect but highly significantly (P<0.01) affected by location and sowing date. Bako location reached to 50% flower initiation and days to physiological maturity on average 48.52 and 87.80 days respectively. However Chawaka location reached to 50% flower initiation and days to physiological maturity on average 37.26 and 73.93 days. The difference may be due to altitude and temperature difference. The effects of increased temperature evident in an increased rate of maturity (senescence). Similarly, Thomas George *et al.* (1990) reported days to flower initiation and physiological maturity between sites differed significantly and both phenological events were delayed considerably at the higher elevations compared to the lowest elevation

Early flowering (42.44 at Bako and 33.89 at Chawaka) was observed from late July sowing. That is, 10 and 5.33 days earlier than late June sowing; that flowered 52.44 at Bako and 39.22 at Chewaka) (Table 3). The Results revealed that late sown (Late July) flowered earlier than those of early sown (late june) which might be due to the fact that higher temperature reduced vegetative growth and enhanced flowering (Summer *et al.*, 1985). Days to Physiological maturity was also significantly (P<0.01) affected by sowing date. Late July sowing date was the earliest to mature (80.11 at Bako and 68.33 at Chawaka) (Table 3). This indicates that late sown (late July) matured about 12.50 ad 11.11 days earlier than that of early sown (late June). Higher temperature increase rate of plant development (Entz and Fowler, 1991) and reduced length of the reproductive period (Angadi*et al.*, 2000). Akther*et al.* (2013) mentioned that sowing dates greatly influenced vegetative and reproductive growth stages as well as crop maturity. A. Ouji and M. Mouelhi (2017) stated that the delay of sowing decreases the number of days until flowering as well the number of days until maturity.

Plant Height (cm)

Plant height was highly significantly (P<0.01) affected by the main effect of sowing dates. The tallest plant height (35.08cm at Bako and 50.56cm at Chawaka) was recorded from late June sowing date and the shortest plant height was recorded (27.13cm at Bako and 37.93cm at Chawaka location) from late July sowing date (Table 3). The tallest plant height recorded was probably due to comparatively longer growing period along with the optimum environmental conditions. This result is agreed with Wade and Johnston (1975) who stated that photoperiod sensitivity had marked reduction in growth period due to delayed seeding, which might account for decrease in plant height.

Table 3. Main effects of sowing date and inter row spacing on Phenological and growth parametersatBako and Chawakalocation during 2018 and 2019 main cropping season

Treatments Sowing date	**Bako**			**Chawaka**		
	FD	MD	PH (cm)	FD	MD	PH (cm)
Late June	52.44a	92.61a	35.08a	39.22a	79.44a	50.56a
Early July	50.67b	90.67b	34.61a	38.67b	74.00b	43.76b
Late July	42.44c	80.11c	27.13b	33.89	68.33c	37.93c
LSD (0.05)	0.65	0.92	2.23	1.42	1.19	1.96
Inter row spacing						
20cm	48.44	87.67	33.26	37.00	73.67	43.98
30cm	48.44	87.94	32.14	37.67	74.00	42.11
40cm	48.67	87.77	31.41	37.11	74.11	46.16
LSD (0.05)	NS	NS	NS	NS	NS	NS
CV (%)	1.99	0.58	10.30	3.81	1.62	4.46

DF= days to flower initiation; DM= Days to physiological maturity; PH= plant height LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation; NS =Non Significant

Primary branch per plant

The main effect of inter row spacing was highly significantly (P<0.01) affect number of primary branches per plant. A greater number of branches were produced at wider space (40cm) than narrow space (20cm) at both locations. 20cm inter row spacing gave the lowest number of primary branches (1.34 at Bako and 2.00atChawaka).The highest primary branches (2.68 at Bako and 3.72 at Chawaka)wereobtained from inter row spacing of 40cm (Table 4). Decreasing inter row spacing resulted in a decreased number of branches. The reverse is true. The decrease in number of branches per plant at higher plant density might be due to increased competition for growth resources like space, air, moisture, light and nutrients. The result is in agreement with Muhammad and Muhammad (2002) demonstrated increased number of branches per plant in widely spaced plants than in closely spaced ones. The main effect of sowing date also had a significantly (P<0.01) affect primary branches. The lowest primary branches per plant (1.45 at Bako and 2.04 at Chawaka) were recorded from Late July sowing date (Table 4).

Pod per plant

The main effect of inter row spacing was significant (P<0.01) effect on pod per plant. Inter row spacing of 20 cm gave the lowest number of pod per plant (4.62 at Bako and 8.42 at chawaka). The highest pod per plant (7.89 and 11.89 at Bako and Chawaka respectively) was obtained from inter row spacing of 40cm (Table 4). As the space between rows increased, pods per plant also increased. The wider row spacing the lower competition between the plants and initiate the pod bearing per plant. The higher number of pods per plant recorded by wider rowspacing may be due to lesser intra-specific competition for growth resources when compared to close spacing. Because the wider row spacing haslower plant density and more available growth resources. Also an increase in pods per plant in a wider row is because of an increase in branches that provided more pod bearing space on the plant. But, we cannot say increased number of pods per plant can increase yield per hectare; because total yield is determined by the yield harvested from individual plants and number of plants per hectare. Virk *et al*. (2005) and Abdullah *et al.* (2007) reported that increased plant density decreased the number of pods per plant and as plant density decreased the number of pods per plant increased. In general, the total number of pods per plant was low in plots with the highest plant densities and high in plots containing lowest plant densities.

The main effect of sowing date also had significant ($P<0.01$) effect on pod per plant. Sowing date of Late July gave the lowest number of pod per plant (3.64 at Bako and 6.71 at Chawaka) and the highest pod per plant (8.93 at Bako and 13.13 Chawaka) was obtained from Early July (Table 4). This result could be due to the fact that in early sowing plants get more rainfall for a longer growing period that favored for more production of pods.

Seed per pod

The main effect of sowing date was a significant ($P<0.01$) effect on seed per pod. Seed per pod showed almost similar pattern as observed for pod per plant. The late sown plot seed per pod was lower than the early sown plot. Seed per pod is also significantly ($P<0.01$) affected by the main effect of inter row spacing. Row spacing of 20cm gave the lowest number of seeds per pod (2.57 at Bako and 4.79 at Chawaka) and the highest seed per pod (5.52 and 7.69 at Bako and Chawaka respectively) was obtained from 40cm (Table 4). The number of seeds per pod decreased progressively as the spacing between rows decreased at both locations. This indicates that the number of seeds per pod differed significantly within 20cm and 40cm rows. Competition of crops for light, moisture and nutrients due to smaller space in between rows could be the case for the lower seed number per pod. The finding similar to Mitiku and Getachew (2017) found that the number of seeds per pod of common bean had increased as row spacing increased and decreased as row spacing decreased.

Table 4. Main effects of sowing date and inter row spacing on primary branch per plant, pod per plant and seed per pod at Bako and Chawaka location during 2018 and 2019 main cropping season

Treatment	**Bako**			**Chawaka**		
Sowing date	PBPP	PPP	SPP	BPPP	PPP	SPP
Late June	2.05a	6.94b	5.52a	2.77b	11.00b	7.69a
Early July	2.64b	8.93a	5.61a	3.67a	13.13a	7.79a
Late July	1.45c	3.64c	2.57b	2.04c	6.71c	4.79b
LSD (0.05)	0.12	0.54	0.25	0.14	0.59	0.57
Inter row spacing						
20cm	1.34c	4.62c	4.25c	2.00c	8.42c	6.43b
30cm	2.11b	7.02b	4.56b	2.77b	10.53b	6.75ab
40cm	2.68a	7.89a	4.89a	3.72a	11.89a	7.18a
LSD (0.05)	0.12	0.54	0.25	0.14	0.58	0.59
CV (%)	8.84	12.40	8.19	5.26	5.70	8.53

PBPP= primary branch per plant; PPP= pod per plant; SPP= seed per pod; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation

Hundred seed weight (g)

Statistically significant differences were found for weight of hundred seeds due to sowing time. The lowest hundred seeds weight (2.78g at Bako and 3.53g at Chawaka) wererecorded from Late July (Table 5). The highest hundred seed weight obtained from early sown (late June and early July) plot might be due to the long reproductive and grain filling period that significantly raised the hundred seed weight. These results are similar with Pedersen and Lauer (2004) in case of soybean the average seed weight from early sowing was higher than that from late sowing. Inter row spacing also had significantly (<0.01) affect hundred seed weight at both locations. The highest hundred seed weight was obtained from inter row spacing of 40cm and the lowest hundred seed weight was obtained from inter row spacing of 20cm (Table 5). This may be due to less competition between plants of lower populations on available resources such as water and light, increase the available assimilates per pod and result in increased seed weights. Similar result was reported by Stringi*et al.* (1988) hundred seed weight of faba bean decreased with increasing plant population.

Grain yield (kg ha^{-1})

Analysis of variance showed a significant (P<0.01) variation in grain yield due to the main effect of sowing date. The highest grain yield (827.78 kg ha^{-1} at Bako and 1081.07 kg ha^{-1} at Chawaka) were obtained from sowing date of Early July. The lowest grain yield was obtained from late July at both locations (Table 5). In late plnting, the plant did not achieve its potential ability because light interception and crop simulates partitioning were severely affected and consequently lead to yield decline. In case of early planting then plants get more time for plant growth and development, so grain yield increased (Ahmed MS. *et al.*

2010) and (Calvino PA *et al.* 2003). The reduction of grain yield due to delay in sowing time can also be attributed to shorter growth period at the disposal of the late sown crop as the time taken by the crop to mature decreased with delay in sowing.

The main effect of inter row spacing had a highly significant ($P<0.01$) effect on grain yield. The highest yield (812.94 kg ha^{-1} at Bako and 910.18 kg ha^{-1} at Chawaka ha^{-1}) was obtained from 20cm inter row spacing and the lowest grain yield was obtained from 40cm inter row spacing (Table 4). When inter row spacing was increased the grain yield per plant also increased but the grain yield per area was decreased. The increase in the number of grain yields per plant with wider plant spacing could be due to less competition for nutrient and water. The reduction in yield per plant in high plant density 20cm inter row spacing may be plants may compete against each other, and the performance of individual plants becomes poor while, at low planting density, each individual plant performance was good due to low competition. This result is in collaborated with Nasser A. Al-Suhaibani *et al.* (2013) who reported higher grain yield per plant is obtained at low plant density of faba bean. Singh and Singh (2002) also indicated that the yield potential of an individual plant is fully exploited when sown at wider spacing. Mekonnen SA (2000) reported that the highest grain yield per plant was obtained from minimum plant population (150,000 plants ha^{-1}) and the lowest grain yield per plant was obtained from the highest plant population (350,000 plants ha^{-1}) of haricot bean.

In the narrow inter row spacing (20cm); number of pods per plant, seed per pod and hundred seed weight were low but the grain yield (kg ha^{-1}) was significantly higher. This might be higher plant stand at dense population contributes to high grain yield and effective light interception than sparse population. This indicated that the main determinant of grain yield was plant population. Shad *et al.* (2010) also observed grain yield increased linearly with increase in plant density. Similarly, Nasser A. Al-Suhaibani *et al.* (2013) stated that when the planting density is too low each individual plant may perform at its maximum capacity but there may be insufficient total plants to reach the optimum yield. . Similarly, Aslam M *et al*. (1993) found that narrow inter-row spacing (30 cm) gave the highest grain yield as compared to wider spacing of 45 and 60 cm on soybean.

Table 4. Main effects of sowing date and inter row spacing on hundred seed weight (g) and grain yield (kg^{-1})at Bako and Chawaka location during 2018 and 2019 main cropping season

Treatment	**Bako**		**Chewaka**	
Sowing date	HSW (g)	GY (kg^{-1})	HSW(g)	GY(kg^{-1})
Late June	3.91a	767.96b	4.64a	857.14b
Early July	3.90a	827.78a	4.70a	1081.07a
Late July	2.78b	337.22c	3.53b	322.22c
LSD (0.05)	0.20	40.27	0.35	44.29
Inter row spacing				
20cm	3.46b	812.94a	4.30	910.18a
30cm	3.36b	701.44b	4.10	816.11b
40cm	3.76a	418.58c	4.47	534.1c
LSD (0.05)	0.20	40.28	NS	44.29
CV (%)	8.53	9.29	8.14	5.88

HSW= hundred seed weight; GY= grain yield; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation

Conclusion

Inter row spacingand sowing date is the most important agronomic factor influencing the yield of mung bean. Plant density was positively correlated with yield per unit area but negatively correlated with yield per plant. Certain yield components, such as seeds per plant, pods per plant, and branches per plant, increased in a similar manner when the inter row spacing increased; but it decreased as inter row spacing decreased. At late sowing branches per plant, pod per plant seed per pod and grain yield was decreased but it is increased at early sowing. It concluded that mung bean should be sown Early to avoid the effect of high temperature on flowering and pod setting at late in the season and sown at inter row spacing of 20cm gave maximum grain yield per unit area. Therefore mung bean is sown at inter row spacing of 20cm and early July are the appropriate spacing and time for mung bean production in the study area and similar agro ecology.

REFERENCES

A. Ouji and M. Mouelhi 2017.Influence of Sowing Dates on Yield and yield Components of Lentil under Semi-arid Region of Tunisia. *Journal of new sciences, Agriculture and Biotechnology,* 38(2), 2077-2082

Abdullah, T., Rahmianna, A.A., Hardaningsih, S. and Rozi, F. 2007. Increasing groundnut yield on dry land Alfisols in Indonesia. *Journal of Semi-Arid Tropics Agricultural Research,* 5(1): 84 - 96.

Ahmed MS, Alam MM, Hasanuzzaman M. 2010. Growth of different Glycine max L. Merril varieties as affected by sowing dates. *Middle East Journal of Science Research*. 5:388-391.

Angadi, S. V., H. W. Cutforth, P. R Miller, B. G. McConkey, Entz M. H. S. A. Brandt and K.M. Volkmar. 2000. Response of three brassica species to high temperature stress during reproductive growth. *Canadian Journal of Plant Science*. 80: 693-701.

Aslam M, Khan NA, Mirza MS, Naeemullah 1993. Effect of different row and plant spacing on soybean yield and its components. *Pakistan Journal of Agricultural sciences* 14: 143-148.

BerhanuDebele, 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.

Calvino PA, Sadras VO, Andrade FH. 2003. Development, growth and yield of late sown soybean in the Southern Pampas. *European Journal of Agronomy*. ; 19:265-275.

Central Statics Agency 2019. The federal democratic republic of Ethiopia central statistical agency, Agricultural sample survey. Volume I, Report on area and production of major crops (private peasant holdings, meher season), Addis Ababa, Ethiopia.

Cottenie, A., 1980. Soil and plant testing as a basis for fertilizer recommendations. FAO Soil Bulletin, Rome. 38: 61 – 100.

Entz, M. H. and D. B. Fowler. 1991. Agronomic performance of winter versus spring wheat. *Agronomy journal*. 83: 527-532.

FanuelLaekemariam and WalelignWorku. 2013. Growth, Light Interception, Radiation Use Efficiency and Productivity of Mungbean [*VignaRadiata* (L.) Wilczek] (Fabaceae) Cultivars As Influenced By Sowing Date. *Ethiop Journal of Biological Science* 12(2): 117-133.

Itefa, D. 2016.General Characteristics and Genetic Improvement Status of Mung bean (*Vignaradiata* L.) in Ethiopia. *International Journal of Agriculture Innovations and Research*, 5(2), 2319-1473.

Malik, M.A., M.F. Saleem, A. Asghar and R.A.F. Ishaq, 2006. Effect of sowing dates and planting patterns on growth and yield of mungbean (*Vignaradiate*L.). *Journal of Agricultural Research* 44: 139-146.

Mekonnen SA (2012) Irrigation frequency and plant density affect phenology and crop growth of haricot bean (Phaseolus vulgaris L.). *African Journal of Plant Science and Biotechnology* 6: 34-39

Mitiku, W., Getachew, M., 2017. Effects of common bean varieties and densities intercropped with rice on the performance of associated components in kaffa and benchimaji zones, southwestern Ethiopia. *Global Journal of Science Frontier Research.* 17 (3), 29–41, 1.

Nasser A. Al-Suhaibani, Salah El-Hendawy and UrsSchmidhalter . 2013. Influence of varied plant density on growth, yield and economic return of drip irrigated Faba bean (Viciafaba L.). *Turkish Journal of Field Crops*, 18, 185–197.

Olsen, S. R., Cole, C.V., Watanable, F.S. and Dean, L.A., 1954. Estimation of available phosphorous in soils by Extraction with Sodium Bicarbonate. U. S. Department of Agriculture, 939: 1-19.

Page,A.L., 1982. Methods of soil analysis part two. Chemical and microbilogical properties. *American Society of Agronomy*, 3:128-133.

Patel, D.B., K.R. Purphit and R.R. Shah, 1992. Physiological analysis of yield variation in Mungbean. *Journal of Agronomy Crop Science.* 168: 128-132.

Pedersen P, Lauer JG 2004. Response of soybean yield components to management system and planting date. *Agronomy of Journal*. 96:1372-1381

Sarkar A.R., H. Kabir, M. Begum and A. Salam, 2004. Yield performance of mungbean as affected by planting date, variety and plant density. *Journal of agronomy* 3: 18-24.

Shad, K., Khalil, A., Wahab, A., Rehman, F.M., Wahab, S., Khan, A., Amin, R. (2010). Density and planting date influence phenological development assimilate partitioning and dry matter production of faba bean. *Pakistan Journal of Botany, 42*, 3831–3838.

Singh, N. P., & Singh, R. A. (2002). Scientific crop production. Delhi: Press Graphics.

Stringi, L., G.S. Amato and L. Gristina, 1988. The effect of plant density on faba bean in semi–arid Mediterranean conditions.*Italian journal of agronomy* 22: 293–301

Summer, F., R. J., E.H. Roberts, W. Erskine and R. H. Killis. 1985. Effects of temperature and photoperiod and flowering in lentils (Lens culinaris Medic.). *Annals* of *Botany journal*. 56(5): 659-671.

TekalignMamo, Haque, L. and Aduayi, E.A., 1991. Working Document: Soil, Plant, Fertilizer, Animal Manure and Compost Analysis Manual, International Livestock center for Africa, No. B13, Addis Ababa, Ethiopia.

Thomas George, Duane P. Bartholomew and Paul W. Singleton 1990. Effect of temperature and maturity group on phenology of field grown nodulating and non nodulating soybean. *Isolines .journal of B1otronics* 19: 49-59.

Virk AS, Kaul JN, Bhangoo BS, Singh A . 2005. Influence of planting techniques and plant population on Biology and pod productivity of summer groundnut varieties. *Research Crops* 6(1):173-174

Wade, F.F and T. H. Johnston. 1975. Effect of seeding date on growth and performance of rice in

Wafaa WM, El-Marakby AM, Abdel-Halim AA, Afaf MT 2002’ Evalution of performance and stability of some soybean genotype under different environments*Annals* of *Agricultural Sciences journal* ; 47:621-40.

Walkley, A. and Black, I.A., 1934. An examination of Digestion of Degrjareff Method for Detrmining Soil Organic Matter and Proposed Modification of the Chromic Acid Titration Method. *Journal of Soil Science*, 37:29-38.

Wanns M.N. J., D. H. Denes and R.J. Barcen. 1986. Effects of planting density and design on pod yield of bush snap bean (Phaseolus vulgaris L.). *Canadian Journal of Plant Science*, 66: 669-675,

Effect of NPS and Nitrogen Fertilizers on Growth, Yield and Yield components of Linseed (*Linumusitatissimum L.)* at West Shewa and HorroGuduruWollega Zones of western Ethiopia.

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ABSTRACT
The study was conducted at Chaliya district Chobi Tulu Chorikebele and Horo District Gitilo Dole Kebeleduring2018 and 2019 main cropping season to identify optimum agronomic and economic threshold of NPS and Nitrogen fertilizers. The experiment consisted of two factors(0, 25, 50, 75 and 100 kg ha^{-1} NPS rates) and (0, 23, 46 and 69 kg ha^{-1} Nitrogen rates). A total of 20 treatments were laid out in Randomized Complete Block Design with three replications in 5x4 factorial arrangement. The results indicated that primary branch, capsule per plant and yield of linseed were significantly influenced by the effects of NPS and nitrogen fertilizers. The highest grain yields (1400kg and 1382 kg ha^{-1}) were obtained from the application of 25 kg ha^{-1} NPS + 69 N kg ha^{-1} and 25 kg ha^{-1} NPS + 46 kg ha^{-1} N fertilizers respectively. The lowest grain yield (520 kg ha^{-1}) was recorded from the control treatment (0 kg ha^{-1}NPS + 0 kg ha^{-1}N fertilizers). This indicates that 62.86% yield reduction was recorded as compared to the application of 25 kg NPS ha^{-1} + 69 kg N ha^{-1} fertilizer The partial budget analysis indicated that highest net benefit (35389ETB) and acceptable marginal rate of return (2038%) were obtained from the application of 25 kg NPS ha $^{-1}$ + 46 kg N ha^{-1}. Therefore application of 25 kg NPS + 46 kg N ha^{-1} fertilizer rates was recommended for linseed production in the study area and similar agroecology.

Key words:*Fertilizer, linseed, marginal rate of return, net benefit.*

INTRODUCTION

Linseed, (*Linumusitatissimum L.*) (n = 15), also called flax, is an important oilseed crop which belongs to the family linaceae having 14 genera and over 200 species. Linseed is one of the oldest crops known to man and it has been cultivated for both fiber and seed oil. Originated from Europe and Southern Asia (Casa *et al.,* 1999). Linseed is thought to have been an early introduction to Ethiopia (Belayneh&Alemayehu, 1988).The oil, which is approximately found in the rate of 35-46% in the linseed (ZukM. *et al.,* 2015).

Nitrogen is often the most important plant nutrients, which influences the amount of protein, protoplasm and chlorophyll formed, consequently increases cell size, leaf area and photosynthetic activity. The response of linseed to nitrogen has been well established, as has the sensitivity of crop emergence and seed yield to seed-placed nitrogen (Lafond*et al.,* 2003). Soethe*et al.* (2013) also reported that nitrogen levels influenced plant height, number of capsules/plant, 1000-seed weight and seed yield ha^{-1}. Phosphorus fertilizer is also critical for plant growth and yield of linseed. In this respect, Khan *et al.* (2000) reported that mean performances of linseed differed for seed and straw yields with the application of phosphorus fertilizer. Lafond*et al.* (2003) stated that linseed response to phosphorus fertilizer addition is highly variable, supporting the importance of maintaining medium to high soil P levels to optimize linseed yields. Kadar *et al.* (204) reported that P did not significantly increase the yield. You*et al.* (2007) concluded that to optimize crop nutrition, phosphorus must be available to the crop in adequate amounts during the growing season

Ethiopia is one the 5th major producer of linseed in the world after Canada, China, USA and India and the first producers in Africa, which is mainly produced in central highland of the nation (Delesa*et al.*, 2010). It has a long history of cultivation by smallholder farmers and the second most important oil crops next to Noug, exclusively for its oil in the traditional agriculture of Ethiopia (Delesa*et al.*, 2010). About 25% of the total land allocated for oil crop production in Oromia region was covered by linseed (CSA, 2019). Even though the production area of linseed is the second largest next to Noug, its productivity is still low as compared to its potential productivity.

Optimumagronomic practice can considerably enhance the productivity of the crop. Despite its diverse use and wide production, linseed production in Ethiopia in general and in central highlands of Western Oromia is characterized by low yield and poor product quality mainly due to environmental and genetic factors as well as poor management practices such as lack of proper weed management system, poor seed and field hygiene, poor seed bed preparation, inappropriate seeding rates and methods, improper threshing ground and improper cleaning. Alsolittle attention has been given to the fertilizer requirements of the linseed crop production in the country. Farmer use of fertilizers with linseed has been minimal to date. Even though fertilizer types applied in Ethiopia agriculture system are only urea and di-ammonium phosphate which contain only nitrogen and phosphorous. However, they may not probably satisfy the nutritional requirements of crop plants. To solve this situation the Ministry of Agriculture of the country has recently introduced a new fertilizer containing nitrogen, phosphorous and sulfur with the ratio of 19% N, 38% P2O5 and 7% S (NPS fertilizer) that substituted DAP in Ethiopian agriculture. Thus, this research was aimed;

- To determinate the optimum agronomic and economic threshold of NPS and Nitrogen fertilizers.

MATERIAL AND METHODES

Description of the Study Area

The study was conducted at Chaliya district, Chobi Tulu Chorikebele and HoroDistrict,Gitilo Dole Kebele for two consecutive years (2018 and 2019). ChobiTulluChorikebel is located between 9o0’00’’N to 9o3’30’’N, 37o32’00’’E to 37o8’00’’E and its altitude 2450m and Gitilo Dole kebele is located between 9o30’30’’N to 9o34’30’’N, 37o0’30’’E to 37o8’00’’E and its altitude 2800m (Fig.1). Both locations receive a monomodal pattern of rainfall distribution that receives from May to September, which is the main rain season and the soil of the areas is reddish. Wheat, Barley, Faba bean, Field bean, Linseed and Noug are the major crops that are commonly grown in the area

Figure 1. Map of the study area

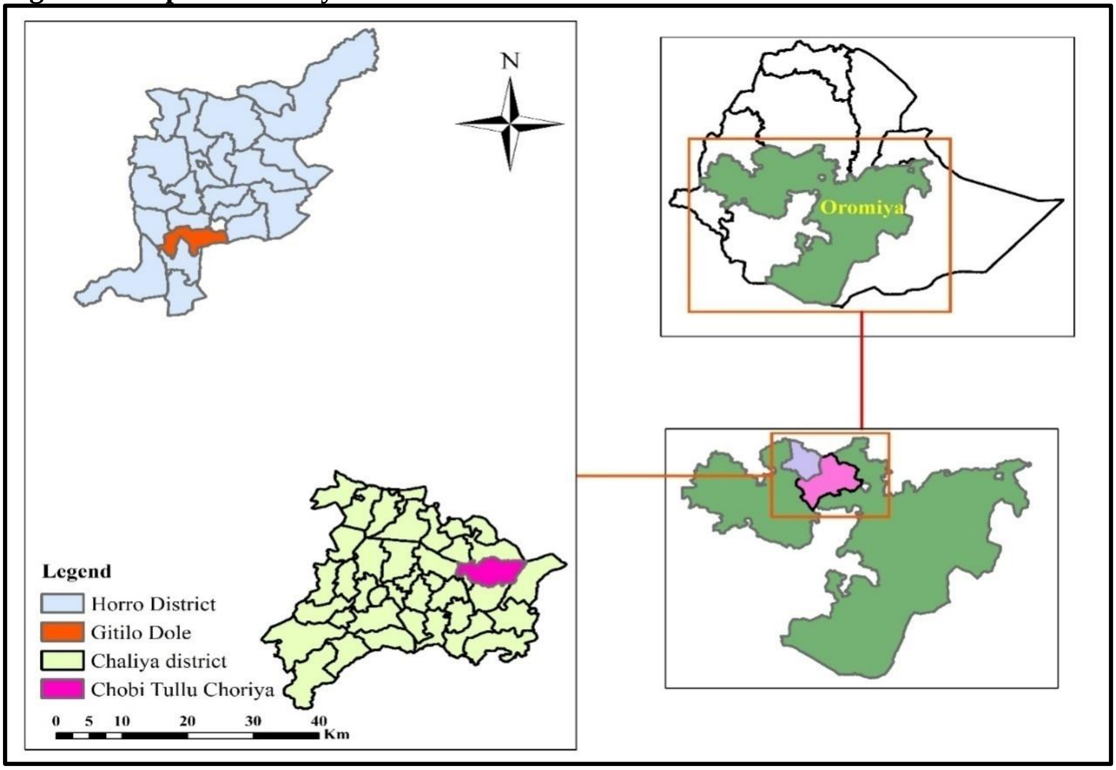

Table 1: Physico-chemical properties of experimental soil before planting

Soil characteristic	Value		
	Chobi Tulu Chori	**Gitilo Dole**	**Description**
Textural class	Clay loam	Clay loam	
pH (1:2.5 H2O)	5.02	5.07	acidic
Organic matter (%)	2.74	1.83	Low according to Berhanu (1980.
Total nitrogen (%)	0.14	0.09	Poor according to Tekalign et al. (1991).
Available phosphorous (ppm)	8.23	8.58	low According to Tekalign et al. (1991)

Treatments and Experimental Design

The experiment consisted of two factors (0, 25, 50, 75 and 100 kg ha^{-1} NPS rates) and (0, 23, 46 and 69 kg ha^{-1} Nitrogen rates). A total of 20 treatments were laid out in Randomized Complete Block Design with three replications in 5x4 factorial arrangement.Recently adapted linseed variety to the study areas (Kulumsa-1) was used as a test crop. Each treatment was planted in a plot consisting of six rows of 4 m long with spacing of 20 cm between rows at a seed rate of 25kg/ha

Experimental Procedures and Field Managements

The experimental plotwere plowed by oxen three times andfine seed beds were prepared before planting. The seeds were sowed at spacing of 20 cm between rows on the experimental plot. NPS fertilizer was applied in the row as per the treatment and mixed with soil just at the time of planting while nitrogen fertilizer was applied in split, 50% during planting and the remaining 50% at vegetative stage of the crop.

Soil Sampling and Analysis

Soil samples were taken at a depth of 0-30 cm in a zigzag pattern randomly from the experimental field before planting from both locations. Composite samples were prepared separately for both locations to determine the physico-chemical properties of the soil of the experimental locations. The composite soil sample was air-dried, ground and sieved to pass through a 2 mm sieve. Total nitrogen was determined following the kjeldahl procedure as described by (Cottenie, 1980); the soil pH was determined by using a digital pH meter (Page, 1982). Organic carbon was determined following wet digestion method as described by (Walkley and Black, 1934); and the available phosphorus was measured using Olson II methods (Olsen *et al.,* 1954)

Data Collection and Measurements

Crop Phenology and growth:Days to flowering, Days to maturity, Plant height (cm) and Number of primary branches per plant.

Yield and Yield Components:Number of capsule per plant Biomass yield (kg ha^{-1}) andyield (kg ha^{-1})

Quality parameters:Oil content (%)

Statistical Data Analysis:

Analysis of variance was carried using General Linear Model of ANOVA using SAS software. Mean separation was carried out using Least Significance Difference (LSD) test at 5% probability level.

RESULTS AND DISCUSSION

Crop Phenology and Growth

The analysis of variance over locations and years showed that days to flowering and days to physiological maturity were not significantly affected by the main and interaction effects of NPS and N fertilizer rates;rather is a significantly affected due to location difference.The crop took 77 days to flower and 158 days to mature at Chobi Tulu Chorilocation.However, it reached flowering and maturity at 87 and 183 days, respectively at GitiloDolelocation. (Table 2). The difference could be due to altitude and temperature differences. Prolonged crop phenology at higher altitude and lower temperature. The effects of increased temperature exhibit a larger impact on grain yield than on vegetative growth because of the increased minimum temperatures. These effects are evident in an increased rate of maturity (senescence) which reduces the ability of the crop to efficiently fill the grain. Similarly, Thomas George *et al.* (1990) reported Days to flower initiation and physiological maturity between locations differed significantly and both phenological events were delayed considerably at the higher elevations compared to the lowest elevation.

Table 2. Main effects of NPS and N fertilizers on days to flowering and days to physiological maturity

Treatment	Chobi Tulu Chori		Gitilo Dole	
	DF	DM	DF	DM
Nitrogen fertilizer				
0	77.26	159.03	87.27	183.60
23	77.13	158.23	87.13	182.93
46	77.00	158.10	86.93	182.87
69	76.87	157.43	86.20	182.73
LSD	NS	NS	NS	NS
NPS fertilizer				
0	77.33	158.00	87.67	182.75
25	77.17	157.83	86.25	182.50
50	77.00	158.17	86.92	183.58
75	77.00	158.50	86.93	183.25
100	76.83	158.50	86.67	183.08
LSD (0.05)	NS	NS	NS	NS
Mean	77.00	158.20	86.88	183.03
CV (%)	0.38	1.02	1.50.	0.67

DF= Days to flower initiation; DM= Days to physiological maturity; LSD = Least Significant Difference ($P< 0.05$); CV = Coefficient of Variation; NS =Non Significant

Plant height (cm)

Plant height was significantly ($P<0.05$) affected by the main effect of N fertilizer rates but not affected by the main effects of NPS fertilizer rates and the interaction effects. Thehighest plant height (86.01cm and 85.99 cm) were recorded from 69 kgha^{-1} and 46 kg N ha^{-1} respectively (Table 3). As the amount of nitrogen increased from 0 kg to 69kg the plant height also increased. The increase in plant height with increasing mineral N fertilizer rate up to 69 kg N ha^{-1} could be explained by the stimulation effect for cell elongation directly after division (Dixit and Sharma, 1993) and the increase in plant height in response to application of N fertilizers is pattributed due to availability of nitrogen which enhanced more leaf area resulting in higher photo assimilates and thereby resulted in more dry matter accumulation. In agreement with this result, GeovanSoethe*et al.* (2013) reported that plant height was increased as the amount of urea fertilizer increased from 0 kg to 200 kg. Similar to the present findings, plant height exhibited positive response to applications of high rates of N fertilizer (Genene *et al.*, 2006) also Pande*et al.*, 1970) reported that increasing levels of N from 0 to 22.4 and 44.8 kg ha^{-1} significantly influenced the plant height. El-Nagdy*et al.* (2010) also found that plant height was 66.8, 83.7 and 105. 9cm by adding 25, 50 and 100% of the recommended mineral N fertilizer rate of linseed, respectively.

Table 3. Linseed plant height and seeds per capsule as affected by NPS and N fertilizers at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season

Treatment	NSPP	PH (cm)
Nitrogen		
0	8.37	82.74b
23	8.49	84.66ab
46	8.32	85.99a
69	8.40	86.01a
LSD	NS	2.48
NPS		
0	8.37	84.25
25	8.50	84.97
50	8.21	85.20
75	8.48	84.43
100	8.40	85.38
LSD (0.05)	NS	NS
CV (%)	12.86	8.13

Means within the same column followed by the same letter or by no letters of each factor do not differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation; NS =Non Significant;; NSPP= Number of seed per capsule; PH= plant height

Primary branch per plant

The analysis of variance over locations and year showed that primary branch was highly significantly ($p<0.01$) affected by main effect as well as their interaction effect of NPS and nitrogen fertilizer rates. The highest number of primary branches per plant (5.33.00 and 5.15) were recorded from application of 50 kg NPS ha^{-1} + 69 kg N ha^{-1} and 25 kg NPS ha^{-1} + 69 kg N ha^{-1} respectively. These results are also in agreement with researchers (Nayital and Singh 1984b) stated that the number of primary and secondary branches per plant increased significantly when N level increased up to 90 kg $ha^{-1.}$ Also Sharma and Rajput (1984) stated that the growth attributes like plant height and number of primary branches per plant were significantly superior with the application of 20 kg N and 20 kg P_2O_5 ha^{-1} as compared to no fertilizer application**.**

Table 4. Linseed primary branch as affected by the interaction of NPS and Nitrogen fertilizer rates at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season

Nitrogen fertilizer	**NPS fertilizer**				
	0	25	50	75	100
0	2.97h	3.66fg	3.54g	3.63fg	3.85e-g
23	4.25c-e	4.15d-f	4.23c-e	4.26c-e	4.23c-e
46	4.59cd	4.75bc	4.77a-c	4.67b-d	4.13d-f
69	4.78a-c	5.15ab	5.33a	4.58cd	4.28c-e
LSD (0.05)			0.56		
CV (%)			16.22		

Means within the column and rows followed by the same letter do not differ significantly at 5% probability level; LSD = Least Significant Difference; CV = Coefficient of Variation

Nitrogen fertilizer	**NPS fertilizer**				
	0	25	50	75	100
0	29.25i	31.15g-i	39.16b-d	30.28hi	32.31g-i
23	32.20g-i	33.35f-h	37.20d-f	34.73e-g	29.35i
46	38.8c-e	42.10ab	41.66a-c	37.15e-f	32.70g-i
69	39.16b-d	45.16a	40.33b-d	34.78e-g	3311g-i
LSD (0.05)			3.91		
CV (%)			13.77		

Yield and yield components

The analysis of variance over locations and year showed that yield and yield components except seed per capsules were significantly ((P<0.01) affected by application of N and NPS fertilizer. The responses of linseed to NPS fertilizer rates were very low when compared to its responses to N fertilizer rates but when nitrogen fertilizer was increased from 0 kg to 69 kg ha^{-1} yield and yield components were significantly increased.

Capsule per plant and seeds per capsule

The combined analysis of variance over locations and years revealed that capsule per plant was highly significantly (p<0.01) affected by the main effect of NPS and N fertilizer rates and their interaction effect. The highest capsule per plant (45.16 and 42.10) was obtained from the application of 25 kg NPS ha^{-1} + 69 kg N ha^{-1} and 25 kg NPS ha^{-1} + 46 kg N ha^{-1} respectively (Table 5). In contrast, number of seeds per capsule were not affected by NPS and N fertilizer rates (Table 3). The highest capsule per plant at higher N fertilizer could be due to the availability of nitrogen for plants is more when compared to the control treatment (0 kg NPS and 0 kg N). This indicates that Nitrogen is an important factor on distribution of photosynthetic assimilates between vegetative and reproductive organs. This result was in agreement with Singh (1968) increased levels of nitrogen (0, 25, 50 and 75 kg ha^{-1}) increased the number of capsules per plant. Pawar*et al*. (1990) reported that with increased levels of nitrogen (0, 15, 30, 45 or 60 kg N ha^{-1}) there was an increase in the number of capsules per plant (77.81 to 98.03).

Table 5. Capsule per plant of linseed as affected by the interaction of NPS and Nitrogen fertilizer rates at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season

Nitrogen fertilizer	NPS fertilizer				
	0	25	50	75	100
0	39.56jk	36.60k	43.50g-j	44.09g-j	41.26i-k
23	42.46h-j	41.98h-j	46.96e-h	44.98f-i	44.27g-j
46	50.62b-e	53.82b-c	47.87d-g	45.75e-i	45.86e-i
69	55.47ab	59.33a	53.15b-d	52.51b-d	49.93c-f
LSD (0.05)			629		
CV (%)			14.10		

Means within the column and rows followed by the same letter do not differ significantly at 5% probability level; LSD = Least Significant Difference; CV = Coefficient of Variation

Above ground dry biomass (quintal ha^{-1})

Above ground dry biomass was highly significantly ($p<0.01$) affected by the main effect of NPS and N fertilizer rates and their interaction effect. As the amount of nitrogen increased from zero to 69 kg ha^{-1} the amount of above ground dry biomass also increased from 39.56 to 55.47 quintal ha^{-1}. The highest above ground dry biomass (59'33 quintal) was obtained from the application of 25 kg NPS ha^{-1}+ 69 kg N ha^{-1}. The increase in biomass with increased Nitrogen rates could be attributed to the fact that the enhanced availability of N significantly increased plant height, number of capsules per plant and to the overall vegetative growth of the plants that contributed to higher aboveground biomass. This result was in line with that of Veeresh (2003) who reported that total dry matter production per plant increased significantly from 12.0 to 16.03 g due to increased nitrogen application from 40 to 120 kg N ha^{-1} on French bean.

Table 6. Aboveground dry biomass of linseed as affected by the interaction of NPS and Nitrogen fertilizer rates at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season

Nitrogen fertilizer	NPS fertilizer				
	0	25	50	75	100
0	520j	645ij	874.17fgh	771.67hi	775.83ghi
23	922.50ef	930ef	995c-f	956.67def	1039.17cde
46	1085bcd	1382a	1126.67bc	908.33efg	1011.67cde
69	1097.50bc	1400a	1110.83bc	1180b	950def
LSD (0.05)			135.76		
CV (%)			17.14		

Means within the same column and rows followed by the same letter do not differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of variation

Grain yield (kg ha^{-1})

The combined analysis of variance over locations and years revealed that the main effects of NPS and nitrogen fertilizers and their interaction highly significantly (P≤0.01) affectedgrain yield. The highest grain yield (1400 kg ha^{-1} and 1382 kg ha^{-1}) were obtained from application of 25 kg NPS ha^{-1} + 69 kg N ha^{-1} and 25 kg NPS ha^{-1} + 46 kg N ha^{-1} respectively. The lowest grain yield (520 kg ha^{-1}) was recorded from the control treatment (0 kg NPSha^{-1} + 0 kg N ha^{-1}) (Table 7). This indicates that 62.86% yield reduction was recorded as compared to the application of 25 kg NPS ha^{-1} + 69 kg N ha^{-1} fertilizer. The response of grain yield to NPS fertilizer was smaller in magnitude than N fertilizer. In other words when nitrogen fertilizer was increased from 0 kg $ha^{-1}$to 69 kg ha^{-1} the yield was increased significantly but, as fertilizer rates of NPS vary from 0 ha^{-1}kg to 100 kg ha^{-1} the observed difference was low on yield. The lower yield difference due to NPS may be due to the Mycorrhizae soil fungi that live in a symbiotic relationship with plants receive carbohydrates from the plants, and in return, the plant receives mineral nutrients from the mycorrhizae, particularly phosphate.When linseed is not fertilized with P, yield is maintained and mycorrhizae infection is high. When linseed receives fertilizer P, mycorrhizae infection is reduced (Grant *et al.*, 2004). According to Thingstrup I. *et al* (1998) the effect of the mycorrhizal fungi increased with decreasing soil P levels. The increase of grain yield due to increasing mineral nitrogen fertilizer levels might be due to the role of nitrogen in protoplasm and chlorophyll formation, enhancement of meristematic activity and cell division, consequently increases cell size which improves vegetative growth, plant height and branch number and capsule number. Moreover, nitrogen encourages plants to uptake other elements activating, thereby growth of plants, consequently enhancing growth measurements and all seed yield components. Also Nitrogen is an important factor on distribution of photosynthetic assimilates between vegetative and reproductive organs. These results are also in agreement with those of several researchers (Fataneh P. K. *et al.* 2012) the highest grain yield (2290.79 kg $ha^{-1)}$ was obtained with 90 kg N ha^{-1} ; Soethe*et al.* (2013), and Ibrahim M.H. *et al* (2016) the highest grain yield was obtained from the highest N fertilizer.

Table 7. Grain yield (kg ha^{-1}) of linseed as affected by the interaction of NPS and Nitrogen fertilizer rates at Chobi Tulu Chori and Gitilo Dole site during 2018 and 2019 main cropping season

Means within the same column and rows followed by the same letter do not differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of variation

Oil content (%)

The oil content of linseed showed no significant response to NPS and Nitrogen fertilizers. Also the growingenvironments had no effect on oil content. However the result of laboratory tests indicated that the mean oil content was 38.56% .Whichis found in the standard range of linseed oil 35-46% (Zuk M. et al., 2015).

Economic evaluation

The economic assessments were made using partial budget analysis as described by CIMMYT (1988). Economic analysis is based on the average yield of each treatment. Therefore, the net benefit estimate for 20 treatments is presented in Table 8. The highest net benefit (35389 ETB) was obtained from the application of 25 kg NPS ha^{-1} + 46 kg N ha^{-1}. The lowest net benefit (14040 ETB) was obtained from control treatment (0 kg NPS ha^{-1}+ 0 kg N ha^{-1}). The highest net benefit obtained from the application of 25 kg NPS ha^{-1} + 46 kg N ha^{-1} indicated that the optimum level of fertilizer rate and net benefit increased until this fertilizer rate. However, beyond this fertilizer rate the total costs that vary increased and the net benefit obtained decreased.

Dominance analysis

The dominant analysis showed that the net benefit of all treatments were dominated except unfertilized plot and application of 25 kg NPS ha^{-1} + 0 kg N ha^{-1}, 0 kg NPS ha^{-1}+23 kg N ha^{-1}, 50 kg NPS ha^{-1} + 23 kg N ha^{-1}, 0 kg NPS ha^{-1} + 46 kg N ha^{-1} and 25kg NPS ha^{-1} + 46 kg N ha^{-1} (Table 8). This result indicated that the net benefit decreased as the total cost that varies increased beyond undominated treatment (application of 25kg NPS ha^{-1} + 46 N kg ha^{-1}). So dominated treatments not selected in comparison with the undominated treatments and dominance analyses helps in avoiding the dominated treatments for further estimation of marginal rates of return.

Marginal rate of return

Marginal rate of return calculated by marginal benefit (change in benefit) divided by the marginal cost (the change in costs) expressed as a percentage. Note that the marginal rates of return appear in between the two treatments. It makes no sense to speak of the marginal rate of return of a particular treatment; rather, the marginal rate of return is a characteristic of the change from one treatment to another. Because dominated treatments are not included in the marginal analysis, the marginal rate of return will always be positive CIMMYT (1998). This analysis was conducted and presented in (Table 9). As shown in (Table 9) the result of analysis of dominant treatments indicated that for each one birr invested, it was to recover one birr plus an extra 6.50, 22.01, 1.91, 23.79 and 20.38 birr ha^{-1} as the fertilizer application changed from unfertilized plot until optimum level of 25 kg NPS ha^{-1} and 46 kg N ha^{-1}. From the control treatment (no fertilizer) that had the lowest costs to the end of the treatment which had the highest cost, that varies, the marginal rate of return obtained was above the minimum acceptable marginal rate of return. According to CIMMYT (1998) the minimum rate of return acceptable to farmers will be between 50% and 100%. If the technology is new to the farmers 100% minimum rate of return is a reasonable estimate. 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. The best recommendation for treatments subjected to marginal rate of return is not based on the highest marginal rate of return, rather, based on the minimum acceptable marginal rate of return, and the treatment with the highest net benefit together with an acceptable rate. Therefore in this study, 50 % was considered as the minimum acceptable rate of return for farmer's recommendation. In line with this study the application of 25 kg NPS ha^{-1} and 46 kg N ha^{-1} was the best for linseed production in the study area and similar agroecology.

Table 8. Net benefit estimation and Dominance analysis of the combined application of NPS and N fertilizers on linseed in 2018 and 2019 for both locations
ETB= Ethiopian birr, D= Dominated

Treatment (NPS + N)	Average Yield kg ha^{-1}	Adjusted yield (10%) kg ha^{-1}	Cost of NPS ha^{-1}	Cost of N ha^{-1}	Cost of labor for fertilizer Application ha^{-1}	Total variable cost	linseed Price (ETB kg $^{-1}$)	Gross return (ETB kg $^{-1}$)	Net benefit (ETB kg $^{-1}$)
0kg + 0kg	5.2	4.68	0	0	0	0	30.00	14040	14040
25kg + 0kg	6.45	5.805	375	0	75	450	30.00	17415	16965
0kg + 23kg	9.22	8.298	0	700	75	775	30.00	24894	24119
50kg + 0kg	8.74	7.866	750	0	75	825	30.00	23598	22773 D
25kg + 23kg	9.3	8.37	375	700	75	1150	30.00	25110	23960 D
75kg + 0kg	7.72	6.948	1125	0	75	1200	30.00	20844	19644 D
50kg + 23kg	9.95	8.955	750	700	2	1452	30.00	26865	25413
0kg + 46kg	10.85	9.765	0	1400	150	1550	30.00	29295	27745
100kg + 0kg	7.76	6.984	1500	0	150	1650	30.00	20952	19302 D
25kg + 46kg	13.82	12.438	375	1400	150	1925	30.00	37314	35389
75kg + 23kg	9.57	8.613	1125	700	150	1975	30.00	25839	23864 D
0kg + 69kg	10.98	9.882	0	2100	225	2325	30.00	29646	27321 D
100kg + 23kg	10.39	9.351	1500	700	150	2350	30.00	28053	25703 D
50kg + 46kg	11.27	10.143	750	1400	225	2375	30.00	30429	28054 D
25kg + 69kg	14	12.6	375	2100	225	2700	30.00	37800	35100 D
75kg + 46kg	9.08	8.172	1125	1400	225	2750	30.00	24516	21766 D
50kg + 69kg	11.11	9.999	750	2100	300	3150	30.00	29997	26847 D
100kg + 46kg	10.12	9.108	1500	1400	300	3200	30.00	27324	24124 D
75kg + 69kg	11.8	10.62	1125	2100	300	3525	30.00	31860	28335 D
100kg + 69kg	9.5	8.55	1500	2100	300	3900	30.00	25650	21750 D

Table 9. Marginal rate of return of NPS and N fertilizers application on linseed in 2018 and 2019 for both locations

TVC = Total variable cost; MC= marginal cost, NB=net benefit MB= marginal benefit, MRR= marginal ret of return, ETB= Ethiopian birr,

Treatment (NPS +N)	TVC(ETB ha $^{-1}$)	MC (ETB ha $^{-1}$)	NB (ETB ha $^{-1}$)	MB (ETB ha $^{-1}$)	MRR (%)
0kg + 0kg	0.00		14040		
25kg + 0kg	450	450	16965	2925	650
0kg + 23kg	775	325	24119	7154	2201
50kg + 23kg	1452	677	25413	1294	191
0kg + 46kg	1550	98	27745	2332	2379
25kg + 46kg	1925	375	35389	7644	2038

CONCLUSION AND RECOMENDATION

Linseed production in Ethiopia in general and in central highlands of Western Oromia is characterized by low yield and poor product quality mainly due to environmental and genetic factors as well as management. Also little attention has been given to the fertilizer requirements of linseed production in the country. These situations should be diverted in order to improve income, livelihood and health of farmers.

The results revealed that the response of capsule per plant and grain yield to NPS fertilizer was smaller in magnitude than N fertilizer. When nitrogen fertilizer was increased from 0 kg ha^{-1} to 69 kg ha^{-1} the capsule per plant and yield was increased significantly but, as fertilizer rates of NPS vary from 0 ha^{-1} kg to 100 kg ha-1 the observed difference was low

The highest grin yield (1400 kg ha $^{-1}$ and 1382 kg ha $^{-1}$) was obtained from the application of 25 kg NPS ha $^{-1}$ + 69 kg N ha^{-1} and 25 kg NPS ha $^{-1}$ + 46 N kg ha^{-1} respectively. The lowest grain yield (520 kg ha^{-1}) was recorded from the control treatment (0 kg NPS ha^{-1} + 0 kg N ha^{-1}).This indicates that 62.86% yield reduction was recorded as compared to the application of 25 kg NPS ha^{-1} + 69 kg N ha^{-1} fertilizer. Whenfertilizer rates of nitrogen increased from 0 kg ha^{-1} to 69 kg ha^{-1} the yield was increased significantly but, as fertilizer rates of NPS vary from 0 ha^{-1} kg to 100 kg ha^{-1} the observed difference was low on yield. The partial budget analysis indicated that highest net benefit (35389ETB) and acceptable marginal rate of return (2038%) were obtained from the application of 25 kg NPS ha $^{-1}$ + 46 kg N ha^{-1}. Therefore application of 25 kg NPS + 46 kg N ha^{-1}fertilizer rates was recommended for linseed production in the study area and similar agroecology.

REFERENCES

Belayneh H, Alemayehu N (1988). Verification of improved linseed production practices on farmers’ fields. In: Proc. of the Fourth Oilcrops Network shop. Njoro, Kenya, 25-29 January 1988. IDRCMR 205e IDRC, Ottawa Canda. pp.92-95.

BerhanuDebele, 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.

Casa, R., G. Russell, B. Lo Cascio, and F. Rossini. 1999. Environmental effects on linseed (Linumusitatissimum L.) yield and growth of linseed at different stand densities. *Europe journal of agronomy* 11:267-278.

CIMMYT Economics program (1988). From agronomic data to farmer recommendations: An economics training manual. 27: CIMMYT.

Cottenie, A., 1980. Soil and plant testing as a basis for fertilizer recommendations. FAO Soil Bulletin, Rome. 38: 61 – 100.

CSA (Central Statistical Agency) 2019. Agricultural Sample Survey Report on Area and Production of Major Crops, 1: 21-22.

Delesa, A., Choferie, A. and Aka, E., 2010. Registration of Kulumsa-1 Linseed (Linumusitatissimum L.) Variety. *East African Journal of Science*, 4(2), pp.123-127.

Dixit S.P. and P.K. Sharma (1993). Effect of line and potassium on yield and uptake of nutrients in wheat (Triticumaestivum L.), soybean (Glycine max) and linssed (Linumusitatissinum L.) cropping sequence in an acid alfsal. *Indian. Journal ofAgriculture Research.* 63 (6): 333 – 339.

El-nagdy GA, Nassar DMA, El-kady EA, El-Yamanee GSA (2010). Response OfLinseed Plant (Linumusitatissimum L.) To Treatments with Mineral And Bio-Fertilizers From Nitrogen And Phosphorus. *Journal of American science*. 6:207-217.

FatanehParhizkarkhajani Hamid IrannezhadMajidMajidian Hussein Oraki (2012)Influence of different levels of nitrogen, phosphorus and potassium on yield and yield components of linseedseed oil (Linumusitatissimum L.) variety Lirina*Journal of Medicinal Plants Research* Vol. 6(6), pp. 1050-1054

Genene G, Habtamu S, Kedir N, Tilahun G, Ashinie B (2006). Response of linseed to nitrogen and phosphurus fertilizers in the highlands of Bale, South-estern Ethiopia. Sebil. Proceedings of the 12th Annual Conference of the Crop Science Society of Ethiopia 22- 24 May 2006, Addis Ababa, Ethiopia. 12:117-125.

GeovanSoethe, Armin Feiden, DoglasBassegio, Reginaldo Ferreira Santos, Samuel Nelson, Melegari de Souza and DeonirSecco 2013. Sources and rates of nitrogen in the cultivation of linseed. *African Journal of Agricultural Research* Vol. 8(19) pp. 2249-2253, 23 May, 2013

Grant, D., M. Monreal, B. Irving, D. McLaren and R. Mohr. 2004. The role of P fertility and mycorrhizae in linseed production. p. 213-218. In 2004 Great Plains Soil Fertility Conference Proceedings. A.J. Schlegel, ed. March 2-3, 2004, Denver CO. Phosphate & Potash Inst., Brookings, S.D.

Ibrahim M.H.; M.E. Kineber; A.Y. Ragab and W.F.M. A.Galoo 2016. Impact of Nitrogen fertilizer level and times of foliar spraying with potassium on yield and its components of some linseed genotypes. *Journal of agriculture research*kafr el-sheikh University. pp: 580-598, vol. 42(4)

Kadar I ,Lukacs D , Laszlo S . Effects of nutrient supplies on the yield,quality and element uptake of oil flax . *Journal of Agrokemia-es-Talajtan* . 2004;53 (1/2): 55 – 74

Khan, N.I. ; M. Akbar ; N. Iqbal and S. Rasul (2000). Bio-agronomic evaluation of linseed genotypes. *Pakistan Journal of. Biological. Science.* 3 (7): 1172-1173.

Lafond, G.P. ; C.A. Grant ; A.M. Johnston ; D.W. McAndrew and W.E. May (2003). Nitrogen and phosphorus fertilizer management of notilllinseed. Better Crops, 87(1): 6-*11*.

Nayital, S. C. and Singh, C. M., 1984b, Effect of crop establishment methods, seed rates and nitrogen fertilization on yield, quality and economics of linseed in North-Western Himalayas. *Indian Journal ofAgriculture Science*.54: 659-663.

Olsen, S. R., Cole, C.V., Watanable, F.S. and Dean, L.A., 1954. Estimation of available phosphorous in soils by Extraction with Sodium Bicarbonate. U. S. Department of Agriculture, 939: 1-19.

Page,A.L., 1982. Methods of soil analysis part two. Chemical and microbilogical properties. *American Society of Agronomy*, 3:128-133.

Pande RC, Singh M, Agrawal SK, Khan RA (1970). Effect of different levels of irrigation, nitrogen and phosphorus on growth, yield and quality of linseed (Linumusitatissimum Linn.).*Indian Journal ofAgronomy*. 15: 125-130

Pawar, R. D., Khade, K. K., Pawar, H. K. and Dubbal, A. R., 1990, A study on uptake of NPK by linseed varieties under different levels of nitrogen. *Journal of Maharashtra Agriculture. University*.15: 339-341.

Sharma, R. S., and Rajput, V. S., 1984, Performance of seven linseed varieties with and without use of fertilizers. *JNKVV Research of. Journal*, 18 (1-4): 195-196.

Singh, K. D., 1968, Studies on the effect of varying levels of nitrogen and dates of sowing on yield and quality of linseed. *Indian Journal of Agronomy*.13: 215-218.

Soethe, G. ; A. Feiden ; D. Bassegio ; R.F. Santos ; S.N.M. Souza and D.Secco (2013). Sources and rates of nitrogen in the cultivation of linseed. *African Journal of Agriculture research* 8(19): 2249-2253.

TekalignMamo, Haque, L. and Aduayi, E.A., 1991. Working Document: Soil, Plant, Fertilizer, Animal Manure and Compost Analysis Manual, International Livestock center for Africa, No. B13, Addis Ababa, Ethiopia.

Thingstrup, I., Rubaek, G., Sibbesen, E. (1998). Linseed (Linumusitatissimum L.) depends on arbuscular mycorrhizal fungi for growth and P uptake at intermediate but not high soil P levels in the field. *Journal of Plant and Soil* 203, 37–46

Thomas George, Duane P. Bartholomew and Paul W. singleton 1990. Effect of temperature and maturity group on phenology of field grown nodulating and non nodulating soybean. *Isolines .journal of B1otronics P*P 49-59, 19

Veeresh NK (2003). Response of French bean (Phaseolus vulgaris L.) to fertilizer Levels in Northern transitional Zone of Karnataka. MSc. (Agriculture) Thesis, University Agricultural Science. Dharwad. pp. 37-79.

Walkley, A. and Black, I.A., 1934. An examination of Digestion of Degrjareff Method for Detrmining Soil Organic Matter and Proposed Modification of the Chromic Acid Titration Method. Soil Science, 37:29-38.

You, J. ; A.G. Cynthia and D.B. Loraine (2007). Growth and nutrient response of linseed and durum wheat to phosphorus and zinc fertilizers. Canadian *Journal of Plant Science*. 87(3): 461-470.

Zuk Magdalena, Dorota, Richter, Jan Matuła and Jan, Szopa (2015) Linseed, the multipurpose plant *journal of industrial crops and products 75 165-177*