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Evaluation of Black Cumin genotypes for yield and yield related parameters in Bale Mid land, Southeastern Ethiopia

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Abstract

Fourteen black cumin genotypes were evaluated against standard checks for two consecutive years at Sinana, Goro and Gindhir to identify high yielding and stable black cumin varieties. The mean total seed yield of genotypes across environment ranged from 24.5 to 16.1Qt/ha. The highest total seed yield was recorded from genotypes 242826-2 followed by 242826-2 (24.5 and 23.3Qt/ha) while, the lowest total seed yield was obtained from local check. These two high yielding genotypes had showed a yield advantage of 22.4 and 14.9% over the standard check variety Derbera. Based on their performance across locations over standard checks these two genotypes will be promoted as candidate variety for release in the coming year.

***Key words**: Black Cumin, genotype, oleoresin content*

Introduction

Black Cumin (*Nigella sativa* L.) is an annual herbaceous plant belonging to the family Ranunculacea (Hammo, 2008). Its seed constituents have unique chemical properties with more than one hundred different chemical components (Bardideh *et al* 2013). The Ethiopian variety of black cumin seed constitutes up to 50% thymol, amonocyclic phenolic compound which make valuable source for health care (Merga *et al* 2018). Black cumin is used principally to flavor food, either as whole grain in powdered form or as an oleoresin extract (Black M. *et al* 2005). Within Ethiopia, its main use is as a spice, which is typically grounded and mixed with other spices. There is also some use as a traditional medicine (Aminpour and Karimi 2004). The vast majority of Ethiopia's black cumin exports go to Arabic countries, which together with other predominantly Muslim countries (Orgut, 2007). Moreover, the production and land coverage of black cumin in Bale mid altitude has been increasing while, the productivity is still less than national average 1.7 ton per hectare (Girma *et al*, 2015). In Bale mid altitude, highland seed spices viz. black cumin, fenugreek and coriander are produced widely. About 42,000 ha of black cumin produced per year both in "Gena" and "Bona" cropping season in Bale districts (Goro, Ginnir, Golocha and some part of Sawwena and Sinana. Due to increased demand of black cumin seed for local consumption and other importance, such as oil and oleoresin for medicinal purposes, its export market, its being potential crop in crop diversification in the area, income generation and its importance to reduce the risk of crop failure and others made the crop as a best alternative crop under Bale mid altitudes. But the yield of black cumin in these areas is not as much as the potential of the crop due to many factors among which lack of high yielder and stable varieties are the majors. Hence, developing an improved variety, after screening of lines/accessions with desirable traits, is one of the immediate objective of breeding for the mandate areas. Accordingly, this activity was initiated to evaluate and identify the genotypes of black cumin that are high yielding and tolerant to major disease in mid altitude of Bale.

Materials and Methods

Twelve black cumin genotypes were evaluated against standard checks viz. Derbera, Dirshaye and Eden and one local check for two consecutive years (2009-2010 E.C) under rainfed conditions at Sinana, Goro and Gindhir. The areas possess a bimodal pattern of rainfall type. This bimodal rainfall pattern has created favorable condition to the produce crops including black cumin in the areas twice per year.

The trial was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each variety was planted in four rows at spacing of 30 cm between rows with the total plot area of 2.4 m^2. Fertilizer application was made as per the national recommendation made for the crop which is 100 kg ha-1 all applied at planting. Data on mean seed yield and disease scores of genotypes were computed using genstat 15th edition.

Results and Discussions

The mean total seed yield of genotypes across environment ranged from24.5 to 16.1 Qt/ha. The highest total seed yield was recorded from genotypes 242826-2 followed by genotype 242826-2 (24.5 and 23.3 Qt/ha respectively) while, the lowest total seed yield was obtained from local check. These two high yielding genotypes had showed a yield advantage of 22.4 and 14.9% over standard check Derbera. The mean for capsule number per plant, biomass and primary branch was ranged from 10.7 to 6.9, 63.7 to 39.8 and 4.7 to 3.3 (Table 2). The highest number of capsule per plant (10.7), biomass (63.9 t/ha) and primary branch (4.67) were recorded from genotype 242826-2 followed by genotype 205167-2. This implies that these agronomic parameters were contributed directly or indirectly to total seed yield for black cumin. Similar findings were also reported previously by Hailemicael *et al*. (2016) and Fufa (2016) who indicated black cumin seed yield is positively correlated with plant height, number of capsules per plant, number of primary branches per plant, and number of seeds per capsule. Days to maturity and days to flowering were ranged from 144.8 to 128 and 90 to 80 respectively. Genotype 242826-2 has two weeks early maturing genotype as compared to other test genotypes which this trait is useful for scaping drought stress due to shortage of rainfall the phenomenon which mostly occurs in the study area. The highest mean of total seed yield was recorded from Ginnir (23.6 Qt/ha) followed by Sinana (21.8 Qt/ha). This may be due to the potential of the these districts for the crop production as compared to other location (Goro).

Table 1: Means of seed yield (Qt/ha) of 14 black cumin genotypes across location and years

	Ginnir		**Goro**		**Sinana**		
Genotype	**2009**	**2010**	**2009**	**2010**	**2009**	**2010**	**Grand Means**
205167-2	26.55	26.60	18.60	19.35	24.05	24.80	23.32
207540-2	22.63	22.68	14.68	15.43	20.13	20.88	19.41
208688-1	24.99	24.94	17.04	17.69	22.49	23.14	21.72
242826-2	28.46	27.13	20.51	19.88	25.96	25.33	24.54
242842-1	20.92	22.94	12.97	15.69	18.42	21.14	18.68
90510-2	24.41	24.46	16.46	17.21	21.91	22.66	21.18
90514-2	21.66	23.57	13.71	16.32	19.16	21.77	19.36
90516-2	23.16	23.88	15.21	16.63	20.66	22.08	20.27
90575-2	23.45	23.50	15.50	16.25	20.95	21.70	20.23
910619-2	17.78	23.28	9.83	16.03	15.28	21.48	17.28
Derbera	22.48	22.81	14.53	16.39	19.98	21.01	19.53
Dirshaye	19.62	22.00	11.67	14.75	17.12	20.20	17.56
Edan	21.83	21.74	13.88	14.49	19.33	19.94	18.53
Local	18.16	20.49	10.21	13.24	15.66	18.69	16.07
Mean	22.58	23.57	14.63	16.38	20.08	21.77	19.83
CV	4.3	9.5	6.7	14.1	4.9	10.3	18.70
LSD	1.79	3.75	1.63	3.88	1.63	3.75	2.43

Note: DF=Days to Flower, DM=Days to Maturity, PH=Plant Height, PB= Primary Branches/plant SB=Secondary Branches/plant, CPP=Capsule Per Plant, BMTH= BioMass Ton per Hectare, and SY= Seed yield in Quintal per hectare.

Table 2. Summary of Mean Yield and other agronomic traits on the two promising Black cumingenotypes Selected as candidate for release and checks in regional variety trial over the six environments

Genotypes	DF	DM	PH	PB	SB	CPP	BM	SY
205167-2	81.58	135.50	50.90	4.44	2.17	9.22	58.89	23.32
207540-2	88.25	140.17	58.90	3.33	0.61	7.17	51.48	19.41
208688-1	82.58	133.50	51.23	3.72	2.61	7.17	55.14	21.72
242826-2	90.92	144.83	58.90	4.61	3.44	10.72	63.94	24.54
242842-1	80.58	128.50	49.90	4.28	1.44	8.56	39.79	18.68
90510-2	89.58	133.50	55.57	4.61	1.44	8.61	43.06	21.18
90514-2	80.58	129.50	50.23	4.67	1.78	8.56	50.33	19.36
90516-2	81.58	134.50	56.57	3.78	1.50	8.67	48.50	20.27
90575-2	86.58	143.50	57.57	4.56	1.17	8.61	49.28	20.23
910619-2	86.58	138.50	58.90	4.28	0.94	7.28	44.51	17.28
Derbera	81.58	138.50	48.57	4.17	1.72	8.94	43.17	19.53
Dirshaye	83.58	137.50	49.23	3.72	1.50	8.78	42.55	17.56

Genotypes	DF	DM	PH	PB	SB	CPP	BM	SY
Edan	83.58	133.50	50.90	4.22	0.56	6.94	49.94	18.53
Local	84.58	133.50	49.90	4.11	2.11	7.33	43.21	16.07
Mean	84.44	136.07	53.38	4.18	1.64	8.33	48.84	19.83
CV	6.90	4.90	7.60	22.00	35.00	14.00	11.10	18.70
LSD	3.80	4.33	2.70	0.60	0.37	0.80	3.55	2.43

Note: DF=Days to Flower, DM=Days to Maturity, PH=Plant Height, PB= Primary Branches/plant SB=Secondary Branches/plant, CPP=Capsule Per Plant, BMTH= BioMass Ton per Hectare, and SY= Seed yield in Quintal per hectare.

Conclusions and Recommendations

Generally considering the yield performance of two black cumin genotypes (242826-2) and (205167-2) across environment and yield advantage of these two genotypes over standard checks with the value of 22.4 and 14.9% respectively make them to be a promising black cumin genotypes for the studied locations. Hence this suggested that, both genotypes were recommended to be promoted to variety verification trial in the coming year in Bale mid land and similar agro ecologies.

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References

Aminpour and Karimi 2004.Underutilized medicinal spices. Spice India. 17: 5-7.

Black M, Bewley D, Halmer 2005. The Encyclopedia of seed science, technology and uses.wallinoford. CAB P 7. 63

Bardideh K, Kahrizi D, Ghobadi ME (2013) Character association and path analysis of black cumin (Nigella sativa L.) Genotypes under different irrigation regimes. Not SciBiol 5: 104-108.

Fufa, 2016. Correlation Studies in Yield and Some Yield Components of Black Cumin (Nigella sativa L.) Landraces Evaluated at Southeastern Ethiopia. Adv Crop Sci Tech 4: 239. doi: 10.4172/2329-8863.1000239

Girma H, Digafie T, Edossa E, Belay YB, Weyessa G (2008). Spices research achievements, revised edition, Ethiopian Institute of Agricultural Research, Addis Ababa Ethiopia, pp 7-25

GirmaHailemichael, HabtewoldKifelew and Haimanot Mitiku,2016. Spices Research Achievements, Challenges and Future Prospects in Ethiopia. Academic Research Journal of Agricultural Science and Research

Hammo YH (2008) Effect of high levels of nitrogen and phosphorous fertilizer, pinching, and seed rate on growth and yield components of Nigella sativa L. 1-vegetative growth and seed yield. Mesopotamia J of Agric 36: 1-8. Effect of high levels of nitrogen and phosphorous fertilizer, pinching, and seed rate on growth and yield components of Nigella sativa L. 1-vegetative growth and seed yield. Mesopotamia J of Agric 36: 1-8.

MergaJibat, WakjiraGetachewommit a, HabetewoldKifelew, AbukiyaGetu."Survey and Identification of Black Cumin (Nigella Sativa L.) Disease in Ethiopia" International Journal of Research in Agriculture and Forestry, 5(11),pp 31-34

The Release of Black Cumin Variety "Qeneni" for mid altitude of Bale, South Eastern Ethiopia

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Abstracts

Qeneni a newly released black cumin variety from Oromia Agricultural research institute, Sinana Agricultural Resarch Center in 2012 E.C. It was released from Arsi Bale landrace collection after pure line development and rigorous performance evaluation. The variety is released with the merits of high seed yield (24.54 Qt/ha) and 45.9% of oleoresin content for Bale mid altitude and similar agro ecologies.

Key words:- Black cumin, oleoresin content, Variety Verification

Introduction

Black cumin (*Nigella sativa* L.) a member of Rananculaceae (diploid, 2n=12) has an aromatic odor and bitter taste. It is used principally to flavor food, either as whole grain, in powdered form or as an oleoresin extract. Within Ethiopia its main use is as a spice, which is typically ground and mixed with other spices. Black cumin seed is widely produced in Oromia, Amhara, SPNN and Tigray regional states among which Oromia takes the lion share. Currently, Ethiopian government has given due attention to the production and promotion of this crop for its export potential to earn foreign currency. More recently, a great deal of attention has given to the seed and oils yields of black cumin. Due to this, their consumption has thus increased and black cumin is the second seed spice exported next to ginger in Ethiopia (Dessalegn Anshiso and Wubeshet Teshome, 2018). The major production constraint in the black cumin in the production area is lack of improved variety that give high seed yield and quality. Sinana agricultural research center is striving in developing improved black cumin varieties for the farming community in the major black cumin growing areas of the zone. Hence, the current objective of this project was to identify high yielding, stable and quality black cumin variety for the farming community in the major production areas.

Materials and Methods.

The trial was conducted at Sinana Agricultural Research Center from advanced observation nursery and primary yield trial. From these early stages of genotypes screening, some promising genotypes were selected and promoted to the regional variety trial. The regional variety trial was conducted at three locations viz. Sinana on station, Goro and Gindhir on farm for three three years (2008-2010 E.C) then in 2011 E.C, the variety verification trial was conducted for verifications of promising genotypes for possible release and the trial was evaluated by the National Variety Releasing Committee (NVRC) and eventually, one promising genotype was released under the name of Qeneni for Bale mid land and similar agro ecologies for production/cultivation.

Result and Discussions

Qeneni (Acc. 20750-1) is black cumin varieties developed and released by Oromia Agricultural Research institute, Sinana Agricultural Research Center from landrace black cumin germplasms collected from different black cumin growing areas. Originally this variety was obtained from land race collections through pure line development procedure following standard black cumin pure line development procedure. Agronomic and morphological descriptors of variety Qenini are presented in Table 1 as follow:

Table 1. Agronomic and Morphological descriptors for newly released Black cumin variety

Variety Name	**Qeneni (Acc. 20750-1)**
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 -10 Broadcasting - 15
Planting date	End of August to late September (for Bale mid altitude)
Fertilizer rate (kg/ha)	NPS = 100
Days to flowering	104
Days to Maturity	170
Plant Height (cm)	70.4
Growth habit	Erect
Seed Color	Black
Flower Color	White
Yield (Qt/ha)	
Research field	17 – 23.2
Farmer’s field	12 – 18
Oleoresin content (%)	45.91
Year of Release	2019
Breeder/Maintainer	*SARC/IQQO

- SARC/IQQO= Sinana agricultural research center of Oromia agricultural research institute

Conclussions and Recommendations

Qeneni black Cumin variety was officially released in September 2012 E.C for Bale mid land and similar agro ecologies with high seed yield of 23.2Qt/ha as compared to the standard and local checks and it also has oleoresin content of 45.91%.

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References

Dessalegn Anshiso, WubeshetTeshome. Economic Value of Black Cumin (*Nigella sativa* L.) Conservation at Bale Zone of Oromia Region, Ethiopia.American Journal of Business, Economics and Management. Vol. 6, No. 4, 2018, pp. 104-109.

Registration of "Gadisa" New Released Coriander Variety

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Abstract

Gadisa (Acc. MAB-030)is coriander variety developed and released by Oromia Agricultural Research institute, Sinana Agricultural Research Center. Originally it was obtained from land race collections through pure line development from landrace populations. Variety verification trial was conducted during 2011 E.C for verification and evaluation by the National Variety Releasing Committee and eventually released for Bale mid land and similar agro ecologies under the local name of Gadisa.

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

Introduction

Coriander (*Coriandrum sativum* L, 2n=2x=22) is a diploid annual plant, belonging to the Apiaceae/Umbliferae family (Hedburg and 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 in pharmaceuticals industries (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). 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 (Beemnetetal 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. Among factors contributing to low production and productivity of coriander is lack of improved varieties that are high yielding and resistance/tolerant to disease with wide adaptability which results in low yield. 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.

Materials and Methods

The variety verification trial was done at three locations viz. Sinana, Goro and Gindhir in 2011 E.C under rain feed condition during "bona" cropping season. The trial was sown on 10x10 m^2 with non-replicated plots using standard check Derbera and one local check. All agronomic managements was done as per recommendation for the crop.

Results and Discussions

The verification trial was evaluated by National Variety Releasing Committee (NVRC) and eventually release for Bale mid midland and similar agro ecologies. The variety has merits of high yield performance, stability and acceptable quality parameter called Oleoresin content. Details of yield Morphological and agronomic characters of the variety is presented listed in Table 1 as follow:

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

Conclusions and Recommendations

Verification result after being evaluated by National Variety releasing committee, Gadisa officially released for Bale Mid altitude and similar agro ecologies. Gadisa is stable, high yielding variety with short days to maturity which make it to produce in both "Gena" and "Bona" cropping season for bimodal rain fall areas like Bale**.**

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References

BeemnetMengesha, GetinetAlemaw and BizuayhuTesfaye. 2010. Performance of Ethiopian Coriander (Coriandrumsativum 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, I and Hedburg, O. 2003.Flora of Ethiopia and Eritrea Apiaceae to Dipsacaceae.Hedeger, I., S. Edwards and SileshiNemomsa (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.

Performance Stability for Grain yield and Genotypes by Environment Interaction in Field pea Genotypes in the highlands of Bale Southeastern Ethiopia

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Abstract

Thirteen field pea genotypes were evaluated along with two standard checks, Harena and Tullu shenen, and local cultivar for three consecutive years 2016 to 2018 main cropping season, bona, in the highlands of Bale, Southeastern Ethiopia. The study was conducted using randomized complete block design with four replication in order to identify high yielding, stable field pea genotypes with resistance or tolerant types of reaction for major diseases in the study areas. Genotypes X environment interaction and grain yield stability *were analyzed and estimated using AMMI model analysis. The AMMI model analysis revealed significant variation for genotypes, environment, genotype x environment interaction at (P<0.01 %.). The environment accounted for 82.99% of the total variation for yield whereas the genotypes accounted for 9.54% and the Genotypes x environment interaction explained for 7.46% of the total variation for grain yield. This indicates that the tested genotypes responded differently to the environment or the environment differently discriminate the genotypes. The first two AMMI components also showed significant variation and totally accounted for 55.45% which indicates at the model fit for this study. Based on the stability parameters like ASV and GSI used to discriminate the stable genotypes, G14, G8 G4, G16 and G3 had lower ASV and showed stable performance over the testing environments. In order to reduce the effect of GE interaction and to make selection of genotypes more precise and refined, both yield and stability of performance should be considered simultaneously. Accordingly, genotypes with code, G5, G4 and G14 had lower GSI indicating stable performance. But G5 had almost equal mean grain yield with the check (G14). Furthermore, this genotype besides its stable performance over the tested environment, it showed tolerant types of reaction for Powdery mildew, Downey mildew and Aschochtya blight. Therefore, G4, (**ACC32003-2**) was identified as candidate genotypes to be verified in the coming cropping season for possible release for the highlands of Bale and similar agro-ecologies.*

Key words: AMMI, AMMI Stability Value (ASV), Genotypes selection Index (GSI), Grain yield, Stability

1. Introduction

Field pea (*Pisum sativum* L.) is one self-pollinated diploid (2n=14) annual of the most important annual cool season pulse crop and is valued as high protein food(McKay *et al.*, 2003). It is widely grown in the cooler temperate zones and in the highlands of tropical regions of the world. Field pea does well under variety of soil types, but grows best on fertile, light-textured, well-drained soils; however, the crop is sensitive to salinity and extreme acidity. The optimum range of soil pH for field pea production is 5.5 to 7.0 (Hartmann *et al.*, 1988). It grows well with 16 to 39 inches of annual precipitation and it can tolerate temperature as low as 140F (Elzebroek and Wind, 2008). However, the crop is very sensitive to heat stress at flowering, which can drastically reduce pod and seed set. Filed pea is primarily used for human consumption and livestock feed. It contains approximately 21-25 percent protein and high levels of carbohydrates, amino acids, lysine and tryptophan, which are relatively low in cereals. It is low in fiber and contains 86-87% total digestible nutrients, which makes it an excellent livestock feed. Global field pea production for the period 1999-2003 was estimated at about 10.5 million tons from an area of 6.2 million hectares (Brink and Belay, 2006). In Ethiopia this crop is mainly grown for human consumption. During 2007 growing season the total production of field pea was 210,095 tones with an average productivity of 948kg/ha (Schneider and Anderson, 2010). Understanding the extent and pattern of G × E interaction effect can also help to effectively design appropriate breeding strategies, optimize varietal selection *vis-à-vis* the target production environments, and to define suitable areas of recommendation domain, where a given cultivar can be better adapted (Yan and Hunt 2001). In other words, knowledge of the extent and pattern of G × E interaction can help plant breeders to reduce the cost of genotype evaluation by eliminating unnecessary spatial and temporal replication of yield trials (Basford and Cooper 1998).

Genotypes respond to changes in environmental conditions such as temperature, rainfall, soil type, moisture and so on (Robertson, 1959; Cockerham, 1963; Falconer and Mackay, 1995). Therefore genotypes selected in a breeding program should be tested at various locations for several years, and analyzed appropriately to determine the extent of the genotype × environment (G× E) interaction before being released as cultivars. This technique became extensively used after the studies of Finlay and Wilkinson (1963) and Eberhart and Russell (1966). In general genotype by environment (GxE) interaction affects the efficiency of crop improvement programs that may lead to complicates recommendation of varieties across divers' environments. Therefore, information on the structure and nature of GxE interaction is particularly useful to breeders Yayis *et al*., 2015). Because of the changing environmental condition, the performance of field pea genotypes was highly affected in the tested environment. Therefore, this study was initiated to identify the magnitude of Genotypes x environment interaction for grain yield variation for the studied field pea genotypes and to identify high and stable field pea genotypes with tolerant/resistant types of reaction for majority of field pea diseases for possible releases for the highlands of Bale, Southeastern Ethiopia and similar agro-ecologies.

2. Materials and Methods

Thirteen field pea genotypes along with two standard checks, Harena and Tullu shenen, and local cultivar were used in order to assess the grain yield performance and stability of the genotypes across the testing environments. The genotypes were evaluated using randomized complete block design with four replications. The trial was conducted at nine environment (year by locations), where they are representing field pea production in the highlands of bale zone southeastern Ethiopia i.e. Sinana, Sinja and Agarfa for three consecutive years from

2016 to 2018 cropping season. Recommended seed rate of 75 kg/ha and 100 kg DAP/ha was used. The plot size sued was 3.2m^2 (4 rows at 20cm spacing and 4m long). The field pea genotypes were firstly brought from Institute of Bio diversity and Conservation (IBC), and lines were developed at the main research center, Sinana, in the subsequent breeding stge.

2.1. Statistical analysis

Keeping in view the objectives set out for the study, following statistical tools and methods have been analyzed. Combined Analysis of Variance (ANOVA) for the grain yield across the testing environment was analyzed using CropStat7.2 computer program (CropStat., 2009). Univariate analysis method as suggested by Eberhart and Russell's (1966) model used to estimate joining linear regression of the mean of the genotype on the environmental mean as an independent variable. In this model, it defines stability parameters that may be used to estimate the performance of a genotype over different environments. Two stability parameters were calculated based on (a) the regression coefficient, a regression performance of each genotype in different environments calculating means over all the genotypes, and (b) mean squares of deviations (S^2di) from linear regression. The performance of each cultivar in each environment was regressed on the means of all cultivars in each environment. Cultivars with regression coefficient (bi) of unity and variance of regression deviations (S2di) equal to zero will be highly stable. Multivariate analysis method: Genotype and Genotype by Environment interaction AMMI analysis was used to see the GE of the genotypes. For this purpose the combined analysis was used to create an analysis of variance (ANOVA) table to determine the presence or absence of GE interactions. The percentage of total variation attributed to E, G, or GE interaction was calculated using the sums of squares from the ANOVA table. AMMI Stability Value (ASV) the distance from the coordinate point to the origin in a two dimensional of IPCA1 scores against IPCA2 scores was calculated by the method suggested by Purchase *et al.,* 2000. This weight is calculated for each genotypes and environment according to the relative contribution of IPCA1 to IPCA2 to the interaction SS as follows,

$$ASV=\sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1score)\right]^2+[IPCA2]^2}$$

Where, $\frac{SSIPCA1}{SSIPCA2}$ is the weight given to the IPCA1 value by dividing the IPCA1 sum squares by the IPCA2 sum of squares.

Genotype Selection Index (GSI): a selection index GSI, was calculated for each genotype which incorporate both mean grain yield and stability index in a single criteria (GSI_i) as

$GSI_i = RY_i + RASV_i$ suggested by Farshadfar, 2008. Where RYi is the rank given for the grainy yield of the genotypes, RASV is the rank given for the ASV of the genotypes.

Table 1 Lists of field pea genotypes used in the study along with and their codes

Genotype code	**Genotypes**	**Genotype code**	**Genotype**
G1	ACC 32518-1	G9	ACC 32512-4
G2	ACC32021-2	G10	ACC 32487-3
G3	ACC 32197-4	G11	ACC 32180-4
G4	ACC32003-2	G12	ACC32488-4
G5	ACC 32509-1	G13	ACC 32363-3
G6	ACC 32399-4	G14	Harena
G7	ACC 32225-1	G15	T/Shenene
G8	ACC32178-4	G16	Local check

3. Results and Discussions

The combined Analysis of Variance over years and locations revealed highly significant variation at (P<0.01%) for genotypes, Location and Genotype x Environment Interaction (GE) (Table 2). This result was in agreement with the findings of Yayis *et al. 2014*, Girma *et al., 2011*, Tamene *et al., 2013* who reported that significant variation of genotypes, location and GE of grain yield by field pea genotypes.

Table 2. Combined Analysis of Variance for field pea genotypes

Source of Variation	**Degree freedom**	**Sum Squares**	**Mean Squares**
YEAR (Y)	2	212.461	106.23**
Location (L)	2	243.989	121.995**
Replication	3	5.32284	1.77428**
Genotype (G)	15	64.1821	4.27881**
Y X L	4	11.765	25.4413**
L X G	30	3.6498	0.454994**
Y X L X G	90	6.5581	0.406201**
ESIDUAL	429	51.348	0.352793
TOTAL	575	829.276	1.44222

From this study the genotypes which gave maximum grain yield over locations and years as indicated in (Table 3), were G4 (3.57t/ha), followed by G5 (3.38t/ha), G14 (3.23t/ha)), and G15 (3.07t/ha) whereas the maximum grain yield was obtained from the environment Sinana 2017 (4.02t/ha), followed by Sinana 2016 (3.75t/ha), Sinana 2018 (3.50t/ha) and Agarfa 2017 (3.39t/ha).

AMMI Analysis: AMMI analysis of variance for grain yield (kg ha-1) of the 16 field pea genotypes tested in 9 environments showed that the genotypes, environments and G × E interaction effects were significantly different ($p<0.01$). This result also indicated that the environments, which accounted for 82.99% of the total yield variation, significantly influenced the yielding ability of the field pea genotypes. The genotypes accounted for 9.56% whereas the GE accounted for 7.46% of the total variation for grain yield (Table 4). Similar result was also reported by Tamen *et al.*, 2013; Yayis *et al.*, 2014 who have indicated highly significant variation for genotypes, environment and GE for grain yield in field pea genotypes in their AMMI analysis. 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 cultivar(s) that consistently performed the best with large differences among environmental means, causing most of the variation in grain yield (Yan and Rajcan 2002). When the significant GE sum of square value partitioned in to different AMMI components, the first three IPCA showed significant variation for the grain yield. Accordingly, the sum of square due to the first AMMI 1 explained about 31.23% where as the second component, AMMI 2 accounted for 24.22% the third AMMI 3 accounted for 19.54% and the fourth AMMI 4 9.97%. The remaining 15.04% of the interaction effect being the residual or noise hence not interpreted and hence discarded (Gauch, 1993; Purchase *et al.*, 2000). In total the two AMMI components were responsible for 55.45% of the GE variation with degree freedom of 42 (Table 4). The variation in the contribution of these four IPCAs indicated differential performance of genotypes for grain yield across environments. However, for the validation of the variation explained by GEI, the first two multiplicative component axes were adequate (Gauch, 2006). This is because of notable reduction of dimensionality and graphical visualization for the adaptation patterns of genotypes (Annicchiarico, 2002).

Table 3. Mean Grain yield of field pea genotypes over the tested environments

Treatment code	Sinana 2016 (A)	Agarfa 2016 (B)	Sinja 2016 (C)	Sinana 2017 (D)	Agarfa 2017 (E)	Sinja 2017 (F)	Sinana2018 (G)	Sinja 2018 (H)	Agarfa 2018 (I)	TRT MEANS
4	3.74	1.73	3.13	4.83	3.73	3.54	5.02	4.41	1.99	3.57
5	3.30	1.25	2.86	4.28	3.84	3.92	4.68	4.31	1.97	3.38
14	3.48	1.18	3.31	3.98	3.60	3.51	4.45	3.66	1.87	3.23
15	3.11	0.96	2.62	3.74	3.94	3.94	4.85	2.90	1.53	3.07
1	2.46	0.79	3.40	4.08	3.56	3.86	3.79	3.56	1.79	3.03
3	3.13	0.95	2.33	3.65	3.39	3.84	4.23	3.75	1.76	3.00
6	2.58	0.74	2.27	3.99	3.36	2.64	4.42	4.14	1.59	2.86
7	2.72	0.83	2.16	4.11	3.27	3.13	4.10	3.53	1.09	2.77
13	2.26	0.86	3.08	3.79	3.42	3.20	3.80	3.15	1.36	2.77
2	2.15	0.90	2.76	3.71	3.72	2.47	4.06	3.20	1.58	2.73
10	2.25	1.00	2.88	3.24	3.36	3.45	3.86	3.21	1.05	2.70
16	2.65	0.88	1.84	3.15	3.12	3.17	3.37	3.29	1.94	2.60
11	2.02	0.84	2.25	3.53	3.20	2.61	3.62	3.77	1.27	2.57

Treatment code	Sinana 2016 (A)	Agarfa 2016 (B)	Sinja 2016 (C)	Sinana 2017 (D)	Agarfa 2017 (E)	Sinja 2017 (F)	Sinana2018 (G)	Sinja 2018 (H)	Agarfa 2018 (I)	TRT MEANS
8	2.05	0.52	1.83	3.31	3.19	3.23	3.60	3.29	1.18	2.46
12	2.35	0.85	1.84	3.06	2.75	3.30	3.55	2.75	1.34	2.42
9	1.77	0.49	2.19	3.51	2.75	3.53	2.93	3.12	1.20	2.39
Mean	2.63	0.92	2.55	3.75	3.39	3.33	4.02	3.50	1.53	**2.85**
LSD 5%	0.51	0.32	0.76	0.81	0.53	1.18	0.68	0.87	0.63	0.28
CV%	14.0	24.0	21.0	15.0	11.0	24.0	12.0	17.0	23.0	21.0

Table 4. ANOVA for AMMI model

Sources	**Degree Freedom**	**Sum of Square**	**Mean Square**	**TSS explained %**
Genotypes	15	16.0455	1.0697*	9.54
Environment	8	139.554	17.4442**	82.99
G X E	120	12.552	0.1046**	7.46
AMMI 1	22	3.91945	0.178157**	31.23
AMMI 2	20	3.03998	0.151999**	24.22
AMMI 3	18	2.45264	0.136258**	19.54
AMMI 4	16	1.25105	0.782	9.97
GXE RESIDUAL	44	1.88885		
TOTAL	143	168.151		

Stability analysis

The three stability parameters suggested by Eberhart and Russel, 1966 i.e. the mean grain yield, regression coefficient or slop and the deviation from the regression indicates as there are some genotypes which had stable performance over the tested sites. Accordingly, G4, G3, G11, G13 and G14 had score of slope value close to unity and the deviation from regression also close to zero though the mean grain yield performance varied (Table 5). When the ASV is considered to discriminate the stability of the genotypes, G14, G8, G4, G5 and G7 had lower ASV value compared to the rest of the genotypes. However, G7 and G8 had mean grain yield lower than the check (G14). However, since stability in itself should not be the only parameter for selection, as the most stable genotype wouldn't necessarily gives the best yield performance (Mohammadi, 2007), hence, simultaneous consideration of grain yield and ASV in single non-parametric index is needed or the Genotype Selection Index should be used to determine the stability of the genotypes by evaluating their mean grain yield and ASV. Genotype Selection Index (GSI), when the rank of mean grain yield of genotypes across environments and rank of AMMI Stability Value (ASV) considered to identify the tested genotypes in relation to stability, G4, G14 and G5 had the lowest GSI values compared to the other genotypes and showed stable performance over the testing sites. The mean grain yield difference of G5 compared to the check G14 is almost comparable. Furthermore, G3, G7 and G15 had the second lower GSI value and indicating moderately stable performance but gave mean grain yield lower than the check. However, the mean grain yield of G11 was equal to the check used in the study. Therefore, G4 was the stable and high yielder genotypes across the testing environments.

Table 5. Mean grain yield, stablility parameters, ASV, GSI of field pea genotypes

Trt code	Genotypes	Mean (t/ha)	Rank	Slope	MSDE S^2di)	IPCA1	IPCA2	ASV	Rank	GSI
1	ACC 32518-1	3.03	5	1.01	0.14	-0.45	-0.49	0.760	15	20
2	ACC32021-2	2.73	10	0.95	0.15	0.26	-0.52	0.621	13	23
3	ACC 32197-4	3.00	6	1.02	0.07	-0.08	0.49	0.500	7	13
4	ACC32003-2	3.57	1	1.05	0.13	0.54	0.11	0.277	3	4
5	ACC 32509-1	3.38	2	1.10	0.02	0.16	0.19	0.278	4	6
6	ACC 32399-4	2.86	7	1.13	0.15	0.75	-0.05	0.968	16	23
7	ACC 32225-1	2.77	8	1.13	0.05	0.31	0.12	0.418	5	13
8	ACC32178-4	2.47	14	1.05	0.04	-0.07	0.14	0.162	2	16
9	ACC 32512-4	2.39	16	0.95	0.15	-0.48	-0.16	0.638	14	30
10	ACC 32487-3	2.70	11	0.96	0.09	-0.35	-0.25	0.513	8	19
11	ACC 32180-4	2.57	13	0.97	0.09	0.35	-0.29	0.539	9	22
12	ACC32488-4	2.42	15	0.85	0.06	-0.30	0.41	0.566	11	26
13	ACC 32363-3	2.77	8	0.97	0.08	-0.22	-0.50	0.569	12	20
14	Harena	3.23	3	0.96	0.07	0.00	0.00	0.001	1	4
15	T/Shenene	3.07	4	1.11	0.20	-0.31	0.38	0.551	10	14
16	Local check	2.60	12	0.78	0.09	-0.11	0.42	0.445	6	18

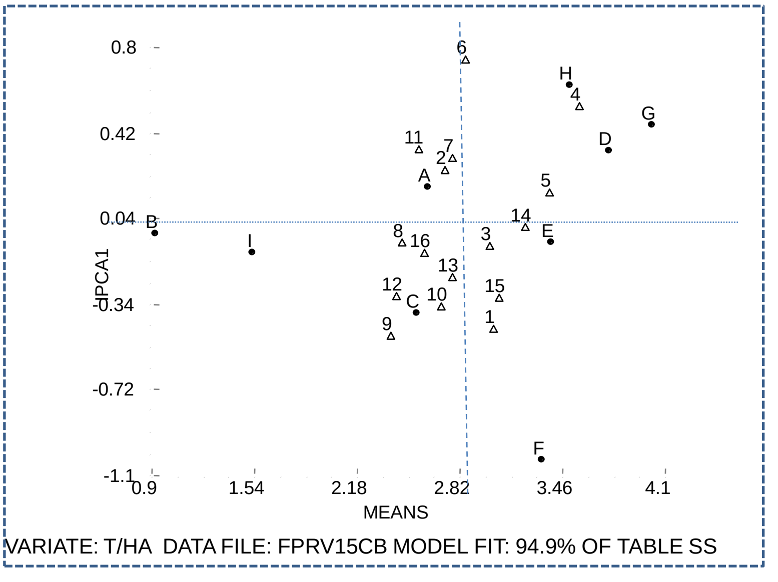
Biplot

Two biplots (AMMI 1 and AMMI 2) were used to demonstrate stability of genotypes for grain yield. AMMI 1 biplot of main effects are shown along abscissa and the ordinate represent first principal component (PC1) score. The basic idea of AMMI 1 biplot is to provide means to select stable high yielding genotypes. AMMI 2 biplot explain the magnitude of interaction of each genotype and environment. The genotypes and environment that are farthest from the origin being more responsive fit the worst. The main purpose of AMMI 2 biplot is to identify genotypes with specific environmental adaptation. In AMMI biplot 1 showing main effects means on the abscissa and principal component (PC) values as the ordinates, genotypes (environments) that appear almost on a perpendicular line have similar means and those that fall on the almost horizontal line have similar interaction patterns (Chaudhary *et al.,* 2012).

Genotypes that group together have similar adaptation while environments which group together influences the genotypes in the same way. Genotypes or environment found to the right of the perpendicular lines gave grain yield higher than the grand mean. In the present study among the genotypes G3, G1, G15, G14, G5 and G5 whereas from the environments Env. F, Env. E, Env. H, Env. D and Env. G gave mean grain yield above the grand mean (2.85t/ha). The rest genotypes and environments gave mean grain yield below the grand mean

(Figure 1). Genotypes having zero PC 1 score are less influenced by the environments and adapted to all environments. Accordingly, G14, G8, G3, G16 and G5 had PCA1 score of zero and close to zero meaning they were stable genotypes. But all of them were lower in their grain yield than the check variety, G14. The other genotypes, like G13, G2, G12 and G4 showed PCA1 score higher than zero showing moderately stability over the tested environments.

Figure 1. Biplot analysis of GEI based on AMMI 1 model for the PCA1 scores and grain yield



AMMI 2 biplot (figure 2) presents the spatial pattern of the first two PC axes of the interaction effect corresponding to the genotypes and helps in the visual interpretation of the G X E pattern and identify genotypes or environments that exhibit low, medium, or high level of interaction effects (Sharma *et al*., 1998). Genotypes near the origin are non-sensitive to environmental interactive forces, hence may be considered stable ones and those distant from origin are sensitive and have large interactions. Accordingly, G14 and G8 which they are found close to the origin than the rest of the genotypes, showed stable performance over the testing sites whereas G5, G4 and G7 which they are found some near to the origin showed moderately stable performance compared to the rest genotypes (Figure 2).

In AMMI 2 biplot, the environment scores are joined to the origin by the site lines. Environments with short spokes (length of arrow lines) do not exert strong interactive forces. Those with long spokes (length of arrow lines) exert strong interaction. In the present study, Agarfa 2016 (B), Agarfa 2918 (I) and Agarfa 2017 (E) having shorter spokes interact less with the genotypes whereas Sinana 2016 (A), Sinja 2016 (C), Sinja 2017 (F) having longer spokes or length of the arrow line exerts high interaction

4. Conclusions and recommendations

As yield is affected by complex factors, Genotype x environment interaction was significant for the grain yield indicating the need to test the genotypes in multiple environments before effective selection can be made. To make the selection of genotypes more precise and refined, both yield and stability of performance should be considered simultaneously to reduce the effect of GE interaction. In the present study it was conclude that genotypes like G1, G3, G4, G5, G6, G14, and G15 gave grain yield above the grand mean. Furthermore when different stability indicator like AMMI Stability Value is considered to identify the stable genotype; G14, G8, G4, G5 and G7 had lower ASV value compared to the rest of the genotypes. But when GSI is considered to identify the stable and high yielding genotype, only genotype (G5, G4 and G14) had lower GSI. But G5though it showed stable performance, it has almost equal mean grain yield with the check (G14) whereas G4, which showed the second lowest GIS and had mean grain yield greater than the checks, it showed moderate stability over the testing environments. Furthermore, this genotype showed tolerant type of reaction for diseases like Powdery mildew, Downey mildew and Aschochyta blight. Therefore, we recommend this genotype to be used as candidate genotype to be verified in the study areas for possible release for the highlands of bale, south eastern Ethiopia and similar agro-ecologies.

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6. Reference

Annicchiarico, P., 2002. Genotype x environment interactions - challenges and opportunities for plant breeding and cultivar recommendations. FAO plant production and protection Paper-174, Rome, Italy.

Basford KE, Cooper M (1998) Genotype-environmental interactions and some considerations of their implications for wheat breeding in Australia. *Australian Journal of Agricultural Research* **49**, 154-174

Brink, M. and G. Belay, 2006. Plant resources of tropical Africa: Cereals and pulses. PROTA Foundation / Backhuys Publishers/ CTA.

Chaudhary, Kaushal Raj and Wu, Jixiang (2012). "Stability analysis for yield and seed quality of soybean [Glycine max (L.) Merril] Across different environments in South

Dakota," *Conference on Applied Statistics in Agriculture*. https://doi.org/10.4148/2475-7772.1033

Cockerham C.C., 1963. Estimation of genetic variances. In: Statistical Genetics and Plant Breeding (Hanson W.D.,

Eberhart S.A., Russell W.A., 1966. Yield and stability of single cross and double cross maize hybrids. Crop Sci 6, 36-40.

Elzebroek, T. and K. Wind, 2008. Guide to cultivated plants. CAB International, Oxfordshire, UK.

Falconer D.S., Mackay t.F.C., 1995. Introduction to Quantitative Genetics. Fourth Edition. Addison Wesley, Longman, Harlow, Essex, UK, pp. 122-143.

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

Finlay W.K., Wilkinson G.N., 1963. The analysis of adaptation in plant breeding programmes. Aust J Agr Res14, 742-754.

Gauch, H., 2006. Statistical analysis of yield trials by AMMI and GGE. Crop Sci., 46(4): 1488–1500.

Gauch, H.G., 1993. Prediction, parsimony and noise: A model can be more accurate than a data used to build it because it amplifies hidden patterns and discards unwanted noise. American Scientist, 81(5): 468-478.

Girma Mangistu, Chemeda Dhaba, Abeya Temesgen, Dangachew Lule and Negash Geleta. 2011. Genotype x Environment Interaction for Yield in Field Pea (*Pisum sativum* L.). East African Journal of Sciences (2011) Volume 5 (1) 6-11

Hartmann, H.T., A.M. Kofranek, V.E. Rubatzky and F. W.J., 1988. Plant science: Growth, development and utilization of cultivated plants. 2nd Edn., Englewood Cliffs, NJ: Prentice Hall Career and Technology.

McKay K., Schatz B., and Endres E. 2003. "Field pea production," *In Production*, vol. 1166, pp. 1–8,

Mohammadi R, Abdulahi A, Haghparast R and Armion M. 2007. Interpreting genotype environment interactions for durum wheat grain yields using non-parametric methods. Euphytica. 157: 239-251.Robertson A., 1959. Experimental design in the evaluation of genetic parameters. Biometrics 15, 219-226.

Schneider, K. and L. Anderson, 2010. Yield gap and productivity potential in Ethiopian agriculture: Staple grains & pulses. EPAR Brief, No. 98, University of Washington, USA, . pp: 24.

Tamene T. Tolessa, Gemechu Keneni, Tadese Sefera, Mussa Jarso and Yeneneh Bekele. 2013. Genotype × Environment Interaction and Performance Stability for Grain Yield in Field Pea (*Pisum sativum* L.) Genotypes. *International Journal of Plant Breeding 7 (2), 116-123*

Yan W and Rajcan I (2002) Biplots analysis of the test sites and trait relations of soybean in Ontario. *Crop Science* **42**, 11-20

Yan W, Hunt LA (2001) Interpretation of genotype × environment interaction for winter wheat yield in Ontario. *Crop Science* **41**, 19-25

Yayis Rezene1, Agdew Bekele and Yasin Goa. 2014 GGE and AMMI biplot analysis for field pea yield stability in SNNPR state, Ethiopia. International Journal of Sustainable Agricultural Research *Vol.1, No.1 pp.28-38*

AMMI Analysis for Grain yield Stability in Lentil Genotypes Tested in the Highlands of Bale, Southeastern Ethiopia

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Abstract

Lentil (Lens culinaris Medik.) is an important cool-season food legume and a valuable source of dietary protein and ranks seventh among grain legumes. Genotype x environment interaction plays an important role in identifying genotypes for high and stable yield. Sixteen lentil genotypes along with one local cultivar were evaluated at two locations, Sinana and Agarfa over three years 2016-2018 in order to identify high yielding genotypes with stable performance. The genotypes were laid out in randomized complete design with four replications in each environment. The objective of this study was to identify and recommend high yielder, stable genotypes for testing sites and similar agro-ecologies using the stability parameters. The analysis of variance revealed significant variation among the genotypes, locations and genotypes by location interaction for mean grain yield indication the diversity of the testing sites and the variation in the performance of the genotypes over the testing environment. The results of AMMI (additive main effect and multiplicative interaction) analysis indicated that the first two AMMI (AMMI1-AMMI2) were highly significant ($P<0.01$). The partitioning of the total sum of square exhibited that the effect of environment was a predominant source of variation followed by genotypes and GE interaction effect. Accordingly, G1, G6, G13, G14, G16 and G17 gave grain yield above the grand mean. Furthermore from the stability indicator like AMMI Stability Value (ASV) indicated that: G4, G15 G8, G6 , G10, had lower ASV value and showed stabile performance while G7, G11 and G1 had relatively lower ASV and showed moderately stable performance over the testing environments indicating wide adaptation. Furthermore, based on the Genotypes Selection Index (GSI) the most stable genotypes with high grain yield were G1 and G15. Therefore these two Genotypes were identified as candidate genotypes to be verified for possible release in the highlands of bale, Sothern Ethiopia and similar agro-ecologies.

Key words: AMMI Stability Value, GE interaction, Genotype Selection Index, Stability

1. Introduction

Lentil is an annual self-pollination diploid (2n = 2x = 14 chromosomes) species and highly valued food legume grown extensively in many part of the world. Lentil seed is a rich source of good protein (up to 28%) in human diets in arid and semiarid areas of west Asia (Sarker *et al*., 2003). It is the fourth most important legume crop in the world. In most lentil production areas yield seem to be no more than one-half of potential yields while improved genotypes contribute to increased lentil production and yields (Erskine, 2009). Selecting genotypes for high mean yield and yield stability has been a challenge for breeders. The requirement for stable genotypes that perform well over a wide range of environments becomes increasingly important as farmers need reliable production quantity (Gauch *et al*., 2008). Therefore, identifying most stable genotypes is an important objective in many plant breeding programs for all crops, including lentil. The performance of a genotype is determined by three factors: genotypic main effect (G), environmental main effect (E) and their interaction (Yan *et al*., 2007). Understanding genotype by environment (GE) interactions is necessary to accurately determine stability in lentil genotypes and help breeding programs by increasing efficiency of selection (Sabaghnia *et a*l., 2008). The GE interactions structure is an important aspect of both plant breeding programs and the introductions of new improved crop cultivars as yield stability analysis (Neacşu, 2011).

A cultivar or genotype is considered to be more adaptive or stable if it has a high mean yield but a low degree of fluctuation in yielding ability when grown in diverse environments (Arshad *et al*., 2003). The additive main effects and multiplicative interaction model is frequently used in the analysis of multi-location trials. AMMI analysis has been shown to be effective because it captures a large portion of the GE sum of squares, it cleanly separates main and interaction effects that present agricultural researchers with different kinds of opportunities, and the model often provides agronomically meaningful interpretation of the data (Gauch, 1992). Additionally, results from AMMI are useful for performing mega-environment analysis in which a crop's growing region is subdivided into homogenous sub-regions that have similar interaction patterns and cultivar rankings, simplifying cultivar recommendations (Zobel and Gauch, 1988). Therefore due to the lack of stable genotypes with high grain yield, this study was initiated with the objective to identify lentil genotype with high mean grain yield with stable performance over the testing sites for the mid and highland areas of Bale and similar agro-ecologies.

2. Materials and Methods

2.1. Testing Sites al Locations

The experiment was carried out at two locations. One of the experiments was conducted at the research farm of Sinana Agricultural Research Center, Oromia Agriculture Research Institute, Sinana, and the other two were at a site in the farmer's field representing for linseed production. The experiment was conducted at each location on vertisol clay loam soil under rain fed conditions during the meher season (August-January) of 2016 to 2018 cropping season. Because of the suitability of the locations for lentil production, it is expected that the test genotypes would express their genetic potential to a higher extent for the traits under consideration.

Fifteen lentil genotypes along with one standard check, Asano, and local cultivar were tested in order to determine their stability across the testing sites during the main cropping season, Meher, for three consecutive years (2016-2018) at two locations (Sinana, and Agarfa) representing the highlands of bale zone, south eastern Ethiopia. The experimental layout at each environment was complete randomized block design with four replications. The plot size used was $3.2m^2$ (4 rows at 20cm apart and 4m long). The two central rows were used for data collection. Combined analysis of variance using balanced ANOVA was computed using CROPSTAT program. The additive main effect and multiplicative interaction (AMMI) analysis was performed using the model suggested by Crossa *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 yield of the i^{th} genotype in the j^{th} environment, μ is the grand mean, g_i is the mean of the i^{th} genotype minus the grand mean e_j is the mean of j^{th} environment minus the grand mean, λ_n is the square root of the eigen value of the principal component Analysis (PCA) axis, α_{ni} and Y_{nj} are the principal and the principal component scores for the PCA axis n of the i^{th} genotype and j^{th} environment, respectively and R_{ij} is the residual. The GE biplot was projected for the 17 genotypes tested at 6 environments. The regression of yield for each variety on yield means for each environment was computed and parameters MS-REG, the contribution of each variety to the regression component of the treatment x location interaction and MS-TL the contribution of each variety to interaction MS, were estimated with the CropStat 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 Purchase *et al.*, 2000. Because of the IPCA1 score contributes more to the GE interaction sum of square, a weighted value is needed. This weight is calculated for each genotypes and environment according to the relative contribution of IPCA1 to IPCA2 to the interaction SS as follows,

$$ASV=\sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1score)\right]^2+[IPCA2]^2}$$

Where, $\frac{SSIPCA1}{SSIPCA2}$, the weight given to the IPCA1 value by dividing the IPCA1 sum squares by the IPCA2 sum of squares. The larger the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller IPCA score indicate a more stable genotype across environment.

Genotype Selection Index (GSI)

Based on the rank of mean grain yield of genotypes (RY_i), across environments and rank of AMMI Stability Value ($RASV_i$), a selection index (GSI) was calculated for each genotype which incorporate both mean grain yield and stability index in a single criteria (Farshadfar, 2008).

$GSI_i = RY_i + RASV_i$

Table 1. Genotype code and the name of 17 lentil genotypes

No.	Genotype code	Name
1	G1	DZ -2012-LN-0085
2	G2	DZ -2012-LN-0057
3	G3	DZ -2012-LN-0059
4	G4	DZ -2012-LN-00118
5	G5	FLIP-96-49L
6	G6	DZ -2012-LN-0038
7	G7	DZ -2012-LN-00107
8	G8	DZ -2012-LN-0058
9	G9	DZ -2012-LN-0048
10	G10	FLIP-97-33L
11	G11	DZ -2012-LN-0065
12	G12	FLIP-86-38L
13	G13	FLIP-89-19L
14	G14	DZ -2012-LN-0095
15	G15	DZ -2012-LN-0051
16	G16	Asano
17	G17	Local check

3. Result and Discussion

The combined Analysis of Variance (Table 2) revealed that significant variation among genotypes, locations and GE interaction for mean grain yield of lentil. Similar result was found by Karimizadeh *et al.,* 2010 who sated that significant variation of genotypes and genotypes by environment interaction. Furthermore, they have explained that the significances variation among the environments indicate that these locations can be used as testing stations for different environments while significant differences among genotypes reveals the differential response of genotypes to different environments. The explained percentage of sum of square (SS) of grain yield by environment is 29.65%, for genotype it was 8.11% and for the genotype x environment interaction it was 4.42% (Table-2).

Table 2. The combined ANOVA for grain yield of lentil over locations and years

Source of Variation	**Degree freedom**	**Sum Squares**	**Mean Squares**	**% explained of TSS**
YEAR (Y)	2	42.5821	21.291	15.68
Location (L)	1	80.5456	80.5456	29.65
Replication	3	0.260409	0.0868	0.10
Genotype (G)	16	22.0293	1.37683	8.11
Y X L	2	44.0381	22.019	16.21
G X E	16	12.0086	0.750539	4.42
Y X L X G	64	31.642	0.494406	11.65
RESIDUAL	303	38.5488	0.127224	14.19
TOTAL	407	271.655	0.667457	

Environment significantly explained the largest variation (29.65%) of the total sum of squares. This largely yield variation, explained by environments, indicated that the environments were diverse and a major part of variation in grain yield can be resulted from environmental changes. The same result was reported by Akter *et al.*, 2014 and Karimizadeh and Mohammadi, 2010.

AMMI Analysis

The combined analysis of variance showed highly significant differences for environment, genotype and their interactions; combined analysis of variance and AMMI analysis is shown in Table 3.

Table 3. Analysis of Variance for grain yield of lentil for the AMMI model.

Sources	**DF.**	**SS**	**MS**	**TSS explained %**
Genotypes	16	5.50732	0.344207**	9.46
Environment	5	41.7914	8.35829**	71.79
G X E	80	10.9126	0.136408**	18.75
AMMI COMPONENT 1	20	5.07988	0.253994**	46.55
AMMI COMPONENT 2	18	3.75266	0.208481**	34.39
AMMI COMPONENT 3	16	1.3651	0.085319**	12.51
AMMI COMPONENT 4	14	0.434769	0.031055**	3.98
GXE RESIDUAL	12	0.28024		
TOTAL	101	58.2114		

It is indicated in Table 3 that 71.79% of the total variation is attributed for environmental effect whereas 9.46% and 18.75% of the variation was accounted for genotypes and genotypes by environment interaction, respectively. A large sum of squares for environments indicated that the environments were diverse, with large differences among environmental means causing variation in the plant grain yields. The AMMI model demonstrated the presence of G x E interactions, and this has been partitioned among the first two IPCA (Interaction Principal Components Axes). Of the total variation observed, AMMI1 explained 46.55% of the interaction sum of squares whereas AMMI2 explained 34.39% of the interaction sum of squares (Table 3). The first two AMMI components totally accounted for 80.94% of the variation observed. This indicates that the use of AMMI model fit the data well and justifies the use of AMMI2. According to Crossa *et al.,* 1991, Zobel and Gauch, 1988 the first two interaction principal component axis best predictive model explains the interaction sum of squares.

Stability analysis by AMMI model

AMMI Stability Value (ASV): Purchase *et al.,* 2000 indicated ASV as the distance from the coordinate point to the origin in a two dimensional scatter gram of IPCA1 scores against IPCA2 score should also seen to decide the stability of a genotypes. The ASV and other stability parameters values along with the mean yield of the genotype are presented in Table 4. The highest mean grain yield of genotypes averaged over environments was obtained from DZ -2012-LN-0085 (2.31t ha-1) followed by DZ -2012-LN-0051 (2.06t ha-1) and DZ -2012-LN-0095 (1.98t ha-1). The genotypes with low stability value (ASV) is said to be stable and the breeder chose the stable genotypes, having grain yield above the mean grand yield. In this study genotype G4 showed lowest ASV followed by G5, G8, G6, and G10 (Table 5) indicating these genotypes can be suitable for the studied environments.

Table 4. Mean yield, First and second IPCA and various yield-stability statistics investigated in lentil.

Trt Code	Mean	Rank Yi	Slope (bi)	MS-DEV (S^2di)	IPCA1	IPCA2	ASV	Rank ASV	GSI
G1	2.31	1	0.86	0.07	0.15	-0.35	0.43	8	9
G2	1.70	11	1.30	0.31	-0.42	0.73	1.01	15	26
G3	1.54	15	1.48	0.12	-0.58	-0.15	0.97	14	29
G4	1.96	4	0.98	0.02	-0.03	0.03	0.05	1	5
G5	1.82	10	1.14	0.06	-0.24	-0.21	0.45	9	19
G6	1.88	6	1.03	0.06	0.03	-0.24	0.24	4	10
G7	1.85	7	1.15	0.10	-0.11	-0.30	0.35	6	13
G8	1.54	15	1.01	0.04	-0.05	-0.19	0.21	3	18
G9	1.85	7	1.36	0.02	-0.39	0.02	0.64	12	19
G10	1.85	7	1.02	0.05	-0.02	0.29	0.29	5	12

G11	1.64	12	1.22	0.05	-0.18	-0.20	0.36	7	19
G12	1.96	4	1.25	0.11	-0.27	-0.36	0.57	11	15
G13	1.59	13	0.68	0.11	0.44	0.30	0.78	13	26
G14	1.98	3	0.85	0.11	0.29	0.18	0.51	10	13
G15	2.06	2	1.00	0.02	-0.09	-0.08	0.17	2	4
G16	1.59	13	0.39	0.13	0.65	0.47	1.17	16	29
G17	1.32	17	0.29	0.32	0.82	-0.65	1.50	17	34

However, since stability in itself should not be the only parameter for selection, as the most stable genotype wouldn't necessarily gives the best yield performance (Mohammadi *et al.*, 2007), hence, simultaneous consideration of grain yield and ASV in single non-parametric index is needed or the Genotype Selection Index should be used to determine the stability of the genotypes by evaluating their mean grain yield and ASV.

Genotype Selection Index (GSI), when the rank of mean grain yield of genotypes across environments and rank of AMMI Stability Value considered to identify the tested genotypes in relation to stability, G4 , G15, G1 and G6 had the lowest GSI values compared to the other genotypes and showed stable performance over the testing sites. Therefore, G1 and G15 were the stable and high yielder genotypes across the testing environments.

AMMI 1 biplot

Biplots are graphs where aspects of both genotypes and environments are plotted on the same axes so that inter relationships can be visualized. There are two basic AMMI biplot, the AMMI 1 biplot, where the main effects of grain yield (genotype mean and environment mean) and IPCA1scores for both genotypes and environments are plotted against each other. On the other hand, the second biplot is AMMI 2 biplot where scores for IPCA1 and IPCA2 are plotted. In the AMMI 1 biplot, the usual interpretation of biplot is that the displacements along the abscissa indicate differences in main (additive) effects, whereas displacements along the ordinate indicate differences in interaction effects. Genotypes that group together have similar adaptation while environments which group together influences the genotypes in the same way (Kepton, 1984). The graph shows that the genotypes which are in the right side of perpendicular *i.e* G9, G7, G5, G10, G6, G4, G12, G4, G14, G15, and G1 gave higher grain yield than mean value(Figure-1). This indicated that these genotypes are less affected by GxE inter action.

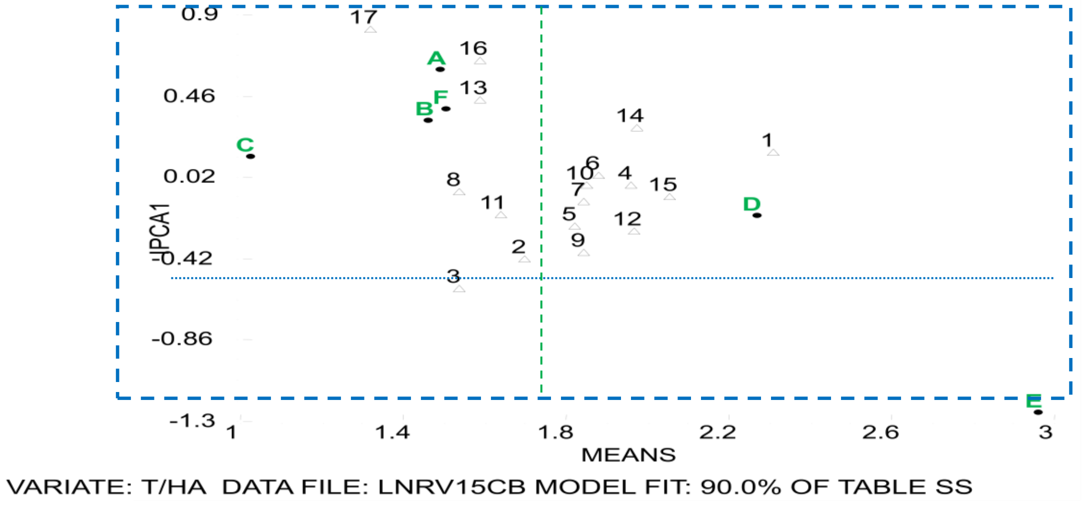

Figure 1. Biplot analysis of GEI based on AMMI 1 model for the PCA1 scores and grain yield

AMMI 2 biplot

The existence of interaction is displaced by biplot, especially when the interaction is portioned between two interaction principal component axis. The superiority of the genotypes determined by first principal components (IPCA1 and IPCA2) and to create a two dimensional GGE biplot. The genotypes close to ordinate expressed general adaptation, whereas the farthest genotypes depicted more specific adaptation to environments (Ebdon and Gauch, 2002). The environmental scores are joined to the origin by side lines. Sites with short arrow do not exert strong interactive forces. Those with long arrow exert strong interaction. The genotypes close to ordinate expressed general adaptation, whereas the farthest genotypes depicted more specific adaptation to environments (Ebdon and Gauch, 2002; Gauch HG, Zobel et *al., 1996)*. According to the present study, G4, G15 and G8 are the most stable genotypes and showed wider adaptation over the studied environments whereas G6, G10, G1, and G14 showed moderately stable performance. Therefore when all the stability parameters and mean grain yield are considered in order to identify best lentil genotypes, G1 and G15 were the best genotypes. Furthermore these two genotypes have tolerant types of interaction for the majority of the diseases scores observed during the growing period (Table 3). Therefore, we have identified and recommended these two genotypes to be verified for possible release for the highlands of bale zone and similar agro-ecologies.

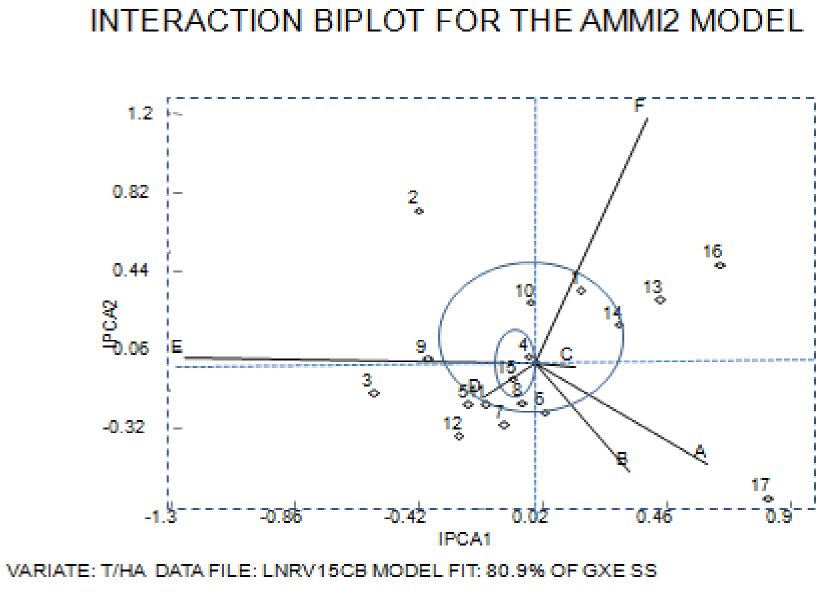

Figure 2. Interaction biplot for the AMMI model

Conclusion and recommendation

Crop yield is a complex trait that is influenced by a number of component characters along with the environment directly or indirectly. AMMI statistical model could be a great tool to select the most suitable and stable high yielding genotypes for specific as well as for diverse environments. In the present study, AMMI model has shown that the largest proportion of the total variation in grain yield was attributed to environments. The genotype, G1 and G15 showed higher grain yield than all other genotypes over all the environments and performed better at most of the places. Furthermore, these two genotypes showed stable performance with high mean grain yield over the testing sites. The two genotypes have yield advantage of 45.28% and 29.56% over the standard check, Asano (1.59t/ha). Therefore, we have conclude and recommended these two varieties to be used as candidate varieties to be verified in the coming cropping season for possible release in the highlands of bale and similar agro-ecologies.

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References

Akter A, Jamil Hassan M, Umma Kulsum M, Islam MR, Hossain K,(2014) AMMI Biplot Analysis for Stability of Grain Yield in Hybrid Rice (Oryza sativa) analysis of genotype-by-environment data. Crop Sci., 47: 643-655.

Arshad M, Bakhsh A, Haqqani AM, Bashir M (2003) Genotype - environment interaction for grain yield in chickpea (*Cicer arietinum* L.). Pak. J. Bot. 35(2): 181-186.

Crossa J, Fox PN, Pfeiffer WH, Rajaram S and Gauch HG. 1991 AMMI adjustment for statistical analysis of an interactional wheat yield trial. *Theor. App Gent*, 81: 27-37

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

Erskine W. Global production, supply and demand // The lentil: botany, production and uses / Erskine W. et al. (eds). – UK, 2009, p. 4–13

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

Gauch H. G., Piepho H. P., Annicchiaricoc P. 2008. Statistical analysis of yield trials by AMMI and GGE. Further considerations // Crop Science. vol. 48, p. 866–889

Gauch HG, Zobel RW, Kang MS & Gauch HG. 1996. AMMI analysis of yield trials. Genotype by-environment interaction, pp: 85-122. Gujarat Agric Uni Res J. 22: 101-102.

Gauch, H. G., 1992. Statistical Analysis of Regional Yield Trials: AMMI Analysis of Factorial Designs. *Elsevier,* Netherlands, Amsterdam.

Gauch, H. G., 1982. Multivariate analysis in community ecology. Cambridge Univ. Press, London and New York.

Karimizadeh. R and M. Mohammadi, 2010. AMMI adjustment for rain fed lentil yield trials in Iran. Bulg. J. Agric. Sci., 16: 66-73

Mohammadi R, Abdulahi A, Haghparast R and Armion M. 2007. Interpreting genotype environment interactions for durum wheat grain yields using non-parametric methods. Euphytica. 157: 239-251.

Neacşu A. 2001. Grain protein concentration and its stability in a set of winter wheat cultivars, grown in diverse environments and management practices // Romanian Agricultural Research. vol. 28, p. 29–36

Purchase JL, Hatting H and Vandenventer CS. 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

Sabaghnia N., Sabaghpour S. H., Dehghani H. 2008. The use of an AMMI model and its parameters to analyse yield stability in multi-environment trials // Journal of Agriculture Science.vol. 146, p. 571–581

Sarker, A., W. Erskine and M. Singh, 2003. Regression models for lentil seed and straw yields in Near East. *Agricultural and Forest Meteorology*, 116: 61–72.

Yan W., Kang M. S., Ma B., Wood S., Cornelius P. L. 2007. GGE biplot vs. AMMI analysis of genotype-by-environment data // Crop Science. vol. 47, p. 643–655

Zobel, R. W. and H. G. Gauch, 1988. Statistical analysis of a yield trial. *Agron. J.*, 80: 388-393.

Grain Yield Performance Evaluation of Mung bean (Vigna radiate) in the lowland district of Bale zone, Southeastern Ethiopia

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Abstract

A field experiment was conducted at the sub site, and on farm of Dellomena district representing the lowland district of Bale zone, Southeastern Ethiopia using seven improved mung bean varieties under rain fed condition during 2018 and 2019 main cropping season. The study was envisaged to assess the adaptability of seven improved mung bean varieties at Dellomena district. The field experiment was laid out in a Randomized Complete Block Design (RCBD) with two replications for two years (2018 and 2019) on a plot size of 7.2 m (six rows at 40 cm spacing and 3 m length). The combined analysis f variance revealed that, there was highly significant difference among the test varieties for mean grain yield. It was found that variety MH-97-6 (Boreda) (3.70 qt/ha) showed best yield performer followed by Humera Local (3.35 qt/ha) and Gali (3.20 qt/ha). Besides, variety MH-97-6 has tolerant type of disease reaction during the entire cropping season. Therefore, based on overall performance, this variety is recommended for production in the study areas to be used by the farming community in order to boost their production and productivity till another variety out yielding this variety is availed for the area.

Key words: Adaptation, Mung bean, Variety

Introduction

Mung bean is one of the most important pulse crops, grown from the tropical to sub-tropical areas around the world (Khan MA et al., 2012). It is an important wide spreading, herbaceous and annual legume pulse crop cultivated mostly by traditional famers (Ali MZ et al., 2010). The crop is characterized by fast growth under warm conditions, low water requirement and excellent soil fertility enhancement *via* nitrogen fixation (Yagoob H. et al., 2014). Fertilization of this crop occurs through self-pollination without requirement of other pollinators like insects, water and wind (Rashid K.et al., 2013). Among legumes, mung bean is noted for its protein and lysine-rich grain, which supplements cereal-based diets (Minh NP.et al., 2014). The crop is utilized in several ways; seeds, sprouts and young pods are all consumed and provide a rich source of amino acids, vitamins and minerals (Somta P. et al., 2007). The grain contains 24.2% protein, 1.3% fat and 60.4% carbohydrate (Hussain F. et al., 2011). It is also known to be very healthy and packed with a variety of nutrients such as vitamin B, vitamin C, protein, manganese and a lot of other essential nutrients required for effective functioning of the human health. Mung bean has low in calories and rich in fiber and easily digestible crop without cause flatulence as happens with many other legumes (Minh NP.et al., 2014).

The optimum temperature range for good production is 27- 30°C (Imrie, 1998). Mung bean 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. Smallholder farmers in drier marginal environments in Ethiopia grow mung bean. Farmers in some moisture stress areas have been producing mung bean to supplement their protein needs and also effectively use scanty rainfall (Asrat A , et al., 2012). There is a need to expand its production to other potential areas where moisture stress is a challenge for producing long maturing crops. Even in mung bean producing areas, its farming is based on local cultivars that are low yielder, late maturing and susceptible to disease. These varieties are challenged by current climate change. Moreover, there is huge demand for mung bean in the international market particularly in south-east Asia. However, the improved varieties are not yet availed to farmers in moisture stress areas particularly in Bale lowlands, including Dellomana dstrict. Therefore, this activity was carried out to test and select the best performing mung bean variety for the target areas. Sowing of mung bean mainly occurs during summer when sufficient rain is available for growth but it is sensitive to water logging. It is grown in several types of cultivation systems, including sole cropping, intercropping, multiple cropping and relay cropping, where it is planted after cereals using residual moisture (Omid, et al,. 2008). Production of mung bean is influenced by biotic and abiotic limiting factors. Water stress, drought stress, salt stresses are among biotic factors that influence mung bean growth and development. Negative impacts of the stress can be seen in the production of leaves, pods and flower parts at key growth stage of mung bean crop. Thus, depending on the growth stage when the stress occurs, it can significantly reduce final grain yield (Pandey A, et al,. 2011). As Asfaw *et al.* (2012) reported, in Ethiopia mung bean is mostly grown by smallholder farmers under drier marginal environmental condition and the production capacity is lower than other pulse crops. For resource poor farmers in Ethiopia, mung bean is mainly used as food, but growing it for income generation can also be important. The varieties used for income generation may be different than those which can give a stable yield under harsh environmental conditions. Result from farming practice used as food, medicine, economic, ecological, socio-cultural, religious and cultural needs. Mung bean is cultivated for its edible seeds, income generation and fodder for livestocks.

Mung bean is a warm season crop requiring 90-120 days of frost-free conditions from planting to maturity (depending on the variety). The optimum temperature range for growth is between 27 °C and 30 °C. This means that the crop is usually grown during summer. Seed can be planted when the minimum temperature is above 15 °C. Mung beans are responsive to daylight length. Short days result in early flowering, while long days result in late flowering. However, mung bean varieties differ in their photoperiod response. Mung bean is considered to be heat and drought tolerant. Mung beans are propagated from seed. A seeding rate that will ensure a plant population of 200 000 to 350 000 plants/ha under dry-land conditions and 400 000 plants/ha under irrigation, is recommended.

According to ECXA (ECXA, 2014) mung bean is being cultivated as a recently introduced crop in Ethiopia. As Asfaw et al., 2012 reported, in Ethiopia mung bean is mostly grown by smallholder farmers under drier marginal environmental condition and the production capacity is lower than other pulse crops. For resource poor farmers in Ethiopia, mung bean is mainly used as food, but growing it for income generation can also be important.

Among pulses, mung bean is the most important cash crops in the world (Singh R, et al., 2011). It is a vital crop in developing countries where it is consumed as dry seeds, fresh green pods or leaves due to its high protein, vitamin and mineral content. It is also consumed as forage or green pods and seeds as vegetables (Somta P, et al., 2007). Primarily, the purposes of this crop are for its protein rich edible seeds and fresh sprout. The seed of mung bean mainly used for making soups, bread and biscuits (Rashid K, et al., 2013) . Other than food it is importance to assistance in normal use of land, water resource and enrichment of the soil through nitrogen fixation. Adaptation to short growth duration, low water requirement, ability to increase soil fertility and usefulness in crop rotation practices are also another significances of mung bean (Asrat A, et al., 2012). And also it has the Ability of improving soil fertility by fixing atmospheric nitrogen into available form with the help of rhizobia species for plant's growth and development are characters of mung bean (Jat SL, et al., 2012).

Mung beans do best on fertile, sandy loam soils with good internal drainage and a pH in the range of 6.3 and 7.2. Mung beans require slightly acid soil for best growth. If they are grown in rotation, lime to attain pH of the most acid sensitive crop. Root growth can be restricted on heavy clays. Mung beans do not tolerate saline soils and can show severe iron chlorosis symptoms and certain micronutrient deficiencies on more alkaline soils. It is known that Bale is predominated by cereal crops (particularly Teff, Wheat and maize) production. This monoculture makes the soil degradation and erosion. Rotation of cereals with legume crops is not practiced. Although now days some legumes are rarely grown on small scale around lowland (Mung bean, Haricot bean) and highlands (faba bean, field pea, lentil) of Bale zone. The Community in this area produced Mung bean of unknown source which gives very low yield. They produced cultivar which is very susceptible to diseases. Since the district has potential for mung bean production, and farmers produce low yielding cultivar to use it as cash crop, it is important to bring and evaluate the adaptability and yielding potential of some improved mung bean varieties to the area. Therefore this study was initiated with the objective of identifying and recommending best adapted mung bean variety with tolerant or resistant type of disease reaction to the lowland of Delomena.

Materials and Methods

Description of experimental site: The study was conducted under rain fed conditions at Dellomena sub-site of Sinana agricultural research center and on farmer field. Dellomena, is located at the latitude of 5° 51'-6° 45' north and longitude of 39° 35'-40° 30' east, in the middle and lowland areas and at the altitude of 1314-1508 meters above sea level, with a prevalence of lowlands. The experimental area is characterized as low land climate. The mean rainfall is about 986 mm for the last five years. The rainfall has a bimodal distribution pattern with heavy rains from April to June and September to November. The mean annual temperatures are 22.5 °C for the last five years.

Experimental materials

Seven mung bean varieties were used as the experiment materials. These planting materials were collected from Humera agricultural research center. The study was conducted under rain fed condition for two consecutive years during 2018 and 2019 main cropping season. The experimental plots were laid out in Randomized Complete Block Design (RCBD) with two replications for two years in six rows per plot with 2.4 m wide and 3 m long, and with spacing of 40 cm between rows and 10 cm between plants. Data were taken on days to 50% flowering, days to maturity, plant height, number of pod per plant, number of seed per pod, thousand seed weight and grain yield (g/plot). Data were analyzed using Gen STAT 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.

Table 1. Lists of Mung bean varieties used in this study along with their source

Source of Varieties	Varieties
Humera Agricultural Research Center	MH-97-6
Humera Agricultural Research Center	Arkebe
Humera Agricultural Research Center	Shewa Robit
Humera Agricultural Research Center	Gali
Humera Agricultural Research Center	N-26
Humera Agricultural Research Center	N-23

Results and Discussion

The results of the first year (2018) showed that there was no significant difference on flowering, maturity, plant height, number of pod per plant and grain yield per hectare. But significant difference was observed on: number of seed per pod, stand percentage, and thousand seeds weight. Maximum grain yield of 235 kg/ha was harvested from Humera Local followed by MH-97-6 (213kg/ha). The result again showed that flowering date, maturity date, pod per plant and grain yield had showed non significant difference in 2018 whereas number of seed per pod, thousand seed weight showed significance difference at $p<0.05\%$. The maximum grain yield was harvested from Humera Local (235kg/ha) followed by Borada (213 kg/ha). The minimum grain yield was harvested from N-23 (103 kg/ha). (Table 2).

Table 2. Mean values of yield and yield components of mung bean varieties during 2018 cropping season

GEN	DF	DM	PLH	NPPP	NSPP	ST%	TSW	YLD kg/ha
Gali	41	83	60	6	8	89	35	192
Local	41	81	55	6	8	88	26	235
MH-97-6	41	81	57	6	7	90	23	213
Arkebe	41	82	52	6	8	88	26	199
Shewa Robit	42	81	53	6	8	90	26	160
N-26	42	81	54	5	9	89	27	108
N-23	42	82	52	4	10	84	29	103
Mean	41	82	55	5	8	88	27	173
5%LSD	NS	NS	NS	NS	2.2	4.9	6.2	NS
CV%	3.1	2.8	11.0	21.0	17.9	3.8	15.5	24.0

NB. DF= days to Flowering, DM=days to maturity, PLH= plant height(cm),NPPP= number of pods per plant, NSPP= number of seeds per pod, St%= Stand percentage, TSW= Thousand seed weight (gm), YLD= Yield per hectare

While in the second year, the analysis of variance revealed that non-significant differences among the varieties for all the traits except thousand seed weight and seed yield (Table 3). This difference was attributed to the variation in the rainfall pattern which was very erratic and not uniform during the first year compared to the second year. During 2019 cropping season the highest yield (4.75 qt/ha) was obtained from variety MH-97-6 (Boreda) while lowest yield 2.35 and 2.97 qt/ha was obtained from varieties N-23, N-26 respectively while varieties Gali, Humera Local, and Arkebe gave medium mean seed yield of 4.06, 4.01, 3.44 qt/ha respectively.

Table 3. Mean values of yield and yield components of mung bean varieties during 2019 cropping season at Dellomena

ENTRY	DF	DM	PLH	PPP	SPP	St%	TSW	YLD/ha
Arkebe	40.5	85.3	59.8	5.8	7.3	72.5	36.9	344.2
Gali	39.8	86.0	62.7	5.7	8.3	75.0	47.5	405.8

Local	40.0	85.5	63.0	5.7	8.2	70.8	35.8	400.9
MH-97-6	40.3	85.7	66.5	7.2	6.7	75.8	38.2	474.6
N-23	40.7	85.8	57.5	4.5	8.8	72.5	47.1	235.3
N-26	41.0	85.8	62.7	5.0	8.3	71.7	48.4	297.2
Shewa Robi	40.8	86.0	58.2	4.5	8.5	72.5	38.9	321.3
Mean	40.4	85.7	61.5	5.5	8.0	73.0	41.8	354.2
LSD	NS	NS	NS	NS	NS	NS	8.66	50.01
CV	3.7	2.87	14.64	45.7	21.2	6.66	17.65	11.7

NB. DF= days to Flowering, DM=days to maturity, PLH= plant height(cm),NPPP= number of pods per plant, NSPP= number of seeds per pod, St%= Stand percentage, TSW= Thousand seed weight (gm), YLD= Yield per hectare

In the combined ANOVA (Table- 4), there was significant difference among the varieties for all the traits being considered except for traits such as days to follower, days to maturity, plant height (cm), and stand percentage. The interaction effect of year with variety was significant for thousand seed weight (TSW) and total seeds per plant (TSPP), which implies that, the varieties performance for these traits is not variety potential/its actual potential/ but it is cumulative effect of year and variety. Across season, the highest seed yield (3.70qt/ha) was obtained from variety MH-97-6 (Boreda) followed by Humera Local (3.35), Gali (3.20qt/ha), and Arkebe (2.86qt/ha). Significant effect of mung bean genotypes on seed yield had been reported by different researchers including Omid, 2008; Ahmad et al. (2003) and Khan et al. (2003).

Table 4. Mean values of yield and yield components of mung bean varieties combined over season.

ENTRY	DF	DM	PLH	NPPP	NSPP	St%	TSW	YLD/ha
Arkebe	40.5	84.1	56.6	5.7	7.5	78.5	32	286
Gali	40.3	84.9	61.4	5.6	8.0	80.5	42	320
Local	40.4	83.8	59.6	5.8	8.1	77.5	32	335
MH-97-6	40.5	83.8	62.6	6.5	6.8	81.5	32	370
N-23	41.2	84.1	55.2	4.3	9.1	77.0	40	182
N-26	41.2	84.0	59.3	5.1	8.7	78.5	40	222
Shewa Robi	41.2	84.1	56.1	5.1	8.2	79.5	40	257
Mean	40.8	84.1	58.9	5.4	8.1	79.0	36	282
LSD	NS	NS	NS	1.9	1.4	NS	8.8	63.2
CV	3.4	4.1	16.2	38.4	19.8	11.8	27.4	24.7

NB. DF= days to Flowering, DM=days to maturity, PLH= plant height(cm),NPPP= number of pods per plant, NSPP= number of seeds per pod, St%= Stand percentage, TSW= Thousand seed weight (gm), YLD= Yield per hectare

Mean performance of the mung bean varieties

Differences in mean performance of the mung bean varieties for the characters studied in two seasons (2018 and 2019) at Dellomena sub-station is presented in the Tables 2 and 3. The results indicated that the differences among the means of the mung bean varieties for grain yield was not significant at 5% probability level for first seasons (2018), but there was significant difference among the test varieties for the same trait at 5% probability level during 2019 cropping season. Across season, the highest seed yield (3.70qt/ha) was obtained from variety MH-97-6 (Boreda) followed Humera Local (3.35), Gali (3.20 qt/ha), Arkebe (2.86 qt/ha). The interaction effect of year with variety was significant for thousand seed weight (TSW) and total seeds per plant (NSPP), which implies that, the varieties performance for these traits is not variety potential/its actual potential/ but it is cumulative effect of year and variety.

Conclusions and Recommendations

Generally, the present study entails the presence of significant variations among mung bean varieties for grain yield. Results revealed that MH-97-6 (Boreda) (3.70 qt/ha) showed to be best performing variety in terms of grain yield followed by Humera Local, Gali, Arkebe, Shewa Robit (3.35, 3.20, 2.86, 2.57 qt/ha) and N-26 (2.22 qt/ha). Varieties were not expressed their full yield potential due to the moisture stress and sudden pest damage occurred during the cropping season. Even the variety Boreda (MH-97-6) has the potential of giving about 8.6 qt/ha as previously reported by releasing center while currently gave only (3.70 qt/ha) which is due to the factors mentioned above. Therefore, we have concluded that, variety MH-97-6 has adapted in the study area compared to other varieties. Therefore, until other or new varieties introduced to the areas, variety MH-97-6 is recommended for production to the farming community in the study areas.

REFERENCE

Ahmad, R., Ikraam, M., Ullah, E. and Mahmood, A. (2003).Impact of different fertilizer levels on the growth and productivity of three mung bean cultivars. *Intl. J. Agric. Biol.* 5(3): 335-338.

Ali MZ, Khan MAA, Rahaman AKMM, Ahmed M, Ahsan AFMS (2010) Study on seed quality and performance of some mungbean varieties in Bangladesh. Int J Expt Agric 1(2): 10-15.

Asrat A, Fekadu G, Fetsum AYR (2012) Analysis of multi-environment grain yield trials in mungbean (Vignaradiata L.) Wilczek based on GGE bipot in Southern Ethiopia. Agr Sci Tech 14(2): 389-398.

Das S, Shekhar UD, Ghosh P (2014) Assessment of molecular genetic diversity in some green gram cultivars as revealed by ISSR analysis. Advances in Applied Science Research 5(2): 93-97.

ECX 2014. Ethiopia Commodity Exchange Rings Bell for mungbean Addis Ababa.

Hussain F, Malik AU, Haji MA, Malghani AL (2011) Growth and yield response of two cultivars of mungbean (Vignaradiata L.) to different potassium levels. The Journal of Animal & Plant Sciences 21(3): 622- 625.

Imrie, B. (1998). *The New Rural Industries*: *A Hand Book for Farmers and Investors: Mung bean (http://www.rirdc.gov.au/pub /handbook/mung bean.html)(Accessed on November 10, 2009).*

Jat SL, Prasad K, Parihar CM (2012) Effect of organic manuring on productivity and economics of summer mungbean (Vignaradiata Var. radiata). Ann Agric Res New series 33(12): 17-20.

Khan MA, Naveed K, Ali K, Ahmad B, Jan S (2012) Impact of mungbean-maize intercropping on growth and yield of mungbean. Weed science society of Pakistan department of weed science. J Weed Sci Res 18(2): 191-200.

Kumari R., Shekhawat K.S., Gupta R. and Khokhar M.K. 2012. Integrated management against root- rot of mungbean (*Vigna radiata* (L.) Wilczek) incited by macrophomina phaseolina. *J Plant Pathol Microb* **3**:5.

Minh NP (2014) Different factors affecting to mungbean (Phaseolus aureus) tofu production. International Journal of Multidisciplinary Research and Development 1(4):105-110.

mungbean genotypes. *Peak Journal of Agricultural Science* **2** (3): 30-35.

Omid, S.P. (2008). Effect of withholding irrigation at different growth stages on yield and yield components of mung bean (*Vigna radiate* L. Wilczek) varieties

Pandey A, Kumar A, Ramya P (2011) Genetic diversity in green gram accessions as revealed by STMS markers. African Journal of Biotechnology 10(75):17081-17087.

Ranawake A., Dahanayaka N., Amarasingha U., Rodrigo W. and Rodrigo U. 2011.Effect of water stress on growth and yield of mungbean (*Vigna radiata* L.). *Tropical Agricultural Research and Extension* **14** (4).
Rashid K, Daran ABM, Nezhadahmadi A, Yusof MFBM, Azhar S, et al. (2013) Intraspecific crosses and morphological studies of two cultivars of Vigna radiate through in-vitro and in-vivo techniques. Life Science Journal 10 (2): 2549-2555.
Sehrawat N, Bhat KV, Sairam RK, Pawan KJ (2013) Identification of salt resistant wild relatives of mungbean (Vignaradiata L.) Wilczek). Asian Journal of Plant Science and Research 3(5): 41-49.
Singh R, Heusden AW, Yadav RC (2011) A comparative genetic diversity analysis in mungbean (Vignaradiata L.) using inter-simple sequence repeat (ISSR) and amplified fragment length polymorphism. AFLP 12(47): 6574-6582.
Somta P, Srinives P (2007) Genome research in mung bean (Vignaradiata L.) Wilczek) and black gram (V mungo L.) Hepper). Science Asia 33(s1): 69-74.
Tang D, Dong Y, Ren H, He C (2014) A review of photochemistry metabolite changes and medicinal uses of the common food mungbean and its' sprouts (Vignaradiata). Chemistry Central Journal 8: 4.
Yagoob H. and Yagoob M. 2014. The effects of water deficit stress on protein yield of

The registration of "Moybon and Tosha", faba bean varieties for the highlands of Bale, South eastern Ethiopia

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Abstract

At different breeding stage, a number of faba bean lines were evaluated in order to identify high yielder and stable faba bean genotypes. Accordingly eighteen faba bean lines were evaluated at three locations, Sinana, Agarfa and Sinja for three consecutive years (2016-2018) during main cropping seasons. Out of eighteen genotypes, EH00021-1/Tosha/ቶሻ/) and EH011088-3/Moybon/ሞይቦን/ were found to be superior in their yield, and also showed stable and tolerant performance to major faba bean diseases. The variety "moybone" is highly characterised with large seed weight associated with high grain yield (31-43k Qt/ha) with a yield advantage of 35% over the local and 22% over standard check Gebelcho variety respectively; whereas the other variety, "Tosha" had more number of pods/plant and gave grain yield of (34-52 Qt/ha) with yield advantage 51%, and 38% over the local cultivar and the standard check, respectively. Furthermore, this variety had stable performance across the tested sites, and showed tolerant to *chocolate spot (Botrytis fabae* Sard.*), Rust(Uromyces Vicia-fabae) and aschochyta blight (Aschocyta fabae Speg*.) diseases*. Due to these merits varieties "Moybon, and Tosha" were released in 2019 cropping season for production in the highlands of Bale and similar agro-ecologies.*

Key Words: Moybon, Tosha, Stablity Variety Release,

1. Agronomic and Morphological characteristics

Variety Tosha needs 64 and 138 days for flowering and maturity, respectively. Furthermore, Tosha is characterized by more numbers of pods/plant i.e. 15 pods/plant compared to the variety used as standard check, i.e Gebelcho which only had 12 pods/plant. In addition, this variety has plant height of 121cm with an erect type of growth habit having thousand seed weight of 673.3 gm with cotyledon color of yellow and seed color of light green. Whereas, the other variety Moybon, flowers in 61 days and gets physiological maturity within 138 days. Thousand seed of this variety weights 774.5 gm which is higher than the standard check, Gebelcho (766.4 gm). Its plant height reaches as high as 119 cm with an erect type of growth habit. Moybon variety has similar cotyledon and seed color with that of variety Tosha. Summary of the agronomic and morphological characteristics of these released varieties are presented in Appendix I and II.

2. **Yield Performance**

In the screening stage from 2014 to 2015, these two varieties were evaluated along with other lines at the main station, Sinana for yield and other agronomic traits and showed better performance than the checks and promoted to the next breeding stages. During the multi-location evaluation trials, Tosha gave mean grain yield of 44.3 Qt/ha whereas Moybon gave an average mean yield of 39.24 Qt/ha on the research field whereas on farmer's field, Tosha gave 36.82 Qt/ha while Moybon gave 33.01 Qt/ha. Tosha has yield advantage of 37.63% whereas Moybon has 21.78% as compared to the standard check used, Gebelcho (28.83 Qt/ha).

3. **Stability Performance**

Yield stability analysis was considered for eighteen faba bean lines using AMMI model. Based on different stability parameters, like the mean grain yield along with their liner regression coefficient and deviation from regression and AMMI Stability Value, (ASV), and Genotype Selection Index (GSI) developed by Farshadfar, 2008), all thse stability analysis were considered to evaluate the stability performance of the varieties. Based on results of these stability parameters, these two faba bean varieties were found to be stable compared to the rest genotypes across the tested sites.

4. **Disease reaction**

These two varieties had showed tolerant type of reaction to chocolate spot, Achochyta bilght and rust diseases which are common yield limiting disease in faba bean crop.

5. **Conclusion**

These varieties, Tosha and Moybon, are high yielder, stable and showed tolerant types of disease reaction compared to the standard checks used. Variety Tosha has more number of pods/plant whereas variety moybon has large seed size which contributes to have more seed yield per unit area. These varieties were released for the highlands of Bale, south-eastern Ethiopia. Tosha has got its name from one of the locally named village at Goba district, which is suitable for faba bean production, whereas moybon has got its name since its performance is above all faba bean varieties adapted in the highlands of Bale and win them for most of the agronomic parameters.

6. **Reference**

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

Table 1. Summary of mean grain yield and other agronomic traits for the two varieties

Variety	Days to		Plant ht. (cm)	Number of		Stand %	1000 seed wt. (g)	Seed yield (kg/ha)	Disease score (1-9 scale)		
	Flower	Maturity		Pods/Plant	S/Pod				Cho.sp	Rust	ASBLT
Tosha	63	137	116	12	3	73	787.5	2795	3	4	4
Moybon	64	138	123	13	3	74	775.0	2951	3	4	3
Gebelcho	63	138	119	15	3	73	637.1	2940	5	5	5
Local cultivar	64	137	121	13	3	76	741.4	2790	5	4	4

Cho.sp= Chocolate spot, ASBLT= Aschochyta Blight

Appendix 1. Agronomic and morphological characteristics of Tosha/ቶሻ/ (**EH00021-1)**

No	Agronomical and Morphological Characteristics	
1	Adaptation area	Sinana, Goba, Agarfa, Gassera, Goro (Meliyu), Adaba, Dodola and other similar agro-ecologies
2	Altitude (m.a.s.l.)	2300 – 2600
3	Rainfall (mm)	750 – 1000
4	Seed Rate (Kg/ha)	175-225
5	Planting date	End of July to Early August
6	Fertilizer Rate (DAP kg/ha)	100

No	Agronomical and Morphological Characteristics		
7	Days to Flower		64
8	Days to Maturity		138
9	Plant Height (cm)		121
10	Growth habit		Erect
11	1000 Seed Weight (gm)		673.3
12	Seed Color		Light green
13	Cotyledon Color		Yellow
14	Flower Color		White with black spot
15	Yield (Qt/ha)	On-station (Research Field)	44.43
		On-farm	36.82
16	Disease reaction		Tolerant to chocolate spot, Rust and Aschochyta blight
17	Yield advantage over Gebelcho (%)		37.63
18	Year of Release		2019
19	Breeder and Maintainer		SARC(OARI)

Appendix 1. Agronomic and morphological characteristics of Moybon **/ሞይቦን/ (EH011088-3)**

No	Agronomical and Morphological Characteristics		
1	Adaptation area		Sinana, Goba, Agarfa, Gassera, Goro (Meliyu), Adaba, Dodola (W. Arsi) and other similar agro-ecologies
2	Altitude (m.a.s.l.)		2300 – 2600
3	Rainfall (mm)		750 – 1000
4	Seed Rate (Kg/ha)		175-225
5	Planting date		End of July to Early August
6	Fertilizer Rate (DAP kg/ha)		100
7	Days to Flower		61
8	Days to Maturity		138
9	Plant Height (cm)		119
10	Growth habit		Erect
11	1000 Seed Weight (gm)		774.5
12	Seed Color		Light green
13	Cotyledon Color		Yellow
14	Flower Color		White with black spot
15	Yield (Qt/ha)	On-station (Research Field)	39.24
		On-farm	33.01
16	Disease reaction		Tolerant to chocolate spot, Rust and Aschochyta blight
17	Yield advantage over Gebelcho (%)		21.78
18	Year of Release		2019
19	Breeder and Maintainer		SARC(OARI)

The Registration of "Horesoba", Newly Released Linseed variety for the highlands of Bale, South eastern Ethiopia

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Abstract

*Fourteen linseed lines were evaluated at Sinana and Agarfa for three years (2013-2014) during main cropping season in order to identify high yielding and stable genotypes with tolerant to powdery mildew, downey mildew and wilt. Out of these tested lines, Horesoba /*CHILALO X R12-N27G/SPS6/ was *found to be superior in its yield, stable and tolerant to the aforementioned major diseases. Variety Horesoba is characterised with more stand %, higher thousand seed weight and gave high grain yield (15-21 Qt/ha) with a yield advantage of 37% over the local and 19% over standard check, Jitu, respectively. Because of all these merits and advantage over the standard and local checks, variety Horesoba was approved to be released for the highlands of Bale and similar agro-ecologies.*

Key Words: Horesoba, linseed, Stability, Variety

1. Agronomic and Morphological characteristics

Variety Horesoba needs 71 and 156 days for flowering and for physiological maturity, respectively. This variety has plant height of 71cm with an erect types of growth habit . The variety horesoba also has an average thousand seed weight of 6.2gm with brown seed color. The variety has good oil content, 38.8% compared to the check, Jitu (34%). Summary of the agronomic and morphological characteristics of the variety is presented in Appendix I.

2. **Yield Performance**

In the preceding screening stages of the years 2011 to 2012 cropping seasons, upon evaluation of the variety along with large number of genotypes in the main station for yield and other agronomic traits, Horesoba showed superior performance over the checks (both standard and local) and retained for further evaluation in the subsequent breeding stages. During the multi-location evaluation trials, on average, this variety gave an average grain yield of 16-19 Qt/ha on research field and 12-15 Qt/ha on farmers field. This variety has yield advantage of 18.97% compared to the standard check variety Jitu (13.55 Qt/ha) (Table 1).

3. **Stability Performance**

The stability analysis of yield for fourteen linseed genotypes was studied for three consecutive years across two locations. Based on different stability parameters considered, variety Horesoba was high yielder and showed stable performance across the tested sites (Tadele *et al.*, 2017).

4. **Disease reaction**

The variety Horesoba showed tolerant reaction to the major linseed diseases prevailing in the linseed production areas of Bale highland such as powdery mildew, downey mildew and wilt diseases.

5. **Conclusion**

The variety Horesoba is high yielder, stable and showed tolerant types of disease reaction compared to the standard checks used. Furthermore, variety Horesoba has good seed size with large oil content compared to the standard check and the local cultivar tested along with it. Because of these merits, the variety was released for the highlands of Bale, South-eastern parts of Ethiopia. Horesoba has got its name from one of the locally named village in Dinsho district.

6. **Reference**

Tadele Tadesse, Amanuel Tekalign, Gashaw Sefera, Behailu Muligeta. AMMI Model for Yield Stability Analysis of Linseed Genotypes for the Highlands of Bale, Ethiopia. *Plant*. Vol. 5, No. 6, 2017, pp. 93-98. doi: 10.11648/j.plant.20170506.12

Table 1. Summary of mean grain yield and other agronomic traits for Horesoba variety

Variety	Stand %	Days to		Plant ht. (cm)	1000 seed wt. (g)	Seed yield (kg/ha)	Disease score (0-5 scale)		
		Flower	Maturity				DM	PM	Wilt
Horesoba	80	71	156	90	6.2	3	3	3	1613
Jitu	79	72	156	88	6.0	4	5	3	1355

DM= Downey mildew, PM= Powdery Mildew

Appendix 1. Agronomic and morphological characteristics of Horesoba /**ሆረሶባ**/ Chilalo X R12-N27G/SPS6Tosha

No	Agronomical and Morphological Characteristics	
1	Adaptation area	Sinana, Goba, Agarfa, Gassera, Adaba, Dodola) and other similar agro-ecologies
2	Altitude (m.a.s.l.)	2300 – 2600
3	Rainfall (mm)	750 – 1000
4	Seed Rate (Kg/ha)	25-30 (for row and broadcasting, respectively)
5	Planting date	End of July
6	Fertilizer Rate (DAP kg/ha)P_2O_5/N_2	23/23

No	Agronomical and Morphological Characteristics		
7	Days to Flower		71
8	Days to Maturity		156
9	Plant Height (cm)		90
10	Growth habit		Erect
11	1000 Seed Weight (gm)		6.2
12	Seed Color		Brown
13	Flower Color		Pink
14	Oil content (%)		38.8
15	Yield (Qt/ha)	(Research Field)Average of three years	19.33
		On-farm	12.93
16	Disease reaction		Tolerant to Powdery Mildew, wilt and pasmo
17	Yield advantage over Jitu (%)		18.97
18	Year of Release		2019
19	Breeder and Maintainer		SARC(OARI)

Analysis of Bread Wheat Genotypes for Yield Stability Using the GGE Biplots

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Abstract

Evaluation of different genotypes in a multi-environment and years is used to determine high yielding cultivars that best represent the target environment. However, genotypes grown in different environments frequently show significant fluctuations in yield performance and these changes caused by the different environmental conditions. Understanding the cause of GE interaction is used to identify ideal genotypes and test environments and hence to recommend genotypes based on areas of optimal genotype adaptation. Thus the objective of this study was to identify stable and high yielding genotypes using GGE biplots. A total of twenty bread wheat genotypes including Sanate and (st. check) and Mada walabu (local check) were evaluated for two consecutive years 2017 and 2018 during main cropping season at three locations: Sinana, Agarfa and Goba. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The result of combined analysis of variance showed highly *significant differences for Genotype, Environment and Genotype by Environment interaction. The environmental effect accounted for 67.7%, genotype effect 29.6% and GE interaction only accounted 2.6% of the total variation. Genotypes near to environmental vector were performed more than mean yield. Based on this, G13, G11, G20, G17 and G16 were performed than mean yield of the test genotypes. Eventhough G20 showed higher yield, it is unstable genotype across tested locations. G11 is best genotype followed by G13 and G17 because they gave high mean grain yield with stable performance across locations as compared to other test genotypes. Therefore, these genotypes are recommended as candidate variety for next year to release as a variety.*

Key words: AMMI, Genotype, High yield, IPCA, Stability

Introduction

Wheat is among the major cereal crops that received considerable focus by the agricultural research system. This is justifiable because of the fact that wheat is among the most important crops not only in Ethiopia but also worldwide. It has played a significant role in feeding a hungry world and improving global food security. It contributes about 20% of the total dietary calories and proteins worldwide (Shiferaw *et al*., 2013). Wheat produced in Ethiopia is used mainly for domestic food consumption, seed, and raw material for agro-industries. It accounts for about 10-15% of all the calories consumed in the country (Berhane *et al.*, 2011). Moreover, estimated total wheat consumption (for food, seed and industrial use) is rapidly increasing at the national level (CSA, 2017).

Ethiopia is the leading wheat producer in Sub Saharan Africa with a total production of 4.6 million tons (FAO, 2018; CSA, 2018). Accordingly Oromia National Regional State contributes a total production of 2.7 million tons in the country. Among the wheat producing zones of Oromia, Arsi, West Arsi and Bale zones are considered as the wheat belts of Eastern Africa. Although the productivity of wheat has increased in the last few years in the country, it is still low as compared to other wheat producing countries in other parts of the world. The national average of wheat productivity is estimated to be 2.7 t ha^{-1} (CSA, 2017), which is below the world average of 3.0 t ha^{-1} (Hawkesford *et al*., 2013).

This low productivity of the crop is attributed to a number of factors including biotic, abiotic, shortage of high yielding and stable genotypes. High yield stability usually refers to a genotype's ability to perform consistently across a wide range of environments (Annicchiarico, 1997). In order to ensure consistent stability and high yields, new genotypes are developed, and tested for their yield performances in different environments (Mehmet and Telat, 2006). Genotype × environment interactions are of major importance, because they provide information about the effect of different environments on genotype performance and have a key role in assessment of stability of the breeding materials (Moldovan *et al.,* 2000).

Several statistical models have been proposed for studying the GEI effect and exploiting its positive part in variety development process. The practical utility of different statistical models to explain GEI and facilitate variety release decision has been extensively reviewed and published (Ferreira *et al.,* 2006; Hussein *et al.,* 2000; Zobel *et al.,* 1988). However, not all of them are always effective enough in analyzing the multi-environment data structure in breeding program (Navobi *et al.,* 2006; Zobel *et al.,* 1988). The Additive Main Effects and Multiplicative Interactions (AMMI) and Genotype x Environment Interaction (GGE) biplot models are defined as powerful tools for effective analysis and interpretation of multi-environment data structure in breeding programs (Zobel *et al.,* 1988, Ebdon and Gauch, 2002; Samonte *et al.,* 2005). The objective of this experiment was to apply GGE biplot models to evaluate the magnitude of GEI effect on bread wheat grain yield and identify the best performing genotype for selection.

Materials and Methods

A total of twenty bread wheat genotypes: Eighteen advanced bread wheat genotypes, including Sanete (standard. check) and Mada walabu (Local check) were considered in this study as planting materials. The experiment was evaluated at three locations viz. Sinana, Agarfa and Goba for two consecutive years during 2017 and 2018 main cropping season. Each year, each location was considered as a separate environment, making totally six test environments for this study. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The plot size was 6 rows of 0.2 m spacing between rows and 2.5 m length (giving a gross plot area of 3 m^2 and net plot area of 2 m^2). Seed rate of 150 kg ha^{-1} and fertilizer rate of 41/46 N/P_2O_5 $kgha^{-1}$ respectively was used. The detail descriptions of the twenty test genotypes included in this study are given in Table 1.

Table 1. Lists of bread wheat genotypes used in this study along with their pedigrees/selection history.

SN	Genotype code	Genotypes
1	G1	KINDE/4/CMH75A.66//H567.71/5*PVN/3/AERI
2	G2	Sanate
3	G3	CHYAK/RL6043/3*GEN C
4	G4	C80.1/3/BATAVIA//2*WBLL1/3/C80.1/3*QT4522//
5	G5	BLOUK#1/DANPHE#1BECARD
6	G6	PASTOR//HXL7573/2*BAU/3/WBLL1/4/1447/PASTOR
7	G7	WBLL1*2/BRAMBLING/5/BABAX/LR42//BABAX*2/4/
8	G8	WBLL1*2/BRAMBLING/5/BABAX/LR42//BABAX*2/4/
9	G9	T.DICOCCON PI254157/AE.SQUARROSA(879)/4/
10	G10	MOUKA-4/RAYON
11	G11	FLORKWA2/6/SAKER'S'/5/ANZA/3/KVZ/HYS//YMH/TOB/4/BOW'S'/7/DAJAJ-
12	G12	KUAZ/PASTOR//FLAG-4
13	G13	RANA96/SIDS-1
14	G14	Mada walabu
15	G15	ETBW7670
16	G16	ETBW6435
17	G17	ETBW6861
18	G18	ETBW8469
19	G19	ETBW8146
20	G20	WAXWING//PFAU/WEAVER/3/FRNCLN

Statistical analysis

The grain yield data was subjected to analysis of variance using Genstat software 18th edition. Homogeneity variance was tested and combined analysis of variance was done using the Genstat procedure to partition the total variation into components due to genotype (G), environment (E) and G × E interaction effects. The following model was used for combined ANOVA:

$$Y_{ijk} = \mu + G_i + E_j + GE_{ij} + B_{k(j)} + \epsilon_{ijk}$$

Where: Y_{ijk} is an observed value of genotype i in block k of environment j; µis a grand mean; G_i is effect of genotype i; E_j is an environmental effect; GE_{ij} is the interaction effect of genotype i with environment j; $B_{k(j)}$ is the effect of block k in environment j; ϵ_{ijk} is an error effect of genotype i in block k of environment j.

Results and Discussions

Genotype performance

Homogeneity variance was tested by using Bartlett's test and it indicated homogenous error variance for grain yield in the six environments and hence allowed for a combined analysis across environments. The result of combined analysis of variance for gain yield (t ha^{-1}) of the twenty bread wheat genotypes tested across six environments showed highly significant differences ($p \leq 0.01$) for genotypes, environment and GE interaction. The environmental effect accounted for 67.8% of the total yield variation, whereas, genotype and G × E interaction effects accounted for 29.6% and 2.6% of the total variation, respectively. This shows that grain yield of bread wheat genotypes were found to be significantly affected by changes in the environment, followed by genotypic effects and G × E interaction (Table 3). This in turn indicates that, the effect of environment in the GE interaction, genetic variability and possibility of selection for stable genotypes (Table 3). Previous reports for bread wheat also indicated that the environmental effect accounted for the largest part of the total variation (Hintsa *et al.*, 2011; Mohammadi *et al.*, 2017).

The average environmental mean grain yield across genotypes ranged from the lowest of 0.48 t ha^{-1} (G10) at Agarfa 2017 to the highest of 5.91 t ha^{-1} (G16) at Goba 2017, with a grand mean of 3.55 t ha^{-1} (Table 2). Thirteen bread genotypes gave higher mean grain yield than the grand mean. In general, G11, G13 and G20 gave the highest grain yield, while G10 and G11 had showed lowest mean yield performance across environments.

Table 2. Mean Grain yield (t ha^{-1}) performance of twenty bread wheat genotypes in six Environments

SN	**Genotype Code**	**Year 2017**			**Year 2018**			**Mean**
		Sinana	**Agarfa**	**Goba**	**Sinana**	**Agarfa**	**Goba**	
1	G1	4.18	3.28	3.85	3.57	2.74	2.83	3.41
2	G2	4.71	3.50	5.81	2.01	2.76	**4.27**	3.84
3	G3	3.81	3.45	3.84	2.98	2.91	2.81	3.30
4	G4	5.06	3.51	5.02	3.35	3.19	3.03	3.86
5	G5	4.30	3.51	5.41	3.43	2.79	3.38	3.56
6	G6	4.56	2.84	4.13	3.91	3.29	3.93	3.78
7	G7	1.94	3.46	4.83	3.56	3.49	2.71	3.83
8	G8	4.65	2.94	4.72	3.68	3.43	3.74	3.86
9	G9	4.64	2.20	4.62	2.71	3.42	3.58	3.53
10	G10	1.17	0.48	0.62	1.19	1.82	1.35	1.10
11	G11	5.01	3.56	5.09	4.15	**3.82**	3.94	**4.26**
12	G12	4.07	2.80	4.15	2.99	2.60	3.58	3.36
13	G13	4.13	**4.54**	5.28	4.12	3.40	3.68	**4.18**
14	G14	3.01	0.97	1.71	2.35	1.50	2.07	1.93
15	G15	4.52	2.82	4.78	3.43	3.03	3.33	3.65
16	G16	4.76	3.26	**5.91**	3.41	2.64	3.54	3.92
17	G17	4.88	3.60	5.78	3.31	3.14	3.80	4.09

18	G18	3.36	3.16	4.62	3.74	2.82	3.20	3.48
19	G19	4.50	2.67	4.60	3.46	3.48	3.55	3.71
20	G20	**5.76**	3.47	4.03	**5.00**	3.30	4.06	**4.27**
Mean		5.02	3.00	4.44	3.32	2.98	3.32	3.55
CV(%)		10.7	22.5	20.7	20.6	20.3	14.2	24.6

CV (%): Coefficient of variation

AMMI Analysis

The application of AMMI model for partitioning of GEI (Table 3) revealed the first two terms of AMMI were significant at ($P<0.05$) using an approximate F-statistic (Gollob,1968). These two multiplicative component sums of squares, with their cumulative degrees of freedom of 44, were captured 66.7% of the G × E interaction sum of squares. In this study, the proportion of the first interaction Principal Component Axis sum of squares (IPC1 = 43.7%) to the interaction sum of squares was far greater than that of the second interaction principal component (IPC2 = 23. 0%) (Table 3). This indicated that the existence of different yield responses among these genotypes across the testing environments due to the presence of significant G × E interaction effect (Tamene, 2015). Therefore, in order to identify a genotypes with specific or relatively broader adaptation, studies on the magnitude and patterns of G × E interaction effect is important in highlands of Bale.

Table 3. Combined and AMMI analysis of variance and contributions of the principal components for grain yield of 20 bread wheat genotypes in 6 environments

Source of variation	Degree of freedom	Sum square	Mean square	SS%
Environment	5	119.50	23.89**	67.8
Genotypes	19	198.16	10.43**	29.6
Interactions	95	87.54	0.92**	2.6
AMMI 1	23	42.38	1.84**	43.7
AMMI 2	21	20.46	0.97*	23.0
AMMI 3	19	12.78	0.67ns	15.9
AMMI 4	17	6.93	0.40ns	9.5
AMMI 5	15	4.99	0.33ns	7.8
Residuals	51	150.83	0.63	
Error	228	121.80	0.53	
Total	359	556.0	1.55	

AMMI= additive main effect and multiplicative interaction, ns = not significant, * and ** significant at the 0.05 and 0.01 probability level, respectively.

Test for AMMI indicated that, AMMI with only the first two multiplicative component axes were adequate for cross-validation of the variation explained by the G × E interaction (Zobel Gauch and 1996; Zobel *et al.*, 1988 and Tamene, 2015). The present investigation has also revealed that, the first two multiplicative components of the interaction term AMMI 1 and AMMI 2 were significant at $p \leq 0.001$ and $p \leq 0.05$, respectively (Table 3). Thus, the interaction pattern of the twenty bread wheat genotypes with 6 environments was best cross-validated with the first two multiplicative terms of genotypes and environments that easily visualized with the aid of a biplot (Figure 1).

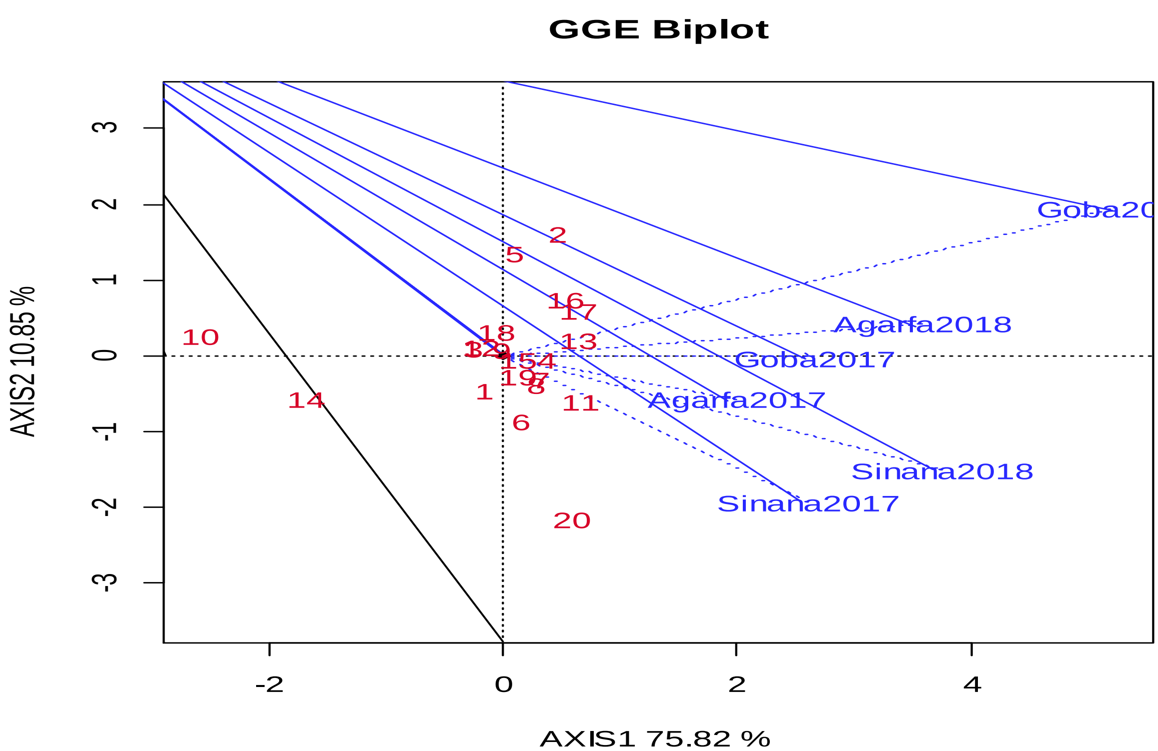


Figure 1: AMMI biplot analysis showing the mega-environments and their respective high yielding genotypes.

Genotype stability and Environment Evaluation

AMMI biplot where genotypes and environments are depicted as points on a plane is shown on Figure 1. The abscissa showed the main effects and the ordinate showed the first multiplicative axis term (PCA1). The horizontal line showed the interaction score of zero and the vertical lines indicated the grand mean yield (t ha^{-1}). Displacement along the vertical axis indicated interaction differences between genotypes and between environments, and displacement along the horizontal axis indicated difference in genotype and environment main effects. The genotypes with PCA1 scores close to zero expressed general adaptation whereas the larger scores depicted more specific adaptation to environments with PCA1 scores of the same sign (Ebdon and Gauch, 2002). Accordingly, genotypes G3, G12, G18, G9, G15, G19, G7, G8, G11 and G13 with their relative IPC1 scores close to zero, have less response to the interaction and showed general adaptation to the test environments. Genotype G20 with larger PCA1 score was better adapted to Sinana in 2017 with larger and same sign PC1 score (Figure 1) which combination results in a larger positive interaction. In contrast, G2, G16, G5 and G17 with the larger negative IPC1 scores were adapted to environment Goba 2018 (Figure 1). The best genotype should hold high yield with stable performance across a range of environments. Based on this, genotypes, G11 and G13 were had the highest mean yield over test environments (Table 2) with demonstrated low IPC1 scores (Figure 1) and are hence considered as the most stable genotypes with relatively less variable yield performance across environments (Figure 1).

Sinana and Agarfa had the relatively smaller variation in the interaction (PC1 score) between the two years while Goba had the largest interaction value (Figure 1). This indicated that, the relative ranking of genotypes were stable at Sinana and Agarfa as compared to at Goba. Goba is described as a location that combined larger main effects with larger interaction effects making it less predictable location for bread wheat genotypes evaluation.

AMMI 2 biplot was generated using genotypic and environmental scores of the first two AMMI multiplicative components to cross-validate the interaction pattern of the twenty bread wheat genotypes within six environments (Figure 2). Connecting vertex genotypes markers in all direction forms a polygon, such that all genotypes are contained within the polygon and a set of straight lines that radiate from the biplot origin to intersect each of the polygon sides at right angles form sectors of genotypes and environments (Hernandez and Crossa, 2000; Yan, 2011). Based on AMMI2, a biplot with six sections were observed depending upon signs of the genotypic and environmental IPC scores (Figure 2).

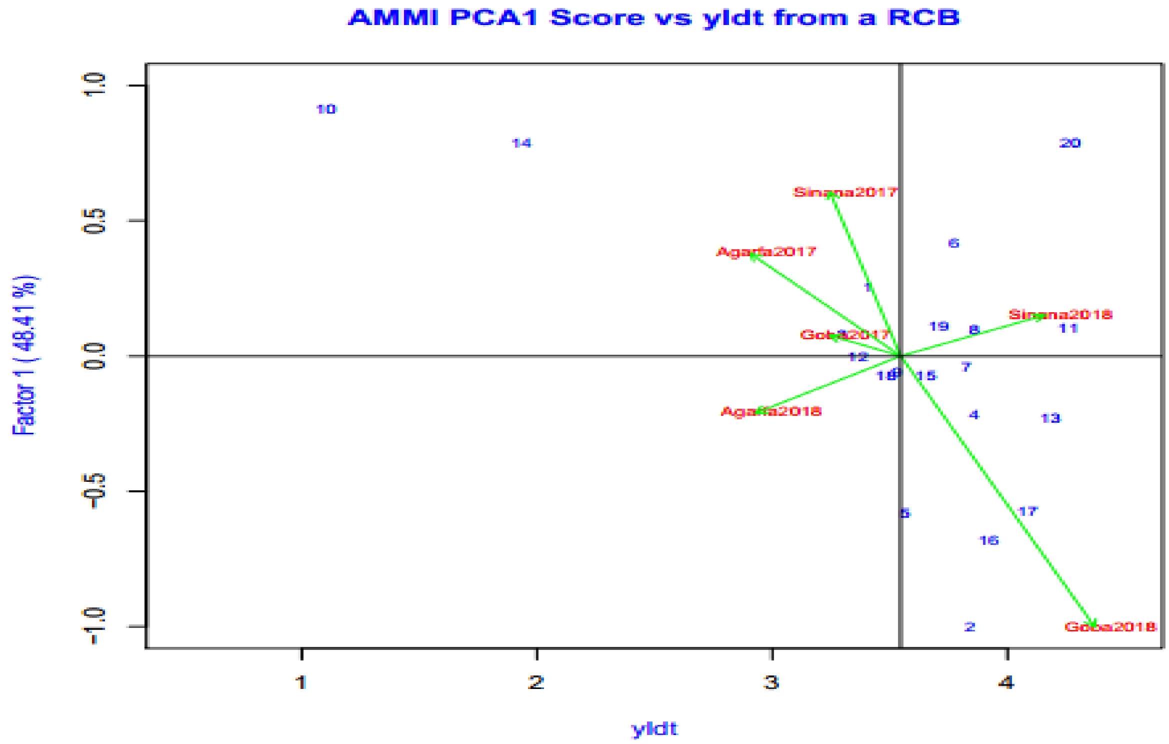
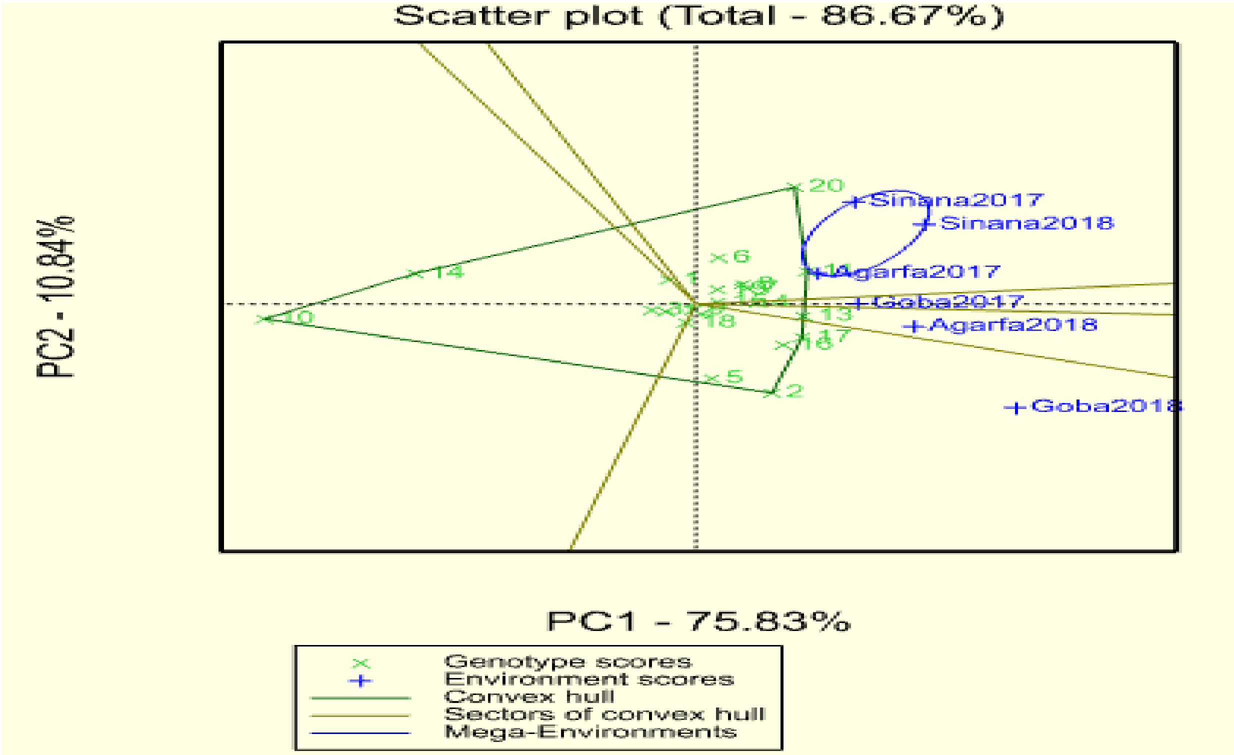


Figure 2: AMMI1 biplot showing the mean (main effect) vs. stability (IPC1) view of both genotypes and environments on grain yield.

The vertex cultivars in each sector are considered best at environments whose markers fall into the respective sector. Environments within the same sector are assumed to share the same winner genotypes. Genotype-environment affinity depicted as orthogonal projections of the genotypes on the environmental vectors to identify the best cultivars with respect to environments. The best genotype with respect to environment Sinana 2017 and Sinana 2018 was genotype G20. Genotypes G2, G16 and G17 were better adapted to environments viz. Goba 2018 and Agarfa 2018, respectively. Similarly, G11 and G13 were better adapted to Agarfa 2017 (Figure 3).



Conclusions and recommendations

To develop varieties it is very essential for breeders to evaluate their genotypes at multi-location based on years and locations. Environmental variations are important in determining performance of elite materials. This study also clearly demonstrated the GGE biplot model was found effective for determining the magnitude and pattern of G × E interaction effect. It visualized the yielding ability and stability of wheat genotypes of the test environments. Goba 2018 is the most representative environment and it was good environment to evaluate genotypes. G20 was high yielder but unstable genotype across tested locations. G11 and G13 are high yielder than the G2 (Sanata st.check) and stable across tested locations. Therefore these genotypes were recommended as candidate varieties for next year for release as a variety.

Reference

Annicchiarico P., 1997 Additive main effects and multiplicative interaction (AMMI) analysis of genotype location interaction in variety trials repeated over years. Theoretical and Applied Genetics 94(8): 1072-1077.

Berhane G., Paulos Z., Tafere K., and Tamiru S. 2011. Food grain consumption and calorie intake patterns in Ethiopia. ESSP II Working Paper No. 23, International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.

CSA (Central Statistical Authority). 2017. Agricultural sample survey 2016/17. Report on area and production of major crops for private peasant holdings, meher season. Statistical 584(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, meher season. Statistical 584(1), Central statistical agency, Addis Ababa, Ethiopia.

Ebdon J.S., Gauch H.G., (2002). Additive main effect and multiplicative interaction analysis of national turf-grass performance trials: Crop Sci. 42: 489-496.

FAO (Food and Agriculture Organization). 2014. Food balance sheets. Rome: FAO. Accessed at http://faostat.fao.org/site/368/DesktopDefault.

FAO (Food and Agriculture Organization). 2018. Food balance sheets. Rome: FAO.

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

Gauch G.H., Zobel R.W., (1996) . AMMI Analysis of Yield Trials. In: Genotype-by Environment Interaction, Kang MS, GauchHG. (Eds.). Taylor and Francis, Boca Raton, FL., 1996; 85-122.

Hawkesford, M.J., Araus, J., Park, R., Derini, D.C., Miralles, D., Shen, T., Zhang, J. and Parry. M.A.J. 2013. Prospects of doubling global wheat yields. *Food and Energy Security* 2: 34-48.

Hernandez M.V., Crossa J. (2000). The AMMI analysis and graphing the biplot. Biometrics and Statistics Unit, CIMMYT, Mexico, March 2000. http://repository.cimmyt.org:8080/xmlui/bitstream/handle/10883/585/73247.pdf.

Hintsa G., Mariam A.H., and Belay T., (2011). Genotype by Environment interaction and grain yield stability of early maturing bread wheat (*Triticum aestivum* L.) genotypes in the drought prone areas of Tigray region, Northern Ethiopia. EJAST. 1(2):3-7.

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

Mehmet A., and Telat Y., (2006) Adaptability performance of some bread wheat (*Triticum aestivum* L.) genotypes in the Eastern region of Turkey. Turk Int J Sci & Technol 1(2): 82-89.

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

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

Samonte SOP, Wilson LT, McClung AM, Medley JC. Targeting cultivars onto rice growing environments using AMMI and SREG GGE biplot analyses. Crop Sci. 2005; 45: 2414-2424.

Shiferaw B, Smale M, Braun HJ, Duveiller E, Reynolds M, MurichoG. (2013). Crops that feed the world 10. Past successes and future challenges to the role played by wheat in global food security. Food Security, 5: 291-317.

Tamene T., Tolessa., (2015) Application of AMMI and Tai's Stability Statistics for Yield Stability Analysis in Faba bean (Vicia faba L.) Cultivars Grown in Central Highlands of

Ethiopia. Journal of Plant Sciences. Vol. 3, No. 4, 2015, pp. 197-206. doi: 10.11648/j.jps.20150304.15

Yan W., (2011). GGE biplot vs. AMMI graphs for genotype-by environment data analysis. J. Indian Soc. Agric. Stat. 2011; 65: 181-193.

Zobel RW, Wright MJ, Gauch HG.(1988) Statistical analysis of a yield trial. Agron. J. 1988; 80: 388-393.

Stability Analysis of Bread Wheat Genotypes Using the AMMI Stability Model

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Abstract

Ethiopia is the largest wheat producer in Sub- Saharan Africa. The productivity of wheat has increased in the last few years in the country, but low as compared to other countries. This low productivity is attributed to a number of factors including biotic, abiotic, shortage of high yielding and stable varieties. The objective of the present study is to identify high yielding and stable bread wheat genotype. A total of twenty bread wheat genotypes including Dambal (st. check) and Mada walabu (Local check) were evaluated for two cropping season of 2017 and 2018 at four locations viz.Sinana, Agarfa, Goba and Gololcha. The experiment was laid out in Rondomized Complete Block Design (RCBD) with three replications. The result of combined analysis of variance showed highly significant differences for genotypes, environment and GE interaction. The result of AMMI analysis indicated that, 36.3 %, of the total variability was attributed to environment, 28.6% to genotypes and 34.9% to GE interaction whereas, IPCA 1 and IPCA 2 both captured about 74.2% of the total GE effects. Based on Genotype Selection Index (GSI), a single criteria for stability and high grain yield, genotypes such as G9, G1, G14,G10, G15 and G12 had showed the smallest genotype superiority index which means they were stable and high yielding genotypes. The best genotype with respect to environment Gololcha 2017 and Gololcha 2018 was genotype G10. Genotypes G3 and G17 were better adapted to environment of Agarfa 2017. G12 is high yielder stable across tested locations. Therefore genotype G12 is identified as candidate genotypes to be verified for possible release in the coming cropping season.

Key words: AMMI, ASV, GSI, IPCA, Stabile Genotype

Introduction:

Ethiopia is leading wheat producer in Sub Saharan Africa with a total wheat production of 4.64 million tons during 2018 cropping season (CSA, 2018). Besides, Oromia National Regional State contributes a total production of 2.67 million tons of wheat production in the country. Among the wheat producing zones of Oromia, Arsi, West Arsi and Bale are considered as the wheat belts of Eastern Africa. Although the productivity of wheat has increased in the last few years in the country, it is still very low as compared to other wheat producing countries in other parts of the world. The national average of wheat productivity is estimated to be 2.74 t ha^{-1} (CSA, 2018), which is below the world average of 3.0 t ha^{-1} (Hawkesford *et al*., 2013). This low productivity is attributed to a number of factors including biotic, abiotic, shortage of high yielding and stable varieties.

In most of the plant breeding programs, GE interaction effects are of special interest for identifying the most stable genotypes, mega-environments and other adaptation targets. Various methods for yield stability analysis are based on different stability concepts and can be classified accordingly (Flores *et al.,* 1998). Information regarding crop stability is applicable for selection of genotypes with constant yield across environments. Many of researchers have been reported to depict the responses of genotypes to the different condition of environments for simultaneous selection of yield and stability. These techniques use statistical parameters to estimate stability of genotypes to variation in environments. Linear regression approach is used widely for identifying of high yielding and stable genotypes (Alberts, 2004).

The additive Main Effect and Multiplicative Interaction (AMMI) method is an approach for evaluation of genotypes stability under different environments. The AMMI method merges Principal Components Analysis (PCA) and Analysis of Variance (ANOVA) into an integrated approach and can be used to analyze the multi-location experiment trias (Zobel *et al.,* 1988). The AMMI analysis is effective because it provides agronomically meaningful interpretation of data (Gauch, 1992). The AMMI model can be utilized for three main purposes (Gauch, 1988; Crossa *et al.,* 1990): (i) useful in the initial stage of statistical analyses of yield experiments, (ii) to summarize the relationships between genotypes and environments (GE) and (iii) applicable for understanding the nature of complex genotypes × environment interaction effects. AMMI analysis has been applied extensively with great success to interpret genotype × environment interaction in wheat (Petrovic *et al.,* 2010; Mohammadi *et al.,* 2013). In any breeding program, including identifying high yielding and stable wheat varieties in multilocational trials, evaluation of a number of germplasm is necessary and a prerequisite. Accordingly, Sinana agricultural research center of wheat breeding program conduct multilocation trials on wheat in different wheat production areas before releasing wheat variety to see the over location performance of the candidate genotypes for possible release. Hence, the objective of this study was to select high yielding and stable bread wheat genotypes/genotype for possible release.

Materials and Methods:

Experimental Design and Methods

The experiment was conducted at four locations during 2017 and 2018 main cropping season viz. at Sinana, Agarfa, Goba and Gololcha which are the major wheat growing areas in the highlands of Bale zone. The detailed description of environments is presented in Table 1. A total of twenty bread wheat genotypes which includes eighteen advanced bread wheat genotypes, one standard check (Dambal) and one local check (Mada walabu) were tested as test materials. The experimental materials were laid out in Randomized Complete Block Design (RCBD) with three replications. A plot size of 6 rows with row spacing of 0.2 meter and row length of 2.5 meter was used and the four middle rows were used for data collection and analysis. Seed rate 150 kg ha^{-1} was used and drilled manually to the six rows. Fertilizer rates of 41 kg ha^{-1} N and 46 kg ha $P_2 O_5$ were applied at planting. Other agronomic practices were applied as per the recommendation for the crop.

Table 1. Descriptions of the Experimental areas

Location	Altitude (m)	Latitude	Longitude
Sinana	2404	07 09.49’	40 13.77’
Agarfa	2486	07 15.29'	39 54.44'
Goba	2565	07 03.22'	39 59.04'
Gololcha	1970	07 45.04’	40 57.29’

Statistical analysis

Mean grain yield data of the experiment were statistically analyzed using AMMI model analysis. This analysis consists of the sequential fitting of a model of analysis of experiments, initially by ANOVA (additive fitting of the main effects) and then by analysis of Principal Components (multiplicative fitting of the effects of interaction). The AMMI model equation is:

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

Where ij Y is the yield of the i^{th} genotype in the j^{th} environment; μ is the grand mean; i g and je are the genotype and environment deviations from the grand mean, respectively; λ_n is the square root of the eigen value of the principal component Analysis (PCA) axis, α_{ni} and Y_{nj} are the principal are the principal component scores for the PCA axis n of the i^{th} genotype and j^{th} environment, respectively and R_{ij} is the residual. The analysis was done using GEA-R software (Genotype x Environment analysis with R for windows) version 4.1.

AMMI Stability Value (ASV)

The ASV is the distance from the coordinate point to the origin in a two dimensional of IPCA1 score against IPCA2 scores in the AMMI model (Purchase *et al.,* 2000). Because of the IPCA1 score contributes more to the GE interaction sum of square, a weighted value is needed. This weight is calculated for each genotypes and environment according to the relative contribution of IPCA1 to IPCA2 to the interaction SS as follows,

$$\text{ASV}=\sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1score)\right]^2+[IPCA2]^2}$$

Where, SSIPCA1/SSIPCA2 is the weight given to the IPCA1 value by dividing the IPCA1 sum squares by the IPCA2 sum of squares. The larger the IPCA score, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller IPCA score indicate a more stable genotype across environment.

Genotype Selection Index (GSI)

Based on the rank of mean grain yield of genotypes (RY) across environments and rank of AMMI Stability Value (RASV) a selection index GSI was calculated for each genotype which incorporate both mean grain yield and stability index in a single criterion (GSI) as suggested by Bose *et.al*., (2014) and Bavandpori *et.al*., (2015) as indicated as: **GSI = RASV + RY**

Results and Discussions

The results of homogeneity tests of variance indicated that, error variance for grain yield in the eight environments were homogenous and allowed for a combined analysis across environments. The combined analysis of variance (Table 3) indicated that, the main effects of random environments and fix genotypes were significant for grain yield that exhibiting the presence of variability in genotypes and diversity of growing conditions at different environments. The combined analysis of variance was conducted to determine the effects of environment (location by year combination), genotype, and their interactions on grain yield of bread wheat genotypes

(Table 3). The main effects of environment (E), genotypes (G) and GE interaction were highly significant at $P < 0.01$. Environment had the largest effect, explaining about 74.6% of total variability, while genotypes and GE interaction explained 21.6 and 3.8% of total sum of squares, respectively (Table 3). A large contribution of the environment indicated that, environments were diverse, with large difference among environmental means causing most of the variation in grain yield and higher differential in discriminating the performance of the genotype. The same result was also reported by Farshadfar, (2008), Jacobsz *et al.,* (2015) and Tadele *et al.,* (2017).

Mean grain yield of genotypes was highest at Gololcha in 2018 main cropping season, and at Sinana in 2017 main cropping season. Similarly, mean grain yield of genotypes was lowest at Agarfa in 2018 main cropping season (Table 2). Genotype G5 was the highest yielding genotype at Goba 2017 and the lowest at Agarfa during 2017main cropping season. Genotypes such as G12, G19 and G10 gave 13.2, 4.7 and 1.2 tha^{-1} grain yield advantage over standard check (G5) respectively, while they gave 86.1, 72.2 and 66.4 tha^{-1} grain yield advantage over local check (G11), respectively (Table 2).

Table 2. Mean performance of 20 bread wheat genotypes in 8 Environments

SN	Genotype Code	Year 2017				Year 2018				Mean
		Sinana	Agarfa	Goba	Gololcha	Sinana	Agarfa	Goba	Gololcha	
1	G1	4.2	3.4	5.6	4.7	3.6	3.1	4.3	4.0	4.11
2	G2	4.4	3.5	5.1	4.2	3.3	3.1	3.5	4.4	3.95
3	G3	3.6	3.9	4.6	3.6	3.7	3.6	4.4	3.9	3.91
4	G4	4.3	3.4	4.6	4.7	3.6	3.3	3.4	5.1	4.05
5	G5	5.2	3.5	5.8	4.2	3.3	3.5	3.4	5.2	4.26
6	G6	4.3	4.0	4.7	3.4	3.0	3.0	3.5	5.1	3.89
7	G7	4.2	4.2	3.8	4.0	2.6	3.4	3.6	4.8	3.85
8	G8	4.7	3.9	4.9	3.5	2.7	3.0	3.2	4.4	3.78
9	G9	4.7	4.0	4.3	3.9	2.3	3.7	4.0	5.1	4.00
10	G10	4.4	5.2	4.9	4.0	3.0	3.5	4.6	5.0	4.31
11	G11	2.8	0.8	1.8	4.8	2.1	1.4	1.8	5.2	2.59
12	G12	5.5	5.5	5.4	4.4	3.6	3.7	5.1	5.3	4.82
13	G13	5.3	3.6	4.2	3.5	3.0	2.9	3.1	4.7	3.78
14	G14	3.9	3.9	3.9	3.8	2.9	2.7	3.4	4.4	3.61
15	G15	4.7	4.8	4.3	3.9	3.5	2.9	3.8	4.5	4.06
16	G16	4.1	3.2	3.9	3.9	2.7	2.6	4.4	4.3	3.63
17	G17	4.2	4.6	4.1	3.7	3.7	2.9	4.6	4.2	3.99
18	G18	2.6	2.6	1.9	3.8	2.8	2.2	3.5	4.1	2.97
19	G19	5.3	4.9	5.3	3.7	3.9	3.6	4.5	4.4	4.46
20	G20	4.4	3.8	3.0	3.8	3.3	2.2	3.8	4.2	3.63

AMMI model analysis: in AMMI model, principal component analysis is based on the matrix of deviation from additivity or residual was analyzed. In this respect, both the results of AMMI analysis, the genotypes and environment were grouped based on their similar responses (Gauch, 1992; Pourdad and Mohammadi 2008; Tadele *et al.*, 2017). The result of AMMI analysis also showed that the first principal component axis (IPCA1) accounted for 49.2% over the interaction SS, IPCA 2, IPCA 3 and IPCA 4 which explained 25.0%, 15.8% and 10.0% of the GE interaction Sum of Squares respectively. The first two IPCA scores were significant at (P<0.01%) and cumulatively accounted for 74.2% of the total GE interaction. This indicates that the use of AMMI model fit the data well and justifies the use of AMMI2.

Table 3. ANOVA for grain yield of Bread wheat genotypes for the AMMI model

Source	d.f.	SS	MSS	SS%
Genotypes	19	108.2	5.69**	21.6
Environments	7	137.5	19.64**	74.6
Block	16	14.6	0.914*	
Interactions	133	132.7	0.998**	3.8
IPCA 1	25	61.8	2.47**	49.2
IPCA 2	23	31.4	1.37**	25.0
IPCA 3	21	19.8	0.94**	15.8
IPCA 4	19	12.5	0.66*	10.0
Residuals	85	39.6	0.465	
Total	479	538.9	1.125	

d.f.=degree freedom, SS= Sum of square, MSS= Mean Sum of square, SS%= Percentage of sum of square, IPCA 1, 2, 3 and 4= first, second, third and fourth principal component

AMMI Stability Value (ASV): ASV is the distance from zero in a two dimensional scatter gram of IPCA1 scores against IPCA2 scores. Since the IPCA1 score contributes more to the GE sum of square, it has to be weighted by the proportional difference between IPCA1 and IPCA2 scores to compensate for the relative contribution of IPCA1 and IPCA2 to the total GE interaction sum squares. According to this stability parameter, a genotype with the least ASV score is the most stable. The high interaction of genotypes with environments was also confirmed by high ASV value and difference in their rank order, suggesting unstable yield across environments. In general, the importance of AMMI model is in reduction of noises even if principal components didnot cover much of the GE Sum of Squares (Gauch, 1992; Gauch and Zobel 1996).

Results of ASV parameter showed, genotypes such as G9, G14, G7 and G16 as the most stable genotypes, respectively. The most unstable genotypes were G11 and G18 (Table 4). Although, ASV parameter was reported to produce a balanced measurement between the two first IPC's (IPC1 and IPC2) scores, however, it seems that, this parameter is useful when the portion of explained total variation was relatively high (Sabaghnia *et al.,* 2008). In most of the times, genotypes showed inconsistency in rank of grain yield across different tested environment i.e, genotype ranked first in one environment may not be first in another tested environment. Hence, it is advantageous to look for single criteria which help researchers to identify elite genotypes simultaneously for their high yielding and stable across tested environment. GSI (Genotype Selection Index) is a single criteria for stability and high grain yield which successfully used by Bose *et.al*., (2014) and Bavandpori *et.al*., (2015) to interpret interaction between genotype performance and environments. High yielding genotype with better stability has smallest values of GSI. The smallest Genotype Selection Index (GSI) were exhibited by Genotypes G9 (GSI =9), G1 (GSI =11), G15 (GSI =14) and G10 (GSI =10). These genotypes were high yielder and comparatively stable. The Highest GSI (GSI=40) was exhibited by genotype G11 which was highly unstable and lowest yielding genotype among tested genotypes (Table 4).

Table 4 Mean of 20 genotypes, AMMI stability values, Genotypic selection index and coefficient of variation

Genotype	Mean	ASV	RASV	RYI	GSI	CV%
G1	4.11	0.35	6	5	11	19.7
G2	3.95	0.43	9	10	19	17.7
G3	3.91	0.48	10	11	21	10.0
G4	4.05	0.64	14	7	21	17.7
G5	4.26	0.91	18	4	22	23.3
G6	3.90	0.34	5	12	17	20.2
G7	3.84	0.17	3	13	16	17.0
G8	3.78	0.62	13	14	27	21.4
G9	4.02	0.12	1	8	9	20.5
G10	4.30	0.57	12	3	15	18.2
G11	2.59	2.35	20	20	40	61.2
G12	4.83	0.64	15	1	16	16.7
G13	3.78	0.39	7	15	22	22.7
G14	3.61	0.12	2	17	19	15.8
G15	4.05	0.42	8	6	14	16.6
G16	3.63	0.27	4	16	20	19.5
G17	4.00	0.74	16	9	25	14.4
G18	2.93	1.23	19	19	38	26.6
G19	4.45	0.88	17	2	19	15.7
G20	3.58	0.56	11	18	29	19.2

ASV= AMMI stability value, RASV=Rank of AMMI stability value, RYI=Rank of yield index, GSI=Genotypic selection index and CV%=coefficient of variation in percentage

The vertex cultivars in each sector are considered best at environments whose markers fall into the respective sector. Environments within the same sector are assumed to share the same winner cultivars. Genotype-environment affinity depicted as orthogonal projections of the genotypes on the environmental vectors to identify the best cultivars with respect to environments. The best genotype with respect to environment Gololcha 2017 and Gololcha 2018 was genotype G10. Genotypes G3 and G17 were better adapted to environment of Agarfa 2017 (Figure 1).

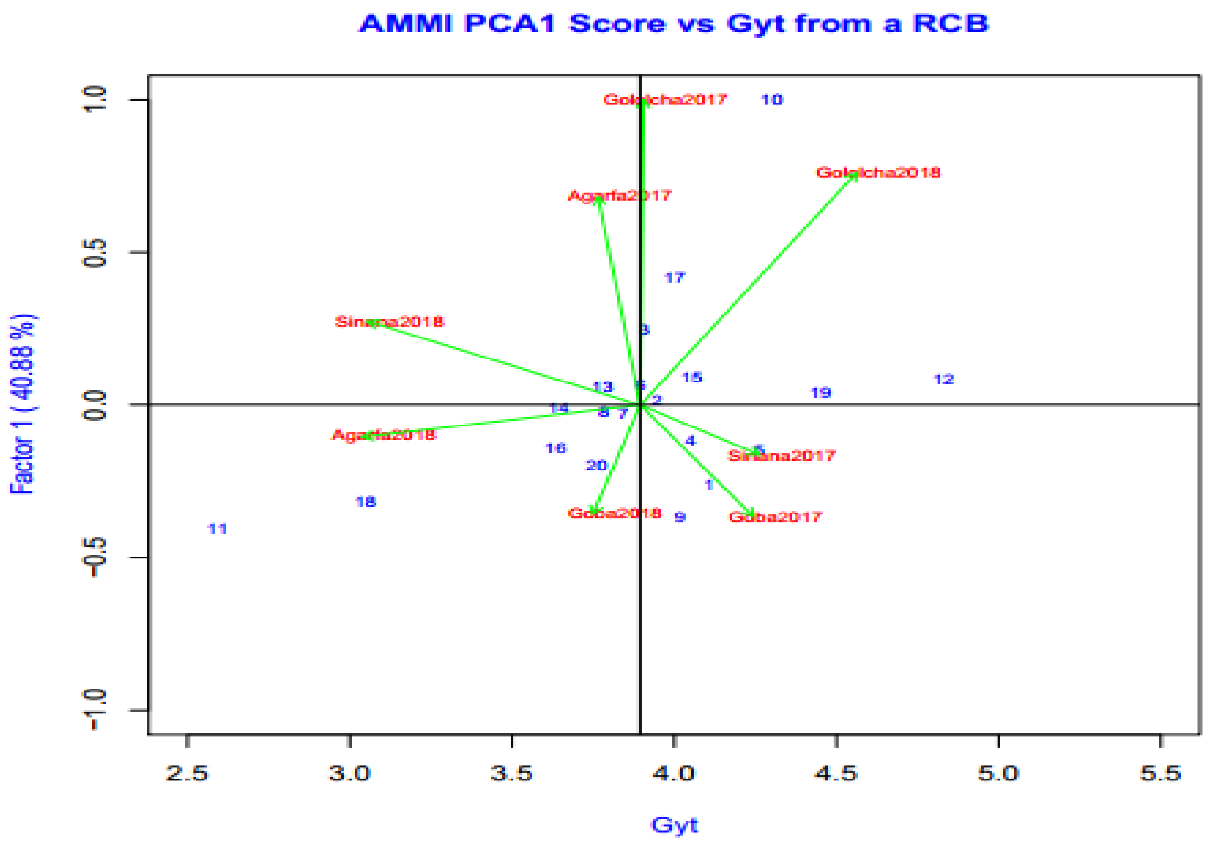

Figure: AMMI biplot showing the mean (main effect) vs. stability (IPC1) view of both genotypes and environments on grain yield

Conclusions and Recommendations

To develop varieties, it is essential for breeders to evaluate their genotypes across years and locations. Both yield and stability performance of the test genotypes should be considered simultaneously to reduce the effect of GE interaction and to make selection of genotypes more precise. For such evaluations, a number of stability analysis statistics were developed by researchers. In this study, different stability parameters were employed to evaluate the yield performance and stability of twenty bread wheat genotypes across different environments. Based on ASV results, genotype with least ASV scores are the stable and hence, genotypes such as G9, G14, G7 and G16 were stable genotypes according to their orders. Based on GSI single criteria for stability and high grain yield genotypes results, genotypes such as G9, G1, G14, G10, G15 and G12 were found to be stable genotypes. Overall, G12 was found as high yielder and stable genotype across tested environments. Hence, this genotype (G12) was identified as the most promising candidate genotype to be verified for possible release in the coming cropping season for these test locations.

References

Alberts, M.J.A. (2004): A comparison of statistical methods to describe genotype × environment interaction and yield stability in multi-location maize trials. Plant Breeding MSc Thesis, University of the free state Bloemfontein. 100 p.

Bavandpori F., Ahmadi J., Hossaini S.M., (2015) Yield Stability Analysis of Bread Wheat Lines Using AMMI Model. Agricultural Communications 3(1):8-15.

Bose L.K., Jambhulkar N.N., Pande K., Sing O.N., (2014). Use of AMMI and other stability statistics in the simultaneous selection of rice genotypes for yield and stability under direct-seeded conditions. Chilean Journal of Agriculture Research 74(1)

CSA (Central Statistical Authority). 2018. Agricultural sample survey 2017/18. Report on area and production of major crops for private peasant holdings, meher season. Statistical 584(1), Central statistical agency, Addis Ababa, Ethiopia.

Crossa, J., Gauch, H.G. & Zobel, R.W. (1990): Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. Crop Sci. 30, 493500

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

Gauch, H.G. (1988): Model selection and validation for yield trials with interaction. Biometrics 44, 705–715.

Gauch H.G.,1992. Statistical anlyis of regional yield trials. AMMI analysis of factorial designs. 1st edn, Elsevier, New York, ISBN: 0-444-89240-0

Gauch H.G., and Zobel R.w., 1996. AMMI analysis of yield trials. In: Kang MS, Gauch HG (eds) Genotype by environment interaction. CRC press Boca Raton FL

Hawkesford, M.J., Araus, J., Park, R., Derini, D.C., Miralles, D., Shen, T., Zhang, J. and Parry. M.A.J. 2013. Prospects of doubling global wheat yields. *Food and Energy Security* 2: 34-48.

Jacobsz M.J., Merwe W.J., and Westhuizen M.M., (2015). Additive Main Effects and Multiplicative Interaction Analysis of European Linseed (*Linum Ustatissimum* L.) Cultivars under South African Conditions. Adv Plants Agric Res 2(3): 00049. DOI: 10.15406/apar.2015.02.00049

Mohammadi, M., Karimizadeh, R. & Hosseinipour, T. (2013): Parameters of AMMI model for yield stability analysis in durum wheat. Agric. Con. Sci. . 78, 119-124.

Petrovic, S., Dimitrijevic, M., Belic, M., Banjac, B., Boskovic, J., Zecevic, V. & Pejic, B. (2010): The variation of yield components in wheat (Triticum aestivum L.) in response to stressful growing conditions of alkaline soil. Genetika, 4(3), 545-555.

Pourdad SS and Mohammadi R. 2008. Use of stability parameters for comparing safflower genotypes in multienvironment trials. Asian J. Plant Sc, i 7: 100-104

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

Sabaghnia, N., Sabaghpour, S.H. & Dehghani, H. (2008): The use of an AMMI model and its parameters to analyze yield stability in multi-environment trials. J. Agric. Sci. 146, 571–581.

Tadele Tadesse, Amanuel Tekalign, Gashaw Sefera, Behailu Mulugeta. (2017). AMMI Model for Yield Stability Analysis of Linseed Genotypes for the Highlands of Bale, Ethiopia. Plant. Vol. 5, No. 6, 2017, pp. 93-98. doi: 10.11648/j.plant.20170506.12

Zobel, R.W., Wright, M.J. & Gauch, H.G. (1988): Statistical analysis of a yield trial. Agron. J. 80, 388–393.

Analysis of Genotype x Environment Interaction Effect and Stability on Yield of Black Cumin (*Nigella sativa* L.) Genotypes.

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Abstract

Black cumin is an erect annual herb cultivated for its seed, growing on all kinds of soils. In Ethiopia black cumin is cultivated as rain fed crop in the highlands from 1500 to 2500 meters above sea level. Genotype × environment interaction and yield stability analysis are important in measuring the genotypic yield stability and suitability for cultivation across seasons and ecological conditions. The objective of this study was to assess the stability of black cumin genotypes under different agro-ecological conditions of East Shoa and West Arsi zones. Fifteen black cumin genotypes were evaluated at six locations in Randomized Complete Block Design (RCBD) with three replications during 2018/19 main cropping season. Analysis of variance for each location revealed the presence of significant differences among genotypes for seed yield. The combined analysis of variance over locations showed significant differences amongst *genotypes. Gammachis variety recorded the highest mean yield (1.35 ton ha^{-1}) followed by variety Dirshaye (1.26 ton ha^{-1}) while genotype 90575-2 recorded the lowest (0.78 ton ha^{-1}) mean seed yield. Additive Main Effects and Multiplicative Interaction (AMMI) analysis of variance had showed that the major part the total variations (41.99%) is attributed to the environmental effects and the rest were attributed to the genotypic effects (31.96%) and the GEI (10.96%). AMMI stability analysis identified variety Dirshaye as the most stable genotype whereas genotype MAB-057 was the most unstable genotype. In general, genotypes (such as Dirshaye, Gammachis, Soressa and Derbera) could recommended for cultivation at all the test locations since they perfomed well as compared to the other tested black cumin genotypes.*

Keywords: Adaptation trials, Black cumin seed, *Nigella sativa*, Seed yield performance

1. Introduction

Black cumin (*Nigella sativa*L.) is a diploid and an erect annual herb cultivated for its seed, growing on all kinds of soils (Jansen, 1981). It is a medicinal plant belonging to the family *Ranunculaceae* grown naturally in Southwest Asia and the Mediterranean region (Toncer and Kizil, 2004). It originated in Egypt and East Mediterranean countries, but is widely cultivated in Iran, Japan, China and Turkey (Shewaye, 2011). *Nigella sativa* is probably indigenous to the Mediterranean region and the Middle East up to India. Black cumin is cultivated in the subtropical belt extending from Morocco to Northern India and Bangladesh, East Africa and in the former Soviet Union. In Europe, North America and South-East Asia, it is cultivated on a minor scale, mainly for medicinal use (Akhtar and Saha, 1993). It is also cultivated in sub-Saharan Africa particularly in Niger, and Eastern Africa especially Ethiopia (Iqbal *et al*., 2010). In Ethiopia, black cumin is cultivated as rain fed crop in the highlands from 1500 to 2500 meters above sea level. In Ethiopia, *Nigella sativa* can be intercropped with barley and wheat (Ahmed and Haque, 1986). However improved production technology must be available (Ministry of Agriculture and Rural Development, 2003).

Black Cumin has a long history of uses for food flavors, perfumes and medicinal values. It is used as an essential ingredient in preparing soup, sausages, cheese, cakes and candies. Studies have shown that *Nigella sativa* seeds have high nutritional values: proteins content ranging from 20 to 27%, carbohydrates ranging from 23.5 to 33.2%, moisture content ranging from 5.52 to 7.43% and ash content ranging from 3.77 to 4.92% (Al-Jassir, 1992; Al-Ghamdi, 2001 and Nergiz and Otles, 1993). It grows on a wide range of soils. Sandy loam soil rich in microbial activity is the most suitable for its cultivation. Areas with moderate rainfall and well drained soils with pH of 7-75 are quite suitable for black cumin production (Orgut, 2007). Some studies shown that black cumin is able to tolerate moderate water stress and responds well to soil fertilization (Mozzafari *et al*., 2000; Bannayan*et al*., 2008).

In Ethiopia, Amara, Oromia, South Nations, Nationalities and Peoples, (SNNP) and Gambella regions are the major growing regions of (Atta, 2003 and Takrun*et al*., 2008).

The productivity of black cumin depends on the genetic potential of varieties and the suitability of environmental factors across production areas. Identification of high yielding and well adapted genotypes is achieved through analyzing the effect of genotype × environment interaction (GEI) and yield stability. Genotype × environment interaction and yield stability analysis are important in measuring varietal stability and suitability for cultivation across seasons and ecological conditions (Romagosa and Fox, 1993). Globally, several stability analysis methods are available, and they have been used in different research efforts to determine the magnitude of GEI effects for many different crops by different researchers (Akcura*et al*., 2005).

Additive Main Effects and Multiplicative Interaction (AMMI) model has found to be more effective in selection of stable genotypes (Crossa*et al.,* 1991; Haji and Hunt, 1999; Ariyo and Ayo-Vaughan, 2000; Taye*et al.,* 2000). It is used to analyze multi-location trials (Gauch and Zobel, 1988; Zobel*et al.,* 1988; Crossa*et al.,* 1990). AMMI integrates the analysis of variance and principal component analysis into a unified approach (Bradu and Gabriel, 1978).

The genetic potential contained within the crop, the environmental effects and their interaction plays a great role in determining the performance and stability of the crop to a given environment. Therefore, the current experiment was conducted with the objective of evaluating and identifying the high yielding, stable, and adaptable black cumin genotypes at Eat Shoa and West Arsi zones.

2. Materials and Methods

2.1. Study Area

The experiment was conducted in East Shoa and West Arsi zones at six locations viz; two sites in East Shoa zone: Adami Tullu Agricultural Research Center (ATARC) on research station at Adami Tullu Jiddo Kombolcha district and Bekele Girrisa kebeles at Dugda district and four sites in West Arsi zone viz. Ali Woyyo, Makko Oda, Bute and Umbure during the 2018/19 main cropping season under rain fed condition. The locations are the representative for the diverse agro-ecologies of spice crops growing environments in East Shoa and West Arsi zones.

Table 1. Description of the test locations used in the study

Locations	Altitude (m.a.s.l)	Average Annual RF (mm)	Soil Types	Global Positions	
				Latitude	Longitude
ATARC	1650	760.9	Sandy, Clay and Silt (34%, 48% and 18%)	7^o 9' N	38^o 7'E
Bekele Girrisa	1600	700-800	Sandy and Clay	7^o58' N	38^o43' E
Ali Woyyo	1960	900	NA	7^o 23' N	38^o 43' E
Makko Oda	1980	920	NA	7^o 33' N	38^o 62' E
Bute	NA	980	Sandy	7^o 23' N	38^o 24' E
Umbure	NA	1057	Sandy	7^o 12' N	38^o 36' E

Key: *'NA' stands for not available and 'ATARC' for Adami Tullu Agricultural Research Center*

2.2. Experimental Materials and Managements

A total of fifteen black cumin genotypes i.e., ten accessions viz; AC-BC-4, AC-BC-9, AC-BC-10, AC-BC-19, MAB-042, MAB-057, 90575-2, 20750-1, 242834-1and 244654-1 along with five standard checks viz; Derbera, Dirshaye, Eden, Gammachis and Soressa that were obtained from Sinana Agricultural Research Center were used in this study. The materials were evaluated using Randomized Complete Block Design (RCBD) with three replications at six locations in the main cropping season of the year 2018/19.

The plot size for each experimental unit was 1.2m × 2m (4 rows, each 2m long).The total area of a plot was $2.4m^2$.The spacing between rows, plots and blocks were 0.35m,0.5m and 1m, respectively. Sowing was done by hand drilling and covered slightly with the soil. Fertilizer rates of 46 kg Di-Phosphorus pent-oxides (P_20_5) ha^{-1} and 60kg Nitrogen (N) ha^{-1} were used to facilitate and increase root development and increases yield in black cumin (Champawat and Pathak, 1982).

2.3. Data Collection and Analysis

The following data were recorded: days to emergence, days to 50% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of capsules per plant, seed yield per hectare (ton ha^{-1}) and thousand seed weight (g). Data were collected from the middle two harvestable rows for traits estimated from a plot. Data were also collected from ten randomly selected plants from the central two rows and the average values were calculated.

All the recorded data were subjected to analysis of variance following the standard procedure for each location and combined analysis of variance over locations and were computed using the Gen-Stat 18th Edition Statistical Computer Software Programs. Bartlett's chi-square test was used to determine the validity of the combined analysis of variance and homogeneity of error variances among environments. Then combined analysis of variance was carried out to estimate the additive effects of environment (E), genotype (G) and their interactions (GEIs).

2.4. Stability Analysis

The additive main effects and multiplicative interaction (AMMI) stability analysis was used to integrate the analysis of variance and principal component analysis into a unified approach. An initial analysis of variance was performed for each environment to verify the existence of differences among the genotypes. Thereafter, 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 GEIs.

Different researchers have been working with AMMI stability analysis as stability measuring parameter for studying the stability of seed yield and quality of different crop genotypes, particularly wheat across various environments (Desalegn *et al*., 2004; Ferney *et al*., 2006; Mohammadi and Amri, 2008; Mohammed, 2009; Mut *et al*., 2010).

The AMMI model used was indicated as follow:

$$\mathbf{Y_{ij} = \mu + G_i + E_j + \sum \lambda_k \, a_{ik} \, Y_{jK} + e_{ij}}$$

Where;

$\mathbf{Y_{ij}}$ is the yield of the i^{th} genotype in the j^{th} environment,

$\boldsymbol{\mu}$ is the grand mean,

$\mathbf{G_i}$ and $\mathbf{E_j}$ are the genotype and environment deviations from the grand mean respectively.

$\boldsymbol{\lambda_k}$ is the eigen value of the interaction principal component axis K;

$\boldsymbol{\alpha_{ik}}$ and $\mathbf{Y_{jk}}$ are genotype and environment principal component scores for axis K

$\mathbf{e_{ij}}$ is the error term.

AMMI Stability Value (ASV), $IPCA_1$ and $IPCA_2$ were computed to identify the stable genotype with consistence yielding performance across the testing environments. The degrees of freedom for the IPCA axes were also calculated based on the following method (Zobel *et al*., 1988).

$$\mathbf{df = G + E - 1 - 2n}$$

Where;

df is degree of freedom

G is number of genotypes,

E is the number of environments and

N is the n^{th} axis of IPCA

The AMMI stability value (ASV), was also calculated for each genotype and each environment as follows according to Purchase *et al*., 2000:

$$ASV = \sqrt{\left[\frac{SS_{1PCA1}}{SS_{1PCA2}}[IPCA1_{score}]\right]^2 + [IPCA2_{score}]^2}$$

Where,

ASV is AMMI stability value

SS is sum of squares and;

$IPCA_1$ and $IPCA_2$ are the first and second interaction principal component axes, respectively

Accordingly, genotypes with the least AMMI stability value (ASV) were considered as the most stable genotypes, where as those which have the highest ASV were considered as unstable (Purchase, 1997).

3. Results and Discussions

The analysis of variance of an individual environment revealed that seed yield showed a highly significant difference (P ≤0.01) at all test environments (Table 2). This indicated that, genotypes might not express the same seed yield performance at a specified test location's environmental conditions; or different genotypes may respond differently to a specified environment. Accordingly, at location Bute, the variety Soressa ranked 1^{st} in its seed yield performance of 1.20 ton ha^{-1}, while the same variety ranked 5^{th} in its seed yield performance of 1.54 ton ha^{-1} at location Makko Oda.

Table 2.Analysis of variance for seed yield of fifteen black cumin genotypes at each of the six test locations

Sources of Variations	**df**	**Sum of Squares**						**F-ratio**
		ATARC	Bekele Girrisa	Ali Woyyo	Makko Oda	Bute	Umbure	
Replication	2	0.005	0.005	0.012	0.003	0.006	0.001	
Genotypes	14	0.137 **	0.125 **	0.047 **	0.22 **	0.07 **	0.061 **	

Error	28	0.003	0.006	0.008	0.005	0.003	0.005	2.667
CV (%)		6.0	8.4	7.2	5.4	5.3	7.3	

Key: ** = *highly significant (P ≤ 0.01) at 1% level of significance, df= degree of freedom*

The highest and the lowest mean seed yield performance of the tested genotypes across the testing environments were 1.35 ton ha^{-1} and 0.78 ton ha^{-1}, which were obtained from genotypes Gammachis and 90575-2 respectively (Table 3).

Table 3.Mean seed yield of fifteen black cumin genotypes tested at six locations

Genotypes	Testing Environments						EM
	ATARC	Bekele Girrisa	Ali Woyyo	Makko Oda	Bute	Umbure	
Derbera	1.00^{bc}	1.02^{cd}	1.35^{abc}	1.61^{a}	1.13^{abcd}	1.12^{ab}	1.204
Dirshaye	1.02^{b}	1.22^{b}	1.41^{ab}	1.57^{ab}	1.17^{abc}	1.14^{ab}	1.256
Eden	0.94^{bc}	1.01^{cd}	1.34^{abc}	1.56^{abc}	1.10^{bcd}	1.05^{bc}	1.165
Gammachis	1.39^{a}	1.36^{a}	1.42^{a}	1.55^{abc}	1.19^{ab}	1.19^{a}	1.350
Soressa	0.95^{bc}	1.12^{bc}	1.34^{abc}	1.54^{abc}	1.20^{a}	1.10^{ab}	1.208
AC-BC-4	0.74^{e}	0.84^{efg}	1.28^{abc}	1.54^{abc}	0.97^{ef}	0.91^{def}	1.046
AC-BC-9	0.71^{ef}	0.72^{gh}	1.22^{cd}	1.55^{abc}	1.08^{cd}	0.97^{cd}	1.041
AC-BC-10	0.92^{cd}	0.95^{de}	1.22^{cd}	1.39^{d}	0.95^{fg}	0.91^{def}	1.057
AC-BC-19	0.67^{efg}	0.77^{fgh}	1.05^{ef}	0.93^{fg}	0.86^{hi}	0.83^{efg}	0.849
MAB-042	0.62^{fg}	0.69^{gh}	1.24^{bcd}	1.43^{cd}	0.81^{i}	0.80^{fg}	0.933
MAB-057	0.97^{bc}	0.93^{de}	1.20^{cde}	1.05^{f}	0.84^{i}	0.75^{g}	0.954
90575-2	0.58^{g}	0.66^{h}	1.00^{f}	0.89^{g}	0.72^{j}	0.84^{efg}	0.782
244654-1	0.85^{d}	0.90^{def}	1.31^{abc}	1.46^{bcd}	1.05^{de}	0.93^{cde}	1.083
242834-1	0.71^{ef}	0.82^{efg}	1.27^{abc}	1.22^{e}	0.88^{ghi}	0.88^{defg}	0.959
20750-1	0.63^{fg}	0.70^{gh}	1.08^{def}	0.90^{g}	0.95^{fgh}	0.77^{g}	0.839
GM	0.85^{f}	0.91^{e}	1.25^{b}	1.35^{a}	0.99^{c}	0.95^{d}	1.048
MSE	0.003	0.006	0.008	0.005	0.003	0.005	0.01
SE(d)	0.041	0.063	0.073	0.059	0.043	0.057	0.06
LSD	0.085	0.129	0.149	0.122	0.089	0.117	0.12
CV (%)	6.0	8.4	7.2	5.4	5.3	7.3	6.60

Key: *ATARC = Adami Tullu Agricultural Research Center, GM = Genotypic means, EM = Environmental means, MSE = Mean square of error, SE (d) = Standard error of difference, LSD = Least Significant Difference. Values with the same letters in a column are not statistically significantly different.*

On the other hand, the combined analysis of variance for seed yield revealed the presence of highly significant difference among genotypes, environments and GEI. This result is in agreement with the finding of Fufa (2018) with the result of combined ANOVA showing highly significant variation ($P \leq 0.01$) among different genotypes evaluated across location for seed yield.

Table 4.Combined analysis of variance for mean seed yield of fifteen black cumin genotypes across locations

Sources of variations	df	Mean Squares	Sum Squares
Total	269		
Locations	5	1.812**	9.061
Genotypes	14	0.4935**	6.896
Blocks (within locations)	12	0.014^{ns}	0.027
G×L	70	0.034**	2.365
Residual	168	0.005	0.864

Key:* *and** stand for significant differences at ($P \leq 0.05$) and ($P \leq 0.01$), respectively; ns for non-significant difference, df= degree of freedom and G×L = Genotype by location interaction*

The mean seed yield values of genotypes averaged across the environments showed that genotype Gammachis had the highest mean yield (1.35 ton ha^{-1}) followed by genotype Dirshaye (1.26 ton ha^{-1}) while genotype 90575-2 had the lowest (0.78 ton ha^{-1}) mean seed yield. This indicates that the test environments were highly variable and showed high contribution in varying the yield performance of black cumin genotypes. The presence of blocking and/or replicating within the testing environments could not influence the yield performance of the tested genotypes. In addition to this, the combined analysis of variance across the locations for seed yield revealed that genotypes, environments, GEI, error variance and block within environments contributed 35.89%, 47.16%, 12.31%, 4.50% and 0.14%, respectively (Table 5).

Table 5.Percent contribution of genotypes, environments, GEI and error sum squares over locations

Traits	G (14)		E (5)		GEI (70)		Blocks (12)		Residual (168)	
	SS	SS (%)	SS	SS (%)	SS	SS (%)	SS	SS (%)	SS	SS (%)
D50%F	40.719	5.73	539.53	75.88	56.082	7.89	0.985	0.14	73.682	10.36
DM	23.719	0.10	23092.163	99.51	37.615	0.16	0.119	0.00	51.882	0.22
PH	2439.02	18.55	6851.42	52.11	1982.01	15.08	4.05	0.03	1870.2	14.23
NPB	184.756	49.15	85.689	22.80	46.756	12.44	0.6	0.16	58.067	15.45
SYPH	6.896	35.89	9.061	47.16	2.366	12.31	0.027	0.14	0.864	4.50

Key: *Values with the same letters have no significant difference and the numbers in the brackets stand for the degree of freedom. D50%F = Days to 50% flowering, DM = days to maturity, PH = Plant height, NPB = Number of primary branches and SYPH = Seed yield per hectare*

AMMI analysis of variance for seed yield of fifteen black cumin genotypes evaluated at six locations indicated that most of the total sum square of the model (41.99%) was attributed to the environmental effects and the rest were attributed to the genotypic effects (31.96%) and the GEI (10.96%) (Table 6).

Table 6.AMMI analysis of variance for seed yield of fifteen black cumin genotypes across locations

Sources of variations	df	Mean Squares	% explained From TSS	% explained From GEI
Total	269	0.0714		
Genotype	14	0.4926**	31.96	
Locations	5	1.8122**	41.99	
Blocks (within locations)	12	0.0055^{ns}	0.31	
GEI	70	0.0338**	10.96	
$IPCA_1$	18	0.0824**	6.87	62.67
$IPCA_2$	16	0.0336**	2.49	22.71
Error	168	0.0049^{ns}	3.82	

Key:*, ** *represent significant at P ≤ 0.05 and P ≤ 0.01, respectively, ns for non-significance, df= degree of freedom, MS = Mean Square and TSS = Total Sum Square*

The observed large sum of square and highly significant mean of square of location showed that, the locations were highly diverse, with large differences among the location means causing most of the variation in seed yield. AMMI stability value (ASV) was calculated for each of the fifteen black cumin genotypes. Accordingly, the variety Dirshaye was the most stable with an ASV value of (0.093) followed by genotypes 242834-1 and Soressa with their ASV value of (0.095) and (0.109), respectively. Genotype MAB-057 was the most unstable with its ASV value of 1.004 followed by genotypes AC-BC-9 and Gammachis with their respective ASV of (0.985) and (0.913) (Table 7).

Table 7.$IPCA_1$ scores, $IPCA_2$ scores and ASV scores of fifteen black cumin genotypes

Genotypes	GM	$IPCA_1$	$IPCA_2$	ASV
Gammachis	1.350 (1)	-0.307	0.341	0.913 (13)
Dirshaye	1.256 (2)	-0.017	0.08	0.093 (1)
Soressa	1.208 (3)	0.039	-0.01	0.109 (3)
Derbera	1.204 (4)	0.12	0.075	0.340 (7)
Eden	1.165 (5)	0.108	0.064	0.306 (5)
244654-1	1.083 (6)	0.12	0.021	0.333 (6)
AC-BC-10	1.057 (7)	-0.018	0.168	0.176 (4)
AC-BC-4	1.046 (8)	0.281	0.046	0.776 (11)
AC-BC-9	1.041 (9)	0.354	-0.113	0.985 (14)

Genotypes	GM	$IPCA_1$	$IPCA_2$	ASV
242834-1	0.959 (10)	0.007	-0.094	0.095 (2)
MAB-057	0.954 (11)	-0.359	0.163	1.004 (15)
MAB-042	0.933 (12)	0.31	0.039	0.857 (12)
AC-BC-19	0.849 (13)	-0.24	-0.218	0.698 (10)
20750-1	0.839 (14)	-0.208	-0.331	0.662 (9)
90575-2	0.782 (15)	-0.191	-0.231	0.576 (8)

Key: *The number in the parenthesis represent the rank of the values; GM= Grand Mean, $IPCA_1$= Interaction principal component axis one, $IPCA_2$= Interaction principal component axis two and ASV = AMMI Stability Values*

Regarding AMMI analysis of variance, the location effect was found the most influential factor in discriminating the seed yield of fifteen black cumin genotypes that were evaluated at six locations, contributing about 41.99% of the total variation as compared to that of the genotypic effect and GEI effect with their percent contribution of 31.96% and 10.96%, respectively.

Generally, AMMI stability analysis identified the genotypes Dirshaye, Soressa, AC-BC-10 and 242834-1 as the most stable genotypes. On the other hand, the location Ali Woyyo was identified as the most favorable black cumin growing environment.

4. Summary and Conclusion

The analysis of variance of an individual environment revealed that seed yield showed highly significant difference ($P \leq 0.01$) at all individual test environments. This pointed out that genotypes might perform differently at a specified test environment. After the significant difference of genotype × environment interaction and homogeneous residual variation were corroborated, combined analysis of variance was computed and showed that there were highly significant differences among the black cumin genotypes, environments and GEI. The observed highest variation to the total variations was attributed to the environmental effects. This in turn shows that the environment had contributed a great influence in varying the seed yield of the the test genotypes. Accordingly, environment had contributed about 47.16% of the total variations.

The combined mean seed yield values of genotypes averaged across the environments showed that variety Gammachis had the highest mean yield (1.35 ton ha^{-1}) followed by Dirshaye (1.26 ton ha^{-1}) while genotype 90575-2 had the lowest (0.78 ton ha^{-1}) mean seed yield. Most of the total sum of squares of the AMMI model (41.99%) was attributed to the environmental effects and the remaining variation were attributed to the genotypic effects (31.96%) and the GEI (10.96%).

AMMI stability analysis identified the genotypes Dirshaye as the most stable with ASV value of (0.093) followed by the genotype 242834-1 and Soressa with their ASV value of (0.095) and (0.109), respectively. On the other hand, the location Ali Woyyo was identified as the most favorable black cumin growing environment among the test locations. In general, genotypes such as Dirshaye, Gammachis, Soressa and Derbera could be recommended for cultivation at all the test locations since they perfomed well in these locations as compared to the other tested black cumin genotypes.

5. References

Ahmed NU and Haque KR (1986).Effect of row spacing and time of sowing on the yield of black cumin (*Nigella sativa* L.).*Bangladesh Journal of Agriculture*, 11:21-24.

Akcura M, Yaya Y and Tanner S (2005). Genotype × environment interaction and phenotypic stability analysis for grain yield of durum wheat in the Central Anatolian region. *Turkish Journal of Agriculture*, 29: 369-375.

Akhtar MS and Shah MU (1993).Elemental constituents of ant diabetic screening of a folkloric medicinal plant prescription.*International Journal Toxic, Occupation Environment Health*, 2: 46-47.

Al-Ghamdi MS (2001).The anti-inflammatory analgesic and antipyretic activity of *Nigella sativa*.*Journal of Ethnopharmacol*, 76:45-48.

Al-Jassir MS (1992).Chemical composition and micro flora of black cumin (*Nigella sativa* L.) seeds growing in Saudi Arabia.*Food Chemistry*, *45*: 239-242.

Ariyo OJ and Ayo-Vaughan MA (2000).Analysis of genotype × environment interaction of okra (*Abelmoschusesculentus*(L) Moench).*Journal of Genetic Breeding*, 54:33-40.

Atta MB (2003). Some characteristics of black cumin (*Nigella sativa* L.) seed cultivated in Egypt and its lipid profile.*Journal of Food Chemistry*, 83:63–68.

Bannayan MF, Nadjafi F, Azizi M, Tabrizi L and Rastgo M (2008). Yield and seed quality of Plantagoovata and *Nigella sativa* under different irrigation treatments: Indian Crops Production, 27: 11–16.

Bradu D and Gabriel KR (1978). The bi-plot as a diagnostic tool for models in two way tables: Techno metrics, 20: 47-68.

Champawat RS and Pathak VN (1982). Role of nitrogen, Phosphorus and potassium fertilizers and organic amendments in cumin (*Cuminumcyminum*L.) with incites by

Fusariumoxysporumf. sp. cumin. *Indian Journal Agricultural of Science*, 58 (9): 728-730.

Crossa J (1990). Statistical analysis of multiplication trials: Advances in Agronomy,44: 55-85.

Crossa J, Fox PN, Pfeffer WH, Rajaran S, and Gauch HG (1991). AMMI adjustment for statistical analysis of an international wheat trial.Theoretical Applied Genetics, 81:27-37.

Desalegn D, Solomon G, Balcha Y, Bedada G, Berhanu M, and Debebe M, (2004). Grain Yield Stability of Bread Wheat Genotypes in Favorable and Stressed Environments: 76-85.

Ferney GH, Alexei M and Aigul A (2006).Evaluation of Grain Yield Stability, Reliability and Cultivar recommendations in Spring Wheat (*Triticumaestivum*L.) from Kazakhstan and Siberia.*Journal of Central European Agriculture*, 4:649-660.

Fufa M (2018). Agronomic Performance, Genotype × Environment Interaction and Stability of Black Cumin Genotypes Grown in Bale, Southeastern Ethiopia.Adv Crop Sci Tech. 6: 358. doi:10.4172/2329-8863.1000358

Gauch HG and Zobel RW (1988).Predictive and postdictive success of statistical analysis of yield trials.Theoretical Applied Genetics, 76: 1-10.

Haji HM, Hunt IA (1999).Genotype × environment interactions and underlying environmental factors for winter wheat in Ontario.*Canadian Journal of Plant Sci*ence, 79:49-505.

Iqbal MS, Ghafoor A and Qureshi AS (2010).Evaluation of *Nigella sativa* L. for genetic variation and ex-situ conservation.*Pak. Journ. Bot.,* 42: 2489-2495.

Jansen PCM (1981). Spices, condiments and medicinal plants in Ethiopia; Their taxonomy and agricultural significance, Addis Ababa.Center for Agricultural Publishing and Documentation: 111-120.

Ministry of Agriculture and Rural Development (2003).Animal and Plant Health Regulatory Directorate. Crop Variety Register, Addis Ababa, Ethiopia: 183.

Mohammadi R and Amri A (2008).Comparison of parametric and non-parametric methods for selecting stable and adapted durum wheat genotypes in variable environments.*Euphytica*, 159:419- 432.

Mohammed MI (2009). Genotype × Environment Interaction in Bread Wheat in Northern Sudan Using AMMI Analysis.*American-Eurasian Journal of Agricultural and Environmental Science*, 6 (4): 427-433.

Mozzafari FS, Ghorbanli M, Babai A, Faramarzi M (2000).The effect of water stress on the seed oil of *Nigella sativa*.*Journ. Essential Oil Res*., 12: 36–38.

Mut Z, Aydin N, Bayramoglu HO and Ozcan H (2010).Stability of some quality traits in bread wheat (*Triticumaestivum*L.) genotypes.*Journal of Environmental Biology*, 31: 489-495.

Nergiz C and Otles S (1993).Chemical composition of *Nigella sativa* L. seeds. Food Chemistry, 48: 259-261.

Orgut (2007).Market Assessment Study, Ethiopian Nile Irrigation and Drainage Project. Main Report and Annexes, Ministry Of Water Resources, Addis Ababa.

Purchase JL (1997). Parametric analysis to describe genotype × environment interaction and yield stability in winter wheat. Department of Agronomy, Faculty of Agriculture of the Orange Free State: Bloemfontein, South Africa.

Purchase JL, Hatting H and Vandenventer CS (2000). Genotype × environment interaction of winter wheat in South Africa: Stability analysis of yield performance. *South African Journal of Plant and Soil*, 17: 101-107.

Romagosa I and Fox PN (1993). Genotype × environment interaction and adaptation: Plant Breeding Principles and Prospects; Chapman & Hall, London: 373–390.

Shewaye L (2011). Antifungal Substances from Essential Oils: MSc. Thesis, Addis Ababa University.

Takrun HRH, Dameh MAF (2008). Study of the nutritional value of Black cumin seeds agriculture; Duhok University, Iraq.*Mesopotamia Journal Agriculture*, 36 (1).

Taye G, Getachew T, Bejiga G (2000). AMMI adjustment for yield estimate and classifications of genotypes and environments in field pea (*Pisumsativum*L.).*Journal of Genetic Breeding*, 54:183-191.

Toncer O and Kizil S (2004).Effect of seed rate on agronomic and technologic characters of *Nigella sativa* L. *International Journal of Agriculture and Biology,* 3: 529-532.

Zobel RW, Wright MJ andGauch HG (1988).Statistical analysis of a yield trial.*Agronomic Journal,* 80: 388-393.

Registration of Triticale Variety Named 'Kombolcha'

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Abstract

A Triticale (TriticosecaleWittmack.) variety named 'Kombolcha' with the pedigree designation of 2012MS#51 has been released by Bako Agricultural Research Center, Ethiopia. The variety is well adapted to altitudes ranging between 2244-2784 meters above sea level in the western Ethiopia. Kombolcha is characterized by amber seed color, high yielder and has longer panicle. The grain/seed yield of this variety is 13% heavier than the grain weight of the variety used as the standard check 'Moti'. Based on stability parameters, Kombolcha showed relatively better grain yield performance and stable adaptability across locations and across years than the standard check 'Moti'.This variety is resistant to the major triticale diseases such as stem rust, yellow rust and Septoria tritici, and could be cultivated from mid to high altitude areas of western Ethiopia

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

Introduction

Triticale (*TriticosecaleWittmack*, 2n = 6x = 42; BBAARR.) is a hybrid cereal of wheat (Triticum) and rye (Secale) which was developed by using conventional plant breeding followed by embryo culture(Guedes-Pinto et al., 2001;Chaubey and Khanna, 1986; Nkongolo et al.,1991). As the maternal plant was used wheat, rye was the paternal plant. Triticale breeding in North America was formally started in 1954 at the University of Manitoba in Canada, from which the first commercial variety, Rosner, was released in 1969(Larter et al.,1970). Triticale has high feeding value and superior adaptation under stress conditions likewise drought, acidic soils, excess moisture and situations of low fertility where other crops yield less and are poorly adapted. The grain of triticale is much suitable as feed for ruminants and monogastrics, especially for silage and swine feed.

Varietal Origin and Evaluation

Kombolcha (Acc 2012MS #51) and other genotypes were collected from Ethiopian Institute of Agriculture Research, Debreziet Research Center. The genotypes were evaluated along with the standard check, Moti, across two locations (Shambu and Gedo) for three consecutive years (2015-2017). Based on information of combined data analysis of variance from most of traits including grain yield, two genotypes “Acc 2012MS #51and Acc.2012 MS #59” were selected as the most promising candidate varieties and promoted to variety verification trial. Finally, candidate varieties were evaluated along with one best standard check on 10 m x 10 m plots by the national variety release technical committee at two locations, each one on-station and two on-farm fields during the 2018/19 cropping season. Ultimately, acc 2012MS #51was recommended for commercial production and named Kombolcha.

Varietal characteristics

The released variety, Kombolcha (Acc 2012MS #51) is characterized by amber seed color, average 1000 seeds weight of 49.6 grams and has an average panicle length 10.4 cm (Table 2). The variety could be resistance to lodging, the ability to withstand high fertility / nitrogen input and wider adaptation.The detailed agronomic characteristics of the variety are indicated in Table 2 and 3 below.

Yield Performance

The released variety ‘Kombolcha’ is mainly described by high yield over the check and other candidates, which have 6184.78kgh^{-1} h of seed yield (Table 1). The grain yield of this newly released variety has advantages of 13% over the standard check ‘Moti’. Kombolcha(Acc. 2012MS #51) gave seed yield ranging from 39 to 50.1 t h^{-1} on a farmer’s field and 4.6 to 6.3 t h^{-1} on research field (Table 2 and 3).

Table 1. The mean of grain yield among two triticale candidates and one standard check across locations and over years

	Grain yield (kgh^{-1})									
	2015			2016			2017			
Genotypes	Shambu	Gedo	Mean	Shambu	Gedo	Mean	Shambu	Gedo	Mean	Over all mean
2012 MS #51	6107.0	8346.7	7226.9	8233.3	5830.0	7031.7	6685.0	1906.7	4295.9	6184.8
2012 MS #59	6587.0	6250.0	6418.5	5966.7	6490.0	6228.4	6040.0	2106.7	4073.4	5573.4
Moti(st.check)	4813.0	6093.3	5453.2	8196.7	5556.7	6876.7	63.0	1730.0	896.5	4408.8

Table 2. Mean agronomic traits of two triticale candidates and one standard check during 2015-2017 cropping seasons

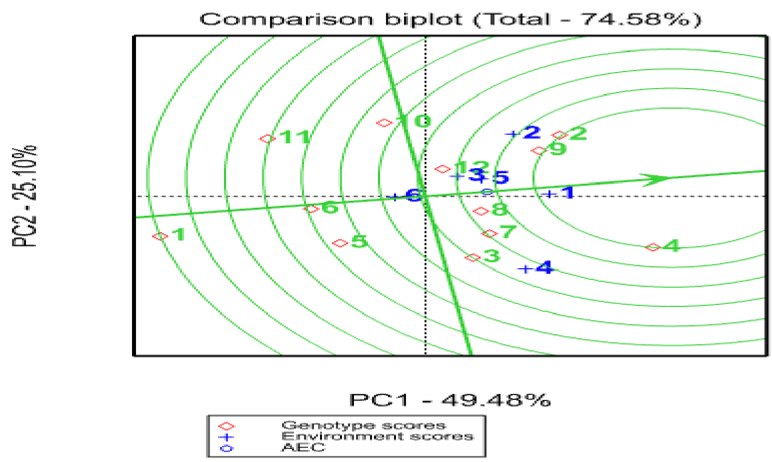
Genotypes	Maturity	Plant height	Panicle length	1000 grain weight	Grain yield (Kg/heck)	Yield advantage%
2012 MS #51	122.2	117.8	10.4	49.6	6108.9	13.0
2012 MS #59	123.2	103.5	9.7	47.0	5573.4	3.1
Moti (st.check)	122.8	103.7	9.8	44.3	5406.7	--

Table 3: Agronomic and Morphological characteristics of Bariso Triticale variety (Acc. 2012 MS #51).

Adaptation area:	Western Oromia (from middle to highland ecologies)
Altitude(masl)	2244-2784
Rainfall	> 800mm
Seed rate	150 kg/ha
Fertilizer rate	
NPS	100gk/ha
UREA	100kg/ha
Days to maturity	121-123.4
1000 seed weight	47.5-51.7
Plant height	113.9-121.7
Panicle length	8.8-11.6
Crop pest reaction	Tolerant to major wheat diseases
Yield (ton/ha)	
Research field	4.6-6.3
Farmers	3.9-5.1
Year of release	2019
Breeder seed maintainer:	OARI/BARC

Stability and Adaptability

The variety 'Kombolcha' was released for the mid-to-high altitude agro-ecologies of the middle and western part of the country receiving >800mm average annual rainfall. It is well adapted to an altitude range of 2244-2784 meters above sea level such Wellega and west Shewa, and similar agro ecologies. GGE biplot analysis revealed that both candidates showed stable adaptability across the two locations and across years. Mainly, Acc. 2012MS #51is fall relatively close to the ideal Environment and in the concentric circle and near to average environment axis, suggested their potential for wider adaptability with better gain yield performances (Fig 1). Based on most stability parameters, 'Kombolcha' showed relatively better performance stability across a range of environments (Fig 1)



Remark: 4=2012 MS #51, 7=2012 MS #59=7 and 12= standard check(Moti)

Fig 1: GGE biplot analysis depicting the stability of tested genotypes and test environment

Reaction of Major Diseases

Develop resistant triticale varieties to major diseases such stem rust (*Puccinia graminis),* yellow rust *(Puccinastriiformis* f) and *Septoria tririci*is among the major objectives of the breeding program. Therefore, Kombolchavariety was showed resistance/moderate disease reaction particularly to stem (0-5MR) and yellow rust(0-5R) while, The standard check was highly infected by stem and yellow rusts (Table 4).

Table 4. Diseases reaction of the varieties "candidates and check ''

Genotypes	Diseases Reaction		
	Stem rust	Yellow rust	*Septoria tritici*
2012 MS #51	0-5MR	0-5R	14.3
2012 MS #59	5-10MR	0-15MR	12.5
Moti (st.check)	10MR-30S	5MR-20S	12.3

Remark: R=Resistance, MR=ModeratelyResistance, S= Susceptible

Conclusion

The Triticale variety 'Kombolcha' was high yielder, showed better adaptability and stable performance than the standard checks. Also, the variety was showed better resistance to rusts and *Septoria tritici.* Therefore, it was released and recommended for western and similar agro-ecology in the country.

Reference

Chaubey, N.K., Khanna. V.K .1986. A study of crossability between wheat, triticale and rye. Curr. Sci. 55: 744–745

Guedes-Pinto, H., Lima-Brito. J., Ribeiro-Carvalho, C.and Gustafson, J.P. 2001. Genetic control of crossability of triticale with rye. Plant Breed. 120: 27–31

Larter, E., Shebeski, L., McGinnis, R., Evans, L., Kultsikes, P. 1970. Rosner, a hexaploid triticale cultivar. Can. J. Plant Sci. *50 122–124.*

Nkongolo, K.K.C., Stpierre, C.A., Comeau, A .1991. Effect of parental genotypes, cross direction and temperature on the crossability of bread wheat with triticale and on the viability of F1 embryos. Ann. Appl. Biol. 118: 161–168 Oettler G, Burger H, Melchinger AE (2003) Het

Release and Registration of 'Kumsa' Finger Millet Variety

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Abstract

Kumsa finger millet (Eleusinecoracana sub spp. coracana) variety is the brown seeded type designated by BKFM 0063 (1) pedigree was developed and released by Bako agricultural research center for western Oromia and similar agro-ecological areas of Ethiopia. Kumsa and other pipeline finger millet genotypes were evaluated against standard check (Gute) for grain yield, disease reaction and other agronomic traits across two locations (Bako and Gute) for three consecutive years (2014-2016) during main cropping season. Additive main effect and Multiplicative Interaction (AMMI), and Genotype and Genotype by Environment Interaction (GGI) biplot analysis showed that Kumsa [BKFM 0063 (1)] is stable, disease tolerant and high yielder (3.17 ton ha^{-1}) with 25.3 % yield advantage over standard check Gute (2.53 ton ha^{-1}), thus released officially in 2019.

Key words: AMMI, *Eleusinecoracana subsp. coracana*, GGI, *Magnaportheoryzea*, stability

Introduction

Finger millet is a climate-resilient and nutritious crop with highly nutritious and antioxidant properties (Gupta*et al*, 2017). It is grown mainly by subsistence farmers and serves as a food security crop because of its high nutritional value, excellent storage qualities and as a low input grown crop (Dida *et al.*, 2008). Despite its importance, it is one of the neglected and underutilized crops of Africa because attention directed toward staple cereal crops such as maize, wheat, rice, and etc.In Ethiopia, finger millet is commonly grown in rural poor farmers at a marginal land with low input and low yield mainly in Amhara and Oromia regions.Lack of stable and high yielding varieties is one of the major bottlenecks for production and productivity of finger millets in Ethiopia (Dagnachew*et al.*, 2015). Therefore, developing adaptable, stable, high yielding and disease resistant variety that withstand the leading climate change is very important.

Varietal Origin and Evaluation

Kumsa [BKFM 0063 (1)] was developed from Bako Agricultural Research Center (BARC) finger millet landraces collection originally from western Oromia. The variety and other fourteen finger millet pipeline genotypes were evaluated against standard check (Gute) for three years (2014-2016) across two locations (Bako and Gute).

Agronomical and Morphological Characteristics

The released variety, Kumsa [BKFM 0063(1)] is characterized by light brown seed color, average 1000 seeds weight of 3.5 grams and has an average plant height 85 cm. The detailed agronomic characteristics of the variety are indicated in table 1 below.

Yield Performance

The multi-location blast prone areas and multi-year evaluation data records indicated that Kumsa [BKFM 0063(1)] is stable and high yielder variety potentially produced 2.5 - 3.2 tons^{-1} on research station. On farm yield evaluation recorded from variety verification plots at Bako and Gute revealed that Kumsa gave an average grain yield ranging from 2.2 - 2.9 tons^{-1} (Table 1).

Stability and Adaptability Analysis

Eberhart and Russell (1966) model revealed that Kumasa [BKFM 0063 (1)] variety showed regression coefficient (bi) closer to unity and thus stable and widely adaptable variety than the remaining genotypes. Both GGE biplot and AMMI analysis also indicated that Kumsa [BKFM 0063 (1)] was stable and high yielding which gave about 25.3% (31.17ton ha^{-1}) yield advantage over standard check Gute (2.53 ton ha^{-1}). Under variety verification trail, Kumsa gave about 13.5% yield advantage over recently released variety (Bako-09) and therefore, officially released and recommended for production for testing locations and similar environmental conditions to boost production and productivity. Accordingly, Kumsa was recommended for western Oromia (Bako, Gute and Bilo) areas with similar agro ecologies.

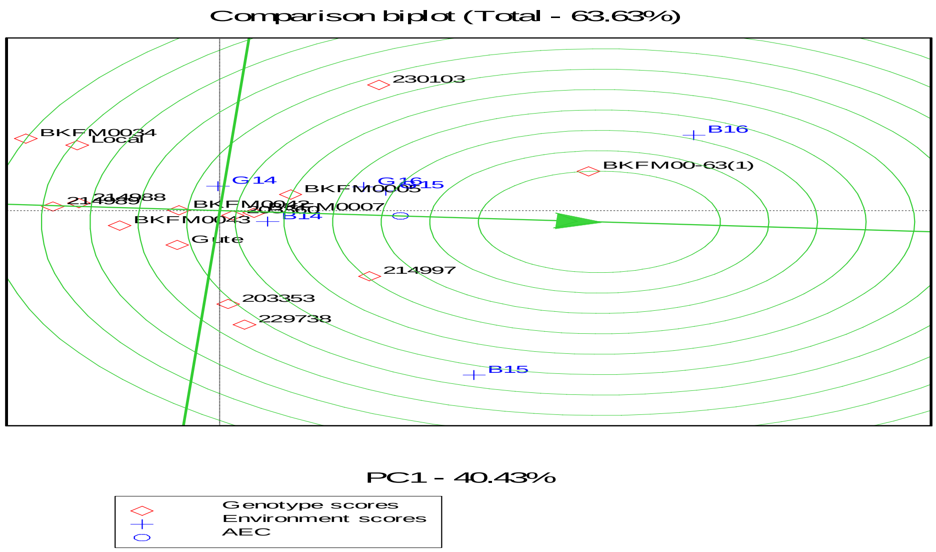

Fig 1: GGE Biplot analysis showing grain yield stability of genotypes and environments

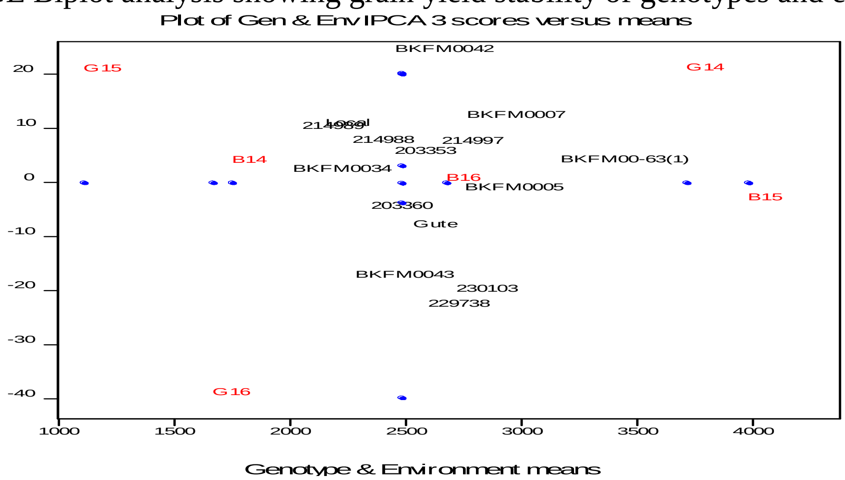

Fig 2: AMMI Biplot showing genotypes grain yield stability and preferential adaptation over environment

Reaction to Major Diseases

Kumsa is moderately tolerant to major diseases particularly blast (*Magnaportheoryzea*), a devastating disease that affect all above ground parts of the plant.

Conclusion

Kumsa finger millet variety was released for its high grain yield, showed better adaptability and stable performance than the standard check. The variety is also tolerant to blast disease in blast stressed areas. Therefore, it was released and recommended for smallholder farmers and other finger millet producers at Bako, Gute, Bilo and areas with similar agro-ecology in the country to boost finger millet productivity.

Acknowledgments

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References

Dagnachew, L., Kassahun, T., Awol, A., Masresha, F., Kebede, D., Girma, M., Geleta, G., Hailu, F., Kassa, M., Chemeda,B., Girma, C., and Gudeta, B. 2015. Registration of "Addis-01" Finger Millet Variety, *East African J. Sci.*, 9 (2) 141-142.

Dida, M.M., Wanyera, N., Dunn, M.L.H., Bennetzen, J.L. and Devos, K.M., 2008. Population structure and diversity in finger millet (Eleusinecoracana) germplasm. *Tropical Plant Biology*, *1*(2), pp.131-141.

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

Gupta, S.M., Arora, S., Mirza, N., Pande, A., Lata, C., Puranik, S., Kumar, J. and Kumar, A., 2017. Finger millet: a "certain" crop for an "uncertain" future and a solution to food insecurity and hidden hunger under stressful environments. *Frontiers in plant science*, *8*, p.643.

Adaptation Study of Mung Bean (*Vigna radiate*) Varieties in Western Parts of Oromia, Ethiopia

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Abstract

Seven mung bean (Vigna radiate) varieties that released in Ethiopia were evaluated for its evaluation and adaptability with the objectives of identifying and recommending the adapted mung bean varieties for Bako and similar agro-ecologies. The study was conducted at three locations, Bako, B/Boshe and Chewaka during 2017 and 2018 main cropping season in randomized complete block design (RCBD) with three replications. Days to 50% flowering (DF), Days to maturity (DM), Plant height (PH), Number of pods per plant (NPPP), Number of seed per pod (NSPP), hundred seed weight (HSW) and Grain yield (GYLD) data were collected. The statistical analysis performed on combined data showed that there were significant differences, $p \leq 0.05$ among the tested varieties in terms of yield, days to flowering and number of pods per plant and highly significant differences, $P \leq 0.001$ among mung bean varieties and test environments for hundred seed weight. The variety x location interaction of NPPP and HSW showed significant difference among the varieties while the interaction of DF, DM, PH, NSPP and GYLD not significantly different. The highest pooled mean performance of mung bean grain yield was 534.4 kgha^{-1}for Chinese and the lowest was 381 kg ha^{-1}for NVL-1 and the grand mean being 433.2 kg ha^{-1}. The GGE-biplot analysis of Borda(MH-97-6) mung bean variety was more stable and environment 4 was ideal for the production of mung bean varieties. Grain yield was correlated positive and highly significant with NPPP (0.45) and negative highly correlation with DM (-0.62) and it had no relation with DF, PH, NSPP and HSW characters. Further breeding activities will be required in the future on this mung bean crop due to its economic importance.

Key words: Adaptation, Correlation, GGE-biplot, Location, Mung bean, Stability

Introduction

Mung bean (*Vigna radiata* L. Wilczek) is a self-pollinated diploid legume with short duration crop (Ketinge, et. al, 2011). Mung bean also known as green gram, maash, moong bean, golden gram, celera bean. It is one of the legume plant species that belongs to the subgenus Ceratotropis in the genus Vigna, about 150 mung bean genus vigna are spread in the world (R.M. et a l., 1985). Among these species, 22 of them indigenous to India, 16 of them also from South East Asia; but, the majority of this crop species are originated from Africa (R.M. et a l., 1985). Mungbean germplasm is available as wild (*Vigna radiata* subsp. *sublobata* and *Vigna radiata* subsp. *glabra*), cultivated (*Vigna radiata* subsp. *radiata*) and weedy populations. It has a nutritional balance with plenty of vitamins and minerals that has healthy benefit; the seeds of mung bean contain an average of 26% protein, 62.5% carbohydrates, 1.4% fat, 4.2% fibers, and vitamins (Mohamed. et. al., 2012).

Mung bean crop is a recently introduced pulse crop in Ethiopia. It is mainly grown in Amhara region of North Shewa, Oromiya special zone and Southern Wollo, SNNPR (Gofa area), concise areas in Oromiyaregion, like Hararge and some woredas of Benishangul Gumuz regional state (EPP, 2004 and ECX, 2014). The average seed yield in kg $ha^{-1}$for mung bean is as low as 600-800 in Ethiopia (EPP, 2004). After five commodities, mung bean is the sixth product that Ethiopian commodity exchange is trading next to coffee, sesame, white pea beans, Maize and wheat (ECX, 2014). Before two years, mung bean crop is not known in Bako area and recently, since it has been a great contributor in national economy, Bako Agricultural Research Center has tested the adaptability of seven mung bean crop varieties at Bako, BilloBoshe and Chewaka for the past two consecutive years 2017 and 2018 with the objectives of identifying and recommending the adapted mung bean varieties for Bako and similar agro-ecologies.

Materials and Methods

Description of the Experimental Area

The study was conducted at Bako Agricultural Research Center and at another two sub sites of BARC (Billoboshe and Chewaka) in 2017 and 2018 main cropping season.

Experimental Materials

About seven mung bean varieties were tested in randomize complete block design with three replications at Bako, Billoboshe and Chewaka in 2017 and 2018. The plot size was $3.6m^2$ (3m length x 0.3m b/n rows x 4 rows). The seven varieties of mung bean and their maintainer center are listed in table 1.

Table 1. List of Mung bean varieties used in the study and their maintainer center

S.N.	Varieties	Maintainer
1	Chinese	HARC
2	Rasa (N-26)	MARC
3	Shewa Robit	MARC
4	Borda (MH-97-6)	SARI
5	NVL-1	MARC
6	NV	HARC
7	Local Check	Chewaka Area

Where: HARC = Hawasa Agricultural Research Center, MARC = Melkasa Agricultural Research Center, SARI = Southern Agricultural Research Institute

Results and Discussions

Growth and Phonological Parameters

Days to 50% flowering: From combined analysis, the seven tested mung bean varieties were affected by days to flowering; which is significantly different at (P<0.05) level of significant. The maximum days to flowering was recorded for variety Borda (MH-97-6) with 40.2 days and the minimum days to flowering was for NV-1 variety (38.3 days) and the grand mean being 39.1 days (Table 4).

Days to 90% Maturity: The maximum days to maturity of mung bean tested varieties was 84.5 days for NVL-1 followed by local check (83.83 days) and Chinese (83.7 days) and the minimum was 82.8 days for Rasa (N-26) with the average of 83.6 days of maturity date (Table 4). The tested varieties were not affected and not significantly different at (p<0.05) level of significance for days to maturity.

Plant Height: The effects of varieties on plant height have no significantly different (p<0.05), Table 4; the highest plant height was recorded for Borda (MH-97-6), 38.67cm. and the minimum plant height is 34.7cm and the average being 36.2 cm (Table 4).

Table 2. Mean square from analysis of variance for performance of mung bean in Phenology and Growth Traits

SOV.	DF	DF50 %	DM %	PH
Loc.	2	483.9**	1447.3**	1552.3**
Year	1	548.9**	1269.8**	2.1ns
Rep.	2	6.15ns	0.72ns	14.9ns
Trt.	6	8.6*	5.2ns	32.2ns
Loc x Trt.	12	1.34ns	2.0ns	10.8ns
Loc x Trt. x Year	20	17.8**	46.0**	23.2ns
Error	82	3.4	3.1	26.3
CV		4.7	2.1	14.2

Where: ** and *, highly significant at p ≤ 0.01 and significant at P ≤ 0.05 respectively; and ns is insignificant; SOV: Source of variation, DF: Degree of freedom, CV: Coefficient of variance, DF50%: Days to 50% flowering, DM, Days to 90% maturity, PH: Plant height (cm).

Yield Components

Number of pods per plant: In legume plants, number of pods per plant is one of the core factors to decide the performance of the plant yields. The analysis of variance revealed that, mung bean varieties had influenced by number of pods per plant and significantly different at ($p<0.05$). The highest mean average pod number was recorded for Chinese variety; 11.2, the minimum plant pod number is 7.6 for NV variety and the mean being 9.2 (Table 4). The same results from Wedajo, 2015 reported that, number of pods per plant is affected by mung bean varieties.

Number of seeds per pod: The analysis of variance showed that, number of seeds per pod had no significantly different among the tested varieties (Table 4). The mean separation indicated that, the maximum number of seed per pod = 10.9 recorded for NVL-1 variety followed by NV = 10.7; the minimum one for Borda (MH-97-6) is 9.6 and the mean is 10.3; however, had no different among the varieties. The result was contrast with the report of Rasul, et al., 2012, who reported the difference of seed per pod among the varieties are due to the difference of genetic.

Hundred seed weight: The result from analysis of variance for seed weight showed that, there is highly significant different ($P<0.001$) among the tested mung bean varieties (Table 4). The highest hundred seed weight value recorded for variety Chinese = 5.0g followed by Rasa (N-26) = 4.5g and NVL-1 = 4.1g and the average being 4.2g (Table 4). Wedajo, 2015 also stated that, the difference of seed weight among mungbean varieties of hundred seeds was because of crop potential of the yield, growth rate, higher nutrients translocation and hereditary superiority.

Grain yield: The analysis of variance for mung bean tested varieties indicated that, there were different among the tested varieties at ($p<0.05$). This means, there were difference among the tested varieties across locations and years (Table 4). The phenology and growth and yield and yield components mean performance of tested mung bean varieties are stated in table 4.

Table 3. Mean square from analysis of variance for mung bean in yield and its components

SOV.	DF	NPPP	NSPP	HSW	GYLD
Loc.	2	13.6ns	7.8*	0.00037ns	1040464**
Year	1	122.4**	12.4*	0.22ns	2283386**
Rep.	2	1.7ns	4.0ns	0.39ns	33230ns
Trt.	6	22.1*	3.7ns	4.57**	55664*
Loc x Trt.	12	21.8**	2.6ns	1.47*	4847ns
Loc x Trt. x Year	20	15.1ns	5.0**	0.86ns	24719ns
Error	82	9.2	2.0	0.69	27200
CV		22	13.9	20	18

Where: ** and *, highly significant at p ≤ 0.01 and significant at P ≤ 0.05 respectively; and ns = insignificant; SOV = Source of variation, DF = Degree of freedom, CV = Coefficient of variance, NPPP = Number of pods per plant, NSPP = Number of seeds per pod, HSW = Hundred seed weight and GYLD = Grain yield.

Table 4. Pooled mean performance of Mung bean varieties for phenology and growth traits and yield and yield components

Variety	phenology and growth traits			yield and yield components			
	DF50 %	DM %	PH	NPPP	NSPP	HSW	GYLD
Chinese	39.0	83.7	34.7	11.2	10.3	5.0	534.4
Rasa (N-26)	38.6	82.8	36.6	9.6	10.6	4.5	396.9
Shewa Robit	39.4	83.4	35.1	9.0	9.9	3.9	436.5
Borda (MH-97-6)	40.2	83.1	38.6	9.6	9.6	3.5	474.8
NVL-1	38.3	84.5	35.2	8.9	10.9	4.2	381
NV	38.5	83.7	36.7	7.6	10.7	4.1	383.5
Local Check	39.7	83.8	36.2	8.6	10.0	3.6	425.2
LSD	1.58	2.14	3.24	2.25	1.07	0.59	103.17
Mean	39.1	83.6	36.2	9.3	10.3	4.2	433.2
CV	4.7	2.1	14.2	22	13.9	20	18

Gge-Biplot Analysis

The Ranking of Genotypes Based on Yield and Stability

The GGE-biplot analysis of Mung bean tested varieties showed that, four varieties: G1 = Chinese, G4 = Borda (MH-97-6), G3 = Shewa Robit and local check gave better yield mean performance with 534.4 kg ha^{-1}, 474.8 kg^{-1}, 436.5 kg ha^{-1} and 425.2 kg ha^{-1} respectively. Both PC1 and PC2 were separated based on their scored for seven mung bean tested varieties in the study area. The designated genotypes code and Environments code were listed in the table below.

Table 5. Genotypes and environments and their codes for tested mung bean varieties

No	Varieties	Genotype code	No	Environments	Env. code
1	Chinese	G1	1	Bako 2017	E1
2	Rasa (N-26)	G2	2	Bako2018	E2
3	Shewa Robit	G3	3	Bilo/boshe 2017	E3
4	Borda (MH-97-6)	G4	4	Bilo/boshe 2018	E4
5	NVL-1	G5	5	Chewaka 2017	E5
6	NV	G6	6	Chewaka 2018	E6
7	Local Check	G7			

The primarily use of GGE-biplot is grading the tested genotypes for the locations. PC1 indicated the mean performance of the varieties while PC2 indicated the G x E associated with each genotype which is the measure of stability or instability (Yan et al., 2000; Yan, 2002). Genotypes having PC1 > 0 were recognized as high yielding while those genotypes having PC1 score < 0 were identified as low yielding, (Kaya et al. 2006). A Borda (MH-97-6) variety is more stable than other tested mungbean varieties and gives higher yield and environment 4 is the best for the production of mungbean crop. The stability and GGE- biplot diagrams are sketch below.

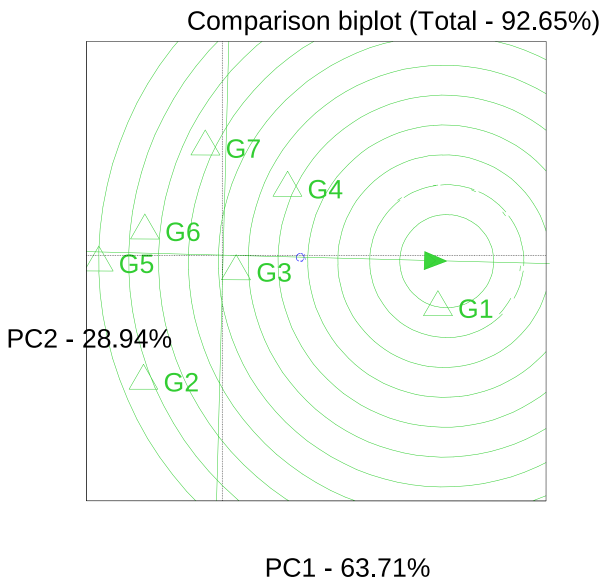

Figure.1. GGE–biplot based on genotype focused scaling for comparison of the genotypes. PC and G for principal component and genotypes respectively.

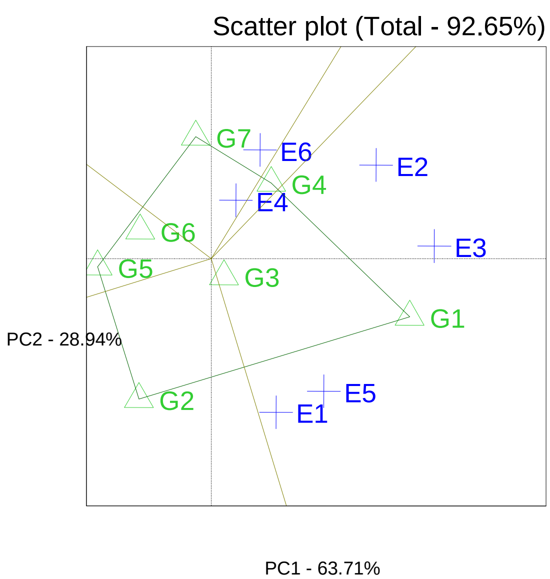

Figure 2. The polygon view of the GGE- biplot based on symmetrical scaling for which -won -where pattern for genotypes and environments. PC, G and E stands for principal component, genotype and environments, respectively.

Associations of Characters

The correlation coefficient is the measures of level of symmetrical association between two traits and it is used for understanding the nature and degree of association among yield and yield components. Association between any two traits or among various traits is of very importance to make desired selection of combination of traits (Ahmad *et al*., 2003). Pearson correlation was done for mung bean variety adaptation and the correlation ranged from 0.002 to 0.45 (Table 6). Grain yield has a strong positive association and negative association with NPPP (0.45**) and DM (-0.62**) respectively. Inversely, grain yield has no correlation with characters like DF (-0.07), PH (0.002), NSPP (0.07) and HSW (0.12). Other characters also highly positively correlated to each other; like PH with DF (0.23**) and DM (0.39**), and NSPP slightly correlated with PH (0.22*) and NPPP (0.17*), while NPPP is highly negatively correlated with DM (-0.27**). This result is in agreement with Kebere*et al*., (2006), who stated, no correlation of grain yield with plant height, hundred seed weight and number of seed per pod for common

Table 6. Pearson correlation coefficients between characters of mung bean adaptation

Characters	DF	DM	PH	NPPP	NSPP	HSW	GYLD
DF	1						
DM	0.11ns	1					
PH	0.23**	0.39**	1				
NPPP	0.01ns	-0.27**	0.13ns	1			
NSPP	-0.12ns	0.07ns	0.22*	0.17*	1		
HSW	-0.03ns	0.11ns	0.02ns	-0.01ns	0.15ns	1	
GYLD	-0.07ns	-0.62**	0.002ns	0.45**	0.07ns	0.12ns	1

bean varieties. Some authors result also contradicts this mung bean result as the positivecorrelation were recorded for grain yield with the number of seeds pod^{-1} and mean seed weight in soybean (Karmakar and Bhatnagar, 1996).

Where: DF: Days to 50% flowering, DM, Days to 90% maturity, PH: Plant height (cm), NPPP: Number of pods per plant, NSPP: Number of seed per pod, HSW: Hundred seed weight and GYLD: Grain yield kg/ha.

Conclusions

Mung bean adaptation activity was done with seven varieties at Bako, B/boshe and Chewaka in 2017 and 2018 cropping season for its evaluation and adaptability. Chinese (534.4 kg ha^{-1}) and Borda- MH-97-6 (474.8 kg ha^{-1}) varieties were selected according to their performance and due to their betterment than local check (425.2 kg ha^{-1}). Both varieties were more stable and gave higher yield and environment 4 (Bilo/boshe 2018) was ideal environment for the production of mung bean crop. Grain yield was highly positively and negatively correlated with 0.45** and -0.62** for NPPP and DM respectively. Further research should be undertaken on this particular crop to develop improved varieties, for the immediate use, Chinese and Borda (MH-97-6) varieties were recommended for Bako and the same agro-ecology areas.

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Reference

Ahmad, M., Mohammad, F., Maqbool, K., Azam, A. and Iqbal, S. 2003. Genetic variability and trait correlation in wheat. Sarhad Journal of Agriculture, 19 (3): 347-351.

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

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

F. Rasul, M. A. Cheema, A. Sattar, M. F. Saleem, and M. A. Wahid, "Evaluating the performance of three Mung bean varieties grown under varying inter-row spacing," Journal of Animal & Plant Sciences, vol. 22, pp. 1030-1035, 2012. View at Google Scholar

G. Wedajo, "Adaptation study of improved mung bean (Vigna radiate) varieties at Alduba, South Omo, Ethiopia," Research Journal of Agriculture and Environmental Management, vol. 4, pp. 339-342, 2015.

J. Ketinge, W. Easdown, A. Yang, R. Chadha, and M. S. Shanmugasundaram, "Overcoming chronic malnutrition in a future warming world: The key importance of mungbean and vegetable soybean," Euphytica, vol. 180, pp. 129-141, 2011. View at Google Scholar | View at Publisher

Karmakar, G. and S. Bhatnagar, 1996. Genetic improvement of soybean genotypes released in India from 1969 to 1993. Euphytica,90: 95-103.

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

KebereBezaweletaw, KetemaBelete, and PrapaSripichitt, 2006. Genetic gain in grain yield potential and associated agronomic traits in haricot bean (Phaseolu vulgaris L.). Kasetsart Journal (Natural Science), 40: 835-847.

M. Ali and S. Gupta, "Capacity of Indian agriculture: Pulse crops," Current Science, vol. 102, pp. 874-881, 2012. View at Google Scholar

R. M. Polhill and L. J. G. vanderMaesen, "Taxonomy of grain legumes," Journal of Biological Sciences, vol. 1, pp. 2127, 1985.

Yan, W. and Hunt, L. A. 2002. Biplot analysis of multienvironment trial data, In: Kang, M. S. (Ed.) Quantitative Genetics, Genomics and Plant Breeding. CAB International, Willingford.

Yan, W., Hunt, A. L., Sheng, Q. and Szlavnics, Z. 2000. Cultivar evaluation and mega-environment investigation based on GGE- biplot. Crop Science, 40: 596-605

Multi-Location Evaluation of Yield and Yield Related Trait Performance in Bread Wheat Genotypes at Western Oromia, Ethiopia

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Abstract

Wheat (Triticum aestivum L) is an important cereal crop, which receives the most attention of specialists in plant breeding and production worldwide. Knowledge of the interaction between genotypes and environment with yield and yield components is a principal aspect of effective selection in crop improvement. This experiment was conducted to evaluate high yielding, insect pest tolerant genotypes with genotype by environmental interaction on grain yield and yield stability across environments. The study used 15 bread wheat genotypes against checks at Haro Sabu Agricultural Research Center (HSARC) sub sites across environments in 2017-2018 cropping season. Ten agronomic traits and four economically important disease reaction data were evaluated. Analysis of variance detected significant difference among genotypes in both separated and combined analysis of variance. The combined ANOVA and the additive main effects and multiplicative interactions (AMMI) analysis for grain yield across environments exhibited significantly affected by environments,which explained 65.06% of the total variation. The genotype and genotype environmental interation were significant and accounted for 13.34 and 9.44 % respectively. Pricipal component (PCA1) and 2 accounted for 7.88 and 1.15 % of the GEI respectively with a total of 9.03 % variation.Generally, G6 and G3 were identified as ideal genotypes for yielding ability and stability, tolerant to diseases and use as parents in future breeding programmes.

Key words: AMMI, GGEI, Performance, stability, wheat

Introduction

Worldwide, wheat (*Triticum aestivum* L.) is an important cereal crop, which receives the most attention of specialists in plant breeding and production. Yet, its production is limited by the adverse environmental conditions. Environmental fulactuation and interaction is the major limitation for wheat production and productivity. Genotype x environment (GE) interaction reduces genetic progress in plant breeding programmes through minimising the association between phenotypic and genotypic values (Comstock and Moll,1963).Therefore,multi-environment yield trials are essential in estimation of genotype by environment interactionn

(GEI) ,identification of superior and stable genotypes in the final selection cycles (Kaya et al., 2006; Mitrovic et al., 2012). Phenotypes are a mixture of genotype (G) and environment (E) components and their interactions (G x E).Genotype by environment interactionn (GEI) complicate process of selecting genotypes with superior performance.Accordingly, Multi-environment trails (METs) are widely used by plant breeders to evaluate the relative performance of genotypes for target environments (Delacy et al., 1996). The additive main effects and multiplicative interaction (AMMI) model have led to more understanding of the complicated patterns of genotypic responses to the environment (Gauch, 2006).These patterns have been successfully related to biotic and abiotic factors.Yan et al.(2000), proposed another methodology known as GGE-biplot for graphical display of GE interaction pattern of MET data with many advantages. GGE biplot is an effective method based on principal component analysis (PCA), which fully explores MET data. It allows visual examination of the relationships among the test environments, genotypes and the GE interactions. The first two principle components (PC1 and 2) are used to produce a two dimensional graphical display of genotype by environment interaction (GGE-biplot). If a large portion of the variation is explained by these components, a rank-two matrix, represented by a GGE- biplot, is appropriate (Yan and Kang, 2003). Using a mixed model analysis may offer superior results when the regression of genotype by environment interaction on environment effect does not explain all the interaction (Yan and Rajcan, 2002).

Therefore, the objective of this study was: to identify bread wheat genotypes with high level of grain yield and yield stability and insect pest tolerant across locations.

Materials and Methods

Study sites: The multi-location yield trial (MLYT) was conducted at three locations in Kellem and West Wollega zones of Haro-sabu Agricultural Research Center at Belem sub site (altitude 1759 masl, 09° 02' N, 035° 104'E), Mata (altitude 2016 masl, 08° 34' N, 034° 44'E) and Badesso(altitude 2054 masl, 08° 40' N, 034°47'E) in western Oromia, Ethiopia, during the 2017-2018 main cropping season.

Breeding materials and experimental design: A total of15 genetically diverse bread wheat genotypes (Table1) were evaluated against the checks (Liban, Kingbird and one local check). Arandomized complete block design (RCBD) with three replications were used. Six rows per plot of 0.2 m spacing between rows and 2.5 m row length, and harvestable plot size was 2 m^2

(four harvestable rows per plot) . A seed rate of 150 kgha^{-1} and fertiliser rate of 100 kg ha^{-1}DAP and 150 kg ha^{-1} Urea were used.

Statistical analysis

Analysis of variance is calculated using the model:

Yij = μ + Gi + Ej + GEij

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

The AMMI model used was: $Y_{ij} = \mu + g_i + e_j + \sum_{1}^{N} \Lambda_k Y_{ik} \delta_{jk} + \varepsilon_{ij}$

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

Table1. List of bread wheat genotypes evaluated for two years at Western Oromia in Ethiopia

No	Codes	Genotypes	Sources
1	G1	Local check	Farmer
2	G2	ETBW7056	KARC
3	G3	ETBW7104	KARC
4	G4	king bird	KARC
5	G5	ETBW7068	KARC
6	G6	ETBW7076	KARC
7	G7	ETBW7077	KARC
8	G8	ETBW7072	KARC
9	G9	Liban	KARC
10	G10	ETBW7075	KARC
11	G11	ETBW7092	KARC
12	G12	ETBW7069	KARC
13	G13	ETBW7052	KARC
14	G14	ETBW7088	KARC
15	G15	ETBW7071	KARC

G-genotype, ETBW- Ethiopia bread wheat, KARC-Kulumsa Agricultural Reaserch center

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

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

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

Where, SS_{IPCA1}/SS_{IPCA2} is the weight given to the IPCA1-value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. The larger the ASV value, either negative or positive, the more specifically adapted a genotype is to certain environments. Smaller ASV values indicate more stable genotypes across environments (Purchase, 1997). Genotype Selection Index (GSI): Stability is not the only parameter for selection as most stable genotypes would not necessarily give the best yield performance. Therefore, based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value RASVi), genotype selection index (GSI) was calculated for each genotype as:

$$GSIi = RASVi + RYi$$

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

Data collection method: Ten plants were selected randomly before heading from each row (four harvestable rows) and tagged with thread and plant based data were collected from the sampled plants.

Plant-based: Plant height, Spike length, and spike weight, spike lets per spike, grain per spike and grain per spikelet.

Plot based: Days to heading, days to maturity, thousand seed weight, grain yield and four economically important disease reactions like stem rust, leaf rust, septoria and fusarium head blight.

Results and Discussions

Combined analysis of variance

Mean square of analysis of variance for all genotypes at different environmental conditions for grain yield and yield related traits are presented in Table2. Highly significant differences were detected among years (P ≤ 0.01) for all parameters, except for stem rust and septoria. The combined analysis of variance revealed that year and location effects were significant for all parameters, except septoria and thousand seed weight. Year*genotypes effects were non-significant for all parameters excluding days to heading, days to maturity, fusarium head blight and spike weight. Year*location *genotypes were significant for some traits such as days to maturity, spike weight, grain per spike and yieldkgha^{-1}.Genotype by environment interaction mean square was highly significant (P≤0.01) for days to maturity, days to heading, plant height, spike length, spikelets per spike and grain yield.

Table 2: Analysis of variance (ANOVA) for grain yield and yield related traits of bread wheat genotypes evaluated in 2017-2018 main cropping season

Source	DF	DH	DM	SR	LR	SEP	FHB	PH
Replication	2	12.68**	12.86	0.22**	0.03	0.02	7.37**	13.08
Genotype	14	265.24**	340.90**	0.05*	0.05	0.01	1.53**	578.88**
Location	2	832.68**	5506.27**	0.11*	0.13*	0.03	1.30*	7274.29**
Year	1	963.33**	3998.23**	0.00	0.49**	0.07*	76.80**	338.08**
Geno .*loc.	28	12.30**	47.71**	0.02	0.03	0.01	0.15	59.27**
Geno .*yr.	14	46.97**	122.82**	0.02	0.05	0.01	1.37**	14.19
Loc.*yr.	2	106.68**	3232.78**	0.11*	0.13*	0.03	1.30*	351.89**
Geno.*loc.*yr.	28	12.3	48.52**	0.02	0.03	0.01	0.15	8.2

Table 2: cont

Source	DF	SL	SW	STPS	GPS	GPST	TSW	Kg/ha
Replication	2	3.29**	0.41	21.25*	364.69**	2.12**	198.23	42646.84
Genotype	14	11.37**	5.72**	35.06**	597.59**	1.31**	513.13*	1831217.12**
Location	2	28.99**	2.48**	293.70**	433.04**	2.72**	2741.55**	13090998.64**
Year	1	101.14**	27.60**	64.68**	3229.91**	5.18**	4066.07**	89102882.12**
Geno .*loc.	28	0.71**	0.25	11.54**	93.93*	0.41	242.62	376887.84**
Geno .*yr.	14	0.51	0.96**	2.99	72.64	0.31	287.65	206156.52
Loc.*yr.	2	202.90**	11.45**	176.97**	4456.30**	4.96**	261.09	4874484.92**
Geno.*loc.*yr.	28	0.47	0.41*	8.00	95.65*	0.37	352.59	167928.97**

ns * ** non-significant, significant at 5% and 1% respectively, Loc *gen= location by genotype, Yr*Loc*gen = year by location by genotype, DF -degree of freedom, DH- Days to Heading; DM- Days to Maturity; PH- Plant Height; SL- spike Length; SW-Spike Weight, STPS-Spikelets per spike; GPS-Grain per spike, GPST-Grain per spikelets TSW- Thousand Seed Weight, YLD Kg/ha- Yield in kilogram per Hectare.

Yield performance across environments

The performance of the tested bread wheat genotypes for grain yield across location and year presented in Table 3. Some genotypes constantly performed best in a group of environments, while some are fluctuated across locations. The average grain yield ranged from the lowest 3524.47 kgha^{-1} at Belem site in 2017 to the highest 5520.17kgha^{-1} at Bedesso site in 2018, with grand mean of 4479.47 kgha^{-1} (Table 3). The grain yield across environments ranged from the lowest of 3925 kgha^{-1}for local check to the highest of 5069 kgha^{-1} for genotype ETBW7076 (Table3). This wide variation might be due to their genetic potential of the genotypes. Genotype ETBW7076 was the topranking pipeline in all environments, except at Belem in 2018.Similarly, genotype ETBW7104 ranked first at all sites, except at Bedeso in 2017 and 2018 cropping season. However, genotype ETBW7072 ranked the least in all environmental sites throughout cropping season (Table3). The difference in yield rank of genotypes across the environments exhibited the high crossover type of genotypes x environmental interaction (Yan and Hunt, 2001; Asrat et al., 2009).

Table 3: Mean grain yield (kgha^{-1}) of bread wheat genotypes evaluated at three environments

	Grain Yield in Kgha^{-1}						
	2017			2018			
Genotypes	Belem	Bedesso	Mata	Belem	Bedesso	Mata	Com.Mean
ETBW7052	3426.5c	3780.6cd	3894.8d	4477.5c-f	5394.6d	4707.4cd	4280ef
ETBW7056	4057.2a	4896a	4744.4ab	3830f	6348.5a	5387.8ab	4877c
ETBW7068	3531.3bc	3689.5cd	4634.2abc	4790.3a-d	5459.4cd	5308.6ab	4568cd
ETBW7069	3278.1cd	3395.1d	3841.1d	4442.3c-f	5132de	4711.1cd	4133fg
ETBW7071	3282.6cd	3735.3cd	4060.6bcd	4466.7c-f	5295.7de	4835.9bcd	4280ef
ETBW7072	3006.9d	3268.7d	3811d	4029.2ef	4889.9e	4636.4d	3940g
ETBW7075	3902.5a	4490ab	4315.8a-d	4353.3c-f	6030.6ab	5056.2a-d	4691c
ETBW7076	4119.9a	4942a	4848.1a	4633.5b-e	6400.2a	5468.4a	5069a
ETBW7077	3228cd	3583.5cd	4436a-d	4477.5c-f	5141.7de	5152.3a-d	4337def
ETBW7088	3320.3cd	3463d	4488.2a-d	5219.3ab	5205.7de	5173.1a-d	4478cde
ETBW7092	3525bc	3668.3cd	4613.9abc	5420a	5429.4cd	5275.7abc	4655bc
ETBW7104	3795.4ab	4125.3bc	4819.6a	5260.8ab	5840.9bc	5430.2a	4880b
kingbird	3295.3cd	3634.5cd	4361.1a-d	4863.7abc	5219.6de	5066a-d	4407de
Liban	3846.8ab	3761.5cd	4663.7ab	4351.8c-f	5834.7bc	5572.4a	4672bc
Local	3251.1cd	3567.4cd	3926.3cd	4107.2def	5179.7de	4721cd	3925fg
Mean	3524.47	3866.71	4363.90	4581.54	5520.17	5100.16	4479.47
R^2(%)	82	77	54	67	85	55	88
CV%	5.63	9.24	9.73	9.49	4.46	6.87	8.05
LSD 5%	331.85	597.27	710.29	727.53	411.72	585.82	237.98
F test	**	**	**	**	**	**	**

ETBW–Ethiopia bread wheat, R^2, R-squire, CV- coefficient of variation, LSD- least significant different

Agronomic performance

Combined mean grain yield and other agronomic traits are presented in Table 4. High means of spike length, spike weight, spikelets per spike, grain per spike, grain per spikelets, thousand seed weight and grain yield and medium days to heading and days to maturity were recorded by genotypes ETBW7076. These offer great flexibility for developing improved varieties suitable for various agro-ecologies with variable length of growing period and high in grain yield status. However, genotypes ETBW7056, ETBW7075 and ETBW7088 were with short mean of days to heading and days to physiological maturity, indicating that early maturing genotypes were desirable when moisture was the limiting factors of production. Similarly, the local check was recorded high plant height, indicating that the variety might be susceptible to lodging; but genotypes ETBW7076 and ETBW7104 were with medium plant height indicated, and the possibility for developing resistant varieties against lodging problems. Moreover, genotypes ETBW7076, ETBW7104 and ETBW7056 recorded the highest grain yield and had 21.3, 10.9 and 4.4% yield advantages over the best standard check (Liban), respectively (Table 4).

Table 4: Combined mean grain yield and other agronomic traits of bread wheat genotypes

Genotypes	DH	DM	PH	SL	SW	STPS	GPS	GPST	TSW	YLD $Kgha^{-1}$	YAD
ETBW7052(G13)	80.2a	121.3c	78.1c	9.6bc	2.14c	16.4bcd	43.09bc	2.64b-f	24.37cd	4280ef	-8.4
ETBW7076(G6)	77.8b	118.2ef	75.04de	10.4a	3.7a	19.02a	55.51a	2.97ab	36.54ab	5669a	21.3
ETBW7092(G11)	76.1c	119.5de	81.9b	7.9hi	1.69de	15.01d	33.82f	2.29fgh	36.83a	4655bc	-0.4
ETBW7069(G12)	75.9c	117.2fg	74.06def	8.5fg	1.9cde	15.36cd	37.05def	2.48c-h	25.48bcd	4133fg	-11.5
ETBW7071(G15)	75.9cd	118.7e	73.54ef	8.8ef	1.9cd	16.26cd	40.48cd	2.46c-h	25.56bcd	4280ef	-8.4
ETBW7072(G8)	75de	120.5cd	76.19cd	8.3gh	1.99cd	15.73cd	37.08def	2.41d-h	25.61a-d	3940g	-15.7
Liban (G9)	74.8e	121.3c	74.05def	8.4fg	2.12c	16.69bc	45.75b	2.78a-d	22.64cd	4672bc	0
Local(G1)	72.6f	123b	93.18a	7.6i	1.3f	12.79e	33.76f	2.67b-e	19.48d	3925fg	-15.9
ETBW7104(G3)	71.6g	113.4h	75.3de	9.2d	3.02b	17.85ab	39.75cde	2.21gh	33.13abc	5179b	10.9
ETBW7077(G7)	71.4g	126.5a	73.47ef	9.1de	2.03c	15.90cd	33.59f	2.12h	22.06cd	4337def	-7.2
ETBW7068(G5)	70.9g	114.2h	78.18c	9.8b	2.02c	15.05d	35.44ef	2.39e-h	29.60a-d	4568cd	-2.2
ETBW7056(G2)	70.3i	116.3g	76.48cd	9.8b	2.06c	16.29cd	41.21bcd	2.52c-g	27.04a-d	4877c	4.4
ETBW7075(G10)	69.7i	114.1h	71.8f	9.4cd	1.98cd	15.58cd	37.62def	2.45c-h	28.28a-d	4691c	0.4
ETBW7088(G14)	69.6i	114.5h	68.46g	9.2cd	1.87cde	15.52cd	41.63bcd	2.81abc	22.54cd	4478cde	-4.2
kingbird(G4)	65.3j	109.6i	72.04f	7.9hi	1.6ef	14.98d	43.90bc	3.06a	21.18d	4407de	-5.7
Mean	73.13	117.89	76.12	8.92	2.09	15.9	39.98	2.55	26.69	4492.83	
CV%	1.91	1.85	5.23	6.71	23.36	14.65	19.06	21.92	63.93	8.05	
R^2 %	96	97	90	92	0.8	0.69	0.73	0.55	0.43	88	
LSD 5%	0.9	1.43	2.62	0.39	0.32	1.53	5.01	0.37	11.22	237.98	
F test	**	**	**	**	**	**	**	**	**	**	

ETBW-Ethiopia bread wheat, DH-Days to heading, DM-Days to maturity, PH-Plant height, SL-spike length, SW-spike weight, STPS-spikelets per spike, GPS-grain per spike, GPST- grain per spikelet, TSW- Thousand seed weight, YLD Kg/ha- Yield in kilogram per hectare, YAD- yield advantage, CV- Coefficient of variation,R^2-R-squere, LSD- least significant.

Table 5: Combined mean of disease reactions (1-5 scale) of bread wheat genotypes evaluated in 2017-2018 main cropping season

Genotypes	SR	LR	SEP	FHB
ETBW7052(G13)	1c	1b	1.03ab	1.8b-e
ETBW7076(G6)	1.1bc	1.08ab	1.03ab	1.9b-e
ETBW7092(G11)	1c	1b	1b	1.3f
ETBW7069(G12)	1.13ab	1.03b	1b	2.4a
ETBW7071(G15)	1c	1b	1b	2.2ab
ETBW7072(G8)	1.03c	1.06ab	1b	1.8b-e
Liban (G9)	1.03c	1b	1b	1.9b-e
Local(G1)	1c	1b	1.03ab	1.8cde
ETBW7104(G3)	1.04bc	1b	1.07a	1.6ef
ETBW7077(G7)	1c	1.08ab	1.03ab	1.7de

ETBW7068(G5)	1.13ab	1.03b	1.03ab	2.1abc
ETBW7056(G2)	1.06bc	1.11ab	1.06ab	2.4a
ETBW7075(G10)	1.17a	1.17ab	1.03ab	2.0bcd
ETBW7088(G14)	1c	1.03b	1b	1.8b-e
kingbird(G4)	1c	1.06ab	1b	1.9b-e
Mean	1.04	1.04	1.02	1.91
CV%	14.14	17.29	9.25	30.15
R^2 %	42	41	38	71
LSD 5%	0.097	0.12	0.062	0.38
F test	**	**	**	**

ETBW-Ethiopia bread wheat, CV- Coefficient of variation, LSD- least significant difference, R^2-R-Squere, SR-stem rust, LR-leaf rust, SEP-septoria, FHB-fusarium head blight.1-5 scale where 1= resistant, 5= susceptible

Major disease reactions

Most genotypes evaluated had significantly low scores for their corresponding economically important disease reactions (Table5). However, some genotypes (ETBW7075 (G10) and ETBW7069 (G12)) were less tolerance to stem and leaf rust and septoria. Similarly, genotypes ETBW7069 (G12) ETBW7071 (G15) ETBW7068 (G5), ETBW7056 (G2) and ETBW7075 (G10) were less tolerance to fusarium head blight (Table 5). On the other hand, genotypes ETBW7076 (G6) and ETBW7104 (G3) were better tolerance to stem and leaf rust and fusarium head blight (Table 5).

Additive main effects and multiplicative interaction (AMMI) model

The combined ANOVA and AMMI analysis for grain yield at six environments exhibited by bread wheat grain yield, was significantly affected by environments. This explained 65.06% of the total treatment variation, while the G and GEI were significant and accounted for 13.34 and 9.44 %, respectively (Table 6).Similar findings have been reported in previous studies (Kaya et al., 2006; Farshadfar et al., 2012). A study by Gauch and Zobel (1997) reported in standard multi-environment trials (METs), environment effect contributes 80% of the total sum of treatments and 10% effect of genotype and interaction.In additive variance, the portioning of GEss data matrix using AMMI analysis, indicated the first PCAs were significant ($P < 0.01$). PCA 1 and 2 accounted for 7.88 and 1.15 % of the GE interaction, respectively; representing a total of 9.03 % of the interaction variation (Table 6).Similar results have been reported in earlier studies (Mohammadi and Amri, 2009).

Large yield variation explained by environments indicated that environments were diverse,with large differences between environmental means contributing maximum of the variation in grain yield (Table 7).Grain yield of environments ranged from 3524 kgha^{-1}in E3 to 5520 kg ha^{-1} in E2. Genotype mean grain yield varied from 3940 kg ha^{-1} for ETBW7072 (G8) to 5069 kg ha^{-1} in ETBW7076 (G6), with the over all mean of 4493 kg ha^{-1} (Table 7)

Table 6: Additive main effect and multiplicative interaction analysis of variances (AMMI) for grain yield of 15 bread wheat genotypes evaluated at six environments

Source of variation	DF	SS	EX.SS%	MS
Total	269	192196683	100	714486
Treatments	89	168813778	87.83	1896784**
Genotypes	14	25637440	13.34	1831246**
Environments	5	125035456	65.06	25007091**
Block	12	3230047	1.68	269171*
GxE	70	18140883	9.44	259155**
IPCA 1	18	15142869	7.88	841271**
IPCA 2	16	2201589	1.15	137599^{ns}
Residuals	36	796424	0.41	22123
Error	168	20152857		119957

DF = degree of freedom, SS = sum of squares, MS = mean squares, IPCA = Interaction Principal Component Axis, EX. SS% = Explained Sum of square ns * ,** non-Significant ,Significant at the 0.5% and 0.1% level of probability respectively

Table 7: Average grain yield (kgha^{-1}) of 15 bread wheat genotypes tested across six environments in 2017-2018 main cropping seasons

Gen/Env	E1	E2	E3	E4	E5	E6	Mean
Local(G1)	3582	5209	3183	4112	3966	4701	4125
ETBW7075(G10)	4532	6007	3856	4354	4340	5060	4691
ETBW7092(G11)	3676	5398	3555	5417	4576	5310	4655
ETBW7069(G12)	3485	5108	3140	4447	3946	4674	4133
ETBW7052(G13)	3843	5370	3340	4480	3965	4683	4280
ETBW7088(G14)	3442	5200	3369	5217	4452	5190	4478
ETBW7071(G15)	3707	5312	3313	4465	4076	4804	4279
ETBW7056(G2)	4836	6381	4129	3829	4674	5416	4877
ETBW7104(G3)	4126	5795	3859	5256	4752	5485	4879
kingbird(G4)	3564	5268	3362	4864	4323	5060	4407
ETBW7068(G5)	3688	5458	3537	4791	4595	5344	4569
ETBW7076(G6)	4885	6393	4237	4628	4771	5497	5069
ETBW7077(G7)	3464	5244	3313	4480	4383	5135	4337
ETBW7072(G8)	3256	4941	2960	4034	3856	4596	3940
Liban (G9)	3915	5720	3713	4350	4785	5548	4672
Mean	3867	5520	3524	4582	4364	5100	4493

Gen-genotype; Env- environment, E1-BD-2017(Bedesso), E2-BD-2018, E3-BL-2017(Belem), E4-BL-2018, E5-MT-2017 (Mata), E6-MT-2018, the number following each location indicates the year, E=environment

The estimation of yield and stability of genotypes were done by using the average coordinates of the environment (AEC) methods (Yan, 2001; Yan and Hunt, 2001). The average environment is defined by the average values of PC1 and 2 for the all environments, and it is presented with a circle. The average ordinate environment (AOE) defines by the line which is perpendicular to the AEA (average environment axis) line and pass through the origin. This line divides the genotypes in to those with higher yield than average and in to those lower yield than average. By projecting the genotypes on AEA axis, the genotypes are ranked by yield;where the yield increases in the direction of arrow. In this case the highest yield had genotypes G6, G3 and

G2,but the lowers had G8, G1 and G12 (Fig1). Stability of the genotypes depends on their distance from the AE abscissa. Genotypes closer to or around the center of concentric circle indicated these genotypes are more stable than others. Therfore, the greatest stability in the high yielding group had genotypes G6, G3 and G2, whereas the most stable and yielder of all was G6 (Fig1)

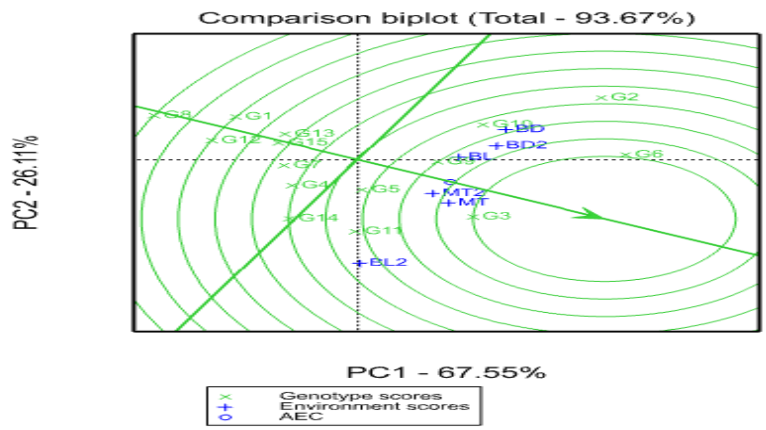

Figure 1; GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability of bread wheat varieties at Western Oromia in Ethiopia

The genotype ranking is shown on the graph of genotype so-called “ideal” genotype (Fig 1). An ideal genotype is defined as one that is the highest yielding across test environments and it is completely stable in performance (that ranks the highest in all test environments; such as genotypes G6, G3 and G2) (Farshadfar et al., 2012; Yan and Kang, 2003). Even though such an “ideal” genotype may not exist in reality, it could be used as a reference for genotype evaluation (Mitrovic et al., 2012). A genotype is more appropriate if it is located closer to “ideal” genotype (Farshadfar et al., 2012; Kaya et al., 2006).So, the closer to the “ideal” genotype in this study was G6 (Figure1). The ideal test environment should have large PC1 scores (more power to discriminate genotypes in terms of the genotypic main effect) and small (absolute) PC2 scores (more representative of the overall environments). Such an ideal environment was represented by an arrow pointing to it (Figure 2). Actually, such an ideal environment may not exist, but it can be used as an indication for genotype selection in the METs. An environment is more desirable if it is located closer to the ideal environment. Therefore, using the ideal environment as the centre, concentric circles were drawn to help visualise the distance between each environment and the ideal environment (Yan and Rajcan, 2002). Accordingly, E3 (BL-2017=Belem), which fell into the centre of concentric circles, was an ideal test environment in terms of being the most representative of the overall environments and the most powerful to discriminate genotypes (Fig2).

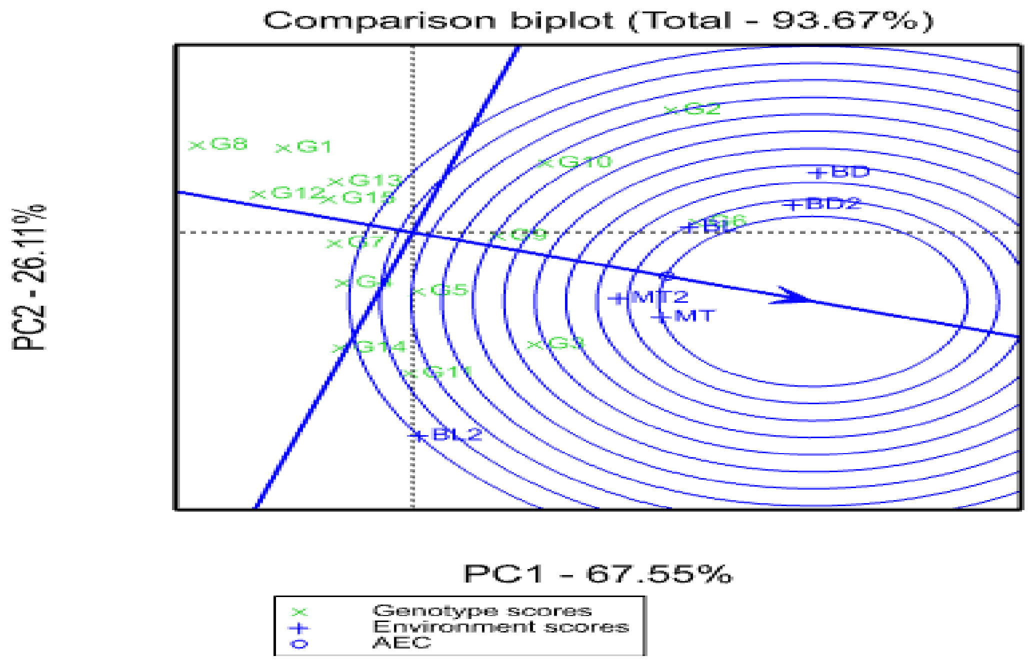

Figure 2: GGE bi-plot based on tested environments-focused comparison for their relationship E1-BD-2017(Bedesso), E2-BD-2018, E3-BL-2017(Belem), E4-BL-2018, E5-MT-2017(Mata), E6-MT-2018, the number following each location indicates the year, E=environment.

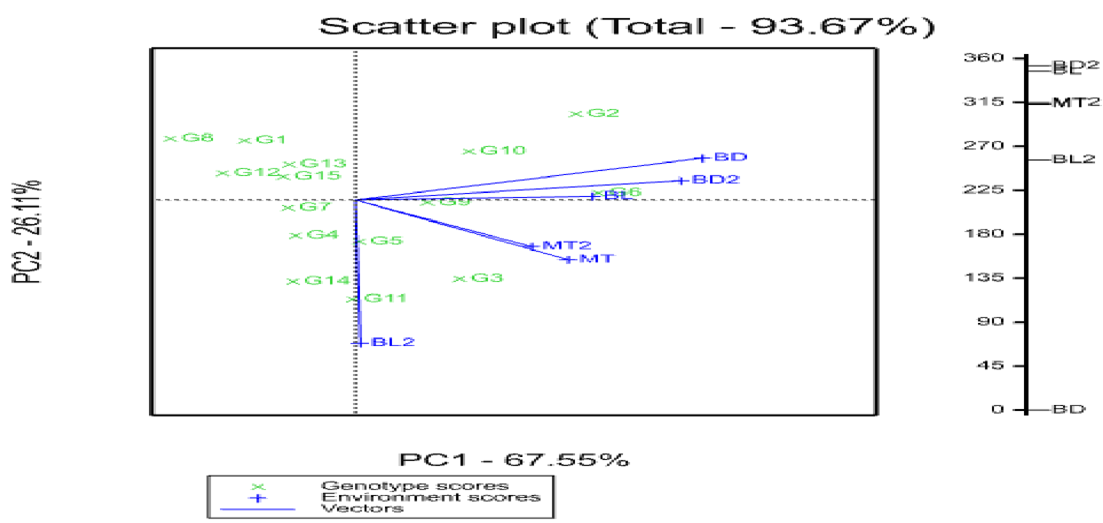

Figure 3: GGE bi-plot based on tested environments-focused comparison for their relationships. E1-BD (Bedesso), E2-BD-2018, E3-BL-2017(Belem), E4-BL-2018, E5-MT-2017(Mata), E6-MT-2018, the number following each location indicates the year, E=environment.

Table 8: Correlation coefficients among six test environments

Environment	E1	E2	E3	E4	E5
E2	0.984**				
E3	0.936**	0.977**			
E4	0.197^{ns}	-0.134 ^{ns}	0.066 ^{ns}		
E5	0.571*	0.701**	0.82**	0.387 ^{ns}	
E6	0.554*	0.687*	0.806**	0.378 ^{ns}	0.999**

^{ns,*}, ** non- Significant , significant at the 0.05 and 0.01 probability level, respectively.

The correlation coefficients among the six test environments and the vector view of the GGE-bi-plot delivered a brief summary of the interrelationship between the environments and correlation coefficients were significant (Fig3) Most environments were positively correlated since the angles among them were smaller than 90^{o}apart from environment E4 (Belem-2018), which had negatively correlated with E1 (BD-Bedesso-2017) and E2(BD-Bedesso-2018) since obtuse angles between them (Figure 3). Similarly, Farshadfar et al. (2012) reported environments ER3 and EI3 which represented rain fed and irrigated conditions in 2011 cropping seasons, respectively, made an obtuse angle with each other, indicated a negative correlation between the response of genotypes to rain fed and irrigated conditions. Indirect selection could be functional in the case where the same character was measured on the same genotypes in different environments. Where there are no correlations of error effects among environments, the phenotypic correlation between environments may be used to investigate indirect response to selection (Cooper and Delacy, 1994). Indirect selection for grain yield can be partial across the tested environments. This means, for instance, the genotypes adaptable or higher productivity in E4 may also show similar responses to E5 and E6 as well.

Additive main effects and multiple interactions (AMMI) stability value (ASV)

AMMI stability value (ASV)

Genotypes exhibited significant genotype by environment interaction effects and the additive and multiplicative interaction effect stability analysis (ASV) implied splitting the interaction effect. In view of mean grain yield as a first criterion for evaluating, G6 was the highest mean grain yield (5069kg ha^{-1}), followed by the genotypes G3 and G2 with the mean grain yield of (4879 and 4877kgha^{-1} respectively). Whereas, genotypes G8, G12 and G1 were with low mean grain yields across the testing locations (Table 7). The IPCA1 and 2 scores in the AMMI model are indicators of stability (Purchase, 1997). Considering IPCA1, G6 was the most stable genotype with IPCA1 value (-16.65), followed by G3 with IPCA1 value of (6.95). Likewise, in IPCA2, G9 was the most stable with interaction principal component value (-18.03). The two principal components have their own extremes, however calculating the AMMI stability value (ASV) is a balanced measure of stability (Purchase, 1997). Genotypes with lower ASV values are considered more stable and genotypes with higher ASV are unstable. According to the ASV ranking in the (Table 7), G8 was the most stable with an ASV value of 1 followed by G1 with ASV value 2. However, G2 was the most unstable since higher ASV value of 15. The stable genotype was followed with mean grain yield above the grand mean and this result was in agreement with (Hintsa and Abay, 2013), who has used ASV as one method of evaluating grain yield stability of bread wheat varieties in Tigray and similar reports been made by Abay and Bjørnstad (2009); Sivapalan et al. (2000) in barley in Tigray and bread wheat using AMMI stability value. A genotype with the least of genotype selection index (GSI) is considered as the most stable genotype (Farshadfar, 2008). Accordingly, G6 was the most stable genotype since with the low of genotype selection index (GSI) and the highest mean grain yield of all (Table7).

Table7: AMMI stability value, AMMI rank, yield, yield rank and genotype selection index and principal component axis

GENOTYPES	ASV	ASV RANK	YLD	YLD RANK	GSI	IPCAg1	IPCAg2
G6	144.3	10.0	5069	1.0	11.0	-16.65	5.04
G3	61.4	5.0	4879	2.0	7.0	6.95	2.55
G2	245.6	15.0	4877	3.0	18.0	-28.98	-6.11
G10	148.8	12.0	4691	4.0	16.0	-15.43	9.17
G9	153.4	14.0	4672	5.0	19.0	-4.16	-18.03
G11	145.9	11.0	4655	6.0	17.0	17.29	3.27
G5	86.4	7.0	4569	7.0	14.0	6.82	-7.88
G14	149.0	13.0	4478	8.0	21.0	17.97	-0.03
G4	82.2	6.0	4407	9.0	15.0	9.88	0.72
G7	92.9	8.0	4337	10.0	18.0	5.42	-9.80
G13	100.3	9.0	4280	11.0	20.0	-1.71	11.97
G15	44.1	3.0	4279	12.0	15.0	0.58	5.29
G12	56.6	4.0	4133	13.0	17.0	4.02	5.51
G1	27.2	2.0	4125	14.0	16.0	-3.16	0.86
G8	23.2	1.0	3940	15.0	16.0	1.16	-2.54

Conclusion

Based on the two analyses of AMMI and GGE-bi-plot models, G6 and G3 considered by high yield and more stability, consequently, G6 close to ideal genotype, so this genotype is adaptable to a wide range of environmental conditions. Therefore, G6 was identified as ideal genotypes in terms of yielding ability and stability, tolerant to diseases for advancement, release and use as parents in future breeding programs.

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References

Abay, F. and Bjørnstad, A. 2009.Specific adaptation of barley varieties in different locations in Ethiopia.*Euphotic*, 167: 181-195

Comstock, R.E. and Moll, R.H.1963. Genotype x Environment Interactions: Symposium on Statistical Genetics and Plant Breeding.National Academy Science National Research Council, Washington, D.C. pp. 164-196

Cooper,M. and Delacy, I.H.1994. Relationships among analytic methods used to study genotypic variation and genotype-by-environment interaction in plant breeding multi-environment trials. Theory Applied Genetic. 88:561-572.

Delacy, I.H., Basford, K.E., Cooper, M. and Bull, J.K. 1996. Analysis of multi- environment trials- an historical perspective. Plant Adaptation and Crop Improvement.Eds. M. Cooper and G. L. Hammer. CAB international, pp. 39-124.

Farshadfar, E 2008.Incorporation of AMMI Stability Value and Grain Yield in a Single Non-Parametric Index (Genotype Selection Index) in Bread Wheat.Pakistan Journal of Biological Sciences11: 1791-1796.

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

Gabriel, K.R.1971. The biplot graphic of matrices with application to principal component analysis. Biometrics 58:453-467pp.

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

Gauch, H.G.and Zobel, R.W. 1997. Interpreting mega-environments and targeting genotypes. Crop Sciences 37:311-326.

Hintsa, G. and Abay, F. 2013.Evaluation of Bread Wheat Genotypes for their Adaptability in wheat growing Areas of Tigray Region, northern Ethiopia. *Journal of Biodiversity and Endangered Species.*

Kang, M.S. 2004. Breeding: Genotype-by-environment interaction. In R.M. Goodman (ed.) Encyclopedia of plant and crop science. Marcel- Dekker, New York. Pp. 218-221.

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

Mitrovic, B., Stanisavljevi, D., Treski, S., Stojakovic, M., Ivanovic, M., Bekavac, G. and Rajkovic, M. 2012. Evaluation of experimental Maize hybrids tested in Multi-location trials using AMMI and GGE bi-plot analysis. *Turkish Journal of Field Crops* 17:35-40.

Mohammadi, R. and Amri, A. 2009. Analysis of Genotype × Environment Interactions for Grain Yield in Durum Wheat. Crop Sciences. 49:1177-1186.

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

SAS Institute Inc. 2008. Statistical analysis Software version 9.2, Cary, NC: SAS Institute Inc. USA

Sivapalan, S., Obrien, L., Ortiz-Ferrara, G., Hollamby,GJ., Barclay, I. and Martin, PJ. 2000. An adaptation analysis of Australian and CIMMYT/ICARDA wheat germplasm in Australian production environments. Crop Science pastures 51: 903-915.

VSN International, 2012. "Gen Stat for Windows 15th Edition. VSN International, Hemel Hempstead, UK." Available: www.genStat.co.uk

Yan, W.2001. GGE bi-plot- a windows application for graphical analysis of multi-environment trial data and other types of two-way data *Journal of Agronomy* 93:1111-1118.

Yan, W. and Kang, MS. 2003. GGE bi-plot analysis: a graphical tool for breeders, In Kang MS, ed. Geneticists, and Agronomist. CRC Press, Boca Raton, FL, pp. 63-88.

Yan, W. and Hunt, LA., Sheng, Q. and Szlavnics, Z. 2000.Cultivar evaluation and mega environment investigation based on the GGE bi-plot. Crop Science.40:597-605.

Yan, W. and Hunt, LA.2001. Genetic and environmental causes of genotype by environment interaction for winter wheat yield in Ontario. Crop Science. 41:19-25.

Yan, W. and Rajcan, I. 2002.Bi-plot analysis of test sites and trait relations of soybeaninOntario.Crop Science. 42:11-20.

Adaptation Study of Released Finger Millet (*Eleusinecoracana* L.) Varieties in Western Oromia, Ethiopia

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Abstract

The experiment was conducted with eight improved finger millet varieties against local check at Haro Sabu Agricultural Research Center (HSARC) on station and Chanka research sub site for two consecutive years (2017-2018) to identify and recommend high yielding, stable and insect pest tolerantvarieties. The seeds were planted in Randomized Completed Block Design (RCBD) with three replications in the net plot size of 3m^2 using four harvestable rows at the spacing of 30cm. Agronomic traits Viz. Days to heading (DH), Days to maturity (DM), Lodging percentage (LDG), Grain yield (GY), Plant height (PH), Finger length (FL), Productive tillers (PTR), Finger per main ear (FPME) Finger weight per plant (FWPP) and Head blast (HB)were collected and analyzed. Analysis of variance revealed significant difference among varieties for most observed traits. The combine ANOVA and the AMMIanalysis for grain yield across *environments revealed significantly affected by environments, that hold 40.84% of the total variation.The genotype and genotype by environmental interation were significant and accounted for 32.67% and 23.44% respectively. Pricipal component 1 and 2 accounted for 17.98 % and 5.09 % of the GEI respectively with a total of 23.07 % variation.In general, Adis-01 and Boneya varietieswere identified as the best varieties for yielding ability, stability, tolerant to diseases and recommended in the area and with similar agro-ecologies.*

Key words: *Adaptability, finger millet (Eleusinecoracana L.) stability varieties*

Introduction

Finger millet, (*Eleusinecoracana* L.) Gaertn. ssp. coracana), is the second most widely grown millets on the continent of Africa and it is an important crop grown in low input farming systems by resource poor farmers in eastern and southern Africa (Damar et al., 2016). This is indigenous to the highlands of Uganda and Ethiopia. Finger millet is widely produced by small scale landholders and consumed locally (Adugna et al., 2011). It is well adapted to heat, drought and poor soil stress that succeed in marginal and degraded soils (Okalebo, 1991). It is valued for nutrition, malt, good storability, income and other uses for animal feeds. In Ethiopia, finger millet covered 456171.54 hectare of land with the productivity of 22.30 qt/ha (CSA, 2017). However, low in yielding due to lack of high yielding cultivars, moisture stress, and lodging effect, diseases and low fertility and poor crop management practices (Degu et al., 2009). Strengthen the seed production and delivery systems for improved varieties also the most bottleneck of the crop in the small-scale farmers. Climatic change also directed to reduce the productivity of many crops around the world. So that a considerable attention should be given to the effect of genotype x environment interaction in the plant breeding programs, the relative performance of cultivars for quantitative traits such as yield and the other characters, which influence yield, vary from an environment to another. Consequently, to develop a variety with high yielding ability and consistency over locations, high attention should be given to the importance of stability performance for the genotypes under different environments and their interactions.

The impacts of phenotypic variation principally based on the environmental situation and the genetic constitution of the varieties. Such variation is more complicated by the fact that not all genotypes respond in a similar way to change in the environment and no two environments are exactly the same. The genotype × environment interaction results in genotype rank changes from one environment to another, a dissimilar in scale among environments, or a combination of these two situations. It is imperative to detect specific genotypes adapted to or stable in environment(s), in that way succeeding quick genetic gain through screening of genotypes for high adaptation and stability under varying environmental conditions prior to release as a variety (Ariyo, 1989; Flores et al., 1998; Showemimo et al., 2000; Mustapha et al., 2001).While, most genotypes show fluctuating yields when grown in different environments or agro-climatic zones. This makes difficulties indicating the superiority of a specific variety. To tackle this challenge, multi- location yield trials are essential to identify adaptable high yielding cultivars and discover sites that best represent the target environment (Yan et al., 2000). Adaptability is the result of genotype, environment and genotype by environment interaction. That means the ability to perform at an acceptable level in a range of environments, stated to as general adaptability, and the ability to perform well only in appropriate environments, known as specific adaptability (Farshadfar and Sutka, 2006).

Combined analysis of variance can quantity G × E interactions and express the main effects however, does not explain the interaction effect (Yuksel et al., 2002; Worku et al., 2013). The main reason of additive main effects and multiplicative interactions (AMMI) is appropriate for agricultural research is that the ANOVA part of AMMI can separate the G and E main effects and the G × E interaction effects (Gauch et al., 2008). Besides, its greatest advantage is its ability to take out interaction Principal Component Axis (PCA) along which there is a maximum variation, thus indicated the number of components necessary to explain the pattern in the interaction residual (Girma, 1999). Additive Main Effect and Multiplicative Interaction model and genotype and genotype by environment interaction (GGE) bi-plot analysis are the most frequently used analytical and statistical tools to determine the pattern of genotypic responses across environments (Gauch and Zobel, 1996; Yan et al., 2000; Yuksel et al., 2002). AMMI and GGE bi-plot (Gauch and Zobbel, 1996; Yan et al., 2000; Yuksel et al., 2002) for graphical display of data and Eberhart and Russell (1966) model are the most commonly used analytical and statistical tools to identify stable, high yielding and adaptable genotype(s) for wider and/or specific environments. Therefore, the objective of the study was to evaluate, select and recommend high yielder, tolerant to diseases, more adapted and stable varieties.

Materials and Methods

Description of locations: The experiment was conducted at two different rain fed locations in Kellem and west Wollega zones of Haro-sebu agricultural research center for two consecutive year on station and Chanka sub-site in western Oromia, Ethiopia, during the 2017-2018 main cropping season, that represent the varying agro ecologies of the finger millet growing areas of the zones.

Experimental materials: Eight finger millet genotypes including improved varieties (Adis-01, Bareda, Boneya,Diga, Gudetu, Urji and Wama)and local checkwere evaluated.

Experimental design and management: Randomized completed block design (RCBD) with three replications were used in all locations. Each experimental plot had six rows of 2.5 m long and 30 cm apart with a plot area of 1.8 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 150 and 100 $kgha^{-1}$ Urea and DAP respectively. All P_2O_5 and half of N were applied during planting, while the rest half splits were applied at tillering stages. A seeding rate of 15 kg ha^{-1} was used. All agronomic management wascarried out accordingly. The data considered for analysis was from the candidates of the net plot, thus the four central harvestable rows. The harvested genotypes were sundried before being tested for moisture content where 12% was the preferred average moisture content using moisture tester. Grain yield data was then obtained by weighing the dried grain using a digital scale.

Data collection method: Plants were selected randomly before heading from each row (four harvestable rows) and tagged with thread and all the necessary plant based data were collected from these sampled plants. **Plot basis:** Days to heading (DH), Days to maturity (DM), Lodging percentage (LDG), Grain yield (GY), and Head blast (HB) was recorded as an economic important of finger millet diseases. **Plant basis:** Plant height (PH), Finger length (FL), Productive tillers (PTR), Finger per main ear (FPME) and Finger weight per plant (FWPP)

Statistical analysis: The collected data were organized and subjected to analyzed using SAS version 9.2 (SAS, 2008) computer software and additive main effect and multiplicative interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 15th edition statistical package (VSN International, 2012).

Results and Discussions

Combined analysis of variance

The mean square of analysis of variance (ANOVA) is presented in Table 1. Highly significant differences were detected among the main and the interaction effects (P ≤ 0.01) for most of the parameters. The combined analysis of variance showed that significant differences were recorded across location for all parameters except head blast. Year*****varieties effects were significant for most traits. Year*****location *****varieties were significant for most traits such as days to heading, days to maturity,finger length,productive tillers, lodging and grain yield.

Table 1: Combined Analysis of variance (ANOVA) for grain yield and yield related traits of finger millet varieties

Source	**DF**	**DH**	**DM**	**PH**	**FL**	**PTL**	**FPME**	**FW**	**HB**	**LDG**	**YLD ($kgha^{-1}$)**
Rep	2	7.1**	2.6	63.3	0.36	6.3**	0.6	24.3	0.3	0.1	14471.49
Vrt	7	189.6**	70.3**	357.1**	1.49	12.2**	6.1**	83.6**	6.9**	2.2**	5989786.2**
Loc	1	256.8**	870**	11194**	142**	5.5**	109.4**	1526**	0.0	6.5**	6490671.8**
Yr	1	2849**	1283**	527.6*	0.29	401.9**	4.4*	9532**	2.3**	6.5**	44471991**
vrt*loc	7	7.5**	11.7**	75.2	2.49**	1.2	2.3*	18.2	0.1	0.5	2098575.5**
vrt*yr	7	49.4**	36.5**	110.5	6.4**	3.6*	1.0	44.9	0.6*	2.2**	1470375.4**
loc*yr	1	25.0**	2214**	585.8*	249.5**	230.5**	1.9	1036**	0.0	0.1	1451713**
vrt*loc*yr	7	9.5**	23.2**	78.2	3.98**	5.1**	0.38	4.1	0.1	0.7*	729102.9**

Key: * **, significant at 5% and 1% respectively, Loc *vrt = location by variety, Yr*Loc*vrt = year by location by variety, DF -degree of freedom, DH- Days to Heading; DM- Days to Maturity; PTL- productive tillers, Head Blast (HB), (LDG)- lodging, (PH)- Plant Height; Finger length (FL); Finger Weight per plant (FW),Finger per main ear (FPME) and Yield Kilogram per hectare ($YLDkgha^{-1}$)

Agronomic performance

Combined mean grain yield and other agronomic traits are presented in Table 2. Adis-01 variety was recorded medium days to heading, days to maturity, and plant height, productive tillers and finger per main ear indicated that, the possibility to resist against lodging problems and also it recorded the highest grain yield. In the other hand, Diga variety was recorded medium days to maturity, plant height, and finger weight but it recorded the lowest days to heading, and susceptible to lodging problem.

Table 2: Combined mean grain yield and other agronomic performances of finger millet varieties evaluated.

Varieties	**DH**	**DM**	**PH**	**FL**	**PT**	**FPME**	**FW**	**HB**	**LDG**	**YLD ($kgha^{-1}$)**
Adis-01	78.7d	131.8b	66.1b	4.5ab	5.6b	5.9b	14.3ab	1.5cd	2.1cd	3424.1a
Bareda	87.1a	127.8c	62.4b	4.3abc	7.5a	5.9b	10.8b	3.0ab	2.5ab	1553.8e
Boneya	74.8g	131.4b	76.4a	4.8a	5.8b	6.0b	16.8a	1.7c	2.0cd	2991b
Diga	74.9g	131.6b	61.4b	4.0bc	7.4a	5.8bc	11.1b	3.1a	2.7a	2116.5d
Gudetu	76.4f	128.6c	58.9b	3.9bc	5.1b	6.3b	14.2ab	1.8c	1.5e	2909.5bc
Local	79.7c	131.7b	65.6b	3.7c	5.2b	5.1cd	12.7b	1.2d	2.3bc	2422.3c
Urji	77.7e	132.5b	60.5b	4.1abc	7.3a	7.2a	10.3b	2.7b	2.7a	1460.6e
Wama	80.7b	135.8a	64.9b	4.0bc	5.9b	4.9d	17.1a	1.5c	1.8de	2163.4d
Mean	78.74	131.4	64.52	4.174	6.252	5.88	13.41	2.055	2.198	2418
R^2	0.985	0.97	0.757	0.901	0.907	0.781	0.892	0.871	0.778	0.97
CV%	1.38	1.254	14.44	22.42	18.44	15.57	37.92	17.99	22.31	10.37
LSD 5%	0.89	1.34	7.6	0.76	0.94	0.75	4.2	0.3	0.4	204.6
F-test	**	**	**	*	**	**	*	**	**	**

Key: * **, significant at 5% and 1% respectively, R^2- R- square, CV-coefficient of variation, LSD-least significance differences, DH- Days to Heading; DM- Days to Maturity; PTL- productive tillers, Head Blast (HB), (LDG)- lodging, (PH)- Plant Height; Finger length (FL); Finger Weight per plant (FW),Finger per main ear (FPME) and Yield Kilogram per hectare (YLDkgha)

Disease reaction with finger millet varieties across environments

Disease reaction: the result revealed that Adis-01, Boneya, Gdetu, Urji and Wama varieties are better tolerance to economically important head blast disease but Diga and Bareda varieties are less tolerance to head blast disease (Table3).

Table 3: Disease reactions for yield and yield related traits of the evaluated improved finger millet varieties

Varieties	Head Blast
Adis-01	1.5cd
Bareda	3.0ab
Boneya	1.7c
Diga	3.1a
Gudetu	1.8c
Local	1.2d
Urji	2.7b
Wama	1.5c
Mean	2.055
R-Square (%)	87.1
CV%	17.99
LSD 5%	0.3
F-test	**

Key: 1-5 scale scoring was used for disease reaction where 1= resistant, 5= susceptible CV =coefficient of variation, LSD =least significant different

Additive Main Effects and Multiple Interaction (AMMI) model

The mean squares for all varieties evaluated under different environmental condition for grain yield are presented in Table4. The result indicated that differences among all varieties were significant ($P \leq 0.01$). Variation due to genotypes by environments interaction was significant for the studied traits, indicated that genotypes differ genetically in their response to different environment. The genotypes by environments interaction was significant effect on the grain yield, which explained 23.44% of the total variation whiles the genotypes, contributed 32.67% of the variation. However, large portion (40.84%) of the total variation was attributed to the environmental effect.

Table 4 Additive main effect and multiplicative interaction analysis of variances (AMMI) for grain yield of eight finger millet varieties

Source	D.F.	S.S.	EX.SS%	M.S.
Total	95	128353731	100	1351092
Treatments	31	124429241	96.94	4013846**
Genotypes	7	41928507	32.67	5989787**
Environments	3	52414333	40.84	17471444**
Block	8	375731	0.29	46966^{ns}
Interactions (GxE)	21	30086401	23.44	1432686**
IPCA 1	9	23083507	17.98	2564834**
IPCA 2	7	6527931	5.09	932562**
Residuals	5	474964	0.37	94993
Error	56	3548759		63371

Key: DF = degree of freedom, SS = sum of squares, MS = mean squares, IPCA = Interaction Principal Component Axis, ** = highly significant, ns = non-significant, EX. SS%-Explained Sum of square

Significant percentage of genotypes by environments interaction was explained by IPCA-1 (17.98 %) followed by IPCA2 (5.09 %). Accordingly, Gauch and Zobel (1996) recommended that the most accurate model for AMMI can be predicted by using the first two PCAs. The genotypes by environments interaction components were smaller than the genotypic components related to predictable environment factor (such as geographic areas, major pest problems,) the breeder searches for a genotypes specific requirements of environment while the interaction is small and unpredictable (micro climatic or yearly variation in weather and management practices) the breeder searches for a genotypes that has general adaptability and unversed performance over the range environments.

Comparison plot for genotypes based on the concentric circle

Based on Figure 1 shows the comparison plot for variety, and an ideal variety is one which is near or at the center of the concentric circle. Accordingly, the plot reflected that Adis-01 and Boneya are the most ideal varieties as shown by their position. It also reflects that, these varieties have high mean grain yield and more stable.

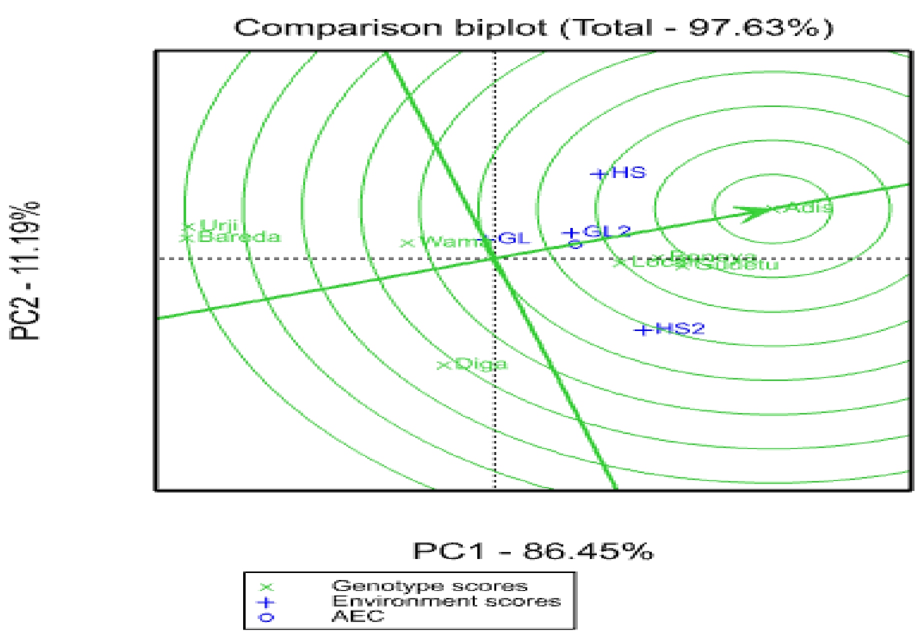

Figure 1: GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability

Conclusions and Recommendations

Combined analysis of variance (ANOVA) result revealed significant difference of grain yield and most of yield contributing traits among evaluated finger millet varieties across locations, years and the interactions. This indicated that, the location and fluctuation of weather condition over the cropping season had affected performance of varieties. Although the GEI of grain yield partitioned in to different IPCAs using AMMI model analysis, the first principal component axis for interaction alone explains most of the interaction sum of squares. The sign and magnitude of IPCA scores showed the relative contribution of each genotype and environment for the genotype and environment interactions. This helps to summarize the pattern and magnitude of GEI and main effects that reveal clear insight into the adaptation of genotypes to environments. This shows that, Adis-01 and Boneya varieties are fewer contributors to the interaction effect and have consistent performances across locations. Therefore,Adis-01 and Boneyawere identified as the best varieties in terms of yielding ability and stability, tolerant to diseases and better agronomic performance.

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References

Adugna A, Tesso T, Degu E, Tadesse T, Merga F, Legesse W, Tirfessa A, Kidane H, Wole A &Daba C (2011) Genotype-by-Environment Interaction and Yield Stability Analysis in Finger Millet (Eleusinecoracana L. Gaertn) in Ethiopia. American Journal of Plant Sciences 2: 408–415.

Ariyo, J. (1989). Factor analysis of pod yield in Okra (Abelmoschusesculentus).Theoretical and Applied Genetics 64: 82–85.

CSA (2017), The Federal Democratic Republic of Ethiopia, Central Statistical Agency agricultural sample survey 2016/2017 (2009 E.C) volume I report on area and production of major crops (private peasant holdings, *Meher* season). Statistical Bulletin no.584, Addis Ababa, Ethiopia, pp. 118

Damar, W. K., Russom, Z., Garba, A.A., Ibrahim, S. A. & Haggai, P. T (2016) Yield Response of Finger Millet (EleusineCoracana (L) Gaertn) To Transplanting Date, Intra Row Spacing and Poultry Manure In Bauchi, Nigeria. International Research Journal of Natural and Applied Sciences Vol. 3, Issue 5.

Degu, E., Adugna, A., Tadesse, T. and Tesso, T. (2009). Genetic resources, breeding and production of millets in Ethiopia, In new approaches to plant breeding of orphan crops in Africa. Proceedings of an International Conference, Bern Switzerland, 19-21 September, 2007.

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

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

Flores, F.; M.T. Moreno and J.I. Cubero (1998) A comparison of uni-variate and multivariate methods to analysis G × E interaction Field – Crops Res. 56: 271- 286.

Gauch, H. G. and Zobel, R.W. (1996). AMMI analysis of yield trials. In: Genotype by environment interaction. pp. 85-122 (Kang, M. and Gauch, H. eds.). Boca Raton. CRC press, New York.

Gauch, H.G., Piepho, H.P. and Annicchiarico, P. (2008). Statistical analysis of yield trials by AMMI and GGE: Further considerations. Crop Science 48:866–889.165

Girma T, (1999). Modeling Genotype by environment interaction: A Review of procedures In: Proceeding of the Eight Annual Conference of the Crop Science Society of Ethiopia, pp 147 – 158, Addis Ababa, and Ethiopia.

Mustapha, A, A.; F.A. Showemino and A. Aminu – kano (2001). Yield stability analysis of promising maize cultivars in Nigeria. J. Arid Agric 11: 1 -4.

Okalebo JR, Jutto PM &Gathera KW (1991) Effect of form and method of phosphate fertilizer application on maize, sorghum and millet growth in semi-arid environment of Kenya. II. Effect of bulrush and finger millet. East African Forestry Journal 55: 239–248.

SAS Institute Inc. (2008). Statistical analysis Software version 9.2, Cary, NC: SAS Institute Science 6: 36–40.

Showemimo, F.A., C.A. Echekwu and M.Y. Yeye (2000) Genotype ×environment interaction in sorghum trials and their implication for future variety evaluation in maize growing areas of northern Nigeria the Plt. Scientist 1: 24 -31

VSN International, (2012) "Gen Stat for Windows 15th Edition VSN International, Hemel Hempstead, UK" Available: www.genStat.co.uk

Worku, A., Henry, M., Zewotir, T. and Taye, G. (2013). Additive main effects and multiplicative interactions model (AMMI) and genotype main effect and genotype by environment interaction (GGE) biplot analysis of multi-environmental wheat variety trials. African Journal of Agricultural Research 8(12):1033-1040.

Yan, W., Hunt, L.A., Sheng, Q., Szlavnics, Z. (2000). Cultivar evaluation and mega environment investigation based on the GGE bi-plot Crop Science.40:597-605

Yuksel Kaya, Cetin Palta, SeyfiTaner (2002). Additive main effects and multiplicative interactions analysis of yield performances in bread wheat genotypes across environments. Turkish Journal Agriculture and Forestry 26: 275-279.

Multi-Location Evaluation of Yield and Yield Related Trait Performance in Sorghum (*Sorghum bicolor* L.) Genotypes at Western Oromia, Ethiopia

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Abstract

The field experiment was conducted on twelve sorghum genotypes (regional variety trial) against checks at Haro Sabu Agricultural Research Center (HSARC) sub sites for three consecutive years (2016-2018) to evaluate high yielding, insect pest tolerant genotypes and to assess genotype by environmental interaction on grain yield and yield stability across four diverse environments. The seeds were sown in Randomized Completed Block Design (RCBD) with three

*replications in the net plot size of 9 m^2 using four harvestable rows at the spacing of 0.75m and 0.15m. Eight agronomic traits and three economically important disease reaction were evaluated. Analysis of variance detected significant difference among genotypes for all observed traits both separated and combined analysis of variance. All observation attained significant differences over years except grain yield. Whereas; locations had significantly affected all observed traits in combined analysis. On the other hand, varieties*location significantly affected all recorded traits excluding days to heading and thousand seed weight. Similarly, Year*variety had significantly differences for all recorded trait except days to maturity, head weight and lodging percentage while varieties*year*location exhibited significant difference for plant height, head height, lodging percentage and grain yield. A pooled analysis of variance for grain yield across four different environments, the G × E interaction was significant (P<0.001), and this justified need for testing for GEI components using the GGE bi-plot analysis to enhance the understanding the effects of components. The results revealed that four environments were identifiable, which Hawa Galan had the most discriminating ability and good representativeness whereby Kombo had a poor discriminating ability as well as least representativeness. GGE bi-plot analysis revealed that G3, G11 and G12 were identified as ideal genotypes in terms of yielding ability and stability and were promoted to VVT for advancement, release and use as parents in future breeding programs.*
Key words: *Sorghum evaluation, GGE, adaptation and yield stability, discriminating ability, representativeness.*

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 (cereal statistics). Sorghum is the most known crop especially in Africa, central America and south Asia and Ethiopia in general and specifically a major cereal crop in west and KellemWollega zones.Sorghum is the most known crop in Ethiopia in general and specifically a major cereal crop in west and KellemWollega zones next to maize(CSA,2017). The national average production of sorghumis 25.25qt/ha (CSA 2017).The area coverage, production and yield (qt/ha) of sorghum in the Wollegazones were 97,711.83 hectares, 2,989,883.74quintals production and 30.60 qt/ha 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 through, the national breeding programmes 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. This is resulting from subjecting the environment centered yield data (due to GGE) to singular value decomposition. This makes it very easy to identify which genotype won in which environments. This is facilitated in the form of a polygon to visualize the interaction patterns between genotypes and environments (Yan and Kang, 2003), whereby greatestgenotypes are connected from the bi-plot origin such thatall genotypes are contained in the polygon (Kaya et al., 2006). Some genotypes will be located on the vertices of the polygon and they are either the best or the poorest in one or more environments (Yan et al., 2000; Yan and Rajcan, 2002; Yan and Tinker, 2006). The rays are drawn perpendicular to the sides of the polygon dividing it into sectors, such that the vertex genotypes in each sector is also the best genotype for sites whose markers fall into respective sector so that sites within the same sector share the same winning genotype (Yan, 2002; Yan et al., 2000). GGE bi-plot is a visual display of the G + GE of multi-environmental data where groups of locations with similar cultivar responses are presented and it identifies the highest yielding varieties for each group.

PC1 tend to correlate highly with the genotype means, the ideal cultivar is the one which possess large scores for PC1, thus indicating high average yield and small PC2 scores indicating less GEI and greater stability.

The objectives of this study were to identify genotype and environmental components that are associated with the G × E interaction across the diverse environments and rank locations based on discriminating ability and representativeness by using the genotype, genotype by environment interaction (GGE bi-plot analysis) and to evaluate high yielding, insect pest tolerant genotypes.

Materials and Methods

Study sites

The multi-locational yield trial (MLYT) was conducted at four different locations in Kellem and west Wollega zones of Haro-sebu agricultural research center at Kombo, Haro-sebu,Guliso and Hawa-Galan research sub-sites (Tablen1)to assess and confirm the effects of genotype, environment and genotype by environment interaction. The locations have different agro-climatic conditions.Hawa-Galan representing the high-potential area with good rains and soils, Guliso representing the intermediate potential area with average rainfall, Haro-Sabu and Kombo representing the low potential area. According to the 2016/7 season weather data collected at study sites, the low potential areas had an average of 1100 mm annual rainfall and temperature was 30^0C, while the high potential areas received an average of 1600 mm and temperature of 22^0C.The sites also characterized by different soil types, which range from the Light red Sandy Clay at Guliso, Brown sandy-loam soils at Hawa Galan and black clay loam at Kombo and light red sandy at Haro Sabu (Table 1).

Table-1. Description of four locations used for evaluation of sorghum genotypes

Locations	code	Geographical position		Altitude (m.a.s.l)	Average rain fall(mm)	Soil type
		Latitude	Longitude			
Harosabu	HS	08^0 19'N	035^0 30'E	1550m	1100mm	Sandy clay
Kombo	KB	08^0 92 'N	035^0 09'E	1440m	1200mm	Sandy loam
Guliso	GL	NI	NI	1600m	1400mm	Sandy Clay
Hawa Galan	HG	08^0 38' N	035^0 50'E	1905m	1600mm	Sandy loam

NI=not identified

Breeding materials and experimental design: Twelve genotypes of sorghum including checks were evaluated for three cropping seasons(2016-2018) at four different locations (Table2). The trial was planted in randomized completed block design (RCBD) replicated three times. Each plot consists of six rows (with four harvestable rows), 3m plot length with inter-row and intra-row spacing of 0.75m and 0.15m respectively and 2m spacing between each block was used. A seed rate of 25 kgha^{-1}and a combination of UREA and NPS fertilizer was applied at the recommend rate of100 kg ha^{-1}(1:1 ratio).NPS fertilizer was applied uniformly for all treatments equally at the time of sowing and split application was carried out for UREA (half at planting time and halfafter six weeks from emergency). All other agronomic practices were performed as per the recommendation for the crop. The trial was raised under rain fed across all the test locations. The data considered for analysis was from the candidates of the net plot, thus the four enteral harvestable rows. The harvested panicles were sundried for two days before being tested for moisture content where 12% was the preferred average moisture content using moisture tester. Grain yield data was then obtained by weighing the dried grain using a digital scale.

Table 2. Description of sorghum landraces used in the multi-locational trials(pass port data)

No	Variety /line code	Code	Region	Zone	Woreda	Village	Altitude	Soil texture	Soil color	Source of collection
1	SLRC-010	G1	Oromiya	K/Wollega	d/Sadi	Laku	1514	sandy	Light red	Field
2	SLRC-06	G8	Oromiya	W/Wollega	Guliso	d/guda	1708	Sandy Clay	Light red	Back yard
3	SLRC-027	G7	Oromiya	W/Wollega	Begi	Shelxa	1433	Clay loam	Black	Field
4	SLRC-028	G5	Oromiya	W/Wollega	Begi	Maganxaya	1584	Sandy loam	Brown	Field
5	SLRC-037	G4	Oromiya	K/Wollega	Gidam	Alchayajilo	1698	Sandy loam	Brown	Field
6	SLRC-043	G3	Oromiya	K/Wollega	Seyo	Minko	1690	Sandy loam	Brown	Field
7	SLRC-046	G12	Oromiya	K/Wollega	Arbigaba	Masarata	1482	Sandy loam	Brown	Field
8	SLRC-048	G6	Oromiya	K/Wollega	Hawawalal	Odamoti	1369	clay loam	Black	Field
9	SLRC-058	G11	Oromiya	K/Wollega	Yamalogiwalel	Hora maka	1429	Clay loam	Black	Field
10	local check	G9	Oromiya							
11	Gamadi	G2	Oromiya							
12	Lalo	G10	Oromiya							

source: HSARC 2013/4 Landrace collection. G-genotype, K/Wollega-KellemWollega,W/Wollega-West wollega

Statistical analysis:

Multivariate method, Additive Main Effects and Multiplicative Interaction (AMMI) model was used to assess genotype by environment interaction (GEI) pattern. The AMMI model equation is: Yger =μ+αg+βe+Σnλnγgnδen+ εger+ρge; where, Yger 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, γgn is the genotype eigenvector for axis n, and δen is the environment eigenvector; εger is error term and ρge 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 (Gauch, 1992; Umma et al.,2014).

AMMI stability value of the ith genotype (ASV) was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 to the interaction SS as follows (Purchase et al.,2000):

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

Where, SSIPCA1/SSIPCA2 is the weight given to the IPCA1 value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. Based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value (RASVi) a selection index called Genotype Selection Index (GSI) was calculated for each genotype, which incorporates both mean grain yield (RYi) and stability index in single criteria (GSIi) as suggested by Farshadfar, 2008. GSIi = RASVi + RYi

Environmental index (Ii) was obtained by the difference among the mean of each environment and the general mean. Analysis of variance was carried using statistical analysis system (SAS) version 9.2 software (SAS, 2008). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis were performed using Gen Stat 15th edition statistical package (VSN International, 2012). The best genotypes were also selected for the angle between the genotype and environment is less than 90° (genotype performed above average on that particular environment), and angle above 90° (below average performance) while that with equal to 90° (near average performance).

Data collection method: Five plants were selected randomly before heading from each row (four harvestable rows) and tagged with thread and all the necessary plant based data were collected from these sampled plants.

Plant-based: Plant height, head height and head weight.

Plot based:Days to heading, days to physiological maturity, lodging percentage, thousand seed weight, grain yield and three economically important insect pest and disease reaction like stalk borer, anthracnose and leaf blight.

Results and Discussions

Combined Analysis of Variance

Mean square of analysis of variance for all genotypes at different environmental conditions for grain yield and yield related traits are presented in Table3. Highly significant differences were detected among years ($P \leq 0.01$) for all parameters except grain yield. The combined analysis of variance showed that year and location effects were significant for all parameters except head weight and grain yield. Year*variety effects were significant for all parameters excluding days to maturity, head weight and lodging percentage. Year*location*varieties were significant for most studied traits such as plant height, head height, lodging percent and grain yield. Genotype by environment interaction mean square was highly significant (P≤0.01) for all parameters except days to 50% heading and thousand seed weight. This indicated the tested genotypes responded differently across environments for those traits.

Table3: Analysis of variance (ANOVA) for grain yield and yield related traits of sorghum genotypes evaluated in 2016-2018 main cropping season

S. of variations	DF	DH	DM	PH	HH	HW	LGD	TSW	YLD qt/ha
Year	2	653.0**	22.5**	62798.1**	55.6*	115810.6**	3274836.1**	413.7**	56482.9^{ns}
Location	3	3472.5**	4859.5**	62051.1**	157.0**	19144.1**	43123.8**	136.6**	6121673.4**
Replication	2	27.6**	10.3^{ns}	358.2^{ns}	18.2^{ns}	670.3*	2363.7^{ns}	61.8**	170615.8*
Varieties	11	484.7**	1005.8**	22369.7**	180.0**	510.5**	4067.6^{ns}	29.4**	20386776**
Year*location	2	60.4**	226.6**	49396.4**	100.7**	4.5^{ns}	15401.4*	99.0**	89092.3^{ns}
Year*variety	22	125.6**	3.4^{ns}	6633.8**	20.1*	90.8^{ns}	4226.2^{ns}	27.3**	96777.2*
loc*vrt	33	4.3^{ns}	9.6**	3571.0**	20.8*	240.2**	7460.6**	13.4^{ns}	334338.4**
Yr*loc*vrt	22	4.0^{ns}	4.9^{ns}	1561.6*	21.0*	4.5^{ns}	9455.1**	10.3^{ns}	115338.2**

Key ns * ** non –significant, significant at 5% and 1% respectively, Loc *Vrt= location by varieties, Yr*Loc*Vrt = year by location by varieties, DF -degree of freedom, DH- Days to Heading; DM- Days to Maturity; PH- Plant Height; HH- Head Height; HW-Head Weight, LGD- Lodging percentage; TSW- Thousand Seed Weight, YLDqt/ha- Yield in quintals per Hectare.

Yield Performance of sorghum genotypes Across Environments

The mean performance of the tested sorghum genotypes for grain yield across location and year presented in Table 4. It indicated some genotypes constantly performed best in a group of environments and some are fluctuating across location (Tamene et al.,2013). The average grain yield ranged from the lowest of 30.45qt ha^{-1} at Kombo (KM-08A) site to the highest of 40.87 qtha^{-1}at Harosebu (HS-10A) site with grand mean of 37.71qt ha^{-1} (Table 4). The average grain yield across environments ranged from the lowest of 24.15 qtha^{-1}for local check to the highest of 50.18 qtha^{-1} for genotype SLRC-046 (Table4). This variation might be due to their genetic potential of the genotypes. Genotype SLRC-043 was the top ranking pipeline at all environments except at Guliso (GU-09A and GU-10A) and Hawa Galan (HG-10A); Genotypes SLRC-058 was ranked first at HS-09A,HG-09A, HS-10A and HG-10A. Similarly, genotype SLRC-046 ranked first at all sites except at KM-08A and HS-08A(Table4). The difference in yield rank of genotypes across the environments exhibited the high crossover type of GxE interaction (Yan and Hunt, 2001; Asrat et al.,2009).

Table 4: Mean grain yield (qt/ha) of sorghum genotypes evaluated at four environments

Genotypes	Grain Yield in qt/ha								
	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	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-Harosebu, 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

Agronomic performance

Combined mean grain yield and other agronomic traits are presented in Table5. High mean of days to heading and days to physiological maturity were recorded by genotypes SLRC-058 and SLRC-046. These offer great flexibility for developing improved varieties suitable for various agro-ecologies with variable length of growing period.However, genotypes SLRC-028 and SLRC-048were with short mean of days to heading and days to physiological maturity indicating that early maturing genotypes were desirable when moisture is the limiting factors for sorghum production. Similarly,genotypes SLRC-010, SLRC-037, SLRC-06, Local check and standard check(Lalo) were recorded high plant height indicating that, these genotypes might be susceptible to root and/or stem lodging butgenotypes like SLRC-043, SLRC-058 and SLRC-046 were with medium plant heightindicating that,the possibility to develop resistant variety against lodging problems. Moreover, genotypes, SLRC-043, SLRC-058 and SLRC-046 were recorded the highest grain yield and they had 23.33%, 21.72% and 24.3% yield advantage over the best standard check (Gamadi) (Table 5).

Table 5: Combined Mean Grain yield and other Agronomic traits of Sorghum genotypes

Genotypes	DH	DM	LDG	PH	HH	HW	TSW	YLD qt/ha	YAD (%) against best check (Gamadi)
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-c	33.45a	49.14a	21.72%
SLRC-046	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: SLRC=Sorghum Landrace Collection, 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, CV- Coefficient of variation, LSD- least significant difference.

Major disease reaction across environments

Most genotypes evaluated had significantly low scores with their corresponding economically important insect pest and disease reactions. However, some genotypes Gamadi (G2) andLalo (G10) were less tolerance to stalk borer but genotypes SLRC-043(G3), SLR-058 (G11) andSLR-

046 (G12) were better tolerance to stalk borer (Table 6). In this study, maximum anthracnose disease reaction was recorded by genotypes Gamadi (G2) and SLRC-048(G6). Likewise, maximum Leaf blight disease reaction observed by Gamadi (G2) and Lalo (G10). On the other hand, genotypes SLRC-043(G3), SLRC-058 (G11) and SLRC-046 (G12) were better tolerance to stalk borer, anthracnose and leaf blight (Table6).

Table 6. Combined mean of disease and insect pest reactions of sorghum genotypes evaluated in 2016-2018 main cropping season.

Genotypes	Stalk borer	Anthracnose	Leaf blight
SLRC-010 (G1)	1.00e	1.36d	2.04e
Gamadi (G2)	1.169a	2.5a	2.88a
SLRC -043(G3)	1.027de	1.4d	2.04e
SLRC-037 (G4)	1.022de	2.29b	2.04e
SLRC-028 (G5)	1.00e	2.29b	2.54b
SLRC -048(G6)	1.078bc	2.417a	2.38c
SLRC -027(G7)	1.00e	1.44d	1.88f
SLRC -06 (G8)	1.11b	1.56c	2.21d
L.Check (G9)	1.056cd	1.08e	2.04e
Lalo (G10)	1.167a	2.33b	2.88a
SLR-058 (G11)	1.00e	1.63c	1.57g
SLR-046 (G12)	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	**	**	**

Key: SLRC=Sorghum Landrace Collection, CV- Coefficient of variation, LSD- least significant difference. 1-5 scale where 1= resistant, 5= susceptible

Additive main effects and multiple interaction (AMMI) models

Combined analysis of variance revealed highly significant (P≤0.01) variations among environments, genotype x environment interaction, IPCA-1 and IPCA-2 (Table7). This result indicated there was a differential yield performance among sorghum genotypes across testing locations and strong GEI.Similar result was reported on wheat (Sial et al., 2000) and rice (Panwar et al.,2008).The GEI significant effect on the grain yield of sorghum genotypes, which explained 7.0% of the total variation whereas the genotypes contributed 80.1% of the variation. However, merely 9.4% of the total variation is credited to the environmental effect (Table7). This also indicated the existence of large amount of reverent response among the genotypes to changes in growing environments and the differential discriminating ability of the test environments. Considerable percentage of GxE interaction was explained by IPCA-1 (4.8%) followed by IPCA2 (1.3%) and therefore used to create a 2-dimensional GGE bi-plot. Gauch and Zobel (1996) suggested that the most accurate model for AMMI can be predicted by using the first two IPCAs. Moreover, several authors took the first and second IPCA for GGE bi-plot analysis and greater proportion of GEI were explained by the first IPCA for maize (Abera and Labuschagne, 2005), bread wheat (Yuksel et al., 2002; Farshadfar, 2008; Worku et al., 2013), common bean (Temesgen et al., 2008) and field pea (Mengistu et al., 2011).

Table 7: Partitioning of the Explained Sum of square (SS) and Mean of square (MS) from AMMI analysis for grain yield of 12 sorghum genotypes evaluated at four environments

Source of variation	D.F	S.S	EX.SS%	M.S
Total	287	31574	100.0	110
Treatments	95	30462	96.5	320.7**
Genotypes	11	2961	9.4	269.2**
Environments	7	25281	80.1	3611.6**
Block	16	120	0.4	7.5^{ns}
Interactions	77	2220	7.0	28.8**
IPCA 1	17	1528	4.8	89.9**
IPCA 2	15	407	1.3	27.1**
Residuals	45	285	0.9	6.3 ^{ns}
Error	176	992		5.6

Key: df = degree of freedom, SS = sum of squares, MS = mean squares, IPCA = Interaction Principal Component Axis, ** = highly significant, ^{ns} = non-significant, EX. SS%-Explained Sum of square

Yield Performance per location and AMMI

Genotype SLRC-043 (G3), SLRC-058 (G11) and SLRC-046 (G12) were produced the best average grain yield (49.79 qtha^{-1}), (49.13 qtha^{-1}) and (50.18 qtha^{-1}) respectively and attained an IPCA-I value relatively close to zero (-0.83) (0.02) and (0.34) respectively. These indicated genotypes were stable and widely adaptable advanced line (Table 8, Fig 1). Genotypic stability was an important in addition to grain yield (Naroui et al., 2013). Genotype SLRC-06 (G8) and (G9) achieved low IPCA-I score (-0.52) and (-0.09) respectively and recorded low grain yield (24.45 qtha-1) and (24.15 qtha-1) respectively (Table8, Fig 1). G1, G4, G5 and G6 were recorded medium grain yield (35.89 qtha^{-1}, 40.51 qtha^{-1}, 36.54 qtha^{-1}, and 43.86 qtha^{-1}) respectively. However, they recorded the highest IPCA-I score (1.33, 1.90, -1.07 and -1.57) respectively implying that, these genotypes were unadaptable and unstable genotypes (Table8, Fig 1).

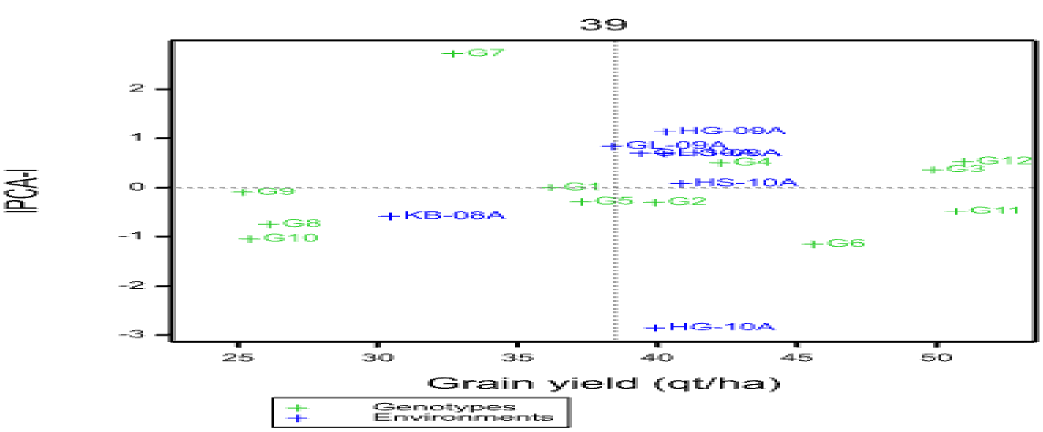

Fig.1 Matrix plot of environment and genotypes mean grain yield (qtha^{-1}) versus Interaction Principal Component Axis (IPCA-I) score. The reference line on the x-axis is the average grain yield (39 qtha^{-1}) and on the y-axis is the IPCA-I value indicating genotype stability (IPCA-I=0)

The result indicated most of the tested environments revealed fluctuating mean grain yields and IPCA scores (Table8, Fig 1). For example, the overall mean grain yield at Harosebu during the 2016 growing season was 32.07qtha^{-1} while the mean grain yield at the same location during the 2017 cropping season was 40.26qtha^{-1}(Table8, Fig1). This variation might be due to weather conditions, experimental plots and other soil factors at the tested environment. However, Hawa Galan is exhibited consistent mean grain yields than the rest test environments

Table8. Mean grain yield (qtha^{-1}) per location and AMMI

Genotypes	Mean grain yield over locations (qtha^{-1})										
	KM-08A	HS-08A	HS-09A	GU-09A	HG-09A	HS-10A	GU-10A	HG-10A	Mean	IPCA-1	IPCA-2
SLRC-010 (G1)	22.27	33.88	39.9	35.6	39.61	37.57	38.25	40.05	35.89	1.33	0.00
Gamadi (G2)	28.88	43.55	42.99	38.18	41.21	43.99	41.18	42.94	40.37	0.73	-0.30
SLRC-043 (G3)	**45.16**	**49.19**	**51.83**	**48.21**	**52.8**	**53.32**	**48.98**	**48.79**	**49.79**	**-0.83**	**0.36**
SLRC-037 (G4)	25.76	28.29	43.43	43.95	43.46	47.73	46.92	44.57	40.51	1.90	0.50
SLRC-028 (G5)	33.95	31.31	36.82	36.66	38.58	38.3	38.63	38.08	36.54	-1.07	-0.29
SLRC-048 (G6)	44.91	31.68	45.03	43.45	46.12	46.25	45.31	48.09	43.86	-1.57	-1.15
SLRC-027 (G7)	31.12	36.59	35.53	33.6	36.86	33.62	34.6	23.6	33.19	-1.88	2.72
SLRC-06 (G8)	20.86	12.76	28.86	26.15	24.75	27.81	25.77	28.64	24.45	-0.52	-0.74
L. Check (G9)	17.51	16.87	25.75	26.36	28.18	25.86	25.38	27.27	24.15	-0.09	-0.10
Lalo (G10)	23.84	17.93	25.01	23.88	25.03	26.44	26.02	27.77	24.49	-1.36	-1.05
SLRC-058 (G11)	**38.57**	**38.17**	**53.32**	**50.08**	**53.29**	**55.63**	**49.23**	**54.78**	**49.13**	**0.02**	**-0.48**
SLRC-046 (G12)	**32.61**	**44.59**	**54.63**	**54.78**	**53.77**	**53.86**	**52.54**	**54.62**	**50.18**	**0.34**	**0.53**
Mean	**30.45**	**32.07**	**40.26**	**38.41**	**40.31**	**40.87**	**39.4**	**39.93**	**37.71**		

Key: KM=kombo, HS=harosebu,GU= guliso, HG=hawagalan

Relationship among test environments

The similarity between two environments is determined by both the length of their vectors and the cosine of the angle between them (Figure2). Harosebu and Hawa Galan had good discriminating ability as shown by a long environmental vector, followed by Guliso site. However, Kombo had poor discriminating ability, as was indicated by its short environmental vector. The study shows Harosebu and Hawa Galan were the most discriminating locations which means such sites gave more information on the performance of the genotypes, while Kombo was the least discriminating environment which means less information about the performance of the genotypes. This means if the study is carried out for several seasons and same site continue to be non-discriminating (less informative); such locations can be dropped and not to be used as test locations. Information on relationships among the test environments was also given (Figure2) as is indicated by the cosine of the angles; acute angle indicates a positive correlation, right angle and obtuse angles indicate no correlation and negative correlation, respectively. Angles between any of the two environments; Hawa Galan (HG-09A) and Harosebu (HS-09A); Kombo (KB-08A) and Harosebu (HS-08A);Guliso (GL-10A) and Hawa Galan(HG-10A) were acute and hence showed positive correlations. Kombo (KB-08A) and Hawa Galan (HG-10A); Harosebu (HS-08A) and Hawa Galan (HG-10A) were obtuse and exhibited negative correlations. The close associations among test environments suggested that the same information in terms of performance can be obtained from fewer test locations and some may be dropped without losing any information about the cultivars under test, thus reducing experimental costs (Yan and Tinker, 2005). The results from the study indicated genotypes G7, G8, G9 and G10 performedbelow average in the four environments.However,G2, G4 and G6 performed above average in Kombo (KB-08A), Harosebu (HS-08A), Guliso (GL-09A), Guliso (GL-10A) and Hawa Galan (HG-10A) locations whereas G3, G11 and G12 were performed above average in all environmental condition(Table8, Figure 2)

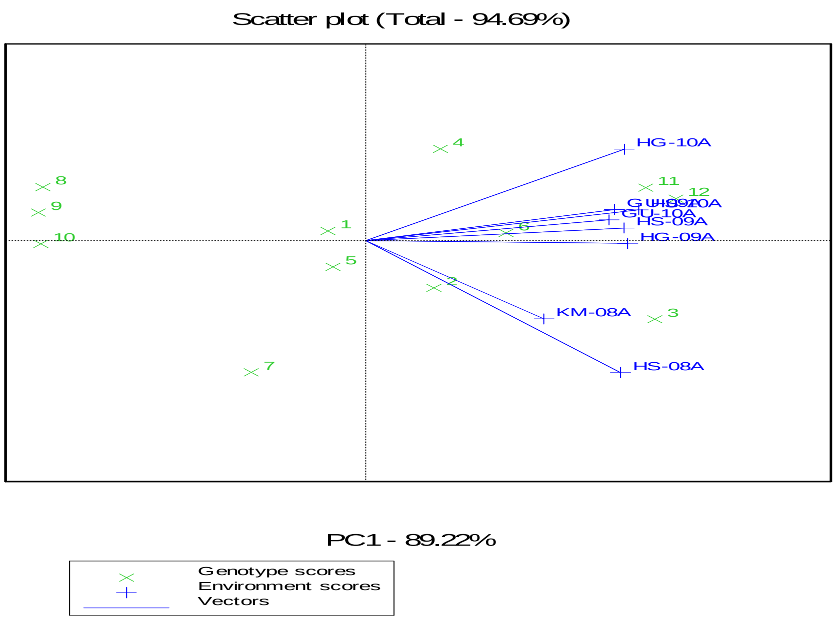

Figure 2: GGE bi-plot based on tested environments-focused comparison for their relationships

An essential feature of the GGE bi-plot (which-won- where) was also anticipated. In environment identification process, furthest genotypes are connected together to form a polygon, and perpendicular lines are drawn to form sectors which will make it easy to visualize environments. Environment concept requires multi-year data, but in this study, environment study was carried out and the results (Figure3) indicated four environments thus four environments, Kombo (KB), Harosebu (HS), Guliso (GL) and Hawa Galan (HG). The winning genotypes for each sector are those placed at the vertex. Therefore, G3 is the winner at Kombo (KB-08A), Hawa Galan (HG-09A), Harosebu (HS-09A) and Guliso (GL) environment, while G12 is at Hawa Galan (HG-09A), Harosebu (HS-09A) and Guliso (GL) locations and G11 as well as G4 are the winner at Hawa Galan (HG-10A) location (Figure3). The equality line between G12 and G4 shows that the G12 was better than G4 in all locations. On the line that connects the two is G11 which means the three can be ranked G12, G11 and G4 in all the environments (Figure3).

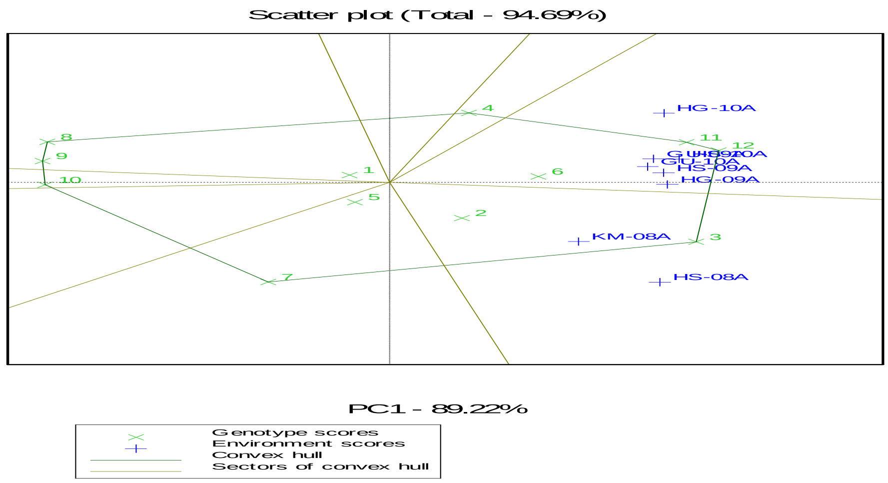

Figure 3. The which-won-where view of the GGE bi-plot to show which genotypes performed best in which environment

Discriminating ability of the test environment 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).An environment is more desirable and discriminating when located closer to the central circle (Naroui et al., 2013). As a result, in the presentstudy, Hawa Galan (HG) wasmore representative and discriminating environments but Kombo (KB) was non-discriminating and less representative site (Fig.2and4) Similarly, Odewale et al. (2013) reported that only one environment was stable, representative and discriminating among the nine environments for the performance of five coconut genotypes.

Ranking based on the genotype-focused scaling assumed that stability and mean grain yield were equally important (Yan and Rajcan, 2002). The best candidate genotypes were expected to have high mean grain yield with stable performance across all the tested locations. Consequently, high yielding and comparativelymore stable genotypes can be considered as base line for genotype evaluation (Yan and Tinker, 2006). Both environments-focused bi-plot and genotype-focused comparison of genotypes shown that genotype SLRC-043 (G3) fell in the central circle indicating its high yield potential and comparatively stableto the other genotypes (Figure 5). As well, genotypes such as SLRC-058 (G11) and SLRC-046 (G12) were fell close to the ideal genotype or around the center of concentric circle indicated these genotypes possessed specific adaptability with best grain yield potential. Therefore, genotypes SLRC-043 (G3),SLRC-058 (G11) and SLRC-046 (G12)were the best performing pipeline cultivars.

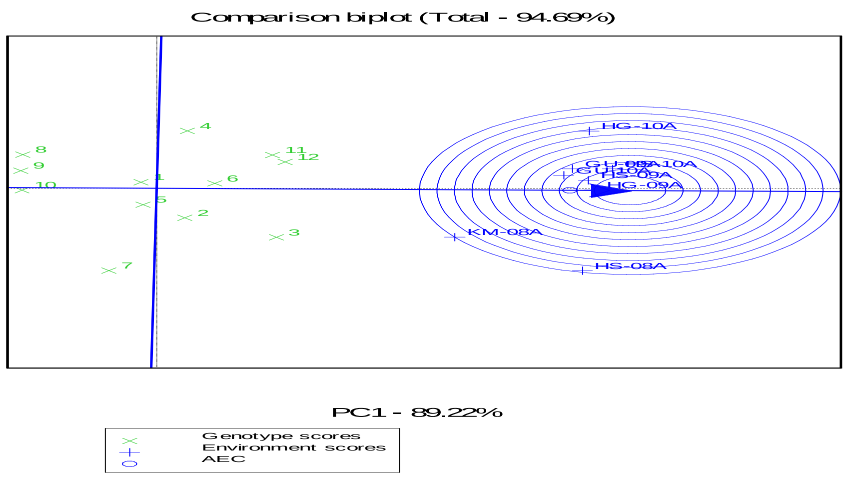

Figure 4 Ranking environments comparatively to ideal environment

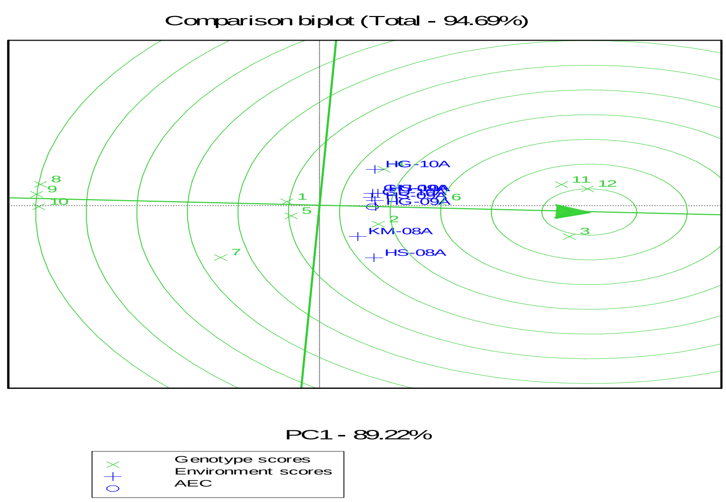

Figure 5: GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability.

Additive main effects and multiple interaction (AMMI) stability value (ASV)

AMMI Stability Value helps selection of relatively stable high yielding genotypes. The best genotype should have high mean grain yield and small ASV value. In view of that, genotype (G9 and G5), showed the lowest ASV (4.29 and 13.11, respectively) but recorded the lowest grain yield (24.15and 36.54 qtha^{-1}), respectively. Moreover, G3, G11 and G12 were the highest yielder genotypes (49.78, 49.14and 50.17 qtha^{-1}) with relatively moderate ASV (18.38, 20.20 and 28.26, respectively) (Table 9). These genotypes revealed reasonably better stability compared to the other genotypes. However, stability needed to be considered in combination with grain yield (Farshadfar, 2008). Similarly, Odewale et al. (2013) evaluated five coconut varieties across nine environments and found two most stable varieties. Farshadfar (2008) evaluated twenty bread wheat genotypes for four years across two locations and found that two genotypes were consistently stable as revealed by AMMI stability value and genotype selection index.

Table 9AMMI Stability Value, AMMI rank, Yield, yield rank and Genotype Selection Index

Genotype	ASV	ASV rank	YLD qt/ha	YLD rank	GSI
G12	28.26	10.00	50.17	1.00	11.00
G3	18.38	6.00	49.78	2.00	8.00
G11	20.20	7.00	49.14	3.00	10.00
G6	24.18	9.00	43.85	4.00	13.00
G4	30.03	11.00	40.52	5.00	16.00
G2	20.43	8.00	40.37	6.00	14.00
G5	13.11	2.00	36.54	7.00	9.00
G1	16.78	4.00	35.89	8.00	12.00
G7	40.22	12.00	33.19	9.00	21.00
G10	16.80	5.00	24.49	10.00	15.00
G8	16.66	3.00	24.45	11.00	14.00
G9	4.29	1.00	24.15	12.00	13.00

G-genotype

Conclusions and Recommendations

The results revealed grain yield performance for the 12 genotypes were significantly influenced by environment, genotype and their interaction. A further analysis on the adaptability and stability across the four environments were conducted. Therefore, in view of these, G3, G11 and G12 presented both high yielding and stable across the test environments. These have been identified as possible candidates for advancement, for release and for use as parents in future breeding programmes. From the test environments, Hawa Galan was the most discriminating location which means it gave more information on the performance of the genotypes. It was exhibited good discriminating ability and representativeness, making it the most ideal environment in this multi-locational yield trials.

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References

Abera, W. and Labuschagne, M. (2005). Stability analysis of Ethiopian maize varieties using AMMI model. Ethiopian Journal of Agricultural Science 18(2):173-180.

Asrat, A., Fekadu, G., and Mulugeta, A. (2009). "AMMI and SREG GGE biplot analysis for matching varieties onto soybean production environments in Ethiopia." Scientific Research and Essay, vol. 4, pp. 1322-1330

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

Farshadfar, E. (2008). Incorporation of AMMI Stability Value and Grain Yield in a Single Non-Parametric Index (Genotype Selection Index) in Bread Wheat. Pakistan Journal of Biological Sciences 11: 1791-1796.

Gauch, G. (1992). Statistical analysis of regional yield trials: Ammi analysis of factorial designs. Amsterdam, The Netherlands: Elsevier Science Publishers.

Gauch, H. G. and Zobel, R.W. (1996). AMMI analysis of yield trials. In: Genotype by environment interaction. pp. 85-122 (Kang, M. and Gauch, H. eds.). Boca Raton. CRC press, New York.

Kaya Y, Akcura M, Taner S (2006). GGE-biplot analysis of multi- environment Yield Trials in bread wheat. Turk. J. Agric. For. 30:325- 337.

Mengistu, G., Daba, C., Temesgen, A., Lule, D. and Geleta, N. (2011). Genotype x Environment interaction for yield in field pea (*Pisumsativum* L.). East African Journal of Science 5(1): 6-11.

Naroui, R.M.R., Abdul Kadir M., RafiiHawa, M.Y., Jaafar, Z.E., Naghavi, M.R.andFarzaneh Ahmadi. (2013). Genotype by environment interaction by AMMI and GGE biplot analysis in three consecutive generations of wheat (*Triticum aestivum*) under normal and drought stress conditions. Australian Journal of Crop Science 7(7):956-961.

Odewale, J.O., Ataga, C.D., Agho, C., Odiowaya, G., Okoye, M.N. and Okolo, E.C. (2013). Genotype evaluation of coconut (Cocos nucifera L.) and mega environment investigation based on additive main effects and multiplicative interaction (AMMI) analysis. Research Journal of Agricultural and Environmental Management 2(1): 1-10

Panwar, L.L., Joshi, V.N. and Mashiat Ali (2008). Genotype x environment interaction in scented rice. Oryza 45(1): 103-109.

Purchase, J. L., Hatting, H., and Vandenventer, C. S. (2000). "Genotype by environments interaction of wheat in South Africa: stability analysis of yield performance." South Africa Journal of Plant Science, vol. 17, pp. 101-107

SAS Institute Inc. (2008). Statistical analysis Software version 9.2, Cary, NC: SAS Institute Inc. USA.

Sial, M.A., Arain, M.A. and Ahmad, M. (2000). Genotype by environment interaction on bread wheat grown over multiple sites and years in Pakistan. Pakistan Journal of Botany 32(1): 85-91

Tamene, T., Gemechu, K., Tadese, S., Mussa, J., and Yeneneh, B. (2013). "Genotype x environment interaction and performance stability for Grain Yield in Field Pea (*Pisumsativum* L.) Genotypes." International Journal of Plant Breeding, vol. 7, pp. 116-123.

Temesgen, A., Daba, C., Mengistu, G., Lule, D. and Geleta, N. (2008). Regression and additive main effects and multiple interactions (AMMI) in common bean (*Phaseolus vulgaris* L.) genotypes. Ethiopian Journal of Biological Science 7(1): 45-53.
Umma, K., Jamil, H., Ismail, H., and Niaz, F. R. (2014). "Stability for BRRI developed Promising Hybrid Rice for Yield and it's Related traits." Journal of Applied Science and Agriculture, vol. 9, pp. 56-62.
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. and Hunt, L. A. (2001). "Interpretation of genotype × environment interaction for winter wheat yield in Ontario." Crop Science, vol. 41, pp. 19-25.
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
Yan W, Kang MS (2003). GGE biplot analysis: A graphical tool for Breeders, Geneticist and Agronomist. CRC press LLC, Boca Roton,Florida, USA
Yan W, Tinker NA (2006). Biplot analysis of multi-environment trial data: Principles and applications. Can. J. Plant Sci. 86:623-645.
Yuksel Kaya, Cetin Palta, SeyfiTaner (2002). Additive main effects and multiplicative interactions analysis of yield performances in bread wheat genotypes across environments. Turkish Journal Agriculture and Forestry 26: 275-279.
VSN International, (2012). "GenStat for Windows 15th Edition. VSN International, Hemel Hempstead, UK." Available: www.genStat.co.uk
Worku, A., Henry, M., Zewotir, T. and Taye, G. (2013). AMMImodel 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.

Multi-Location Evaluation of Yield and Yield Related Trait Performance in Sorghum (*Sorghum bicolor* L.) Genotypes at Western Oromia, Ethiopia

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Abstract

The experiment was conducted on twelve sorghum genotypes against checks at Haro Sabu Agricultural Research Center sub sites for two years (2017-2018) to evaluate high yielding, insect pest tolerant genotypes and to assess genotype by environmental interaction on grain yield and yield stability. The seeds were sown in Randomized Completed Block Design with three replications in the net plot size of 9 m^2 using four harvestable rows at the spacing of 0.75m and 0.15m. Nine agronomic traits and three economically important disease reaction were evaluated.Analysis of variance revealed significant difference among genotypes for all observed traits. All observation attained non-significant differences over years except days to heading, *days to maturity, thousand seed weight and grain yield. Similarly, varieties*location was significantly affected allrecorded traits except root lodging, while varieties*year*location exhibited significant difference for all traits except plant height, head weight and thousand seed weight. The results revealed that, Sayo sub site was the most discriminating ability and good representativeness site. The combined analysis of variances and AMMIanalysis for grain yield across environments exhibited significantly affected by environments, explained 62.59 % of the total variation.The genotype and genotype x environmental interation were significant and accounted for 29.39 % and 6.03 % respectively. Pricipal component one and two accounted for 4.14 % and 1.30 % of the genotype x environmental interation respectively with a total of 5.44 % variation. Generally, G3, G5 and G9 were identified as promising genotypes for yielding ability and stability, tolerant to diseases and use as parents in future breeding programs.*

Key words: Sorghum evaluation, GEI, yield stability, discriminating ability, representativeness.

Introduction

Sorghum bicolor L. (Moench) is an important cereal crop which is ranked 5^{th} in the world based on its use and production after maize, wheat, rice and pearl millet (cereal statistics). Sorghum is the most known crop especially in Africa, Central America and south Asia and in Ethiopia a major cereal crop (CSA, 2017). In Ethiopia, the national average production of sorghum is 25.25qt/ha (CSA, 2017).Sorghum is 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 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 through, the national breeding programmes 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 and Hunt (2001) and has shown extensive usefulness and a more comprehensive tool in quantitative genetics and plant breeding (Yan*et al.,* 2000; Yan and Hunt, 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. This is resulting from subjecting the environment centered yield data (due to GGE) to singular value decomposition. This makes it very easy to identify which genotype won in which environments. This is facilitated in the form of a polygon to visualize the interaction patterns between genotypes and environments (Yan and Kang, 2003), whereby greatest genotypes are connected from the bi-plot origin such thatall genotypes are contained in the polygon (Kaya *et al.,* 2006). Some genotypes will be located on the vertices of the polygon and they are either the best or the poorest in one or more environments (Yan*et al.,* 2000; Yan and Hunt, 2002; Yan and Tinker, 2006). The rays are drawn perpendicular to the sides of the polygon dividing it into sectors, such that the vertex genotypes in each sector is also the best genotype for sites whose markers fall into respective sector so that sites within the same sector share the same winning genotype (Yan*et al.,* 2000; Yan and Hunt, 2002). GGE bi-plot is a visual display of the G + GE of multi-environmental data where groups of locations with similar cultivar responses are presented and it identifies the highest yielding varieties for each group. PC1 tend to correlate highly with the genotype means, the ideal cultivar is the one which possess large scores for PC1, thus indicating high average yield and small PC2 scores indicating less GEI and greater stability.

Therefore, the objective of this study was: to identify stability of nine sorghum genotypes across locations with high level of grain yield and yield stability and insect pest tolerant.

Materials and Methods

Study sites: The multi-locational yield trial (MLYT) was conducted at three different locations in Kellem and west Wollega zones of Harosebu agricultural research center on main station and sub sites (Haro-sebu on station, altitude 1550 masl, 08^0 19'N, 035^0 30'E) (Guliso, altitude 1600 masl) and Sayo research sub-sites FTC**.**

Breeding materials and experimental design: Twelve genotypes of sorghum including checks were evaluated sequentially for two cropping seasons(2017-2018) at three different locations (Table 1). The trial was planted in randomized completed block design (RCBD) replicated three times. Each plot consists of six rows (with four harvestable rows), 3m plot length with inter-row and intra-row spacing of 0.75m and 0.15m respectively and 2m spacing between each block was used. A seed rate of 25 kg ha^{-1} and a combination of UREA and NPS fertilizer was applied at the recommend rate of 100 kg ha^{-1}(1:1 ratio). NPS fertilizer was applied uniformly for all treatments equally at the time of sowing and split application was carried out for UREA (half at planting time and knee stage). All other agronomic practices were performed as per the recommendation for the crop. The trial was raised under rain fed across all the test locations. The data considered for analysis was from the candidates of the net plot (four harvestable rows). The harvested panicles were sundried for two days before being tested for moisture content where 12 % was the preferred average moisture content using moisture tester. Grain yield data was then obtained by weighing the dried grain using a digital scale.

Table 1: List of sorghum genotypes evaluated at multi-location trials in 2017-2018 main cropping season

No	Codes	Genotypes	Sources
1	G1	Gemedi	BARC
2	G2	SA-07MW6054	MARC
3	G3	SA-06AN6083	MARC
4	G5	SA-07MW6064	MARC
5	G9	SA-07MW6002	MARC
6	G11	Chemeda	BARC
7	G12	SA-06AN7013	MARC
8	G13	SA-02BK7072	MARC
9	G16	SA-07MW6073	MARC
10	G17	Local	Farmer
11	G18	SA-06AN7010	MARC
12	G24	SA-201433	MARC

Source: BARC-Bako Agricultural Research Center, MARC- Malkassa Agricultural Research Center, G-genotype.

Statistical analysis: Multivariate method, Additive Main Effects and Multiplicative Interaction (AMMI) model was used to assess genotype by environment interaction (GEI) pattern. The AMMI model equation is: $Yger = \mu + \alpha g + \beta e + \Sigma n \lambda n \gamma gn \delta en + \varepsilon ger + \rho ge$; where, Yger 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, γgn is the genotype eigenvector for axis n, and δen is the environment eigenvector; εger is error term and ρge 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 (Gauch, 1992; Umma*et al.*, 2014).

AMMI stability value of the ith genotype (ASV) was calculated for each genotype and each environment according to the relative contribution of IPCA1 to IPCA2 to the interaction SS as follows (Purchase *et al*., 2000)

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

Where, SSIPCA1/SSIPCA2 is the weight given to the IPCA1 value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares. Based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value (RASVi) a selection index called Genotype Selection Index (GSI) was calculated for each genotype, which incorporates both mean grain yield (RYi) and stability index in single criteria (GSIi) (Farshadfar ,2008).

$$GSIi = RASVi + RYi$$

Environmental index (Ii) was obtained by the difference among the mean of each environment and the general mean. Analysis of variance was carried using statistical analysis system (SAS) version 9.2 software (SAS Institute Inc., 2008). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi-plot analysis were performed using GenStat 15th edition statistical package (VSN International, 2012). The best genotypes were also selected for the angle between the genotype and environment is less than 90° (genotype performed above average on that particular environment), and angle above 90° (below average performance) while that with equal to 90° (near average performance).

Data collection method: Five plants were selected randomly before heading from each row (four harvestable rows) and tagged with thread and all the necessary plant based data were collected from these sampled plants.

Plant-based: Plant height, head height and head weight. **Plot based**: Days to heading, days to physiological maturity, Root lodging, Stem Lodging, thousand seed weight, grain yield and three economically important insect pest and disease reaction like stalk borer, anthracnose and leaf blight

Results and Discussions

Combined analysis of variance

Mean square of analysis of variance for all genotypes at different environmental conditions for grain yield and yield related traits are presented in Table 2. Highly significant differences were detected among years (P ≤ 0.01) for days to heading, days to physiological maturity and grain yield. The combined analysis of variance showed that year and location effects were significant for all parameters except head weight and stalk borer. Year*location *varieties were significant for most studied traits except plant height, head height, head weight and thousand seed weight.

Table2: Combined Analysis of variance (ANOVA) for grain yield and yield related traits of sorghum promising genotypes in 2017-2018 main cropping season

Source . V	DF	DH	DM	PH	HH	LB	Ant	SB
rep	2	38.74**	7.42	243.35	4.58	0.11	0.25	0.01
vrt	11	3769.23**	729.34**	122481.39**	382.28**	0.26**	1.06**	0.30**
loc	2	1850.30**	954.73**	126370.74**	18.00	0.00	0.00	0.06
yr	1	26733.38**	362.96**	1794.24	25.11	0.00	0.01	0.00
vrt*loc	22	54.22**	31.59**	7472.67**	14.99	0.22**	0.74**	0.07**
vrt*yr	11	852.95**	372.19**	909.06	2.88	0.11**	0.17*	0.00
loc*yr	2	1237.06**	661.73**	5179.25*	87.23**	1.25**	1.40**	0.04
vrt*loc*yr	22	25.87**	31.59**	1118.43	9.44	0.35**	1.02**	0.15**

Table 2 Cont…..

Source .V	**DF**	**HW**	**SL**	**RL**	**TSW**	**KGHA**
rep	2	2540.26*	0.03	0.27	167.76*	106057.40*
vrt	11	6212.22**	0.10**	0.88**	216.30**	11805995.20**
loc	2	48857.68**	0.79**	1.40**	4479.16**	7625887.80**
yr	1	314.29	0.02	0.23	349.86*	34291603.10**
vrt*loc	22	4428.63**	0.09**	0.13	139.62**	211385.30**
vrt*yr	11	0.76	0.26**	1.48**	13.06	603589.40**
loc*yr	2	0.42	4.40**	7.09**	425.21**	5718636.20**
vrt*loc*yr	22	0.25	0.06*	0.18*	9.83	55527.30*

Key : * **significant, significant at 5% and 1% respectively, Loc *Vrt= location by varieties, vrt*yr- variety by year, loc*yr- location by year, Yr*Loc*Vrt = year by location by varieties, DF -degree of freedom, DH- Days to Heading; DM- Days to Maturity; PH- Plant Height; HH- Head Height; HW-Head Weight, SL- Stem lodging, RL-Root lodging; TSW- Thousand Seed Weight, YLD Kg/ha- Yield in kilogram per Hectare.

Yield Performance of sorghum genotypes across locations

Mean performance of the tested sorghum genotypes presented in Table 4. It revealed that some genotypes continually performed best in a group of environments and some are fluctuating across location (Tameneet *al*., 2013). The average grain yield ranged from the lowest of 2418.77 $kgha^{-1}$ at Guliso sub site in 2018 to the highest of 3726.66 $kgha^{-1}$at Harosebu on station in 2017 with grand mean of 3233.53$kgha^{-1}$. The average grain yield across environments ranged from the lowest of 2123.6 $kgha^{-1}$for G13 to the highest of 4384.9 $kgha^{-1}$ for G5. This large variation might be due to the genetic potential of the genotypes. G3 and G5 was the topranking pipeline throughout the environments; However, G18 was the lowest yield potential throughout the test locations. The difference in yield rank of genotypes across the locations exhibited the high crossover type of GxE interaction (Yan and Hunt, 2001; Asrat*et al.*, 2009).

Table 4: Over year and across location mean performance grain yield (kg/ha) of sorghum genotype

Genotypes	2017			2018			Comb.mean
	Guliso	Haro-sabu	Sayo	Guliso	Haro-sabu	Sayo	
Chemeda	2235.9ef	2660f	2427.6ef	1564.3ef	1817.5f	2749.6gh	2242.5h
G12	3702c	4115c	3923.5c	2553.9c	2799.7c	3759.4cd	3475.6d
G13	2104.5f	2532.6f	2260.6f	1475.5f	1731.5f	2636.9h	2123.6i
G16	4217.2b	3582de	4425.3b	2901.6b	3114.8b	4098.1b	3723.2c
G18	2361.5ef	2823.4f	2576.1ef	1649.1ef	1927.8f	2849.9gh	2364.6g
G2	4972.5a	4298.6bc	4552.4b	3411.4a	2598.6cd	3383.9ef	3869.6b
G24	2520.9e	2818.9f	2744.1e	1756.6e	1924.8f	2963.3g	2454.8g
G3	4696.8a	5043.2a	4994.2a	3225.3a	3426.2a	4482.1a	4311.3a
G5	4802.7a	5217.2a	4978a	3296.8a	3543.6a	4471.1a	4384.9a
G9	4108.5b	4510.2b	4290.3b	2828.3b	3066.4b	4007bc	3801.8bc
Gemedi	3277.6d	3741.8d	3610.7c	2267.4d	2547.7d	3548.2de	3165.6e
Local	3022.3d	3377e	3225.7d	2095.1a	2301.5e	3288.4a	2885.0f
Mean	3501.88	3726.66	3667.37	2418.77	2566.67	3519.81	3233.53
R^2	97	97	98	97	98	97	98
CV %	6.04	4.95	5.15	5.9	4.85	4.17	5.13
LSD 5%	358.09	312.25	320.11	241.71	210.77	248.59	109.33
F test	**	**	**	**	**	**	**

Grain Yield in kg/ha

Key: G-genotypes, R^2-R-squre, CV-coefficient of variation, LSD-least significant difference, Comb.mean- combined mean.

Agronomic performance

Combined mean grain yield and other agronomic traits are presented in Table 5. Medium mean of days to heading and days to physiological maturity were recorded by genotypes G5 and G9. These offer great flexibility for developing improved varieties suitable for short to medium moisture stress area. However, G13 was recorded with short mean of days to heading and days to physiological maturity indicating that early maturing genotypes were desirable when moisture is the limiting factors for sorghum production. Similarly, G18, G24, Local check and standard checks (Chemeda and Gemedi) were recorded high plant height indicating that, these genotypes might be susceptible to root and/or stem lodging but G9 and G13 were with short to medium plant height indicating that, the possibility to develop resistant variety against lodging problems. Moreover, G3, G5 and G9 were recorded the highest grain yield and hold 36.19 %, 38.52 % and 20.1 % yield advantage over the best standard check (Gemedi) respectively.

Reaction to the major disease and insect pest across environments

Almost all genotypes evaluated had significantly low scores with their corresponding economically important insect pest and disease reactions (Table 6). However, some genotypes such as G13 and G16 were less tolerance to leaf blight but were better tolerance to stalk bore. The result revealed that maximum anthracnose disease reaction was recorded by G16.On the other hand, genotypes G3, G5, and G9 were better tolerance to stalk borer, Anthracnose and Leaf blight.

Table 5: Combined mean grain yield and other agronomic traits of sorghum genotypes

Genotypes	**DH**	**DM**	**PH**	**HH**	**HW**	**RL**	**SL**	**TSW**	**KGHA**	**YLDAVA**
Chemeda	137.1b	177.3b	382.0b	27.0c	91.1cde	1.3a	1.6bc	29.2cd	2242.5h	-29.16
G12	134.7c	174.0d	344.1def	21.1e	122.6ab	1.3ab	1.7b	33.9ab	3475.6d	9.79
G13	99.0i	158.4i	171.2i	32.5ab	76.0e	1.1cd	1.3cde	29.9bcd	2123.6i	-32.92
G16	109.8g	169.7ef	230.0h	30.3b	83.0de	1.2a-d	1.3e	24.2e	3723.2c	17.61
G18	126.9f	175.9bc	414.3a	34.9a	118.1b	1.2bcd	2.0a	29.1cd	2364.6g	-25.3
G2	131.5e	168.8f	335.9ef	23.4de	87.4de	1.1d	1.3de	35.6a	3869.6b	22.24
G24	133.6cd	170.6e	372.9bc	33.8a	106.7bc	1.3abc	1.7b	33.9ab	2454.8g	-22.45
G3	134.5cd	174.2d	325.8f	26.3c	138.2a	1.2abc	1.5bcd	34.2ab	4311.3a	**36.19**
G5	105.4h	164.1h	262.6g	33.7a	89.4cde	1.3ab	1.4cde	28.6cde	4384.9a	**38.52**
G9	108.4g	166.6g	167.3i	25.3cd	90.0cde	1.2cd	1.3e	27.2de	3801.8bc	**20.1**
Gemedi	140.1a	175.7c	351.7cde	33.6a	94.5cd	1.3ab	1.7b	27.8de	3165.6e	0
Local	132.9de	181.5a	362.2bcd	30.6b	88.9de	1.3abc	1.6b	32.4abc	2885.0f	-8.86
Mean ± SEM	124.5±1.36	171.4±0.62	310.0±6.57	29.4±0.39	98.8±2.81	1.2±0.02	1.5±0.04	30.5±0.70	3233.5±66.84	
CV%	2	1.26	11.89	13.29	26.72	13.95	21.64	22.42	5.13	
R^2 %	99	96	90	70	73	81	76	71	98	
LSD 5%	1.64	1.42	24.3	2.57	17.4	0.11	0.22	4.51	109.33	
F test	**	**	**	**	**	**	**	**	**	

Key : G-genotype, DH=Days to heading, DM=Days to maturity, PH= Plant height, HH= Head height, HW-head weight, RL- root lodging, ST- stem lodging, TSW- Thousand seed weight, YLD Kg/ha- Yield in kilogram per hectare, YAD- yield advantage, SEM-standard error of mean, CV- Coefficient of variation, R^2-R-squre, LSD- least significant difference.

Table 6. Combined mean of disease and insect pest reactions of sorghum genotypes evaluated in 2017-2018 main cropping season.

Genotypes	Leaf blight	Anthracnose	Stalk borer
Chemeda	1f	0.83f	1.0b
G12	1.1c-e	1.28cd	1.1b
G13	1.3ab	1.06e	1.1b
G16	1.3ab	1.72a	1.0b
G18	1.2bc	1.50b	1.1b
G2	1.0f	1.00ef	1.0b
G24	1.2bcd	1.14de	1.0b
G3	1.2bc	1.11de	1.0b
G5	1.0f	1.17de	0.7c
G9	1.1cde	1.00ef	1.0b
Gemedi	1.1def	1.36bc	1.0b
Local	1.0ef	1.14de	1.3a
Mean ± SEM	1.13±0.02	1.19±0.04	1.01±0.02
CV%	17.04	24.72	14.36
R^2 %	78	82	74
LSD 5%	0.13	0.19	0.096
F test	**	**	**

Key: G-genotype, SEM-standard error of mean, CV- Coefficient of variation, R^2-R-squre, LSD- least significant difference**,** 1-5 scale where 1= resistant, 5= susceptible

Additive main effects and multiple interaction (AMMI) models

Combined analysis of variance revealed highly significant ($P \leq 0.01$) variations among environments, genotype x environment interaction, IPCA-1 and IPCA-2 (Table7). This result indicated there was a differential yield performance among sorghum genotypes across testing locations and strong GEI. Similar result was reported on wheat (Sial*et al.*, 2000) and rice (Panwar *et al.*, 2008). The GEI significant effect on the grain yield of sorghum genotypes, which account 6.03% of the total variation whereas the genotypes contributed 29.39 % of the variation

However, the large portion, which means 62.59 % of the total variation is credited to the environmental effect. This also indicated the existence of large amount of deferential response among the genotypes to changes in growing environments and the differential discriminating ability of the test environments. Considerable percentage of GxE interaction was explained by IPCA-1 (4.14%) followed by IPCA2 (1.3%) and therefore used to create a 2-dimensional GGE bi-plot. (Gauch and Zobel, 1996) suggested that the most accurate model for AMMI can be predicted by using the first two PCAs. Moreover, several authors took the first and second IPCA for GGE bi-plot analysis and greater proportion of GEI were explained by the first IPCA for maize (Abera and Labuschagne, 2005), bread wheat (Yuksel*et al.*, 2002; Farshadfar, 2008; Worku*et al.*, 2013), common bean (Temesgen*et al.*, 2008) and field pea (Mengistu *et al*., 2011).

Table 7: Additive main effect and multiplicative interaction analysis of variances (AMMI) for grain yield of 12 sorghum genotypes tested.

Source	DF	SS	EX.SS%	MS
Total	215	207479183	100	965019.5
Treatments	71	203357879	98.01	2864195.5**
Genotypes	11	60980550	29.39	5543686.4**
Environments	5	129866058	62.59	25973211.6**
Block	12	339941	0.16	28328.4
Interactions (GxE)	55	12511270	6.03	227477.6**
IPCA 1	15	8594144	4.14	572942.9**
IPCA 2	13	2690075	1.3	206928.8**
Residuals	27	1227051	0.59	45446.3
Error	132	3781363		28646.7

Key: DF = degree of freedom, SS = sum of squares, MS = mean squares, IPCA = Interaction Principal Component Axis, ** = highly significant, ^{ns} = non-significant, EX. SS%-Explained Sum of square

Yield performance of sorghum genotypes per location and AMMI

Yield performance of the evaluated sorghum genotypes in respect to its environments are presented in table 8. Accordingly, G3, G5 and G9 were recorded the best average grain yield (4311 kg ha^{-1}), (4385kg ha^{-1}) and (3802kg ha^{-1}) and attained an IPCA-I value relatively small (8.17) (8.7) and (3.23), respectively indicating stable and widely adaptable genotypes. Genotypic stability was an important in addition to grain yield (10). Similarly, Chemeda, G13 and G18 were achieved low IPCA-I score (-11.86), (-12.91) and (-11.11) but recorded low grain yield (2242 kg ha^{-1}), (2124 kg ha^{-1}) and (2365kg ha^{-1}), respectively.

The result indicated, most of the tested environments revealed fluctuating in mean grain yield and IPCA scores. For instance, the overall mean grain yield at Guliso sub site during the 2017 growing season was 3502 kg ha^{-1} while it was 2419kg ha^{-1} in the same location during the 2018 cropping season. This variation might be due to weather conditions, experimental plots and other soil factors at the tested environment. However, Sayo sub site was exhibited consistent mean grain yield than the rest environments.

Table 8: Mean grain yield (kgha^{-1}) per location and year from the AMMI additive GE model

Genotype	GL	**GL2**	**HS**	**HS2**	**SY**	**SY2**	**Mean**	IPCAg1	IPCAg2
Chemeda	2240	1481	2608	1819	2510	2796	**2242**	-11.86	3.59
G12	3699	2567	4122	2792	3916	3759	**3476**	-0.11	-6.04
G13	2101	1374	2465	1723	2376	2701	**2124**	-12.91	4.4
G16	4183	3196	3754	3066	4167	3972	**3723**	2.49	18.49
G18	2369	1576	2778	1921	2645	2900	**2365**	-11.11	1.8
G2	4993	3226	4189	2623	4716	3469	**3870**	31.34	10.62
G24	2536	1712	2800	1976	2762	2942	**2455**	-8.86	4.74
G3	4705	3325	5113	3449	4870	4405	**4311**	8.17	-11.16
G5	4776	3363	5246	3505	4954	4465	**4385**	8.7	-13.46
G9	4091	2856	4520	3045	4290	4008	**3802**	3.23	-8.47
Gemedi	3305	2280	3761	2561	3552	3534	**3166**	-3.9	-4.51
Local	3024	2069	3363	2319	3248	3286	**2885**	-5.18	-0.01
MEAN	**3502**	**2419**	**3727**	**2567**	**3667**	**3520**	**3234**		

G- Genotype, GL-guliso 2017, GL2-guliso 2018, HS-harosabu 2017, HS2-haro sabu 2018, SY-sayo 2017,SY2-sayo 2018, IPCAg = Interaction Principal Component Axis genotype

Relationship among test environments

The similarity between two environments is determined by both the length of their vectors and the cosine of the angle between them (Fig1). Sayo and Guliso in 2017 had good discriminating ability as shown by a long environmental vector, followed by Haro-sebu 2017. However, Sayo and Haro-sebu in 2018 cropping season had poor discriminating ability, as was indicated by its short environmental vector. Therefore, the study shows Sayo and Guliso in 2017 cropping season were the most discriminating locations that gave more information on the performance of the genotypes, whereas Sayo and Haro-sebu in 2018 cropping season were the least discriminating environment that gave less information about the performance of the genotypes. This means if the study is carried out for several seasons and same site continue to be non-discriminating (less informative); such locations can be dropped and not to be used as test locations.

The cosine of the angles; acute angle indicates a positive correlation, right angle and obtuse angles indicate no correlation and negative correlation, respectively. Angles between any of the two environments; Guliso and Sayo in 2017, Harosebu and Sayo in 2018 cropping season were acute and hence showed positive correlations. However, Guliso 2017 and Sayo 2018 were obtuse and exhibited negative correlations. The close associations among test environments suggested that the same information in terms of performance can be obtained from fewer test locations and some may be dropped without losing any information about the cultivars under test, thus reducing experimental costs (Yan and Tinker, 2006).

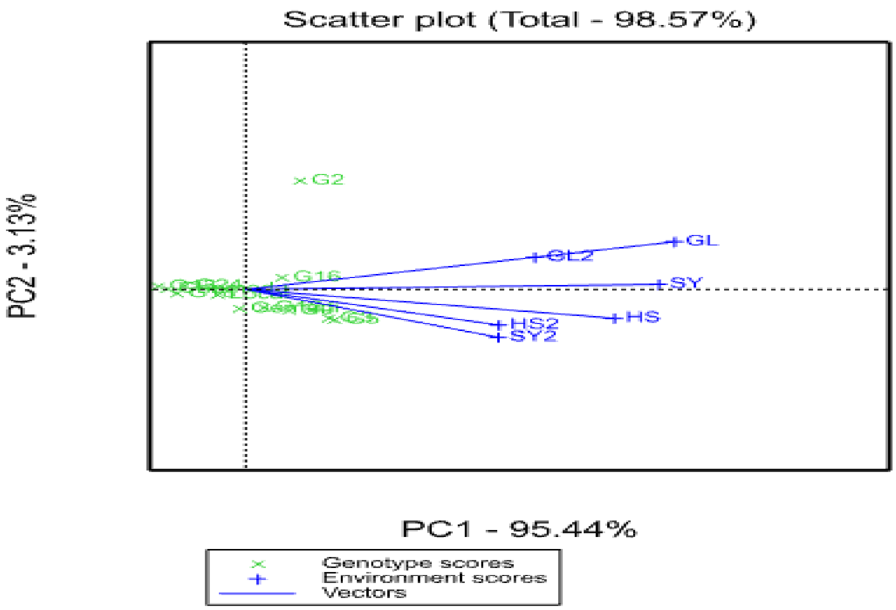

Fig.1: GGE bi-plot based on tested environments-focused comparison for their relationships

An indispensable feature of the GGE bi-plot (which-won- where) was also anticipated. In environment identification process, furthest genotypes are connected together to form a polygon, and perpendicular lines are drawn to form sectors which will make it easy to visualize environments. Environment concept requires multi-year data, but in this study, three environments were carried out such as Guliso (GL), Harosebu (HS), and Sayo (SY). The winning genotypes for each sector are those placed at the vertex. Therefore, G2 is the winner at Guliso (GL), while G3, G5 and G9 are at Harosebu (HS) and Sayo (SY) locations in 2017 cropping seasons (Fig2).

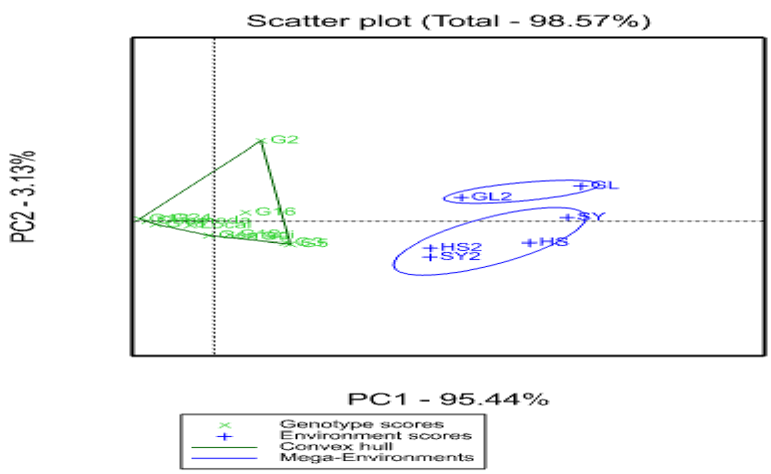

Figure 2. The which-won-where view of the GGE bi-plot to show which genotypes performed best in which environment

Discriminating ability of the test environment 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 Hunt, 2002).An environment is more desirable and discriminating when located closer to the central circle (Naroui*et al.*, 2013). As a result, in this study, Sayo (SY) was more representative and discriminating environments (Fig.3) Similar study by Odewale*et al*. (2013) reported that only one environment was stable, representative and discriminating among the nine environments for the performance of five coconut genotypes.

Ranking based on the genotype-focused scaling assumed that stability and mean grain yield were equally important (Yan and Hunt, 2002). The best candidate genotypes were expected to have high mean grain yield with stable performance across all the tested locations. Consequently, high yielding and comparatively more stable genotypes can be considered as base line for genotype evaluation (Yan and Tinker, 2006). Both environments-focused bi-plot and genotype-focused comparison of genotypes shown that G3 and G5 fell in the central circle indicating its high yield potential and comparatively stable to the other genotypes (Fig. 4). As well, G9 was fall close to the ideal genotype or around the center of concentric circle indicated this genotype possessed specific adaptability with best grain yield potential. Therefore, G3, G5 and G9 were the best performing candidates.

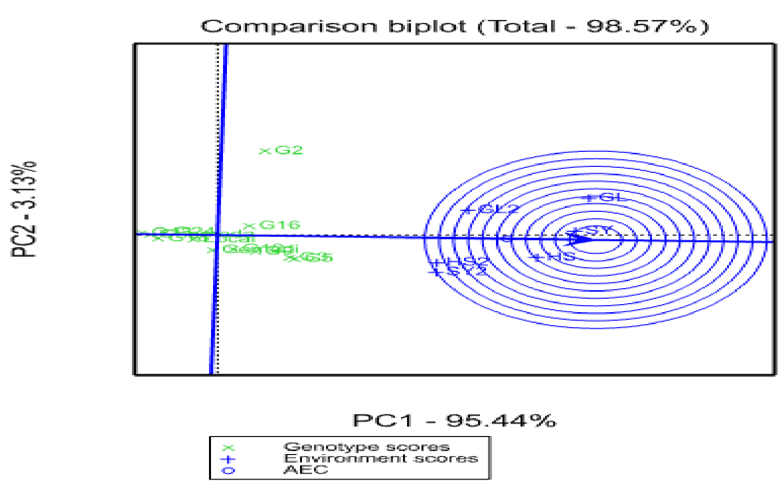

Fig. 3 Ranking environments comparatively to ideal environment

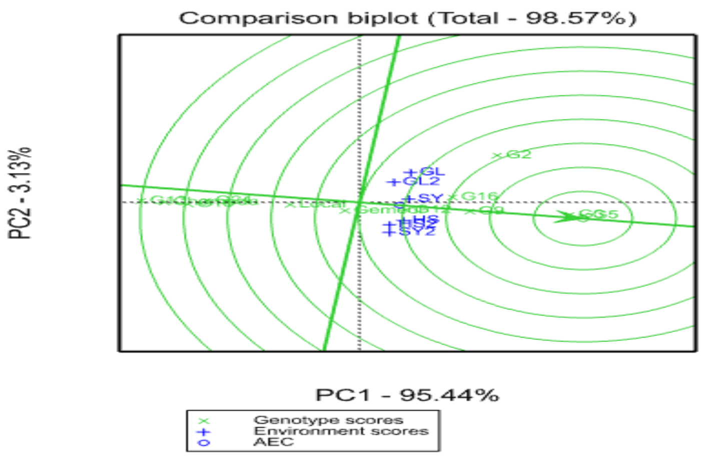

Fig.4: GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability.

Additive main effects and multiplicative interaction (AMMI) stability value (ASV)

AMMI Stability Value helps selection of relatively stable high yielding genotypes. The best genotype should have high mean grain yield and small ASV value. In view of that, local check and standard check (Gemedi) were recorded small ASV (one and two) but low in grain yield (2885 and 3166 kg ha^{-1} respectively). Moreover, G3, G5 and G9 were more yielder genotypes (4311, 4385 and 3802 kg ha^{-1}) with relatively moderate ASV (9, 10 and 4 respectively). A genotype with the least of genotype selection index (GSI) is considered as the most stable and the stability needed to be considered in combination with grain yield (Farshadfar, 2008). Accordingly, G3 and G5 were the most stable genotype with low genotype selection index (GSI) and higher mean grain yield Table 9). Similarly, Odewale*et al*. (2013) evaluated five coconut varieties across nine environments and found two most stable varieties. Farshadfar (2008) evaluated twenty bread wheat genotypes for four years across two locations and found that two genotypes were consistently stable as revealed by AMMI stability value and genotype selection index.

Table 9 AMMI Stability Value, AMMI rank, Yield, yield rank and Genotype Selection Index

GENOTYPES	ASV	ASV RANK	YLD	YLD RANK	GSI
G5	28.62	10.00	4385.00	1.00	11.00
G3	24.70	9.00	4311.00	2.00	11.00
G2	59.10	12.00	3870.00	3.00	15.00
G9	16.19	4.00	3802.00	4.00	8.00
G16	33.32	11.00	3723.00	5.00	16.00
G12	10.79	3.00	3476.00	6.00	9.00
Gemedi	10.65	2.00	3166.00	7.00	9.00
Local	9.25	1.00	2885.00	8.00	9.00
G24	17.95	5.00	2455.00	9.00	14.00
G18	20.10	6.00	2365.00	10.00	16.00
Chemeda	22.13	7.00	2242.00	11.00	18.00
G13	24.36	8.00	2124.00	12.00	20.00

G-genotype

Conclusions and Recommendations

The result revealed the performance of grain yield and yield related components for the nine genotypes were significantly influenced by environment, genotype and their interaction. A further analysis on the adaptability and stability across the three environments were conducted so far. Consequently, G3, G5 and G9 presented both high yielding and stable across the test environments. Therefore, these genotypes have been identified as possible candidates for advancement, for release and for use as parents in future breeding programmes.

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References

Abera W, Labuschagne M (2005) Stability analysis of Ethiopian maize varieties using AMMI model. Ethiopian Journal of Agricultural Science 18(2):173-180.

Asrat A, Fekadu G, Mulugeta A (2009) "AMMI and SREG GGE biplot analysis for matching varieties onto soybean production environments in Ethiopia." Scientific Research and Essay, vol. 4, pp. 1322-1330

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 Survey 2016/2017: Area and production of major crops, (private peasant holdings, Meher season) Vol. I. Addis Ababa, Ethiopia

Farshadfar E (2008) Incorporation of AMMI Stability Value and Grain Yield in a Single Non-Parametric Index (Genotype Selection Index) in Bread Wheat. Pakistan Journal of Biological Sciences 11: 1791-1796.

Gauch G (1992) Statistical analysis of regional yield trials: Ammi analysis of factorial designs. Amsterdam, The Netherlands: Elsevier Science Publishers.

GauchHG, Zobel RW (1996) AMMI analysis of yield trials. In: Genotype by environment interaction. pp. 85-122 (Kang, M. and Gauch, H. eds.). Boca Raton. CRC press, New York.

Kaya Y, Akcura M, Taner S (2006) GGE-biplot analysis of multi- environment Yield Trials in bread wheat. Turky Journal of Agriculture 30:325- 337

Mengistu G, Daba C, Temesgen A, Lule D, Geleta N (2011) Genotype x Environment interaction for yield in field pea (Pisumsativum L.). East African Journal of Science 5(1): 6-11.

Naroui RMR, AbdulKadir M, RafiiHawa MY, Jaafar ZE, NaghaviMR (2013) Genotype by environment interaction by AMMI and GGE biplot analysis in three consecutive generations of wheat (Triticum aestivum) under normal and drought stress conditions. Australian Journal of Crop Science 7(7):956-961.

Odewale JO, Ataga CD, Agho C, Odiowaya G, Okoye MN (2013) Genotype evaluation of coconut (Cocos nucifera L.) and mega environment investigation based on additive main effects and multiplicative interaction (AMMI) analysis. Research Journal of Agricultural and Environmental Management 2(1): 1-10

Panwar LL, Joshi VN, Mashiat Ali (2008) Genotype x environment interaction in scented rice. Oryza 45(1): 103-109.

Purchase JL, Hatting H, Vandenventer CS (2000) "Genotype by environments interaction of wheat in South Africa: stability analysis of yield performance." South Africa Journal of Plant Science, vol. 17, pp. 101-107

SAS Institute Inc. (2008). Statistical analysis Software version 9.2, Cary, NC: SAS Institute Inc. USA

Sial MA, Arain MA, Ahmad M (2000) Genotype by environment interaction on bread wheat grown over multiple sites and years in Pakistan. Pakistan Journal of Botany 32(1): 85-91

Tamene T, Gemechu K, Tadese S, Mussa J, Yeneneh B (2013) "Genotype x environment interaction and performance stability for Grain Yield in Field Pea (Pisumsativum L.) Genotypes." International Journal of Plant Breeding, vol. 7, pp. 116-123.

Temesgen A, Daba C, Mengistu G, Lule D, Geleta N (2008) Regression and additive main effects and multiple interactions (AMMI) in common bean (Phaseolus vulgaris L.) genotypes. Ethiopian Journal of Biological Science 7(1): 45-53.

Umma K, Jamil H, Ismail H, Niaz FR (2014) "Stability for BRRI developed Promising Hybrid Rice for Yield and its Related traits." Journal of Applied Science and Agriculture, vol. 9, pp. 56-62.

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 (2001) "Interpretation of genotype × environment interaction for winter wheat yield in Ontario." Crop Science, vol. 41, pp. 19-25.

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

Yan W, Kang MS (2003) GGE biplot analysis: A graphical tool for Breeders, Geneticist and Agronomist. CRC press LLC, Boca Roton,Florida, USA

Yan W, Tinker NA (2006) Biplot analysis of multi-environment trial data: Principles and applications. Can. J. Plant Sci. 86:623-645.

Yuksel K, Cetin P, Seyfi T (2002) Additive main effects and multiplicative interactions analysis of yield performances in bread wheat genotypes across environments. Turkish Journal Agriculture and Forestry 26: 275-279.

VSN International (2012)"GenStat for Windows 15th Edition. VSN International, Hemel Hempstead UK." Available: www.genStat.co.uk

Worku A, Henry M, Zewotir T, 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

Adaptability Study of Recently Released Small Pod Pepper Variety (*Capsicum frutescens* L.) at West and Kellem Wellega Zones

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Abstract

Small pod hot Pepper (chili pepper) is a seasonal plant of the family Solanaceae. It is grown as an annual crop and produced for its fruits. It is one of the most important vegetable crops for fresh consumption (as chilies), for processing and as a spice (for making stew). A field experiment was conducted at Harosabu on station and Meti sub site of KellemWollega zone, Western Ethiopia, during the 2017/2018 and 2018/2019 main cropping. A total of five small pod hot pepper varieties collected from Melkasa and Bako Agricultural Research and one local check variety were used as planting materials. The combined analysis of variance (ANOVA) for total yield and other agronomic traits of six small pod hot pepper varieties grown at three location locations in 2017/2018 and 2018/2019on number of primary branches per plant, number of fruit(pods, fruit diameter, fruit length and fruit weight revealed significant varietal difference. Likewise, there was highly significant difference of variety on fruit rot and phoshporia blight. The interaction effect of variety and location revealedsignificant effect on 50%days to flowering, 90% days to maturity, marketable yields, unmarketable yield and total yield. In the present experiment, Melka Oli, MelkaDera and Dinsire varieties were found superior in terms of economic yield (marketable yield), tolerant to major disease and other important parameters. Thus, they are recommended for popularization and wider production in test locations and similar agro-ecologies in the Western Oromia in particular and hot pepper producing regions of Ethiopia under main rain fed.

Keywords: *chili, dinsire, melkadera, melkaoli*

Introduction

Hot pepper is a seasonal plant of the family *Solanaceae*. It is grown as an annual crop and produced for its fruits. It is one of the most important vegetable crops for fresh consumption (as chilies), for processing and as a spice (for making stew). It is also a very important crop for spice extraction since it has a lot of oleoresin for dying of food items. Dried peppers may be reconstituted whole, or processed into flakes or powders. Chili or *C. frutescens* (known as barbaré) is important to the national cuisine of Ethiopia, at least as early as the 19th century, "that it was cultivated extensively in the warmer areas wherever the soil was suitable." In Ethiopia, pepper grows under warm and humid weather conditions and the best fruit is obtained in a temperature 21-27^{o}C during the daytime and 15-20^{o}C at night IAR, (1996). It is extensively grown in most parts of the country, with the major production areas concentrated at altitude of

1100 to 1800 masl. MoARD, (2009). It is one of the major vegetable crops produced in Ethiopia and the country is one of a few developing countries that have been producing paprika and *capsicum* oleoresins for export market. Because of its wide use in Ethiopian diet, the hot pepper is an important traditional crop mainly valued for its pungency and color. The crop is also one of the important spices that serve as the source of income particularly for smallholder producers in many parts of rural.

The present situation indicates that in study area there is no improved small pod hot pepper varieties; however hot pepper producer used local cultivar with production per unit area as compared to national average yield. As a result, varietal information for the improvement of the crop for high fruit yield and quality in the existing agro ecology is insufficient. There has also been no research on evaluation of hot pepper which enables the growers to select the best performing varieties in the study area. Evaluation of selected varieties are therefore one of the considerations to ease the existing problems of obtaining the desired varieties for which the output of this study was likely to assist and sensitize hot pepper growers and processors, furthermore the increasing demand for hot pepper to feed the growing human population and supply the ever-expanding pepper industries at national and international level has created a need for the expansion of pepper cultivation in to areas where it has not ever been extensively grown Beyene and David (2007). Better adaptable and well performing variety (varieties) with improved cultural practices could be a possibility to boost quality and marketable production of the crop, so that the farmers benefited by cultivating those adaptable improved verities in the study area. Therefore, present study was initiated with the objective of investigating the performance and adaptation of different varieties of hot pepper for growth and yield of small pod hot pepper varieties for the study area. The diverse climatic soil conditions of Ethiopia allow cultivation of a wide range of fruit and vegetable crops including small pod and large pod hot pepper, which is largely grown in the eastern and central parts of the mid- to low-land areas of the country. However, local production of hot pepper in West and KelemWellega zones is not able to meet the domestic demand due to lack of improved variety, diseases and another new technological packages for hot pepper. Therefore, it is important to evaluate different small pod hot pepper varieties to recommend high fruit yielding and disease tolerant variety/ies for the study area. Thus, the objective of this study was to evaluate the performance of small pod hot pepper varieties and recommend the best performed variety for production in the studied areas and similar agrological zones.

Materials and Methods

Experimental Sites, Designs and Experimental Materials

A field experiment was conducted at Haro Sabu on Station and Meti sub site of KellemWollega zone in Western Ethiopia, during the 2017/2018 and 2018/2019 main cropping season. A total of five small pod hot pepper varieties viz., Kume, Dinsire, Dame, MelkaDera And Melka Oli collected from Bako and Melkasa Agricultural research centers with one local cultivar were used in this study. The experiment was laid out in a randomized complete block design with three replications and with plot size of 3.5 m length and 3 m width. All other crop management practices and recommendations were used uniformly to all varieties as recommended for the crop. The recommended spacing 70 cm between rows and 30 cm between plants were used.

Data collection and statistical analysis

Data were collected in plot and plant basis. Data taken were days to 50% flowering, days to 90% maturity, plant height, number of primary branches per plant, number of fruits(pods) per plant, fruit diameter, fruit length, fruit weight, marketable yield, unmarketable yield and total yield. Besides these parameters disease parts fruit rot and phosphoria blight were taken. All the collected data were subjected to analysis of variance using GenStat computer software (Gen Stat, 2016) and Least Significant Differences (LSD) was used to compare the varieties using the procedures of Fishers protected at the 5% level of significance.

Results and Discussion

The combined analysis of variance (ANOVA) for marketable yield, total yield and other agronomic traits of six small pod varieties grown at three locations in 2017/2018 and 2018 revealed significant varietal difference for all considered traits on varieties and their interaction with location. The main effect of variety revealed a significant effect on fruit diameter, fruit length, and number of primary branches per plant, number of pod per plant, fruit rot and phosphoria blight. This might be due to varietal effect since genetic factor can influence yield related parameters.

Days to flowering

The analysis of variance showed that there was a highly significant effect ($p<0.01$) on days to flowering due to main factors of variety, location and year; and the interaction effect of location and year (Appendix Table 1). The highest (89.17) and the lowest (56.56) days to flowering was record from in year and year two respectively, at Harosabu on station (Table 1). Earliness or lateness in the days to 50% flowering might be to the inherited characters, early acclimatization to the growing area and environmental conditions such as temperature, moisture and soil fertility which enhance growth and developments plants. This result was in agreement with the finding of Seleshi*et al*. (2014) who reported that days to flowering and maturity of hot pepper which could be due to the temperature of the growing area and due to the transplanting disturbance since it is subjected to loss of feeder roots during uplifting, and consumed their energy to repair damaged organs and thus the process demanded them more time to resume shoot growth. Earliness to flowering may be due to inherent characters, different response of varieties to growing environments (e.g. temperature, rainfall, altitude, pests and diseases, etc.), and acclimatization to the growing area and/or due to transplanting disturbance (Sam-Aggrey and Bereke-Tsehai, 2005).

Table 1. Interaction effect of location and year on days to flowering

Location	Year 1	2
Harosabu	89.17a	56.56c
Meti	88.16a	82.17b
LSD (0.05)	2.1	
CV (%)	4	

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Days to Maturity

Analysis of variance showed all the main effects and interaction effects were highly significant (p<0.01 on days tomaturity (Appendix Table 1). The highest (185.7) days to maturity were recorded from Melkaoli in year one at Harosabu on station and lowest (149.0) days to maturity was recorded from variety Dinsire in year two at the same location (Table 2) This variation ascribed to the differences in the growing environment climatic conditions and genetic make-up of the varieties. This agrees with the report of Seleshi*et al*. (2014). Moreover, this finding was in agreement with Haileslassie*et al.* (2015) who reported that days to maturity were significantly affected by pepper varieties.

Table 2. Interaction effect of variety, location and year on days to maturity

Variety	Year	Location	
		Harosabu	Meti
MelkaDera	1	185.7a	184.6a
	2	154.7fgh	176.7b
Melka Oli	1	170.3b	173.3b
	2	151.3hi	164.3cd
Kume	1	164.3c	168.3c
	2	153.7ghi	159.3ef
Dinsire	1	158.7de	162.7de
	2	149i	153.7ghi
Dame	1	163cd	166cd
	2	154.7fgh	157fg
Local check	1	180.7a	183.7a
	2	155.3fgh	174.7b
LSD(5%)	4.8		
CV(%)	1.8		

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Number of primary branches per plant

Analysis of variance showed that there was a significant ($P \leq 0.05$) effect on number of primary branches per plant due to varieties and year. Location and all interactions was no significant (Appendix. Table 1) .The highest (4.46) and the lowest (2.60) number of pod (fruit) per plant were recorded from MelkaDera and Dame varieties, respectively (Table 3). This might be due to different plant canopy among varieties of the same crop. This result was inline with Seleshi*et al* (2014) who reported different branch number per plant of hot pepper varieties. Generally, the differences observed in branching of pepper plants might have been due to **genetic variation**s existed between varieties and or due to favorable influence of organic and inorganic nutrients present in the soils or the growing environment which goes in line with the findings of (El-Tohamy*et al*., 2006), that stated the presence of adequate amount of organic nutrients in the soil improves growth of pepper plants.

Number of pod (Fruit) per Plant

Analysis of variance revealed there was a significant ($P \leq 0.05$) difference on fruit number per plant of on the effect of varieties. Effects location and year, and all the interactions were non-significant (Appendix Table 1). The highest (85.77) and the lowest (29.69) number of pod (fruit) per plant were recorded from Melka Oli and Dame varieties, respectively (Table 3). This might be due to the highest number of primary branches of Melka Oli variety and genetic character which influence number of fruits per plant. The highest fruit number in Melka Oli variety was most likely due to the fruit bearing capacity of the variety and more branch formation nature which leads to contain high number of fruits per plant. In line with this result, Amare *et al*.

(2013) found different fruit number per plant due to variety differences. Furthermore, Seleshietal (2014) reported that number of fruits per plant was highly significantly affected by the interaction of variety by location. These authors also stated that fruit number difference might be due to the associated traits like canopy diameter that could limit the number of branches, the temperature stress of the growing environment and the capability of each varieties to with stand the stress especially on the reproductive development, which is more sensitive to high temperature stress (day and night temperature) than vegetative development.

Plant Height (cm)

Plant height significantly (P<0.05) influence due to varieties, location and interaction effect of location and year (Appendix Table 1). The longest (63.19cm) and the shortest (38.62) plant height was recorded from Melkaoli and Dame Varieties, respectively (Table 3).The significant different of varieties on plant height might be due genetic makeup. This result was in agreement with the finding of MARC (2005), which reported different plant height for different varieties. Similarly, the longest (58.8cm) and the shortest (48.7) plant height was recorded from Harosabu and Metilocations, respectively (Table 3). This might be due to climatic condition such as sun light which might influence vertical growth of plant parts.

Table 3. Main effect of variety and Location on plant height of hot pepper varieties

Variey	Plant height
M/Oli	63.19a
M/Dara	62.48a
L/Check	59.4ab
Dinsire	52.88bc
Kume	46.09cd
Dame	38.62d
LSD(0.05)	7.52
Harosabu	58.8
Meti	48.7
LSD(0.05)	4.34
CV (%)	17

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Fruit Diameter

The main effect of variety, location and year as well as the interaction effect of location and year showed significant ($P \leq 0.05$) effect on fruit diameter (Appendix Table 2). The highest (4.13cm) and the lowest (3.38 cm) fruit diameter were recorded from in year two and year one at Harosabu on station (Table 4). This different might be due environmental conditions like humidity and edaphic factors since they influence the thickness of fruits. This result was related with work of Haileslassie*et al,* (2015) found that fruit diameter was significantly affected due to varietal effect. Similarly, this was conformed to the finding of Tibebu and Bizuayehu (2014) which showed different hot pepper variety have different fruit diameter.

Table 4.Interaction effect of location and year on fruit diameter of small pod hot pepper varieties

Location	Year	
	1	2
Harosabu	3.376b	4.129a
Meti	3.376b	3.389b
LSD(0.05)	0.67	
CV (%)	19.9	

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Fruit Length

The analyzed result revealed that there was highly significant P ≤ 0.01) of variety on fruit length whereas other main effects and interactions were non-significant(Appendix Table 2) the highest(6.4cm) and lowest (3.46cm) fruit length of small pod pepper variety was observed from MelkaDera and Kume varieties respectively (Table 5). The significant difference in fruit length among the hot pepper varieties attributed to the inherited traits and adaptability to the environmental condition of the study area. This current result was supported by the findings of Haileslassie*et al.* (2015) and Seleshi*et al.* (2014) who reported significant fruit length for different hot pepper varieties. Further, Setiamihardja and Knavel (1982) indicated that fruit length and fruit diameterwere quantitatively inherited and governed by additive gene action in crosses of *Capsicumannuum* Moreover, this finding was supported by the work of Tibebu and Bizuayehu (2014).

Table 5.Main effects of variety on number of primary branches per plant, number of pods per plant, plant height(PH),fruit length, fruit rot and phosphoria blight

Variety	NPB	NPPP	PH	FL	FR	PB
MelkaDera	4.458a	67.6ab	62.48a	6.395a	1.083c	1c
MelkaOli	3.917ab	85.77a	63.19a	5.68ab	1.5b	1.333b
Dinsire	3.836ab	45.56cd	52.88bc	5.228bc	1.708ab	2a
Dame	2.603c	29.69d	38.62d	4.681c	1.875a	1.333b
Local check	4.027ab	56.3bc	59.4ab	4.492c	1c	1.333b
Kume	3.45b	44.58cd	46.09cd	3.459d	1c	1c
LSD(.05)	0.68	38.82	7.52	0.81	0.4870	0.2798
CV (%)	22.1	43	17	19.9	30.8	18.1

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Fruit (pod) Weight

The main effect of variety, location and year as well as the interaction effect of variety and year, location and year revealed significant (P ≤ 0.05) effect on the average dry pod weight of hot pepper (Appendix Table 2. Accordingly, the highest (0.83gram) and the lowest (0.37 gram) fruit weight were obtained from Local check in year and Melkaoli in year two, respectively(Table 6).On the other hand the highest(0.67gram) and the lowest(0.36gram)fruit weight was recorded in year two at Harosabu on station and Meti substation respectively(Table 7). The significant of variety on fruit weight might be due to genetic,makeup of the variety since characteristics, such fruit length, fruit diameter and fruit weight are mostly influenced by genetic factors and environmental factors such as sunlight and moisture.

Table 6. Interaction effect of variety and year on fruit weight of small pod hot pepper varieties

	Year	
Variety	1	2
Local check	0.8333a	0.5283cde
MelkaDera	0.72ab	0.495cde
Melka Oli	0.6667abc	0.4393de
Dame	0.5267cde	0.6533abc
Dinsire	0.5533bcde	0.602bcd
Kume	0.52cde	0.3707e
LSD(.05)	0.184	
CV (%)	27.4	

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Table 7. Interaction effect of location and year on fruit weight of small pod hot pepper varieties

	Year	
Location	1	2
Harosabu	0.64a	0.67a
Meti	0.65a	0.36b
LSD(.05)	0.106	
CV(%)	27.4	

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Disease reaction

Analysis of variance showed there was a significant (($P \leq 0.05$) difference on the major disease among varieties of small pod hot pepper varieties and there was no significant effect due to location, year and their interaction (Appendix Table 2). This might be due to genetic characters which makes individual varieties tolerant to major diseases. Among the major diseases fruit rot and phosphoria blight were recorded at 1-5 disease scoring scale. From the result above (Table 5) variety MelkaDera, Melka Oli, Kume and Local Check varieties had lower disease reaction. Whereas Dame and Dinsire varieties had a higher disease reaction which showed they are the most sensitive to the major hot pepper diseases.

Marketable Yield (Kg/ha)

Analysis of variance revealed that there were highly significant (P<0.05) on main effects of varieties, location and year as well as all their interactions locations on marketable yields of small pod hot pepper varieties (Appendix Table 2). The highest (4017.5 kg/ha) dry marketable yield was recorded from Melka Oli variety in year two at Haro Sabu on station and) and lowest (96.1 kg/ha) was recorded from Dame Variety in year one at both station (Table 8). The variation of marketable yield of these varieties could be due to difference in genetic characteristics and agro ecological adaptability nature which is in line with the findings of Fekadu*et al*. (2008) and heritability is necessary in systematic improvement of hot pepper for fruit yield and related traits.

Table 8. Interaction effect of variety, location and year on marketable yield of small pod hot pepper varieties

Variety	Year	Location	
		Harosabu	Meti
Melka Oli	1	553.7efghi	544.7efghi
	2	4017.5a	887.8def
MelkaDera	1	744.6efg	754.4efg
	2	1919.8bc	1063.2de
Dinsire	1	146.4hi	154.5hi
	2	2074.3b	958.7def
Local check	1	542.1efghi	533.2efghi
	2	2003.2bc	454.5fghi
Dame	1	91.6i	102.3i
	2	1438.7cd	729.1efgh
Kume	1	224.1ghi	251.3ghi
	2	496.2efghi	654.5efghi
LSD(0.05)	586.86		
CV (%)	23		

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Unmarketable Yield (kg/ha)

Analysis of variance revealed that there were highly significant (P<0.05) effect of variety, location and year as well as the interaction effect of variety & year, and location and year showed significant effect on unmarketable yields (Appendix Table 2). The highest (287.6 kg/ha) unmarketable yield was obtained from variety Dinsire in year one and the lowest (33.8 kg/ha) was recorded from the Kume variety in year two (Table 9). Similarly, the highest (181.1 kg/ha) unmarketable yield was obtained from Haro Sabu on station in year one and the lowest (55.3 kg/ha) unmarketable yield was recorded from Meti substation in year two (Table 10). The variation of unmarketable yield of these varieties could be due to difference in genetic characteristics and agro ecological adaptability nature which is in line with the findings of Fekadu*et al*. (2008) and heritability is necessary in systematic improvement of hot pepper for fruit yield and related traits.

Table 9. Interaction effect of variety and year on unmarketable yield (kg/ha)

Variety	Year	
	1	2
Dinsire	287.6a	115.3bcd
Melka Oli	273.2a	114.3bcd
Local check	142.4bc	206ab
Kume	141.4bcd	33.8d
Dame	133.1bcd	130.7bcd
MelkaDera	108.9bcd	64.9cd
LSD(0.05)	108.549	
CV(%)	33.4	

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Table 10. Interaction effect of location and year on unmarketable yield (kg/ha)

Location	Year	
	1	2
Harosabu	181.1a	166.4a
Meti	161.6a	55.3b
LSD(0.05)	62.67	
CV (%)	33.4	

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

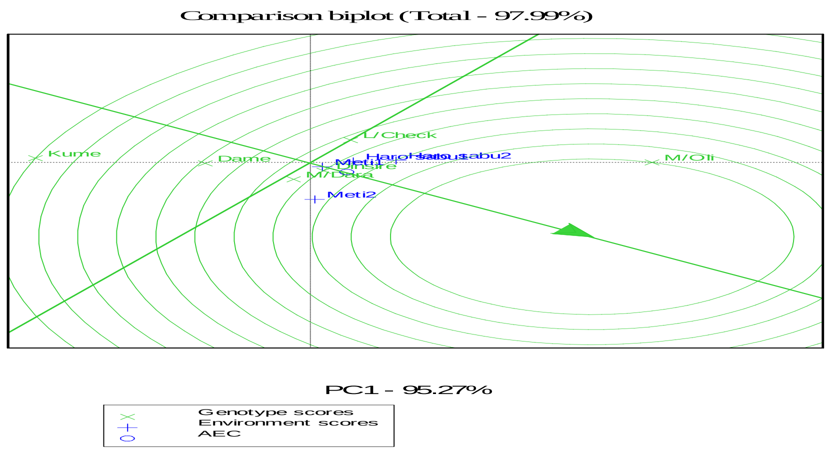
Total Dry Fruit Yield (Qt/ha)

Analysis of variance revealed all the main factors and interactions that there were highly significant (P<0.01) effect on total yield of small pod hot pepper varieties (Appendix Table 2). The highest (4177 kg/ha) dry fruit yield was recorded from Melka Oli variety in year two at Haro Sabu on station and lowest (225 kg/ha) was recorded from Dame Variety in year one at Meti substation (Table 11). The significance difference among varieties on total yield might be due to yield related parameters such as number of pods per plant and branch number per plants.

Table 11. Interaction effect of variety, location and year total yield (kg/ha)

Variety	Year	Location	
		Harosabu	Meti
Melka Oli	1	2089bc	827efghij
	2	4177a	957defgh
MelkaDera	1	1008defg	863efghi
	2	2016bc	1097def
Dinsire	1	1125def	442ghij
	2	2248b	1015defg
Local check	1	1204de	685efghij
	2	2406b	463ghij
Dame	1	784efghij	225j
	2	1566cd	863efghi
Kume	1	268ij	393hij
	2	535fghij	683efghij
LSD(0.05)	614.94		
CV(%)	32.1		

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significant; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.



Conclusions and Recommendations

The significant difference was shown different yield related traits among varieties. Dinsire and Dame were the earliest varieties in to reach 50% days to flowering and days to physiological maturity whereas Melka Oli and MelkaDera were the latest. Generally significant differences for a number of traits among the tested varieties were observed. Evaluation of varieties for adaptation is a fast truck strategic approach to develop and promote agricultural technology. In the present experiment, Melka Oli and MelkaDera varieties were found superior in terms of economic yield (marketable yield) and other yield related parameters. These varieties also stable than others. Thus, they are recommended for popularization and wider production in test locations and similar agro-ecologies in Western Oromia under supplemental irrigation.

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References

AmareTesfawNigussie, Dechasa and Kebede W/Sadik(2013). Performance of hot pepper (*Cupsicum annuum*) varieties as influenced by nitrogen and phosphorus fertilizers at Bure, Upper Watershed of the Blue Nile in Northwestern Ethiopia. *Int. J. Agric. Sci.*, 3(8): 599-608.

El-Tohamy, W.A., Ghoname, A.A. and Abou-Hussein, S.D. (2006). Improvement of pepper growth and productivity in sandy soil by different fertilization treatments under protected cultivation. *J. Appl. Sci. Res.*, 2: 8-12.

FekaduMarame, 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

Gen Stat. 2016. Gen Stat Procedure Library Release. 18th Edition. VSN International Ltd.

Haileslassie, G., Haile, A., Wakuma, B. and Kedir, J. (2015). Performance evaluation of hot pepper (*Capsicum annum* L.) varieties for productivity under irrigation at Raya Valley, Northern Ethiopia. Basic Res. J. Agric. Sci. Rev., 4(7): 211-216, July 2015.

IAR (Institute of Agricultural Research). (1996). Progress Report Addis Ababa. *Institute of Agricultural Research*, Addis Ababa, Ethiopia.

Melkassa Agricultural Research Center. (2005). Progress Report on Completed Activities. 2005. pp: 1-7.

MoARD (Ministry of Agriculture and Rural Development). (2009). Variety Register. Issue No. 9. June 2006. Addis Ababa, Ethiopia.

Sam-Aggrey. W.G. and Bereke-Teshai Tuku. 2005. Proceeding of the1st Horticultural Workshop. 20-22 February. IAR. Addis Ababa. 212p.

SeleshiDelelegn, DerebewBelew, Ali Mohammed and Yehenew Getachew, 2014. Evaluation of elite hot pepper varieties (Capsicum spp.) for growth, dry pod yield and quality under Jimma Condition, South West Ethiopia. *International journal of agricultural research*, *9*, pp.364-374.

Setiamihardja, R. and Knavel, D., 1982, January. Inheritance of certain fruit characteristics in capsicum-annuum-l relative to fruit detachment force. In *hortscience* (vol. 17, no. 3, pp. 477-477). 701 north saint asaph street, alexandria, va 22314-1998: amer soc horticultural science.

Tibebu Simon and Bizuayehu Tesfaye (2014). Growth and productivity of hot pepper (*Capsicum annuum*L.) as affected by variety, nitrogen and phosphorous at Jinka, Southern Ethiopia. Res. J. Agric. Environ. Manage., 3(9): 427-433.

Appendices

Appendix Table 1. Mean squares of ANOVA for days to 50% flowering (DFL), days to 90% physiological maturity(DM),number of primary branches per plant(NPB), plant height(PH) and number of pods per plant(NPPP) of small pod hot pepper varieties

Source of variation	DF	Mean squares				
		DFL	DM	NPB	PH	NPPP
Replication	2	223.347	13.722	3.8306	691.84	5453
Variety	5	220.647**	678.581**	4.8307**	1164.99**	4669**
Location	1	2951.681**	561.125**	0.7476	1828.73**	80.8
Year	1	7060.681**	3828.125**	7.668*	295.5	533.9
Variety. Location	5	16.714	50.692**	0.5776	51.95	468.2
Variety. Year	5	16.714	50.692**	0.3458	198.57	1048.8
Location. Year	1	2951.681**	561.125**	0.7476	1828.73**	80.8
Variety.Location.Year	5	16.714	50.692**	0.5776	51.95	468.2
Error	46	9.898	8.519**	0.6764	83.74	557.9
CV (%)		4	1.8	22.1	17	27.4

DF= degree of freedom; * and **significant at 5% and 1% level of significance, respectively

Appendix Table 2. Mean squares of ANOVA for Fruit diameter (FD), Fruit length (FL), Fruit weight (FW) marketable yield(MY) and unmarketable yield(UMY) and total yield(TY) of small pod hot pepper varieties

Source of variation	DF	Mean squares					
		FD	FL	FW	MY	UMY	TY
Replication	2	0.701	1.2879	0.10907	1006047	57001	1212169
Variety	5	0.6387*	12.4682**	0.07148*	1804360**	31802*	3129467**
Location	1	2.4679*	0.1587	0.4462**	6483096**	55538*	14884840**
Year	1	2.6412*	0.1991	0.26742*	18006872**	88866*	8231826**
Variety.Location	5	0.0673	0.1734	0.02005	908341**	16054	1915272**
Variety. Year	5	0.3707	2.0606	0.08814*	938000**	25710*	248091

Location. Year	1	2.4679*	0.1587	0.4462**	6483096**	55538*	2909163**
Variety.Location.Year	5	0.0673	0.1734	0.02005	908341**	16054	435183*
Error	46	0.233	0.9814	0.02494	127500	8724	139996
CV (%)		13.5	19.9	27.4	23.0	33.4	19.3

DF= degree of freedom; * and **significant at 5% and 1% level of significance, respectively

Evaluation and Selection of Improved Food Barley (*Hordeum vulgare* L.) Varieties for their Adaptability in West Hararghe Zone

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ABSTRACT

An experiment was conducted in three districts of West Hararghe Zone at Gemechis (Qunisegeria FTC), Chiro (Arba Rakate FTC) and Tullo (Gara qufa FTC) in 2018 cropping season in order to identify and promote well adapted improved barley variety/s. The experiment was laid out in Randomized Complete Block Design with three replications. Ten improved barley varieties including local check were used as experimental materials. The most important data of the trial like days to50% flowering, Days to maturity, plant height, spike length, diseases, and yield Qt/ha were collected analyzed using Genstat statistical software and means were separated using least significance difference (LSD). Combined analysis of data revealed that, varieties varied significantly at (P≤0.05) for all traits. HB1307 and Bentu were the two varieties showed relatively better yield with a value of 46.55 *Qtha^{-1}and 44.07 Qtha^{-1}, respectively. HB1965, Shage and Abdane varieties were the least performing varieties in terms of grain yield having a value of 37.43, 36.83 and 38.63Qtha^{-1}respectively. Generally, HB1307and Bentu were the two varieties showed better performance with their mean yield and other measured traits. Therefore, these two varieties were recommended to be demonstrated under farmers' field for further scaling up.*

Key Words*: Adaptation, Barley Variety, Grain yield, Selection*

1. INTRODUCTION

Barley (*Hordeum vulgare* L.) is a major cereal crop in Ethiopia and accounts for 20% of the total cereal production (Wosene *et al*., 2015). It is grown in a wide range of agro climatic regions under several production systems. Barley grows best on well drained soils and can tolerate higher levels of soil salinity than most other crops. Food barley is commonly cultivated in stressed areas where soil erosion, occasional drought or frost limits the ability to grow other crops (Berhanu *et al*., 2005). Barley has persisted as a major cereal crop through many centuries and it is the world's fourth important cereal crop after wheat, maize and rice (Martin *et al*., 2006). The area devoted to barley production in Ethiopia over the past 25 years has fluctuated. It was around 0.8 million hectares in the late 1970s, and rose to more than 1 million hectare in the late 1980s. It then declined and remained between 0.8 and 0.9 million hectare until the beginning of the third millennium. The production of barley, by-and-large, has been below 1 million tons per year for most of the past 25 years, except during the years when the area under barley increased above 1 million hectare. Productivity, however, has never increased above 1.3 t/ha, which is about half the world average. Barley has a long history of cultivation in Ethiopia as one of the major cereal crops and it is reported to have coincided with the beginning of plow culture (Mulatu and Grando, 2011). It is the most important crop with total area coverage of 951,993.15hectares and total annual production of about 21.57 Qt/ha in Ethiopia,451,279.26 hectares with 24.12Qt/ha in Oromia,and 6,737.49 ha in West Hararghe,respectively (CSA, 2018).In the highlands of the country barley is grown in Oromia, Amhara, Tigray and part of the Southern Nations, Nationalities and Peoples' Regional State (SNNPR) in the altitude ranges of 1500 and 3500m, but it is predominantly cultivated between 2000 and 3000 masl (MoA, 1998). In Ethiopia, barely is a dependable source of food in the highlands as it is produced during the main and short rainy seasons as well as under residual moisture (Melle*et al*., 2015). Barley types are predominantly categorized as food and malting barley based on their uses, while in Ethiopia the highest proportion of barley production area is allocated for food barley. Food barley is principally cultivated in the highland areas of Ethiopia where the highest consumption is in the form of various traditional foods and local beverages from different barley types (Zemede, 2000). Barley grain accounts for over 60% of food for the highlands of Ethiopia, for which it is the main source of calories (Ceccarelli*et al*., 1999). According to (Berhanu*et al*., 2005), barley is used in diversity of recipes and deep rooted in the culture of people's diets. Besides its grain value, barley straw is an indispensable component of animal feed especially during the dry season in the highlands where feed shortage is prevalent (Girma *et al*., 1996). Barley straw is also used in the construction of traditional huts and grain stores as thatching or as a mud plaster, as well as for use as bedding in the rural areas (Zemede, 2000).

Barley is an important crop in Ethiopian cereal production and in food security (Berhanu *et al*., 2005). It is currently the fifth most important cereal crop, covering over one million hectares of land. It is grown both in Meher (June–October) and Belg (February–May) seasons. Meher production in the country is categorized into early, intermediate and late production systems. The contribution of the early production system is estimated to be 25% of total barley production. Although barley is considered a highland crop, it is also among the major cereal crops grown in the low rainfall areas of the country, which are part of the early production system. In such areas, the availability and distribution of rainfall during crop growing seasons is the major factor limiting yield. Early ear emergence is the most important feature of barley adaptation to the low moisture areas and is common in Ethiopian landraces from these areas. Thus, the farmers in drought-prone areas grow their own landraces that are well adapted to their environments, but with poor yielding ability. Hence, it was considered essential that barley productivity in low moisture areas be improved to increase the contribution of this system to overall barley grain production. Although Ethiopia is a centre of diversity for barley, most of the farmers in the country still obtain very low yields due to a combination of genetic, environmental and socioeconomic constraints. Research has been on-going since 1955 to address these constraints and improve the livelihoods of farmers by increasing the production and productivity of barley (Mulatu and Grando, 2011).

West Hararghe zone is among some of the places in the region where food barley is grown as one of the major cereal food crops of highland and midland agro ecology. Most farmers of the zone produce food barley on hectares of land (CSA, 2016). However, their average productivity is low per hectare because the existing cultivation is not supported with new and better technologies such as high yielding and adaptive varieties with improved cultivation practices. A critical shortage of improved barley varieties adapted to low-moisture stress conditions is a major problem and hence farmers are forced to grow low yielding genotypes. Drought is one of the major production constraints that reduce crop yields in water-limited areas, where many of the farmers live. This is a serious problem in places where total precipitation is high but unevenly distributed throughout the growing season. As the population continues to grow and water resources for crop production decline, development of drought-tolerant cultivars and water use-efficient crops is a global concern. In the low-rainfall areas (<250 mm annual precipitation) and in most rain fall limiting areas, barley is the dominant crop. Before the 1980s, drought was most protracted in the northern and eastern regions of Ethiopia. However, the number of drought-affected areas has dramatically increased and now includes the most productive regions in the east. Not only is this, but also due to shortage of land in the study area, double cropping system of barley is commonly practiced to increase their income generation per unit area. Therefore, this study was initiated with the objective of the following:

Objective:-To select the best adaptive food barley varieties with high yield and good agronomic trait to the area.

2. MATERIALS AND METHODS

2.1. Description of the study area

The experiment was conducted at Tullo (Gara Qufa FTC), Gemechis (Qunisegeria FTC) and Chiro (Arbarakate FTC) during 2018 main cropping season. Tullo district is found in West Hararghe Zone of Oromia National Regional State, Eastern part of Ethiopia. The district is located about 375 km Southeast of Addis Ababa and 47 km from Chiro town, the capital of West Hararghe Zone (DOA, 2012). Hirna is found within 1758 m above sea level (m.a.s.l). It receives an average annual rainfall of 868mm. The average temperature is 22°C. The black, vertisols and red soils are the three dominant soil types. Gemechis district is found in West Hararghe Zone of Oromia National Regional State, Eastern part of Ethiopia. The district is located about 343 km southeast of Addis Ababa and 17 km from Chiro town, the capital of West Hararghe Zone (DOA, 2012). The district is found within 1300 to 2400 above sea level (m.a.s.l). It receives an average annual rainfall of 850 mm. The district has bimodal distribution in nature with small rains starting from March/April to May and the main rainy season extending from June to September/October. The average temperature is 20°C. The black, brown and red soils are the three dominant soil types constitute 55, 25 and 20%, respectively (DOA, 2012). Chiro district is located in West Hararghe Zone of the Oromia National Regional state at about 324 km East of Addis Ababa, the capital city of Oromia regional national state. The capital town of the district is Chiro, which is also the capital town of the Zone. The district is founded at an average altitude of 1800 m.a.s.l. It has a maximum and minimum temperature of 23^{o}c and 12^{o}c respectively and the maximum and minimum rainfall of 1800 mm and 900 mm respectively (2003 E.C data from Office of Agriculture of the district). The district is mainly dominated with sandy soil, clay soil (black soil) and loamy soil types covering 25.5%, 32%, and 42.5% respectively according to 2003 E.C data from Office of Agriculture and Rural Development. The soil types vary with the topography mainly black soils are observed in the highland and midlands while one can see red soil inthe lowland areas.

2.2. Experimental Treatments and Design

Nine recently released food barley varieties were brought from Sinana Agricultural Research Center and one local check of the respective sub-testing locations were evaluated as experimental materials. These varieties include HB1965, HB1966, Gobe, Robera, Abdane, Bentu, HB1307, Shage, EH1493 and Local check. These materials were randomly assigned to the experimental block and the experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The spacing between blocks and plots was 1.5m and 1m, respectively. The gross size of each plot was $3m^2$ (1.2m x 2.5m) having six rows with a row-to-row spacing of 20cm.The total area of the experimental field will be $270m^2$ (41m X 6.6m).Planting was done by drilling seeds in rows with a seed rate of 100kg ha^{-1} (30g per plot). NPS fertilizer was applied at the rate of 100kg ha^{-1} (30g per plot) at the time of planting; and Urea was also applied at vegetative stage before booting at the rate of 50 kg ha^{-1} (15g per plot).

2.3. Data collected

Data was collected from five plants of six rows of each plot and randomly tagged and the relevant data was recorded. The followings are the major parameters recorded: Days to 50% emergence (days), grain yield (Qt/ha), days to 50% heading (days), disease data (scale), days to 75% physiological maturity (days), plant height (cm), spike length (cm), and plant aspect.

2.4. Data Analyses

GenStat 16th Edition was used to analyze all the collected data from individual locations and the combined data over locations.Various statistical models such as analysis of variance (ANOVA), principal component analysis (PCA) and the additive main effects and multiplicative interaction (AMMI) model. In this model, the additive and multiplicative components of data were integrated into a powerful least square analysis. GGE Biplotwas used. Mean separations was carried out using least significant difference (LSD) at 5% probability level.

3. RESULTS AND DISCUSSIONS

Table.1 Mean values of Barley varieties on grain yield and yield components in each districts of western Hararghe Zone in 2018 cropping season

Varieties	Gemechis (Qunisegeria FTC)					Chiro(Arbarakate FTC)					Hirna (Gara Qufa FTC)				
	DF	DM	PH(cm)	SL(cm)	Yld(Qt	DF	DM	PH	SL	Yld (Qtha	DF	DM	PH(cm)	SL	Yld(Qtha^{-1}
HB1965	81.0ab	114.7^{ab}	76.47^{b-e}	9.47^{ab}	37.85^{b}	54.0^{c}	94.67^{b}	74.73	6.73^{b}	36.02^{b}	65.0^{bc}	98.0^{c}	71.47^{f}	7.8^{a}	38.41^{a}
HB1966	71.3^{a-d}	118.7^{a}	82.13^{a-d}	8.60^{a-c}	37.74^{b}	69.3^{ab}	96.33^{ab}	71.00	7.80^{ab}	50.96^{a}	70.6^{a-c}	101.0^{ab}	80.60^{cd}	7.6^{ab}	33.95^{ab}
Gobe	70.3^{a-d}	100.7^{ab}	71.67^{e}	8.73^{a-c}	46.96^{ab}	54.0^{c}	96.33^{ab}	72.67	7.53^{ab}	42.52^{ab}	73.3^{ab}	98.7^{c}	72.07^{ef}	7.6^{ab}	41.18^{a}
Robera	64.0^{b-d}	101.0^{ab}	73.80^{c-e}	8.00^{cd}	53.52^{ab}	56.0^{c}	96.00^{ab}	67.20	7.13^{b}	44.40^{ab}	65.0^{bc}	$99.0b^{c}$	71.33^{f}	6.5^{c}	31.01^{a-c}
Abdane	54.0d	98.0b	82.13a-d	8.46bc	54.07ab	55.0c	97.33ab	73.53	8.06ab	37.07b	55.0c	99.7bc	77.80de	8.1a	24.74bc
Bentu	64.0b-d	98.0b	72.87de	8.13cd	67.19a	54.0c	98.67a	74.60	8.73a	34.52b	65.0bc	99.7bc	62.67g	7.0bc	30.51a-c
HB1307	79.7ab	110.0ab	83.00a-c	7.93cd	48.96ab	65.3b	97.67ab	72.93	7.66ab	50.29a	75.3ab	101.0ab	84.17a-c	7.6ab	40.40a
Shage	84.7a	110.7ab	91.13a	9.60a	38.41b	74.6a	96.67b	68.73	7.53ab	40.30ab	86.6a	103.0a	86.57ab	7.8a	31.79a-c
EH1493	72.7a-c	112.7ab	81.40b-d	9.0a-c	58.85ab	74.6a	96.33ab	67.73	6.86b	31.84b	86.0a	102.3a	81.33b-d	8.2a	39.11a
Local check	58.0 cd	108.7ab	83.80ab	7.20d	45.52ab	57.6c	95.33ab	68.80	7.86ab	43.96ab	55.0c	98.0c	88.00a	6.6c	28.74cd
GM	69.9	107.30	79.84	8.51	48.91	61.5	96.53	71.2	7.59	41.19	69.7	100.0	77.6	7.5	33.98
CV%	14.9	10.9	6.8	7.7	26.1	5.4	2.3	13.4	11.3	18.0	13.7	1.2	4.4	6.1	17.8
LSD(0.05)	17.9	19.9	9.29	1.13	21.87	5.7	3.86	NS	1.46	12.74	16.3	2.04	5.89	0.79	10.35

Table 2. Combined Mean effect of locations by varieties on yield related components at Quni, Arbarakate and Gara Qufa FTC in 2018 cropping season

Varieties	DF	DM	PH	SL	Dis	PAS
HB1965	66.67^{c-e}	102.4	74.22^{b-d}	8.00^{ab}	1.44^{c}	1.55
HB1966	70.44^{b-d}	105.3	77.91^{a-c}	8.00^{ab}	1.88^{a-c}	1.77
Gobe	65.89^{c-e}	98.6	72.13^{cd}	7.97^{ab}	1.88^{a-c}	1.77
Robera	61.67^{d-f}	98.7	70.78^{cd}	7.22^{b}	1.88^{a-c}	1.44
Abdane	54.67^{f}	98.3	77.82^{a-c}	8.22^{a}	1.88^{a-c}	1.44
Bentu	61.00^{d-f}	98.8	70.04^{d}	7.95^{ab}	2.55^{a}	2.33
HB1307	73.44^{a-c}	102.9	80.03^{ab}	7.75^{ab}	1.77^{bc}	1.33
Shage	82.00^{a}	103.4	82.14^{a}	8.31^{a}	1.44^{c}	4.66
EH1493	77.78^{ab}	103.8	76.82^{a-d}	8.04^{ab}	1.33^{c}	1.77
Local check	56.89^{ef}	100.7	80.20^{ab}	7.24^{b}	2.33^{ab}	1.88
GM	67.04	101.29	76.21	7.87	1.84	
CV%	15.6	8.5	10.7	12.2	40.4	
LSD(0.05)	9.83	NS	7.62	0.89	0.69	

Table 3. Mean grain yield (Qt/ha) of 10 barley varieties at individual environment

Varieties	**Quni FTC**	**Arbarakate FTC**	**Gara qufa FTC**	**Combined Mean**	**Yld Advantage**
HB1965	37.85^{b}	36.02^{b}	38.41^{a}	37.43	-
HB1966	37.74^{b}	50.96^{a}	33.95^{ab}	40.88	3.76
Gobe	46.96^{ab}	42.52^{ab}	41.18^{a}	43.55	10.53
Robera	53.52^{ab}	44.40^{ab}	31.01^{a-c}	42.98	9.09
Abdane	54.07ab	37.07^{b}	24.74^{bc}	38.63	-
Bentu	67.19^{a}	34.52^{b}	30.51^{a-c}	44.07	11.85
HB1307	48.96^{ab}	50.29^{a}	40.40^{a}	46.55	18.15
Shage	38.41^{b}	40.30^{ab}	31.79^{a-c}	36.83	-
EH1493	58.85^{ab}	31.84^{b}	39.11^{a}	43.27	9.82
Local check	45.52^{ab}	43.96^{ab}	28.74^{bc}	39.40	-
GM	48.91	41.19	33.98		
CV%	26.1	18.0	17.8		
LSD(0.05)	21.87	12.74	10.35		

Days to 50% flowering:-Statistical analysis of variance for days flowering were showed significant difference at $P \leq 0.05$ at all testing individual location (table.1). The performance of varieties for days of flowering in combined analysis among varieties and within location were also showed a significance difference at (P≤0.05) in table 2. Among the tested barley varieties evaluated, Shage (82 days) late flowering and the shortest day was recorded by Abdane (54.67 days). Therefore, Abdane was considered as earliest flowering variety as compared to other varieties tested together.

Maturity date: Analysis of variance shows that the individual location data analysis for days of maturity showed significant difference for all varieties at all tested locations (Table 1), but the combined mean effects of varieties showed non-significant difference for all varieties (table 2). The longest days of maturity in combined mean effect of varieties were recorded by HB1966 variety which is (105.3 days) and shorter by Abdane which is (98.3 days) to attain its full physiological maturity.

Plant height: Analysis of variance shows a significant variation except at Arbarakate FTCobserved non-significance difference. The combined mean effect of plant height within variety and location showed a significant difference at P≤0.05 (Table 2). Generally, Shage variety was recorded the highest plant height of (82.14 cm) and Bentuwas recorded the lowest (70.04 cm).

Spike length:-Barley varieties were showed a significance difference for spike length at each location as well as combined mean effect of varietiesfor this trait. A combined analysis of variance showed the highest spike length of (8.31cm) for Shage and the lowest spike length of (7.22cm) for Robera table 2.

Grain yield: Both the individual and combined analysis of the data showed a significant difference at P≤0.05.From the individual analysis, the highest yield was recorded by Bentu (61.19 qt/ha) and the lowest for HB1966 (37.74 Qt/ha) at Qunisegeria, The highest for HB1966 (50.96 Qt/ha) and the lowest for Bentu (34.52 Qt/ha) at Arbarakate and The highest for Gobe (41.18 Qt/ha) and the lowest for Abdane (24.74 Qt/ha) was recorded. Combined analysis variance for treatment means effect of location interaction was showed significance difference on grain yield Qt/ha Table 2. The highest yield (46.55 Qt/ha) was recorded for variety HB1307 followed by Bentu (44.07 Qt/ha) and EH1493 (43.27Qt/ha)whilethe lowest for HB1965 (37.34 Qt/ha).

Table 4.AMMI analysis of variance for grain yield (Qt/ha) of ten barley varieties tested at three locations during 2018 main cropping season.

Source	**DF**	**SS**	**MS**	**SS%**	**F cal.**	**F pr**
Total	89	13289	149.3			
Trt(at each loc)	29	7857	270.9**		3.20	<0.001
Genotypes	9	836	92.8*	6.3	1.10	0.0412
Environments	2	3342	1671.0**	25.15	11.68	<0.001
Block	6	858	143.0		1.69	0.1416
Interactions	18	3680	204.4*	27.69	2.41	0.0066
IPCA 1	10	2887	288.7	78.45	3.41	0.0016
IPCA 2	8	792	99.0	21.52	1.17	0.3345
Residuals	0	0				
Error	54	4573	84.7			

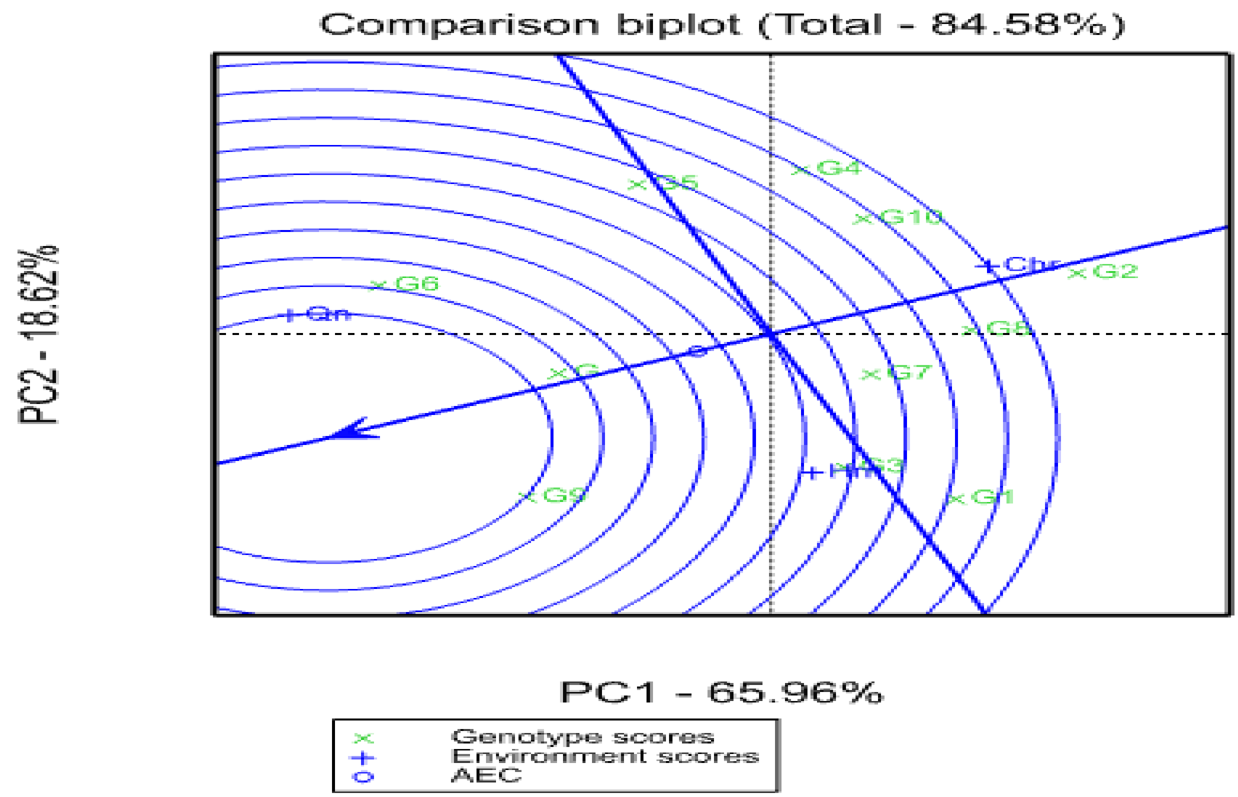
DF=Degree of freedom, SS= Sum of squares, MS= Mean of squares, SS%= percentage of sum of squares

The ANOVA indicated very highly significant differences (P<0.001) for treatments and environments. The total variation explained (%) was 59.12% for treatment and the remaining % for error. The greater contribution of the treatment than the error indicates the reliability of this multi-location experiment. The treatment variation was largely due to GEI variation (27.69%), genotype that accounted 6.3% and 25.15% for the environment variation, respectively. As discussed earlier, the high percentage of GEI is an indication that the major factor that influence yield performance of barley is the interaction effect of GE. In the AMMI ANOVA the GEI was further partitioned by PCA. The number of PCA axis to be retained is determined by testing the mean square of each axis with the estimate of residual through the F-statistics. The result of ANOVA showed that the first IPCA is very highly significant at P<0.001 probability level and this result suggests the inclusion of the first interactions PCA in the model (Table 3).

In particular, the first IPCA captured 78.45% of the total interaction sum of squares while the second IPCA explained 21.52% of the interaction sum of squares.

Genotype Performance per Environment (GGE biplot Analysis)

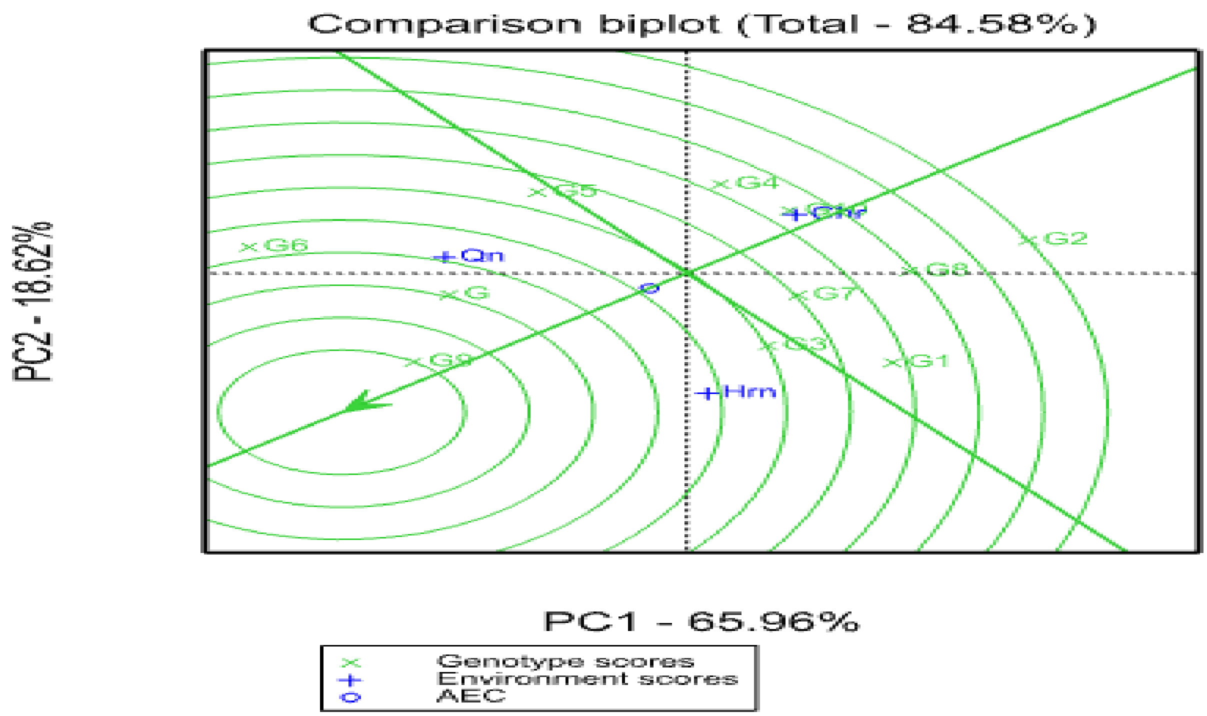
Test locations which are closer to concentric circles like Quni is important under circumstances when selecting genotypes that are widely adapted which is an ideal environment. An ideal environment is the one which is on the intrinsic circle (Figure 1). Thus, Quni is found on the closer proximity or on the edge of the intrinsic circle followed by Hirna. However, Chiro cannot be ideal test location for selecting cultivars which can be adaptable for the whole region, but can be selected as specific adapted location (Figure 1).



Key: G1= HB1965, G2= HB1966, G3=Gobe, G4= Robera, G5= Abdane, G6= Bentu, G7= HB1307, G8= Shage, G9= EH1493, G10= Local

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

Genotypic stability is quite crucial in addition to genotype yield mean; G9, G3 and G7 were more stable as well as having appropriate yield. The ideal genotype might have the highest mean performance and be absolutely stable which is represented by the dot with an arrow pointing to it (Fig 2). Such an ideal genotype is defined by having the greatest vector length of the high yielding genotypes. Concentric circles were drawn to visualize the distance between each genotypes and the ideal genotypes; which is more desirable if it is located closer to the ideal genotype, so that G9, G3 and G7 falls near to the centre of the concentric circles, which were ideal in terms of higher yielding ability and stability (Figure 2).



Key: G1= HB1965, G2= HB1966, G3=Gobe, G4= Robera, G5= Abdane, G6= Bentu, G7= HB1307, G8= Shage, G9= EH1493, G10= Local check

Figure 2. The average genotypes coordination (AGC) views to rank genotypes relative to the center of concentric circles.

The polygon view of the GGE-biplot analysis helps one to detect cross-over and non-crossover genotype-by-environment interaction and possible mega environments in multi-location yield trials (Yan *et al*., 2007). HB1965 (G1), HB1966 (G2), Abdane (G5), Bentu (G6), EH1493 (G9), and Local (G10), were vertex genotypes (Figure 3). They are best in the environment lying within their respective sector in the polygon view of the GGE-biplot and thus these genotypes are considered specifically adapted. Accordingly, G2 was specifically adapted to Chiro, G1 and G3 were adapted to Hirna and G6 was adapted to Quni.

One of the most attractive features of a GGE biplot is its ability to show the mega environment pattern of a genotype by environment data set (Yan and Tinker, 2006). Many researchers find the use of a biplot analysis, as it graphically addresses important concepts such as cross-over GE, mega environment differentiation, specific adaptation, etc as discussed in Yan and Tinker (2006). The polygon is formed by connecting the markers of the genotypes that are far away from the biplot origin such that all other genotypes are contained in the polygon. Genotypes located on the vertices of the polygon performed either the best or the poorest in one or more locations since they had the longest distance from the origin of biplot. The perpendicular lines are equality lines between adjacent genotypes on the polygon, which facilitate visual comparison of them. Those genotypes found in the polygon are widely adapted genotypes. For example, G4, G7 and G8 were widely adapted genotypes (figure 3).

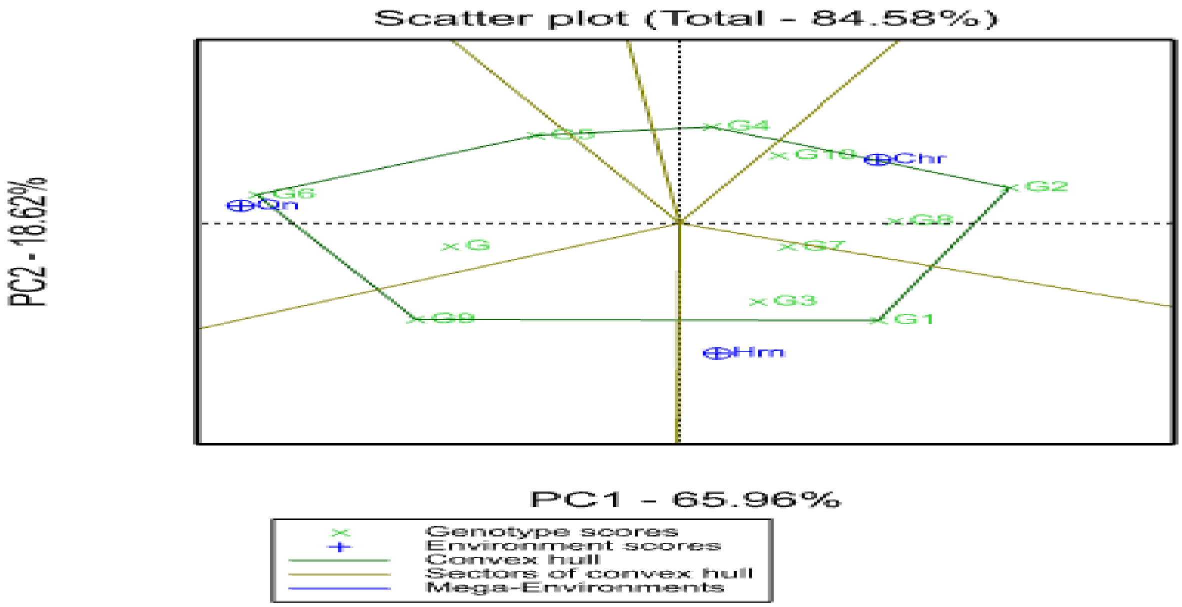


Figure 3. The GGE biplot to show which genotypes performed best in which environment.

4. Conclusions and Recommendations

Studying varietal response to different environment is crucial for plant breeding programmes where there is a diverse natural, environmental, climatic and soil variability is existing. In line with this, a total of 10 barley varieties were studied at three locations (Gemechis (Qunisegeria FTC), Chiro(Arbarakate FTC) and Hirna(Hirna Gara Qufa FTC) during 2018 main cropping season with the objective to select the best adaptive food barley varieties with high yield and good agronomic trait to the area. The result of the experiment showed that barley varieties were showed a significant difference both at individual location and combined mean effects. Varieties were highly affected by environments and their interaction which show the selective adaptation to specific location and wider adaptability that favoring their production. Generally, HB1307 and Bentu were the best varieties thatshowed the stability of these varieties as well as higher yield advantage over the local check .Therefore; these two varieties are recommended as improved varieties and demonstrated on farmers' field for further scaling up.

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5. References

BerhanuLakew, Hailu Gebre and Fekadu Alemayehu. 1996. Barley production and research. Pp 1-8. In: Hailu Gebre and Joob Van Luer (Eds.). Barley Research in Ethiopia: Past work and future prospects. *Proceedings of the first barley research review workshop* 16-19, October. 1993. Addis Ababa, IAR/ICARDA. Addis Ababa, Ethiopia.

Berhanu Bekele, Fekadu Alemayehu and BerhaneLakew. 2005. Food barley in Ethiopia. Pp 53-82. In: Grando, Stefania and Helena Gomez Macpherson (Eds.). Food Barley: Importance, uses and local knowledge. *Proceedings of the international workshop on food barley improvement*, 14-17.January 2002, Hammamet, Tunisia.ICARDA.

Ceccarelli, S.S., Grando, V., Shevostove, Vivar, H., Yahyaoui, A., El-Bhoussini, M. and Baun, M. 1999. ICARDA Strategy for global barley improvement. RACHIS. 18: 3-12.

CSA (Central Statistical Agency), 2016. Agricultural Sample Survey Report on Area and Production of Major Crops. (Private Peasant Holdings, Meher Season). Statistical Bulletin. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency), 2018. Agricultural Sample Survey Report on Area and Production of Major Crops. (Private Peasant Holdings, Meher Season). Statistical Bulletin. Addis Ababa, Ethiopia.

Girma Getachew, Abate Tedila,SeyumBediye and AmahaSebsibe. 1996. Improvement and utilization of barley straw. Pp 171-181. In: Hailu Gebre and Joob Van Luer (Eds.). Barley Research in Ethiopia: Past work and future prospects. *Proceedings of the 1st barley research review workshop* 16-19 October. 1993. Addis Ababa, IAR/ICARDA.

Martin, J.H Walden, R.P and Stamp, D.L. 2006.Principle of field crop production. Pearson Education, Inc. USA.
MelleTilahun, Asfaw Azanaw and Getachew Tilahun. 2015. Participatory evaluation and promotion of improved food barley varieties in the highlands of north western Ethiopia. *Wudpecker Journal of Agricultural Research*. Vol. 4(3), pp. 050 – 053.
MoA (Ministry of Agriculture). 1998. National Livestock Development Project (NLDP) Working Paper 1-4. Addis Ababa, Ethiopia.
Mulatu, B. and Grando, S. (Eds.). 2011. Barley Research and Development in Ethiopia. *Proceedings of the 2nd National Barley Research and Development Review Workshop*.28-30 November 2006, HARC, Holetta, Ethiopia.ICARDA, P. O Box 5466, Aleppo, Syria.pp xiv + 391.
Wosene, G., BerhaneLakew, Bettina I. G., Haussmann and Karl and Schmid, J. 2015. Ethiopian barley landraces show higher yield stability and comparable yield to improved varieties in multi-environment field trials. *Journals of Plant Breeding and Crop Science*, Vol. 7(8), pp. 1-17.
Zemede Asfaw, 2000. The Barley of Ethiopia. Pp 77-108. In: Stephen B. Brush (Eds.). Genes in the Field: *On farm Conservation of Crop Diversity*. IDRC/IPG

Release and Registration of Elemo (ACC. 237261) Sorghum (*Sorghum bicolor*L.Moench) Variety

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Abstract

Elemo (ACC. 237261 ***)*** *is the name for this Sorghum (Sorghum bicolor* L*Moench.) variety with a pedigree designation number of Acc.237261. The variety has been developed and released by Mechara Agricultural Research Center for Mid lands of West Hararghe and similar agro-ecologies of Ethiopia fromsorghum landrace collection through pure line developing selection method. It has been tested at Hirna and Mechara on station during 2013-2016 main cropping seasons and showed consistent better performances in grain yield over standard check (Chiro) variety during Regional variety trial and Fandisha during Variety verification trial. Thus, the variety has shown high mean grain yield and consistently stable across locations and years. It also showed comparable responses to grain mold, head smut, loose smut diseases as compared to local check. On the other hand, as observed during evaluation it possesses resistance or tolerance to long smut disease as compared to Fandisha variety. The early maturing characteristics of the variety suits to the different cropping systems in the area and gives better* *adoption potential by the local farmers. The result of Genotype and genotype by environment (GGE) interaction analysis demonstrated that, this variety was more stable and high yielder than the check and it is released as a new sorghum variety for the area as approved by National Variety Releasing Committee (NVRC).*

Keywords: Sorghum bicolor, Stability,Yield Performance

1. Introduction

Sorghumis the fifth most important cereal crop worldwide after wheat (*Triticum aestivum* L.), rice (*Oryza sativa*L.), maize (*Zea mays* L.) and barley (*Hordeum vulgare* L.). Ethiopia is the primary center of origin and center of diversity for sorghum. Sorghum is now widely found in the dry areas of Africa, Asia, Americas and Australia (Dickon *et al.*, 2006). In lowland areas of Ethiopia, where moisture is the limiting factor, sorghum is one of the most important cereal crops planted as food insurance, especially in the lowlands of Eastern Ethiopia and in the North and North-eastern parts of the country where the climate is characterized by unpredictable drought and erratic rainfall (Degu *et al*., 2009).

Sorghum is 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 to a adverse environmental conditions. This has made sorghum a popular crop in world wide. It is the major source of energy and protein for millions of people living in arid and semi-arid region of the world. It occupied third position in terms of production in Africa after wheat and maize and fifth position in the world after wheat, maize, rice and barley (FAO, 2017).The crop is the major food cereal after maize and tef in terms of area coverage and the third after maize and wheat in terms of grain production in the country (FAOSTAT, 2017).The total sorghum production in Oromia was 735, 263.79 ha which produces annual production of 20,810,667.34 quintals (28.30 qt ha^{-1}). From Oromia region, Eastern and Western Hararghe, most part of West Shoa and East Wolega are among the major sorghum producers, that covers 145, 776.64, 158,230.17, 72,176.19, and 36,605.32 hectares of land; and 2,974,092.51, 3,847,701.06, 2,208,879.10 and 1,112,536.22 quintals of sorghum production, respectively (CSA, 2018).

Elemo (ACC. 237261) sorghum variety is released on May 30/2019 by Oromia Agricultural Research Institute, Mechara Agricultural Research Center (McARC). The material has been evaluated together with other genotypes in different breeding nurseries from 2011-2012 and then advanced to variety trial to see its varietal performance across locations and years in sorghum producing areas of West Hararghe mid lands. The variety was officially released as a new variety in West Hararghe mid lands after its approval by of the Ethiopian National Variety Release Committee in accordance with the guidelines of the national variety release system and variety registration of the country. Breeder seed and foundation seed of the variety is maintained by McARC.

2. Varietal Origin and Evaluation

Elemo (ACC. 237261) was introduced from Institute of Ethiopian Biodiversity Conservation (IBC) which was originally collected from West Hararghe Zone.It was originally developed from Institute of Biodiversity landrace collections and selected by pure line selection methods at Mechara Agricultural Research Center (McARC) to develop a variety with high yielding potential and other better agronomic traits. It was tested together with eleven sorghum genotypes including checks in regional variety trial at two environments for three years in major sorghum producing areas of West Hararghe zone for three consecutive years (2013-2016) during the main cropping seasons. Itwas evaluated along with Chiro variety in regional variety trial and with Fandisha as standard check including local check in variety verification trial at altitudinal ranging from 1750-1768 meter above sea level at Hirna and Mechara on station locations in each year. The variety was consistently gave higher yield and stable performance both across years and locations in all parameters.

3. Varietal Characteristics

Even though the variety is long; it is early maturing variety with erect growth habit. The variety matures with an average of 164 days which is more than two weeks earlier in maturity than the standard variety, Chiro, so that it can utilize moisture more efficiently. This short maturing habit is preferred by the local community as it can be produced efficiently with the existing short rain fall season (May-August). It is also characterized by better resistance/tolerance to main biological insect pest (stem borer) than the standard variety (chiro) (visual observation). The variety is tall with average height of 332 cm which is preferred by local community for animal feed. Therefore, it is selected for dual purpose (food and feed) at the tested locations. The average days to heading and maturity are 104 and 164 days, respectively. On the other hand, seed color is white and has average head weight of 0.17 g (Table 1).

4. Yield and Stability Performance

The results of the evaluation indicated important information regarding variety performance and stability. Thus, grain yield performance of the released sorghum variety and check is described below in Table (1). During evaluation seasons, the overall location mean grain yield of this variety was consistently better than all genotypes means both across locations and years. Beside this, Elemo variety was higher in mean grain yield over check variety, with a yield advantage of 41% over Chiro (standard variety). On research field, variety Elemo gave grain yield ranging from 41 to 48.43 Qtha^{-1}, whereas on farmers' field, it gave an average of 26.8 Qtha^{-1}. In addition, stability analysis was carried out on grain yield using three years (2013-2016) data. In this regard, Elemo variety is relatively stable variety with high mean grain yield, and stable across locations and years. Therefore, it has shown stable yield performance across locations of evaluation as well as higher mean grain yield over check variety (Chiro).

Table 1. Combined Mean values of yield and yield related sorghum genotypes across location

Genotypes	**DF(days)**	**DM(days)**	**PH(cm)**	**HW(g)**	**DIS**	**PAS**	**YldQt ha^{-1}**
241226	115.1^{ab}	174.0^{ab}	316.1^{a}	0.14^{a-c}	2.06^{cd}	2.78^{a-c}	32.71^{bc}
239240	94.5^{e}	161.7^{de}	169.3^{e}	0.09^{c}	2.89^{ab}	2.78^{a-c}	30.74^{bc}
237260	101.3^{de}	161.5^{e}	271.6^{c}	0.12^{bc}	2.61^{a-c}	2.78^{a-c}	31.85^{bc}
237262	101.2^{de}	162.9^{de}	208.9^{d}	0.12^{bc}	2.94^{ab}	2.33^{cd}	34.93^{bc}
241228	107.8^{b-d}	173.2^{a-c}	310.9^{ab}	0.16^{ab}	2.17^{cd}	2.61^{b-d}	36.27^{bc}
242048	104.2^{d}	166.4^{a-e}	275.3^{bc}	0.14^{a-c}	3.11^{a}	2.89^{ab}	29.52^{bc}
239184	107.9^{b-d}	166.1^{b-e}	297.6^{a-c}	0.16^{ab}	2.22^{cd}	2.22^{d}	40.03^{ab}
M-3	105.6^{cd}	169.8^{a-e}	262.4^{c}	0.11^{c}	2.50^{a-c}	3.28^{a}	28.18^{c}
239179	112.5^{a-c}	171.6^{a-d}	320.0^{a}	0.16^{ab}	2.00^{cd}	2.72^{b-d}	36.88^{bc}
237261 (Elemo)	**104.3^{d}**	**164.0^{c-e}**	**332.1^{a}**	**0.17^{a}**	**1.72^{d}**	**2.56^{b-d}**	**48.43^{a}**
Chiro	117.9^{a}	176.4^{a}	309.9^{ab}	0.16^{ab}	2.33^{b-d}	2.61^{b-d}	34.13^{bc}
GM	106.6	168	279.6	0.14	2.41	2.69	34.9
LSD(0.05)	7.39	9.95	36.3	0.05	0.66	0.51	10.81
CV%	10.5	9	19.8	48	41	25.7	25.7

DF= days to flowering, DM= days to maturity, PH= plant height, HW= head weight, DIS= disease, PAS= plant aspect, Yld= Grain yield, GM= grand mean, LSD= Least significant difference, CV= Coefficient of variation.

5. Disease Reaction

Data recording was done for all genotypes including this released variety for major sorghum insect pest such as stem borer and for major diseases such as Anthracnoses (*Colletotrichum graminicola*), leaf blights (*Exserhilum turcicum*), and covered and loose smut which are among the major bottleneck for sorghum production at two locations (Table 1). Providentially, this variety revealed resistance to the above mentioned insect and diseases throughout the study periods.

6. Farmers Evaluation of the Variety

To evaluate the perception and preferences of the local farmers, sorghum variety verification trial and selection was conducted at five representative sites in West Hararghe mid lands during 2018 main cropping season. The national variety releasing committee has made farmers selection and evaluation individually and in group. In this evaluation, Fandisha recently released variety and local variety were included together with **Elemo (ACC. 237261)**. Among these, the candidate variety was almost selected or ranked as first variety preferred by the local farmers mainly due to its yield performance, early maturity, tolerant to grain mold, long smut, loose smut and relatively disease free than both standard and local check varieties included in the trial.

7. Adaptation

Elemo variety is recommended for production in the mid lands of West Hararghe with annual rainfall amount of about 600 mm to 900 mm. Nevertheless, the variety can be adapted to other regions or areas with similar agro-ecologies through adaptation.

Table 2. Agronomic/morphological characteristics of sorghum variety, Acc.237261

Characteristics	**Elemo (ACC. 237261)**
Adaptation area	Mechara, Habro and similar agro-ecologies
Altitude(m.a.s.l)	1700-1800
Rainfall(mm)	900-1236
Fertilizer rate	
Nitrogen(kg N ha^{-1})	42
NPS(kg P_2O_5 ha^{-1})	47
Fertilizer application time	Nitrogen applied in split: first split which is 1/2 of the total dose at planting stage and the second split, which is 1/2 of the total dose at 35-40 days after planting, whereas, the whole dose Phosphorous was applied at planting
Fertilizer application method	Drilled in rows and mixed with soil to avoid direct contact with seed
Planting or seeding	The seed drilled in rows and thinned to adjust plant population
Planting date	Early May to Mid of May
Seed rate(kg ha^{-1})	12-13
Row spacing(cm)	75
Plant spacing(cm)	20-25
Weeding frequency	3-4 depending on weed infestation
Days to flowering (days)	105
Days to Maturity (days)	164
Plant height(cm)	332

Inflorescence compactness	loose
Seed color	white
Crop pest reaction(1-5 scale)	
Leaf blight	2
Stem borer	2
Grain mold	1
Yield(Qt ha^{-1})	
Research field	41-48.43
Farmers' field	26.8
Year of release	2019
Breeder seed maintainer	Mechara ARC/OARI

masl=meter above sea level.

8. Conclusion

Elemo (ACC. 237261) sorghum variety was released for Western Hararghe (Mechara and Habro) areas and similar agro-ecologies based on their higher grain yield, having white grain color, well preferred by local community. In addition, thisvariety was found to be tolerant to grain mold and could be stayed white for longer time even if there is rainfall present than other sorghum varieties.

9. Acknowledgments

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10. References

CSA (Central Statistical Agency). 2018. Agricultural sample survey 2017/2018: report on area and production of crops (private peasant holdings, main season), vol. 1. Addis Ababa: Federal Democratic Republic of Ethiopia, Central Statistical Agency.

Degu, E., Debello, A. and KetemaBelete. 2009. Combining ability study for grain yield and yield related traits of grain sorghum (*Sorghum bicolor* (L.) Moench) in Ethiopia.*Agricultural Crop Science*, 57(2): 175–184.

Dicko, M.H., Gruppen, H., Traore, A.S., Alphons, G.J., Voragen, A.G.J. and Berkel, W.J.H. 2006. Sorghum grain as human food in Africa: Relevance of content of starch and amylase activities. *African Journal of Biotechnology*, 5: 384-395.

FAO (Food and Agriculture Organization). 2017.Sorghum and millet production and nutrition, Chapter 2, www.fao.org/docrep.

FAOSTAT. 2017. Food and Agriculture Organization of the United Nations Data base of AgriculturalProduction.FAOStatisticalDatabases.Availableathttp://faostat.fao.org/site/339/default. aspx.

Yan, W. and Kang, M.S. 2003. GGE Biplot analysis: A graphical Tool for Geneticist, Breeders and Agronomists.CRC press, Boca Raton, FL., U.S.A.

Release and Registration of Milkaye Groundnut (*Arachishypogaea* L.) Variety for midland of West Hararghe

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ABSTRACT

*Milkayeis groundnut (*Arachis hypogaea L.*) variety with breeding designation number of* ***PI-158850*** *is one newly released ground nut variety released by Mechara agricultural research center of Oromia agricultural research institute in 2019***.** *In variety evaluation trials, the performances of seven groundnut genotypes were evaluated for yield and yield components at six (6) environments as Regional Variety Trail (RVT) in western Hararge. Finally, the variety Milkaye (PI-158850) was approved for release in 2019 by the National Variety Release Committee. Milkaye varietyis has an erect type and medium seeded morphology. Milkaye (PI-158850) variety gave 2.20 ton ha^{-1} of dry pod yield (DPY) and has 13.47% yield advantage over the Werer-962 standard check. Milkaye variety has moderately resistant to leaf spot, bacterial blight and wilt diseases and also showed drought tolerance as compared to standard check (Werer-962).Therefore, based on all these mentioned merits, Milkaye variety is recommended for production in areas with elevation of 1332 to 1750 meters above sea level in the West Hararghe and similar agroecologies.The breeder seed of Milkaye variety is maintained by the Mechara Agricultural Research Center.*

Keywords: Milkaye; Arachis hypogaea; Variety Registration;Variety

1. Introduction

In Ethiopia, groundnut (*Arachis hypogaea* L.) is the second most important lowland oilseed crops of warm climate next to sesame. Groundnut was first introduced to Eritrea and then to Hararghe in early 1920s by Italian explorers (Yebio, 1984). Nowadays, groundnut is well disseminated in the warm lowlands of the country. The crop is produced mainly by smallholder farmers and plays a significant role in Ethiopian economy. It provides raw material for the food oil factory; it has high energy content; and it is also the main source of cash income.Groundnut seeds has high source of protein, oil, fatty acid, carbohydrates, vitamins and minerals contents. It contains 45-55% oil, 20-25% protein, 16-18% carbohydrate and 5% minerals (Gulluoglu, 2011; Gulluoglu *et al.,* 2016a).The Eastern lowland areas of Ethiopia have considerable potential for increased oil crop production including groundnut. Particularly areas such as Daro Labu, Babile and Gursum are the major producers of groundnuts for local and commercial consumption (Chala *et al*., 2012).

Groundnut yield in the smallholder farmers is low, 1.79 tons (t) per hectare (ha) (CSA, 2018). The production of the crop is constrained by several biotic and abiotic factors, which include critical moisture stress especially during flowering, lack of improved varieties and appropriate production and post-harvest practices, and diseases affecting both above-and underground parts of the plant (Fredu *et al*., 2015).Therefore, the Pulse and Oilseed Crops Research Team of the Mechara Agricultural Research Center has been striving to develop varieties with high yield, disease resistance, high seed oil content and other desirable agronomic traits to increase the production and productivity of the crop in the study areas. Several groundnut genotypes which were brought from Werer Agricultural Research center were evaluated for yield and other desirable agronomic traits aiming to identify genotypes that have better yield than the existing varieties and cultivars cultivated in the country including the study areas.

Yield trials were conducted using 7 genotypes at three locations (Mechara, Milkaye and Mieso) for two years in Western Hararghe; Eastern Ethiopia.The results showed that, genotype with designation number PI-158850 was superior to the standard check variety Werer-962. The standard check variety Werer- 962 (ICGV-86928) was released in 2004 by Werer Agriculture Research Center (MoANR, 2018).Thus, this new variety was verified and approved by National Variety Release Committee of the country as new variety with local name Milkaye, to be cultivated in lowlands of Ethiopia particularly for lowlands of Western Hararghe.

2. Agronomic and Morphological Characteristics

Milkaye variety has light green leaves with distinct in its agronomic characteristics. It is an erect type, with medium seed size and light red in its testa color. It is preferred by farmers mainly because of its seed size, number of seed per pod and medium maturing variety. Leaf spot and wilt diseases are the major threats in the groundnut production in the areas. Milkaye variety showed moderate resistance to the aforementioned diseases throughout the study periods in the study areas.The new variety (Milkaye) is recommended for production in Ethiopia with the areas having an altitude ranging from 1332 to 1750 meters above sea level. The variety was evaluated without any application of fertilizers. The description of the varieties is presented in Table 1 as it was registered in variety registry book (MoANR, 2019).

Table 1. Agronomic and morphological characters of the new groundnut variety.

Adaptation areas	Mid and Low land of west Hararghe (Daro Lebu,and Mieso) and similar agro-ecology
Altitude (meters above sea level)	1332-1750
Rainfall (mm)	500 - 1236
Planting date	Late April-Early June
Seeding rate (kg/ha)	75-100
Spacing (cm):	10 between plants and 60 between rows
Fertilizer rate(kg/ha):	
NPS	No
N	No
Days to flowering (days)	30-38
Days to maturity(days)	118-130
Growth habit	Erect type
100 seed weight	44.68
Seed color	light red
Flower color	Yellow
Crop pest reaction	Moderately resistant to major disease(Wilt, bacterial blight, Early and late leaf spot)
Oil content (%)	47.1
Protein content (%)	35.15
Seed yield (t/ha):	
Research field	2.20
Farmers' field	1.57-1.87
Year of release	2019
Breeder/ Maintainer	McARC, OARI

3. Origin and Pedigree

Milkaye (PI-158850) variety was imported from the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India; through Werer Agricultural Research Center.

4. Varietal Evaluation

The combinations of the locations (Mechara, Milkaye and Mieso) and years (2015, and 2016) were treated as 6 environments (Mechara 2015, Mechara 2016, Milkaye 2015, Milkaye 2016, Mieso 2015 and Mieso 2016). Werer-962, the best adapted variety in the tested sites, was used as the standard check for comparison. The experiment was arranged in Randomized Complete

Block Design (RCBD) with three replications. The spacing between rows and between plants was 0.60 and 0.10 meter, respectively. Starter fertilizer was not applied into the soil during the experiment. The verification trial was also carried out in multi locations in 2018 and evaluated by the National Variety Release Committee (NVRC). The committee approved this variety for release in 2019.

5. Yield Performance and Stability

The mean dry pod yield performance of the Milkaye variety was found to be superior over the standard check variety Werer-962. On average, Milkaye has 35 pods per plant, 3 seeds per pod and a plant height of 30 cm. The results of the evaluation trials indicated important information regarding variety performance and stability. Accordingly, grain yield performance of this released groundnut variety and checks is described below in Tables (2 and 3). During evaluation seasons, the overall location mean grain yield of this variety was consistently higher than all test genotypes means both across locations and years. Beside, Milkaye was higher in mean grain yield over check variety, having a yield advantage of 13.47% over Werer-962 *(*standard variety). On research field, Milkaye variety gave yield of 2.20 t ha^{-1}, whereas on farmers' field, it ranges from 1.57 to 1.87 t ha^{-1}. In this regard, Milkayeis variety showed stable yield performance with high mean grain yield, and its stability in yield performance is across locations and years. Therefore, this variety was approved for release and production for the study areas and similar agroecologies due to its over all merits mentioned above.

Table 2. Agronomic descriptions of PI-158850 and Werer-962.

Variety	Days to flowering	Days to maturity	Number of pods per plant	Number of seeds per pods	Hundred seed weight (g)
Milkaye	30-38	118-130	35	3	43.43
Werer-962	35	141	30.86	2	34.83

Table 3. Mean dry pod yield of groundnut variety over six environments.

Variety	Mean dry pod yield (t ha^{-1}**)**						Mean t ha-1	yield Adv. Werer-962 (%)	Seed oil contents (%)
	2015			2016					
	Mechara	Milkaye	Mieso	Mechara	Milkaye	Mieso			
Milkaye	1.98	1.08	1.23	2.45	5.85	0.58	2.20	13.47	47.1
Werer-962	2.15	1.17	1.28	2.79	3.61	0.63	1.93	-	-

6. Reaction to Major Diseases

Bacteria leaf blight,Wilt and Leaf spot diseases are among the major groundnut diseases in eastern Ethiopia. On 1 to 5 diseases rating scale, Milkaye scored 1.7, 1 and 1.9 for bacteria leaf blight, Wilt and leaf spot, respectively. Accordingly, Milkaye has showed moderate disease reaction to bacteria leaf blight and leaf spot diseases in the tested environments.

7. Quality Attributes

The seed oil and protein content of the Milkaye variety was 47.1 and 35.15 %, respectively. Milkayeis preferred for roasted grain (*kolo)* because of its medium seed size, and it is confectionery type of groundnut variety.

8. Conclusions and recommendation

The groundnut variety Milkaye gave 2.20 t ha^{-1} of dry pod yield. The variety showed stable performances across environments and hence recommended for production for the areas with altitude ranging from 1332 to 1750 meters above sea level. The result has also revealed that, the variety is relatively stable over locations and seasons, and has additional desirable merits such as resistance to leaf spot and wilt disease. The high seed production potential of the variety implies that increased production and productivity of the crop by smallholder farmers in the country at large. In conclusion, the newly released variety Milkaye could be cultivated profitably and sustainably in the mid and lowlands of Ethiopia, leading to enhance income of smallholder farmers. The breeder seed of Milkaye variety is maintained by Mechara Agricultural Research Center.

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REFERENCES

Chala A, Mohammed A, Ayalew A, Skinnes H (2012). Natural occurrence of aflatoxins in groundnut (Arachis hypogaea L.) from eastern Ethiopia.

CSA (Central Statistical Agency). 2018. Agricultural sample survey 2017/18. Report on area and production of crops (private peasant holdings, Meher Season). The FDRE statistical bulletin, Addis Ababa, Ethiopia.

Fredu, N., Kai, M., KPC, R. and Gizachew, L. 2015. Scoping Study on Current Situation and Future Market Outlook of Groundnut in Ethiopia.International Crops Research Institute for the Semi-Arid Tropics (lCRISAT), pp.40.

Gulluoglu, L. 2011. Effects of Regulator Applications on Pod Yield and Some Agronomic Characters of Peanut in Mediterranean Region. Turk J Field Crops. 16(2):210-214.

Gulluoglu, L., H. Bakal, B. Onat, C. Kurt, and H. Arioglu. 2016a. The Effect of Harvesting Dates on Yield and Some Agronomic and Quality Characteristics of Peanut Grown in Mediterranean Region (Turkey) Turk J Field Crops. 21(2): 224-232 (DOI: 10.17557/ tifc.20186).

MoANR (Ministry of Agriculture and Natural Resources). 2018. Crop Variety Registration Issue No. 21. Addis Ababa, Ethiopia, pp. 166-171.

Yebio W/Mariam. 1984. Groundnut and Sesame in Ethiopia: History, Research and Improvement Prospects. Pp. 75-82. In: Proceedings of the First Oil Workshop, Sept. 3-5, Cairo, Egypt.

Performance evaluation of improved Sesame (*Sesamum indicum* L.) varieties in West Hararghe Zone, Oromia, Ethiopia

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ABSTRACT

Sesame (Sesamum indicum L.*) is an annual crop and one of the important oil crops of the world. The experiment was conducted at Daro lebu district (on Milqaye FTC), and Mieso district (Melkasa sub site) in 2018 main cropping season. The objective of the study was to evaluate and select well adapted sesame varieties with high yield and resistant to major pest and disease in west Hararghe Zone. The treatments include six released sesame varieties and one standard check (Adi) were used as planting materials for this study. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications and the plot size was 2.4m X 3m areas which contain six rows of sesame in spacing of 40cm X 10cm between rows and plants respectively. Each variety was sown at seed rate of 5 kg ha–1 by row planting without any fertilizer application. The result from combined mean analysis of variance revealed significant ($P \leq 0.05$) difference among varieties for days to flowering, days to maturity, disease score , number of seed per capsule, thousand seed weight and grain yield across location. However, statistically non-significance difference among varieties was observed for plant height, pest score, and number of capsule per plant. The grain yields of tested varieties were ranged from 3.92 qt ha^{-1} (Abasena) to 5.91qt ha–1 (Bha Necho). The variety Bha Necho was gave superior grain yield 5.91 qt/ha followed by variety Bha Zeyit 5.70 qt/ha among tested varieties. The combined mean grain yield of Bha Necho and Bha Zeyit varieties showed 48.7% & 41.8% yield* *advantage over standard check (Adi), respectively. Therefore, based on overall performance, these two varieties were selected and recommended for further demonstration for the study areas and similar agro ecologies.*

Keywords: Adaptation, Sesame, yield

1. INTRODUCTION

Sesame (*Sesamum indicum* L) belongs to the genus Sesamum, order Tubiflorae and family pedaliaceae and is a diploid species with 2n = 2x = 26 chromosomes. It is an annual self-pollinating plant with an erect, pubescent, branching stem, and 0.60 to 1.20 m tall. The leaves are ovate to lanceolate or oblong while the lower leaves are trilobed and sometimes ternate and the upper leaves are undivided, irregularly serrate and pointed (Felter and Lloyd, 1898: cited in Morris, 2002). The fruit is an oblong, mucronate, pubescent capsule containing numerous small, oval, and yellow, white, red, brown, or black seeds (Morris 2002; Geremew et al., 2012).

It was one of the first oil seeds from which oil was extracted by the ancient Hindus, whichwas used for certain ritual purposes (Arnon, 1972). Seegeler (1983) reported that it is an ancient oilseed, first recorded as a crop in Babylon and Assyria before 2050 BC. Among the other oilseed field crops, sesame is known as one of the most important crops in the world for edible oil production. It is produced mainly in India, Myanmar, China, Sudan, Ethiopia, Uganda, Nigeria, Paraguay, Niger, Tanzania, Thailand, Pakistan, and Turkey (Anonymous, 2010). Sesame has an important role in human nutrition. Most of the sesame seeds are used for oil extraction and the rest are used for edible purpose. It is grown primarily for its oil-rich seeds. The sesame seed is rich in good quality edible oil (up to 60%) and protein (up to 25%) (Brar and Ahuja1979).The oil is in demand in the food industry because of its excellent cooking quality, flavor, and stability. The world production is estimated at 3.66 million tones with Asia and Africa producing 2.55 million tons (Anon, 2008).

Oil crops are the second largest source of foreign exchange earnings nextto coffee (Fiseha et al., 2019) and sesame is the main oilseed crop in terms of production value. In 2010, Ethiopia was considered as the second main exporter of sesame seeds in the world, behind India (FAOSTAT, 2012). In Ethiopia, sesame is grown chiefly for export (more than 95%) and direct consumption (5%) (Annonymous, 2015). In Ethiopia it grows almost in all regions of the country with an altitude of less than 2000 meter above sea level (Yebiyo, 1985; Adefris *et al*., 2011) and is a well-established crop in Amhara, Tigray, Afar and Oromia regions. Reports on peasant holdings in sesame showed that, 89.95% (2466503.09 tons) of the Ethiopian sesame produce comes from Amhara (48.84%), Tigray (24.52%) and Oromia (16.59%) regions (CSA, 2015). The total sesame production area and production in Oromia is about 337,926.82 ha (2,678,665.46 qt) and 2,170.25 ha (12,996.62 qt) over last year post harvest estimate respectively (CSA, 2016). The national average productivity is about 7.93 qt/ha while that of Oromia is about 5.99 qt/ha (CSA, 2016). In Ethiopia, sesame grows well in the lowlands either as sole crop or intercropped with millet or sorghum (Haile, et al., 2004). Sesame oil and seed are put to great variety of uses. The oil, besides as a cooking medium, is also used for anointing the body. The oil cake which is rich in calcium is used as feed. The seed is used in the preparation of different foods (stew called wet, a souce for porridge, snacks, flavoring, sweets and beverages) (Adefris *et al*., 2011). It is used as a source of food; eaten as raw, either roasted or parched, or as blended oil in the form of different sweets (Weiss, 1971).The seeds are rich source of oil, protein, calcium, phosphorus and oxalic acid (Caliskan*et al*., 2004). Low yield had been attributed to cultivation of low yielding dehiscent varieties with low harvest index values, significant yield loss during threshing and lack of agricultural inputs such as improved varieties, fertilizers and other agro-chemicals (Ashri, 1994, 1998; Weiss, 2000; Uzun and Cagirgam, 2006).

In western Hararghe, about 8,336.38 kuntals was produced by 76,672.00 household during 2016 cropping season (CSA, 2016). According to zonal agricultural office, sesame production is largely produced by Anchar, Doba , Mi'eso, Hawi-gudina, low land of Darolebu and Oda bultum districts. Despite the area is suitable for sesame production, lack improved varieties, biotic and abiotic factors are among the major production constraits that attributed for low production and productivity. Among these constraints, lack of improved variety is very serious question of sesame producers in the area. Therefore, this activity was initiated to evaluate the performance of recently released varieties of sesame in terms of high grain yield and tolerant to disease in the study area for subsequent recommendation.

2. MATERIALS AND METHODS

2.1. Description of the study sites

The field experiment was conducted at Daro lebuand and Mieso districts in West Hararghe Zone during 2018 main cropping season.Milkaye FTC from Daro Labu district and Melkasa sub site from Mieso district were selected and Adaptability studies of improved Sesame varieties were conducted. Daro Lebu lies to the east of Finfinne on 446 km and South of Chiro town, the capital of the zone, at a distance of 115 km. The area has bimodal type of rain fall distribution of short rainy season '*Belg*' lasts from mid- February to April whereas the long rainy season '*kiremt*' is from June to September with annual rainfall ranging from 900-1300 mm (average annual rainfall of 1094 mm) and ambient temperature of the district varies from 14 to 26^{o}C with an average of 20^{o}C (Climate data obtained from Mechara Metrological Station). The nature of rain fall is very erratic and unpredictable causing tremendous erosion some times. The major soil type of the area is sandy clay loam which is reddish in color (Report on farming system of Daro Lebu districts, Mechara Agricultural Research Center, unpublished data).

Mieso is located at 304 km to East of Finfinne and 25 km to West of Chiro. It is bordered by Doba district in East direction, Afar Region in West, Chiro district in South and Somali Region in North. The district has an area of 257,344 ha. It is located at the latitude of 9^{o}13'59.99" and longitude of 40°45'0". The altitude of the district on average is 1332 m.a.s.l. with maximum and minimum temperature of 37^{0}C and 25^{0}C, respectively. The annual rainfall of the district ranges from 500 mm to 700 mm (Jima D and Birhanu A., 2017)

2.2. Treatments and Experimental Design

Six released sesame varieties namely: Bha Necho, Bha Zeyit, Dicho, Chalesa, Obsa, and Aba-sena varieties and one standard check (Adi) were used for this study. These varieties were selected based on average yield performance and agro ecological adaptation. The varieties were obtained from Bako Agricultural Research center and Haramaya University. The experiment was laid out in RCBD with three replications and the plot size was 2.4 m X 3 m areas which contain six rows of sesame in spacing of 40cm X 10cm between rows and plants respectively. The spacing between plots and blocks was0.5m and 1m respectively. Each variety was sown at seed rate of 5 kg ha^{-1} by row plantingwithout any fertilizer application. All other trial management activity was carried out as necessary.

2.3. Data collection

Phenological Parameters

Phenological parameters such as days to flowering (days), days to maturity (days) and plant height (cm) were recorded. Days to flowering was recorded by counting the number of days after flowering when 50% of the plants per plot had the first open flower. Days to maturity was recorded when 90% of capsules were physiologically matured per plot. Plant height at maturity

(PH) (cm): this growth parameter is the stature of the plants in centimeter (cm) from the ground up to the top of the plants.

Grain Yield and Yield Components

Four central rows were harvested for determination of grain yield. Five plants were randomly selected from the four central rows to determine yield and yield components, which consisted of number of capsule per plant and number of seeds per capsule. Capsule number per plant was determined by counting capsules of the five randomly selected plants while number of seeds per capsule was recorded by counting the total number of seeds in a capsule from randomly sampled capsules taken from the five randomly selected plants. Thousand seed weight (gram) (TSW): the average weight of 1000 seeds randomly collected from the harvested grain yield in grams and Grain yield (kg/ha): the total grain yield (kg/ha) harvested from the net plot area.

2.4. Statistical Analysis

All the agronomic data were recorded and being subjected to analysis using the **R** Computer software. Mean separation was carried out using Least Significant Difference (LSD) test at 5% probability level.

3. Results and Discussions

The analysis of variance showed that, there were significant ($P<0.05$) difference among varieties in days to maturity, plant height, disease (bacterial blight), number of seed per capsule, thousand seed weight and grain yield. However, statistically non-significance difference was observed for days to flowering, pest score and number of capsule per plant **among tested varieties.** The grain yields of tested varieties were ranged from 4.57 qt ha^{-1} (Aba-sena) to 7.25 qt ha^{-1} (Bha Zeyit). Bha Zeyit variety (7.25 qt ha^{-1}) gave superior grain yield followed by variety Bha Necho (7.07qt $ha^{-1)}$ among tested varieties. On the other hand, lowest **grain yield** was obtained from Aba sena variety (4.57 qt ha^{-1}) at Milqaye FTC (Table-1)

At Mieso sub site, there was significant ($P\leq0.05$) difference among the tested varieties for days to flowering, days to maturity, plant height, thousand seed weight and grain yield but non-significant difference was observed for disease (bacterial blight), pest score, number of capsule per plant, and number of seed per capsule. The grain yields of tested varieties were ranged from 3.05 qt ha^{-1} (Obsa) to 4.67qt ha^{-1} (Bha Necho). Bha Necho (4.67 qt ha^{-1}) was gave superior grain yield followed by variety Bha Zeyit (4.16qt $ha^{-1)}$. On the other hand, lowest **grain yield** was obtained from variety Obsa (3.05 qt ha^{-1}) (Table-2)

The result from combined mean analysis of variance revealed significant ($P \leq 0.05$) difference among the tested varieties for days to flowering, days to maturity, disease (bacterial blight), number of seed per capsule,thousand seed weight and grain yield across locations. However, statistically non-significance difference was observed among the test varieties for traits such as plant height, pest score, and number of capsule per plant (Table 3).

The grain yields of tested varieties were ranged from 3.92 qt ha^{-1} (Abasena) to 5.91qt ha^{-1} (Bha Necho). Bha Necho gave superior grain yield 5.91 qt/ha followed by variety Bha Zeyit 5.70 qt/ha among tested varieties. On the other hand, lowest **grain yield** was obtained from Aba-sena (3.92 qt ha^{-1}). The combined mean data across locations indicated that, Bha Necho and Bha Zeyit varieties performed better than the standard check (Adi) and other tested varieties (Table-3). This result is in agreement with the reports of Fiseha et al., (2019), who reported that the highest grain yield was obtained from the variety which is well adapted to the growing environment.

The combined mean grain yield of Bha Necho and Bha Zeyit varieties were 48.7% & 41.8% yield advantage over standard check (Adi) respectively (Table-3). These varieties were well performed across all locations. However all varieties were shown grain yield reduction at Mieso sub site as compared toMilkaye (Table 1 and 2). This yield reduction might be occurred due to environmental factor not due to genetic factor, i.e, the nature of rain fall at this area is very erratic and unpredictable causing tremendous erosion during this growing season.Variety Bha Zeyit and Bha Necho had the highest mean number of capsule per plant 67 and 63 respectively and thousand seed weight 4.81and 5.21 respectively while Chalesa and Adi showed the lowest mean number of capsule per plant 60.5 and 57.33 respectively.

Table -1: Mean grain yield and agronomic traits of sesame varieties on Milkaye FTC in2018

Variety	DF	DM	PH	BB	PS	NCPP	NSPC	THSW	GYD	GYD AD%
BhaZeyit	54.66	99.6b	99.3c	1.33ab	1	100.66	69.33b	4.80a	7.25a	49.50%
BhaNecho	55.33	98b	116ab	1.00b	1	84.66	70.66a	5.83a	7.07a	45.80%
Chalesa	55.33	95.6b	106.6bc	1.33ab	1	78.33	63.66ab	4.36ab	5.63b	16.08%
Decho	54.33	97.6b	104.6c	1.33ab	1	83.33	60.66	4.06ab	5.63b	16.08%
Obsa	55	96.3b	105.6	1.33ab	1	95.33	62ab	4.03ab	5.12b	5.56%
Adi	55.6	121.66a	120.3a	2.00ab	1	76.66	54.66b	3.13b	4.85b	
Aba-sena	56	1130a	107bc	2.33a	1	88.66	56b	5.50a	4.57b	
Mean	55.19	103.14	108.5	1.52	1	86.8	62.42	4.53	5.68	
LSD	3.22ns	9.01***	10.28*	1.12*	2.06ns	27.1ns	11.63*	2.12*	1.29**	
CV%	3.31	4.95	5.37	42.03	1.16	17.7	10.56	26.56	12.9	

DF=days to flowering, DM=Days to maturity, PH= plant height (cm), *BB=Bacterial blight*,PS=Pest Score (1-5), NCPP= Number of capsule Per Plant, NSPC=Number of Seed Per capsule, THSW=Thousand Seed Weight (g) and GY= Grain Yield (qt/ha).

Table -2: Mean grain yield and agronomic traits of sesame varieties on Mieso sub site FTC in 2018

Variety	DF	DM	PH(cm)	BB	PS	NCPP	NSPC	THSW(g)	GY(qt/ha)	YD AD%
BhaNecho	51.33b	99.33b	84.33abc	1	1	42.33	63	4.60ab	4.67a	46.4
BhaZeyit	51.66b	100.66b	92.00a	1.66	1	33.33	73.66	4.86a	4.16b	30.4
Decho	50.00b	98.66b	89.66ab	1	1	38	68	2.86b	3.74bc	17.24
Chalesa	53.00ab	102.00b	87.00abc	1	1	42.66	75.33	3.26ab	3.28cd	2.82
Aba-sena	55.66a	109.33a	79.00bc	1.33	1	33.66	61	4.06ab	3.28cd	
Adi	50.33b	107.66a	78.66c	1.66	1	38	63	3.53ab	3.19d	
Obsa	52.66ab	98.33b	77.00c	1	1	30.66	66.66	3.53ab	3.05d	
Mean	52.09	102.28	83.95	1.23	1	36.95	67.23	3.81	3.62	
LSD	3.46*	4.78***	10.69*	0.67 ns	2.1 ns	24.96ns	14.82ns	1.85*	0.46***	
CV%	3.77	2.65	7.22	31.1	1.16	38.3	12.49	27.49	7.21	

DF=days to flowering, DM=Days to maturity, PH= plant height (cm), *BB=Bacterial blight,*PS=Pest Score (1-5), NCPP= Number of capsule Per Plant, NSPC=Number of Seed Per capsule, THSW=Thousand Seed Weight (g) and GY= Grain Yield (qu/ha)

Table-3: The combined mean source of sesame varieties on grain yield and yield component over two locations (Milkaye FTC and Mieso sub site) in 2018

Variety	DF	DM	PH(cm)	BB	PS	NCPP	NSPC	THSW (g)	GY(qt/ha)	YLD AD%
BhaNecho	53.33b	98.66b	100.2	1.00b	1	63	66.83ab	5.21a	5.98a	48.75
BhaZeyit	53.16b	100.16b	95.66	1.50ab	1	67	71.50a	4.83ab	5.70a	41.8
Decho	52.16b	98.16b	97.16	1.16b	1	60.66	64.33ab	3.46c	4.52b	12.4
Chalesa	54.16ab	98.83b	96.83	1.16b	1	60.5	69.50a	3.81bc	4.45b	10.7
Obsa	53.83ab	97.33b	91.33	1.16b	1	63	64.33ab	3.78c	4.08bb	1.24
Adi	53.00b	114.66a	99.5	1.83a	1	57.33	55.83b	3.33c	4.02b	
Aba-sena	55.83a	111.16a	93	1.83a	1	61.16	58.50b	4.78ab	3.92b	
Mean	53.64	102.71	96.23	1.38	1	61.88	64.83	4.17	4.67	
LSD	2.03**	6.29**	10.15 ns	0.64*	4.08 ns	16.78ns	8.85*	1.25*	0.73***	
CV%	3.2	5.17	8.9	39.56	3.44	22.9	11.52	25.31	13	

DF=days to flowering, DM=Days to maturity, PH= plant height (cm), BB=Bacterial blight, PS=Pest Score (1-5), NCPP= Number of capsule Per Plant, NSPC=Number of Seed Per capsule, THSW=Thousand Seed Weight (g) and GY= Grain Yield (qt/ha)

4. CONCLUSIONS AND RECOMMENDATIONS

Evaluation of different varieties under different environment is crucial to determine their responses. In line with this, seven sesame varieties were evaluated at two locations representing Low-land agro-ecologies of West Hararghe zone in 2018 main cropping season with the objective to evaluate and select adaptable, high yielding, early maturing, and diseases resistant/tolerant varieties foe eventual recommendation for production in the study areas. The result of the experiment showed that a significant difference for both individual and combined mean effects for most studied traits. Grain yield was an important character to be considered for variety selection to address the objective of the conducted activity.For this reason, two improved varieties i.e. Bha Necho, and Bha Zeyit were showed better performance for most of the studied characters including **grain yield** as well as showed higher yield advantage over the standard check used**.** Therefore, based on overall performance, these two varieties were selected and recommended to be demonstrated on farmers' field for further scaling up in the study areas.

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5. REFERENCES

Anonymous. 2010. Sesame production data. http://faostat.fao.org/.

Anonymous. 2015. Sesame production data. http://faostat.fao.org/.

Arnon, I. (1972). Crop production in dry regions. Vol. II: Systematic treatment of the principal crops (pp. 683). Leonard Hill, London. Retrieved: http://www.worldcat.org/title/crop-production-in-dry regions/oclc/417518.

Ashri A. 1998. Sesame breeding. Plant Breeding Rev. 16:179-228.

Brar, G.S., and K.L. Ahuja, 1979. Sesame: its culture, genetics, breeding and biochemistry, pp. 245-313. Annu. Rev. of Plant Sci. Kalyani Publishers, New Delhi.

Caliskan, S., M. Arslan, H. Arioglu and N. Isler, 2004. Effect of planting method and plant population on growth and yield of sesame (*Sesamum indicum* L.) in a Mediterranean type of environment. *Asian J. Plant Sci*. 3 (5) 610-613

CSA (Central Statistic Authority). 2015. Ethiopian agricultural sample enumeration : Report on the primary results of area, production and yield of temporary crops of private peasant holdings in meher season, Addis Ababa, Ethiopia.

CSA (Central Statistical Authority). 2016. Report On Area and Crop Production Forecast for Major Crops. Addis Ababa, Ethiopia.

FAO (http://www.fao.org/agriculture/seed/cropcalendar/cropcalendar.do)

Felter, H.W., and Lloyd, J.U. (1898). King's American dispensatory.www.ibiblio.org/herbmed/ eclectic/kings/sesamum.html

FisehaBaraki, YemaneTsehayeandFetienAbay (2016). Analysis of genotype x environment interaction and seed yield stability of sesame in Northern Ethiopia.

FisehaBaraki and MuezBerhe, (2019).Evaluating Performance of Sesame (Sesamum indicum L.) Genotypes in Different Growing Seasons in Northern Ethiopia. International Journal of Agronomy, Volume 2019, Article ID 7804621, 7 pages.

GeremewTerefe, AdugnaWakjira, MuezBerhe, and HagosTadesse .2012. Sesame Production Manual.Ethiopian Institute of Agricultural Research Embassy of the Kingdom of the Netherlands, EIAR, Ethiopia, 49 p.
Haile, M., Tesfaye, M., Tesfaye, A., & Mulat, E. (2004). Export type sesame and groundnuts production and marketing.
Jima Degaga and Birhanu Angasu, (2017).Assessment of Indigenous Knowledge of Smallholder Farmers on Intercropping Practices in West Hararghe Zone; Oromia National Regional State, Ethiopia. Journal of Agricultural Economics and Rural Development, 3(3): 251-258.
Morris, J.B. 2002. Food, Industrial, nutriceutical and pharmaceutical uses of sesame genetic resources, 153-156 pp. In: Janick, J. Whipkey, A. (Eds.), Trends in Crops and New Uses, ASHS, Alexandria, VA.
Raikwar, R. S., &Srivastva, P. (2013). Productivity enhancement of sesame (Sesamum indicum L.) through improved production technologies. African Journal of Agricultural Research, 8(47), 6073–6078.
Seegeler, C. J. P. (1983). Oil plants in Ethiopia, their taxonomy and agricultural significance. [sn].Centre for Agricultural Publishing and Documentation, Wageningen.
Uzun B, Cagirgan MI. 2006. Comparison of determinate and indeterminate lines of sesame for agronomic traits. Field Crops Res. 96:13-18.
Weiss, E.A., 2000. Oilseed Crops. 2nd ed. Blackwell Science, Inc., Malden, MA.

Adaptation Trial of plantain type of Banana Varietiesat Mechara on station

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ABSTRACT

Fruit crops are widely grown in west Hararghe by small household farmers and plays significant role for income generation and nutrition. Plantains are cooking type banana producing fruits that remain starchy at maturity and need processing before consumption. Even though the environment is suitable for the production of fruit, the productivity of the crop is highly constrained by low yielding variety and low moisture stress. In view of this, this trail was conducted to evaluate different plantain type banana varieties for high yield, drought and disease resistant/tolerant at Mechara on station. Four plantain varieties were brought from Melkasa Agricultural Research Center and evaluated for agronomic, yield and yield related traits in Completely Randomized Block Design (RCBD) in three replications. The Analysis of variance results revealed significant variation among plantain varieties for all traits over both *harvesting cycles except for fruit diameter (cm), number of fruit per bunch and unmarketable yield. The highest bunch weight, number of hands per bunch, number of fruits per bunch, marketable yield and total yield was obtained Nijiru variety followed by kardaba. Nijiru variety was resistance to banana diseases (sigatoka and panama diseases) as compared to the other varieties. Whereas, the lowest bunch weight, number of fruits per bunch, marketable yield,and total yield was obtained from Matokke variety. The Pearson correlation coefficient showed that, the average bunch weight, fruit diameter, number of finger per hand and Marketable yield were positively correlated with total yield. It is, therefore, concluded that, Nijiru variety was well performed and can be recommended for the growers at Mechara and similar agro ecology of the area.*

Key words: Adaptation, plantain varieties

1. INTRODUCTION

Bananas and plantains (Musa spps.) are considered as the world's most important fruit and the fourth most important staple food crop (Swennen and Vuylsteke, 2001). They provide a starch staple across some of the poorest parts of the world in Africa and Asia. The all year round fruiting habit of banana and plantains puts the crop in a superior position in bridging the hunger gap' between crop harvests. Nearly all edible plantain cultivar are derived from two wild species, *M. acuminate* and *M.balbisiana* (Robinson, 1996). These wild species are classified on the basis of the proportion of the genetic constitution contributed by each parental source (Robinson, 1996). Plantains are always cooked before consumption and are higher in starch than bananas. These are known as plantains and are plants producing fruits that remain starchy at maturity (Marriot and Lancaster, 1983, Robinson, 1996) and need processing before consumption.

Banana and plantain is contributed significantly to food and income security of people engaged in production and trade, particularly in developing countries. The plantain fruit is nutritious and contains high levels of calories, potassium, vitamin C, magnesium and vitamin B6 (Samson, 1986; Robinson, 1996).There are two types of bananas: the sweet dessert and the cooking banana (including plantains) (Jones, 2000). The dessert banana is left to ripen and then eaten raw, while the cooking banana is peeled and cooked into a dish (Robinson, 1996). Plantain are usually cooked and not eaten raw unless they are very ripe. It is similar to unripe dessert bananas in exterior appearance, although often larger; the main differences in the former being that their flesh is starchy rather than sweet, and they are used unripe and require cooking (Valmayor*et al.*, 2006). Plantain is drought and disease tolerant fruits than desert banana (M. *balbisiana*).The plantain cultivars containing the B-genome that has been reported to exhibit higher tolerance to a biotic stresses (Hu *et al*., 2015).The cultivars grown vary with altitude. For instance, at lower elevations below 1,200 meters above sea level (masl) plantains are mainly cultivated (Dheda *et al*., 2011; Ocimati *et al.,* 2013).

Fruit crops are widely grown in Ethiopia from low to highland agro ecologies.The dessert banana is the major fruit crop grown in different parts of the country and leading both in area and production among the fruit crops. About 104,421.81 hectares of land is under fruit crops in Ethiopia; Bananas contributed about 56.79% of the fruit crop area. More than 7,774,306.92 quintals of fruits was produced in the country; Bananas, took up 63.49% of the fruit production (CSA, 2018). Like other agricultural commodities, banana and plantain production faces several biotic and abiotic constraints and poor provision of production technologies. In resource poor production system, productive varieties that are resistant to pests, diseases and drought are highly suitable for increasing productivity.

Varieties often interact with the environment in an unpredictable manner and as a result evaluating varieties that are tested across locations and/or years to study their adaptation and stability of performance before recommendation is very crucial. Therefore, breeding programs should focus on evaluating and selecting varieties that are high yielding, disease resistant, abiotic stress resistant and altered agronomic performance for target areas. In this study, four plantain varieties were evaluated at Mechara Agricultural Research Center on station for four consecutive cropping seasons. Therefore, this experiment was conducted with the objective to evaluate high yielding, disease resistant/tolerant plantain varieties to the area.

2. MATERIALS AND METHODS

2.1. Description of the study sites

The experiment was conducted at Mechara Agricultural Research Center on station during the main cropping season, in 2016 to 2019. Mechara Agricultural Research Center is situated in the Eastern part of the country at about 434 km away from Addis Ababa, the capital city of Ethiopia and it is located in Eastern part of country lying between 8.34 N latitude and 40.20’ E longitude. The altitude of the area is about 1760 m.a.s.l. It has a warm climate with annual mean maximum and minimum temperature of 31.8^{o}c and 14^{o}c respectively. The area receives mean annual rainfall of about 1100 mm. The major soil of the area is well-drained slightly acidic Nitosol (McARC, 2010).

2.2. Experimental Treatments and Design

Four plantain varieties of suckers; Matoke, Nijiru, Cardaba and Kitawira were collected from Melkasa Agricultural Research Center and used as experimental materials. The trail was laid out in Completely Randomized Block Design (RCBD) with three replications. Six plantain suckers were planted in a single plot with the spacing between plots 3.5m and between row and plant 2.5 m was used for the trail. Recommended agronomic practice was applied uniformly for all treatments.

2.3. Data Collection

Data on the growth, yield and yield components were collected from the two consecutive growing years. These Data were collected for the following characters: Stand count, Number of hands per bunch, average single bunch weight (kg), number of fingers per bunch, number of fingers per hand, finger weight per hand, fruit diameter (cm), fruit length (cm), average weight of single fruit (kg), marketable fruit number and weight in ton ha^{-1},unmarketable fruit number and weight in ton ha^{-1}.

2.4. Data Analyses

Analysis of variance was conducted using Genstat statistical software package (16^{th} edition). The mean separation for any significant effect of the varieties was done using Least Significant Difference test (LSD) at 5% of probability level. Correlation Coefficients among the traits were carried out using procedure of SAS software Version 9.0.

3. Results and Discussion

3.1. Mean performance of plantain varieties

The results of analysis of variance (ANOVA) showed the presence of significant difference among the test varieties for all traits in the first and second harvesting cycle except for unmarketable yield (Tables 1 and 2). All the parameters were significantly increased with the harvesting cycle/crop cycle of plantain varieties. This result is in agreement with Tenkouano and Baiyeri (2007) who reported that both genotypes and cropping cycle significantly influence the yield and other growth trait of the banana cultivars.

Table1. Mean yield and yield components of plantain varieties at Mechara on station, 1st harvesting cycles in 2017/18.

Variety	FD	ABW	NFH	NHB	MY	UMY	TTY
Nijiru	3.4^{ab}	5.7^{a}	53^{a}	5.67^{a}	19.37a	0.66	20.02^{a}
Cardaba	3.2^{b}	4.5^{ab}	47^{b}	3.67^{b}	13.79^{c}	0.48	14.26^{c}
Matoke	3.23^{b}	3.4^{b}	34.33^{c}	4^{b}	12.59^{c}	0.38	12.97^{c}
Kitawira	3.63^{a}	3.2^{b}	50.67^{a}	4^{b}	16.49b	0.8	17.29^{b}
Mean	3.4	4.1	47	4.3	15.56	0.58	16.14
LSD	0.25	1.4	3.35	0.67	1.54	ns	1.43
CV%	3.7	16.8	3.6	7.7	15	50.4	4.4

Table2. Mean yield and yield components of plantain varieties at Mechara on station, 2nd harvesting cycles in 2018/19.

Variety	FD	ABW	NFH	NFB	UMY	MY	TTY	DR
Nijiru	3.7ab	6.5a	55a	5a	3.8	32.4a	36.2a	1c
Cardaba	4.2a	5.1bc	31.7c	4b	4.2	27.1ab	31.3ab	5a
Matoke	3.2b	4.34c	47ab	4.3ab	3.3	20.3b	23.6b	1c
Kitawira	4ab	5.83	35bc	3.67b	2.4	20.1b	22.5b	2b
Mean	3.8	5.4	42.7	4.25	3.4	26	29.5	2
LSD	0.8	1.4	14.5	0.9	1.9ns	11.3	10.8	0.6
CV%	10.3	16.8	17.4	11.1	28.3	21.6	18.4	15.1

Note: TTY=Total Yield (tonha^{-1}), MY=marketable yield(tonha^{-1}), UM=unmarketable yield(tonha^{-1}), FD=fruit diameter(cm), ABW=average bunch weight(kg),NFH=Number fruit per bunches,NHB=Number of hands per bunches

The result of combined mean data analysis showed significance difference among the varieties for most of the traits except fruit diameter (cm), number of fruit per bunch and unmarketable yield in ton ha^{-1} (Table 3).

Table3. Mean yield and yield components of plantain varieties over two harvesting cycles at Mechara ARC 2017-2019.

Variety	FD	ABW	NFH	NFB	MY	UMY	TTY	DR
Nijiru	3.5	6.1a	54.2	8.4a	25.6a	2.3	27.9a	1c
Cardaba	3.8	4.78ab	39.5	6.2b	20.3ab	2.4	22.7ab	5a
Kitawira	3.7	3.8b	42.7	7ab	18ab	1.6	19.6b	2b
Matoke	3.4	4.5b	40.8	7.8ab	16.4b	1.8	18.2b	1c
Mean	3.56	4.8	45.8	7.4	20	2	22	2.3
LSD	0.5ns	1.49	26.9ns	1.9	7.8	0.9ns	7.7	0.6
CV%	10.6	28.5	38.7	21.8	32	37.3	28.9	24.3

TTY=Total Yield(tonha^{-1}),MY=marketableyield(tonha^{-1}),UM=unmarketable yield (tonha^{-1}), FD=fruit diameter (cm), BW=bunch weight(kg), NFH=Number fruit per bunches,NHB= Number of hands per bunches.

Average bunch weight: Varieties showed significant difference on average bunch weight. The highest bunch weight was shown on Nijiru (6.1kg) followed bykardaba (4.78kg) variety, while the lowest bunch weight had recorded for Kitawira (3.8kg) variety.

Number of finger per hand and number of finger per bunch: the results of analysis of variances showed that the presence significant difference among varieties for number finger per bunch while non-significant difference for number of finger per hand. Varietal difference causes significant difference in number of finger per bunch. The Nijiru variety produced more number of finger per hand (54.2) and number of finger per bunch (8.4) and was statistically superior to the other varieties. Nevertheless, Cardaba variety produced the less number of finger per hand (39.5) and finger per bunch (6.2).The highest number of finger per hand in Nijiru variety was most likely due to the fruit bearing capacity of the variety and more fruit per bunch nature which leads to contain high number of finger per hand. These results are in agreement with the reports by other researcher who indicated average number of fingers per bunch ranges of from 27 to 80 (Tekle *et al.*, 2014).

Marketable yield and Total yield (tonha^{-1}): There was significant difference ($P<0.05$) among plantain varieties for marketable yield and total yield. Nijiru variety had the highest mean values for marketable yield(25.6 ton ha^{-1}) and total yield (27.9 ton ha^{-1}) followed by Cardaba variety; 20.3 tonha^{-1} for marketable yield and 22.7 tonha^{-1} for total yield. The lowest mean value of marketable yield (16.4 ton ha^{-1}) and total yield (18.2 ton ha^{-1}) was obtained from Matoke variety. The significant variation in marketable yield and total yield among the plantain varieties could be due to their difference in genetic characteristics and adaptability to the environmental condition of the study area. This result was supported by the findings of Tekle *et al.,* (2014) who reported average yield ranging from 45.333 ton ha^{-1} to 18.533 ton ha^{-1}.There was no disease incidence on Nijiru variety which was resistance to panama and sigatoka banana diseases, whereas Cardaba variety was susceptible to these diseases. Generally, Nijiru variety had significantly the highest average bunch weight, number of fruit per bunch, number of fruit per hand, marketable yield, and total yield than the other test varieties. While the lowest total yield was recorded from Matoke variety.

3.2. Correlation analysis

Phenotypic and genotypic correlation analysis showed that, most of the traits have shown significant correlation with total yield and among themselves except unmarketable yield (Table

3). Average bunch weight, Fruit diameter, number of finger per hand and marketable yield were showed positive and significant correlation both at phenotypic and genotypic levels. These results are in agreement with finding of Baiyeri *et al.,* (2000) reported that most of fruit characters were related to the yield but with varied magnitude and the correlation was affected by the genomic group and environment; these effects might explain the consistent and significant low magnitude correlation of plant height with other growth characters and yield. Average bunch weight, Fruit diameter, number of finger per hand and marketable yield had significant correlation among themselves. Average bunch weight showed significant and positive correlation with number of fingers per bunch both at genotypic and phenotypic correlations (Table 3).

Table 3. Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among different characters of Plantain varieties

Traits	ABW	NFB	NFH	FD	MY	UY	TY
ABW	1	0.750*	0.295*	-0.007ns	0.998*	0.659ns	0.995*
NFB	0.064*	1	0.853*	-0.614*	0.782*	0.244*	0.754**
NFH	-0.075*	-0.3224*	1	-0.875*	0.354*	-0.178*	0.306*
FD	-0.185*	-0.266*	0.465*	1	-0.009*	0.089*	0.020*
MY	0.3134*	-0.381*	0.638*	0.379*	1	0.536ns	0.998*
UY	-0.123*	-0.561ns	0.709*	0.537ns	0.612ns	1	0.588ns
TY	0.263*	-0.432*	0.708*	0.4398*	0.992**	0.705ns	1

TTY=Total Yield (ton/ha), MY=marketable yield(ton/ha), UM=unmarketable yield(ton/ha), FD=fruit diameter (cm), BW=bunch weight(kg), NFB=Number fruit per bunches, NHB= Number of hands per bunches

4. Conclusions and Recommendations

The results of analysis of variance showed that, all the yield and yield related parameters were significantly affected by varieties except fruit diameter, number of fruit per hand and unmarketable yield. Nijiru Variety was superior over all varieties for average bunch weight (6.1 kg), number of finger per bunch (54.2), marketable yield (25.6) and total yield (27.9ton ha^{-1}). Moreover, Nijiru variety gave higher yield over the other varieties in both harvesting cycle, indicating that, the Nijiru variety is stable and can provide reasonable amount of yield regularly. Therefore, it can be concluded that Nijiru variety is recommended for further demonstration in Daro Lebu and similar agro- ecologies.

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5. REFERENCE

Baiyeri KP, Tenkouanoa B, Mbahb BN, Mbagwub JSC (2000). Ploidy and genomic group effects on yield components interaction in bananas and plantains across four environments in Nigeria. ScientiaHorticult. 85:51-62.

CSA (Central Statistical Agency), 2018. Agricultural Sample Survey Report on Area and Production of Major Crops. (Private Peasant Holdings, Meher Season). Statistical Bulletin. Addis Ababa, Ethiopia.

Dheda DB, Nzawele BD, Roux N, Ngezahayo F, Vigheri N, De Langhe E, Karamura D, Picq C, Mobambo P, Swennen R, Blomme G (2011). Musa collection and characterization in central and eastern DR Congo: a chronological overview. ActaHortic. 897:87-94.

Ocimati W, Karamura D, Rutikanga A, Sivirihauma C, Ndungo V, Adheka J, Dhed'a B, Muhindo H, Ntamwira J, Hakizimana S, Ngezahayo F, Ragama P, Lepoint P, Kanyaruguru JP, De Langhe, Gaidashova SV, Nsabimana A, Murekezi C, Blomme G (2013). Musa germplasm diversity status across a wide range of agro-ecological zones in Rwanda, Burundi and eastern Democratic Republic of Congo. In: Blomme, G. et al. (Eds).

Robinson, J.C., 1996. Bananas and Plantains. University Press, Cambridge.

Tenkouano A, Baiyeri KP (2007). Adaptation pattern and yield stability of banana and plantain genotypes grown in contrasting agro-ecologies in Nigeria: African Crop Science Conference Proceedings. 8:377-384.

Adaptability study of Chickpea varieties (*Cicer arietinum* L.) at Bule hora and Abaya, Southern Oromia

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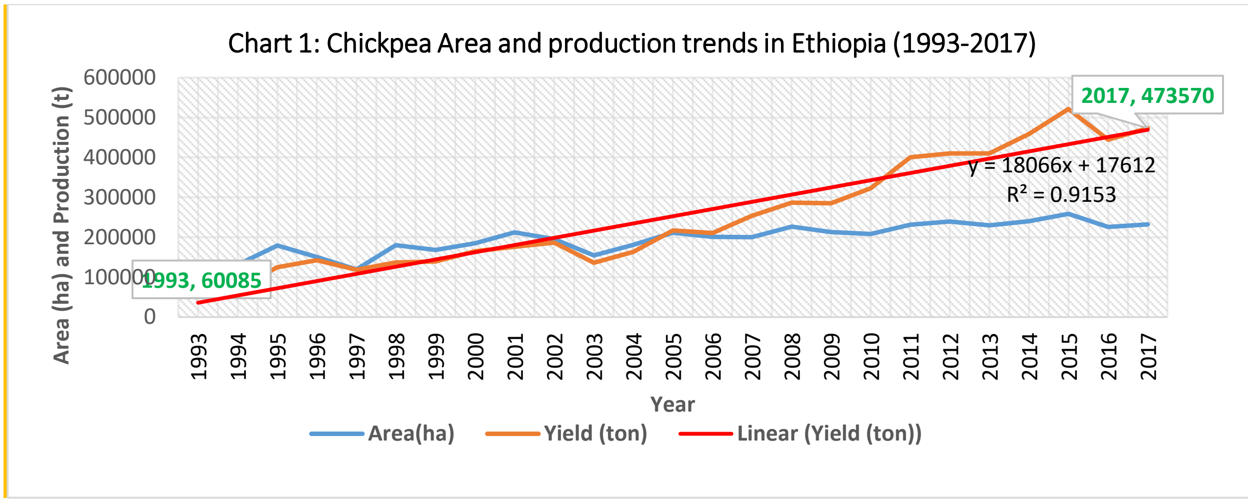
Abstract

Chickpea is among the major pulse crops grown in southern Ethiopia including Borana and West Guji zone. The area has a potential for production of chickpea for food and nutrition security as well as export purpose. However, scarcity of varieties that fit to the environment is one of the major constraints of chickpea production. Therefore, this experiment was conducted to evaluate nine chickpea varieties with aim to select adaptable varieties for yield and *agronomic traits. The field experiment was conducted in 2017 and 2018 cropping season at two locations (Abaya and Bule hora) and varieties were planted in Randomized Complete Block Design (RCBD). Data were collected on yield and important agronomic traits. Analysis of variance computed for individual location and combined analysis over locations revealed significant variations among varieties. Moreover, varieties showed a grain yield as high as 1087.5 kg/ha and 873.79 kg/ha at Bule hora and Abaya respectively. Minjar variety gave significantly high yield at both locations with yield advantage of 26.13% and 52.07% over variety mean at Bule hora and Abaya respectively and therefore recommended for both locations and locations with similar agro ecologies.*

Introduction

Chickpea (*Cicer arietinum* L.*)* is a diploid species with 2n=16 chromosomes. It is a self-pollinated crop, with natural cross-pollination of up to one per cent (Singh, 1987). Chickpea is among the oldest crops, being domesticated in the Fertile Crescent 10,000 years ago (Redden and Berger, 2007) and named as Bengal gram (Indian), Chickpea (English), Garbanzo (Latin America), Hommes, Hamaz (Arab world), Nohud, Lablabi (Turkey), Shimbra (Ethiopia). It is the lone domesticated species among the 44 species comprising 33 perennial and eight annual wild species and highly preferred pulse for human consumption within the genus Cicer (Vander Maesen, 1987), family *Fabaceae*, tribe *Cicerae*. Chickpea is grown in tropical, sub-tropical and temperate regions. It is a valued crop and provides nutritious food for an expanding world population and will become increasingly important with climate change (Bulti and Jema, 2019). Chickpea contains nutritive seeds with high protein content, 25.3-28.9 %, after dehulling (Hulse, 1991), 38-59% carbohydrate, 3% fiber, 4.8-5.5% oil, 3% ash, 0.2% calcium, and 0.3% phosphorus. Digestibility of protein varies from 76-78% and its carbohydrate from 57-60% (Hulse, 1991). Chickpea seeds are eaten fresh as green vegetables, parched, fried, roasted, and boiled; as snack food, sweet and condiments; seeds are ground and the flour can be used as soup, dhal, and to make bread; prepared with pepper, salt and lemon it is served as a side dish (Saxena, 1990). Chickpea is beneficial to a healthy diet. For example a half-cup serving provides 7 g of protein (10% of our daily requirement) and 6 g of fiber (20% of our daily requirement) (USDA, 2015). It plays a significant role in improving soil fertility by fixing the atmospheric nitrogen.It can fix up to 140 kg N ha-1 from air and meet most of its nitrogen requirement (Sheleme et al, 2015).

According to CSA report (2016/17) in Ethiopia, Pulse crops production ranks second in terms of production area. Pulses grown in Ethiopia covered 12.33% (1,549,911.86 hectares) of the grain crop area and 9.69% (about 28,146,331.73 quintals) of the grain production. In Ethiopia, chickpea is mainly grown in the central, northern and eastern highland areas of the country at an altitude of 1400-2300 m.a.s.l., where annual rainfall ranges between 700 and 2000 mm (Bejiga 1994; Anbessa and Bejiga 2002). %. It is best adapted to the areas having Vertisols (Sheleme *et al*, 2015). Chickpea production has increased from 60085 tons (1993) to 473570 tons (2017). The production areas are also increased from 109750 hectare (1993) to 473570 hectare (2017) (FAOSTAT, 2019)



Source: FAOSTAT, 2019

In the study areas, shortage of chickpea varieties that adapt to the prevailing environments are the top chickpea production constraints. Therefore, this study was incited with the objective to test the adaptability of chickpea varieties for yield and yield related traits in the study areas.

MATERIALS AND METHODS

Description of experimental sites

The experiment was conducted at Bule hora and Abaya during 2017 and 2018 cropping season. The experimental areas are located in the Southern part of the country in the Oromia Regional State. Bule hora and Abaya are located at 465 and 365 km far from Addis Ababa city, respectively.

Experimental Materials

For this study, nine released chickpea varieties were obtained from Debrezayit Agriculture Research Centre (DZARC) and evaluated for adaptability of the varieties at these locations.

Table 1: Released Chickpea varieties use in the experiment

S.No	Variety	Year of release	Breeding center
1	Dhera	2016	DZARC
2	Arerti	1999	DZARC
3	Hora	2016	DZARC
4	Ejeri	2005	DZARC
5	Habru	2004	DZARC
6	Natoli	2007	DZARC
7	Minjar	2010	DZARC
8	Dalota	2013	DZARC
9	Dimtu	2016	DZARC

Experimental Design and Managements

The experiment was laid out in Randomized Complete Block Design. Each entry was planted in a plot having 6 rows of 3 meter length. Four rows were harvested and two border rows were left to exclude border effect. The row and plant spacing was kept at 40 cm and 10 cm, respectively. Individual plot size was 2.4 m x 3 m=7.2 m^2 and 1m and 1.5m between plot and block, respectively. 60kg NPS/ha Fertilizer was applied at the time of planting. All other agronomic managements were applied uniformly in all experimental plots as per national recommendation for the crop.

Data Collection

The following data were collected during the experimentation time both from the whole plot, net plot and sampled plants by random selection method from the middle of four rows of each plot.

Data recorded on plant basis

Plant height at harvest (cm): Height of five randomly taken plants during harvest period from each experimental plot was measured in centimeter from the ground level to top of the plants and the average height was recorded.

Number of primary branches: Number of productive branches extending from the main stem was recorded from five randomly selected plants and average branch number was taken.

Pod length (cm): The length of five randomly selected pods from each of the five randomly selected plants was measured at harvesting and the average was used.

Number of pods per plant: this was recorded as average total number of pods of five randomly selected plants from each experimental plot at harvest.

Number of seeds per pod: This was recorded as average total number of seeds of five randomly selected plants from each experimental plot divided by total number of pod of the same plants at harvest.

Seeds per plant: Average number of seeds counted from five randomly selected plants.

Data collection on plot basis

Days to Flowering: The numbers of days from the date of emergence to the date on which about 50% of the plants in each plot produce flowers.

Days to maturity: The number of days from planting to the date when 90% of the morphological observation of the plant turned to yellow straw colour.

Stand count at harvest: This was recorded by counting the total number of plants from the four middle rows of each plot at harvest.

Grain yield (g/plot): Grain yield in grams obtained from the central four harvestable rows of each plot was harvested, threshed and weighted using sensitive balance.

Grain yield (ton/ha): Grain yield obtained from each plot was used to estimate grain yield (tons) per hectare.

Data Analysis

Analysis of variance

Analysis of variance (ANOVA) was computed for grain yield and other traits as per the methods described by Gomez and Gomez (1984) using SAS computer software (Version 9) for Randomized Complete Block Design. Comparison of treatment means was made using Duncan Multiple Range test (DMRT) at 5% level of significance. Location wise analyses were performed and error variances were subjected to F-test for homogeneity test of variances. Variables with homogeneous error variances were directly used for combined analyses, while those with heterogeneous error variances were analyzed in individual locations. The combined analysis was based on mixed model (fixed genotype and random environment).

Individual locations and combined ANOVA were computed using the following mathematical model:

Individual locations ANOVA model

$$Xijkl = \mu + Gi + Bjk + Y + GYi + Eijk$$

Where, $Xijkl$ = Observed value,

μ = general mean,

Gi = effect of variety,

Bjk = effect of replication (block),

Y= effect of year,

GYi = variety x Year,

$Eijk$ = residual effects or experimental error. Additionally, g, r, y are numbers of geneotypes, replications, locations and years, respectively

Combined ANOVA model

$$Xijkl = \mu + Gi + Bjkl + Lk + Yl + GLik + GYil + LYkl + GLYikl + Eijkl$$

Where, $Xijkl$ = Observed value,

μ = general mean,

Gi = effect of genotype,

$Bjkl$ = effect of replication (block),

Lk = effect of location,

Yl = effect of year,

$GLik + GYil + LYkl + GLYikl$ = effects of Genotype x Location, Genotype x Year, Location x Year, and Genotype x Location x Year interactions, respectively.

Eijkl = residual effects or experimental error. Additionally, g, r, l, y are numbers of genotypes, replications, locations and years, respectively.

RESULTS AND DISCUSSION

Analysis of Variance

The experiment was conducted at two locations viz. Bule hora and Abaya. Homogeneity of variance was computed for each location before the combined analysis of variance computed. The analysis of variance were computed for days to flowering, days to maturity, plant height, number of primary branches, pods per plant, seeds per pod, seeds per plant and grain yield per hectare. The individual location and the combined analysis of variance results are presented in subsequent sections.

Individual location analysis of variance

Analysis of variance computed for each location revealed that variation among varieties were highly significant (P<0.01) for all traits at both locations except seeds per pods are significant (P<0.05) at Bule hora and not significant at Abaya (Table 2 and Table 4). The presence of variations among varieties under experiment for all the traits studied indicated the presence of sufficient variability among Chickpea varieties that would be exploited through selection. The year effect was highly significant (P<0.01) at both location, indicated that the performance of varieties are different in different locations. Ercan et al (2013) also reported different performance of Chickpea genotypes in different year and location. In Ethiopia, Getachew *et al* (2015) reported the presence of highly significant variation among 17 Kabuli type Chickpea genotypes conducted in five environments. He also reported the existence of significant variation for days to flowering, days to maturity, plant height, pods per plant, seed per pod, 100 seed weight and Grain yield. Ercan *et al* (2013), Rozina*et al (2015), Dan (2016)*and Desai *et al* (2016) also reported highly significant variation for plant height, pods per plant, seeds per plant, hundred seed weight and grain yieldin Chickpea which is in line with this finding.

Table 2: Mean squares from combined analyses of variance over two years for 8 traits of Chickpea varieties grown at Bule hora in 2010 and 2011 E.C

Source of variation	df	GY (kg/ha)	FD	MD	PH (cm)	NPB	PPP	SPPnt	Spp
Year (Y)	1	9144171.9***	200.3***	852.0***	121.5**	12.9***	4911.6***	4907.8***	0.042
Variety	8	221172.1***	52.0***	94.6***	138.0***	2.3**	238.3**	483.9***	0.055
Reps.withn (Y)	4	12870.1	12.1	28.8**	17.5	4.788***	793.8*	740.1***	0.023
Y* V	8	75879.8***	6.4	5.8	13.6	2.610**	44.297	99.891	0.008
Pooled Error	32	5575.5	6.5	5.5	11.2	0.6	69.1	80.9	0.031
CV (%)		9.3	4.1	2.1	7.8	18.4	26.0	29.9	19.14

ns,* ,**&***,non-significant, significant at P<0.05, P<0.01 and P<0.001, respectively. DF= degree of freedom, FD= days to flowering, GY (kg/ha) = Grain yield in kilogram per hectare, MD= days to maturity, PH (cm) = plant height in centimeter, NPB= number of primary branch, PPP= pods per plant,

Table 3: Mean squares from combined analyses of variance over two years for 8 traits of Chickpea varieties grown at Abaya in 2010 and 2011 E.C

S.V	Df	GY (t/ha)	FD	MD	PH (cm)	NPB	PPP	SPPnt	Spp
Year (Y)	1	660731.1***	168.9***	665.0***	1026.2***	66.2***	156.4**	109.8*	0.0
Variety	8	275176.2***	68.9***	183.7***	172.2***	2.6**	162.7***	260.1***	0.1*
Reps. withn(Y)	4	4170.1	9.5	21.2	23.1	1.9*	12.9	2.1	0.0
Y* V	8	35941.6***	3.2	63.5***	14.3	1.3	6.8	20.6	0.0
Pooled Error	32	2068.3	10.3	8.8	9.5	0.7	14.7	20.4	0.1
CV (%)		10.9	5.8	3.0	8.2	17.6	24.6	31.5	21.1

ns,* ,**&***,non-significant, significant at P<0.05, P<0.01 and P<0.001, respectively. DF= degree of freedom, FD= days to flowering, GY (kg/ha) = Grain yield in kilogram per hectare, MD= days to maturity, PH (cm) = plant height in centimetre, NPB= number of primary branch, PPP= pod per plant

Combined analysis of variance over locations

Location wise analyses were performed and error variances were subjected to F-test for homogeneity of variance. Variables with homogeneous error variances were subjected to combined analysis, and as well as evaluation of varieties performance were conducted using the pooled mean values over locations. Whereas, for those traits with heterogeneous error variances, evaluation of varieties were conducted using each location mean values. Accordingly, pods per plant, seeds per plant and grain yield exhibited heterogeneous error variances and the mean squares for locations were also significant indicating the performance of the genotypes cannot be evaluated on the basis of pooled mean values over locations. However, the homogeneity of error variances for flowering date, maturity date, plant height, number of primary branches andseeds per pods were homogeneous that allowed evaluation of the genotypes on the basis of combined mean values over locations.

The ANOVA results of combined analysis over locations are presented in table 4. The result of combined analysis ofvariance revealed the presence of highly significant ($P<0.01$) difference among locations, varieties and varieties by environment interaction for traits suggested differences in environments and the presence of sufficient genetic variability for these trait that can be exploited in breeding programs. Highly significant variation for grain yield other yield related traits in chickpeawere also reported by various authors (Desalegn and Pichiah 2019; Desai *et al* 2016; Getacho *et al* 2015; Singh et al 1990, Ercan *et al* 2013). The significant differences were observed between locations for all traits. This indicates that the two locations were significantly different for the performance of varieties for these traits. The significant differences between locations were reported in chickpea by Desalegn and Pichiah 2019, Desai *et al* 2016 and Getachew*et al* 2015. The presence of significant verities x location interaction (Table 4) suggested that varieties had differential performance at the two locations for these traits. The differential performance of varieties across environment varies significantly and the performance of plants depends directly on the environmental conditions (Fox *et al*., 1990). Other authors also reported the significant influence of genotype by location interaction on the performance of chickpea (Getachew *et al, 2015*, Desalegn and Pichiah 2019 and Desai *et al* 2016**).**

Mean performance of varieties
Crop phenology

Flowering duration of nine varieties of chickpea ranges from 59.75-69.25 and 49.67-60.00 days at Bule hora and Abaya respectively while the maturity duration of varieties ranges from 109.00-120.67 and 90.5-106.08 days at Bule hora and Abaya respectively. The mean performances of for these traits are presented in Tables 5 and 6. The varieties showed early flowering and maturity at Abaya than Bule hora. This might be due to the altitude and temperature differences of the two locations, where by Abaya is located at an altitude of 1442 m. a. s. l. with mean minimum and maximum temperature of 12.6-29.9 °C while Bule hora is located at an altitude of 2322 m. a. s. l. with mean minimum and maximum temperature of 15-30 °C. The pooled mean over location and year (Table 7) for flowering and maturity date ranges from 54.71-64.63 and 99.75-113.38 days respectively. The earliest maturing varieties was Dimtu (99.75 days) followed by Dalota (101.29 days) and Minjar (102.29 days) while the late maturing variety was Dhera (113.375 days) followed by Hora (110.58) and Areri (109.67) (Table 7). Four varieties exhibit lower number of days to maturity than over all mean.

Table 4: Pooled Mean squares from combined analyses of variance over two locations and two years for four traits of Chickpea varieties grown at B/Hora and Abaya in 2010 and 2011E.C

Source of variation	DF	FD	MD	Pht	NPB
Locations (L)	1	2498.891***	5896.333***	736.333***	3.067*
Replications (L)	4	21.356*	28.01**	22.638	4.803***
Years (Y)	1	368.521***	5.787	926.935***	68.800***
L * Y	1	0.669	1511.259***	220.735***	10.329***
Varieties (V)	8	116.214***	262.318***	283.613***	2.065**
L*V	8	4.787	15.974	26.647*	2.825***
Y*V	8	7.219	50.459***	13.026	0.945
L *V*Y	8	2.315	18.796*	14.843	3.011***
Pooled Error	68	8.143	8.024	10.806	0.720
CV		4.767	2.66	8.12	18.976
Mean		59.85	106.47	40.49	4.47

ns,* ,**&***,non-significant, significant at P<0.05, P<0.01 and P<0.001, respectively. DF= degree of freedom, FD= days to flowering, L =locations, MD= days to maturity, PH (cm) = plant height in centimeter, NPB= number of primary branch, Rep= Replications, V= Variety, Y= year

Growth traits

Mean performances of genotypes for plant height at Abaya ranged from 33.3 cm to 50.06cm with location mean of 37.88 cm; whereas mean performance of varieties for plant height ranged from 37.0 cm to 53.8 cm with location mean of 43.10 cm at Bule hora (table 5 and 6). The mean values of chickpea for plant height ranged from 36.18 to 51.93 with over all mean values of 40.49. Similar result for mean and range for plant height in Chick pea varieties were also reported previously by Getacho *et al* 2015, Dan *et al* 2016 and Ercan *et al* 2013. Genotypes attained higher plant height at Bule hora than at Abaya. Varieties showed considerable variations for number of primary branches that ranged from 3.23 for Ejare to 5.27 for Dalota at Bule hora (table 5); and 3.57 for Dimtu to 5.37 for 5.37 for Dhera at Abaya (Table 6). The mean performance of varieties for number of primary branches were 4.60 at Abaya and 4.30 at Bule hora with pooled mean of 4.47. Six varieties recorded superior number of primary branches than the mean performance of varieties (Table 7). Existence of significant variations among Chickpea varieties for number of primary branches was also reported by (Dan *et al* 2016).

Yield and yield components

The variation of varieties for pods number per plant and seeds number per plant ranged from 23.57 to 44.97; and 21.6 to 52.83, respectively at Bule hora. The variation of these two traits ranged from 9.67 to 27.91 and 7.93 to 30.4, respectively at Abaya. Minjar had significantly higher pods, seeds number per plant and seed per pod at both locations (Table 5 and 6). The existence of considerable variations for pods number, seeds number per plant and seed per pod was also reported by other authors in Chickpea (Getacho *et al* 2015, Dan *et al* 2016 and Ercan *et al* 2013). The mean grain yield of varieties ranged from 571.7 kg to 1087.5kg; 226.57kg to 873.79kg at Bule hora and Abaya, respectively (table 5 and 6). At Bule hora, significantly highest mean grain yield was measured from Minjar (1087.5kg/ha) followed by Natoli (1030.94kg/ha) and the lowest mean grain yield was obtained from Hora (571.7 kg /ha) followed by Dhera (600.35kg/ha). At Abaya the highest grain yield was obtained from variety Minjar (873.79kg/ha) followed by dalota (583.16kg/ha) and the lowest grain yield was measured from Dhera (160.42kg/ha) followed by Hora (226.57 kg/ha). Four varieties gave grain yields greater than mean grain yield of varieties at Bule hora and four varieties had grain yield greater than mean yield of varieties at Abaya as well. In all cases, Minjar is significantly well performing variety at both locations (table 5 and 6).

Table 5: Mean value of yield and yield related traits of 9 Varieties of Chickpea tested at Bule hora in 2010 and 2011 E.C cropping season

Variety	FD	MD	PH(cm)	NPB	PPP	SPPnt	Spp	GY(kg/ha)
Dhera	69.250a	120.667a	53.800a	5.00ab	34.63b	28.20b	0.850b	600.35fg
Areri	65.417bc	115.417b	37.000e	4.367a-c	28.07bc	24.967b	0.867b	689.06de
Hora	67.333ab	116.583b	42.133b-d	4.067b-d	33.33bc	29.36b	0.850b	571.70g

Variety	FD	MD	PH(cm)	NPB	PPP	SPPnt	Spp	GY(kg/ha)
Ejere	65.00bc	115.500b	40.667c-e	3.233d	23.57c	21.60b	0.900b	856.15c
Habru	59.750	116.333b	45.000bc	4.400a-c	31.47bc	27.367b	0.900b	661.29ef
Natoli	66.083a-c	111.500c	39.867de	3.867cd	25.767bc	26.07b	0.967ab	1030.94ab
Minjar	63.417cd	109.583c	45.900b	4.567a-c	44.967a	52.833a	1.150a	1087.50a
Dalota	64.667bc	110.167c	41.733b-d	5.267a	35.40ab	26.067b	0.867b	759.38d
Dimtu	61.083de	109.00c	41.800b-d	3.967b-d	30.10bc	29.167b	0.967ab	975.18b
Mean	64.67	113.86	43.10	4.30	31.92	30.07	0.92	803.50
Range	59.75-69.25	109.00-120.67	37.0-53.8	3.23-5.27	23.57-44.97	21.6-52.83	0.85-1.15	571.7-1087.5

Means with the same letters in the same columns are not significantly differentFD= days to flowering, GY (kg/ha) = Grain yield in kilogram per hectare, MD= days to maturity, PH (cm) = plant height in centimetre, NPB= number of primary branch, PPP= pod per plant, SPPnt= seed per plant, Spp = seed per pod.

Table 6: Mean value of yield and yield related traits of 9 Varieties of Chickpea tested at Abaya in 2010 and 2011 E.C cropping season

Variety	FD	MD	PH(cm)	NPB	PPP	SPPnt	Spp	GY(kg/ha)
Dhera	60.00a	106.08a	50.06a	5.37a	9.67c	9.73cd	1.01ab	160.42g
Areri	57.25ab	103.92abc	35.37cd	5.00ab	13.37bc	10.50b-d	0.78bc	278.13f
Hora	56.750ab	104.58ab	37.93c	5.23a	11.47bc	7.93d	0.72c	226.57f
Ejere	53.750bc	100.42cd	37.80c	5.30a	13.20bc	11.77b-d	0.90a-c	353.94e
Habru	49.667d	101.08bcd	42.53b	4.83a-c	16.57b	14.50bc	0.88a-c	388.72de
Natoli	58.75a	97.75de	33.30d	4.13b-d	15.30b	13.23b-d	0.83a-c	420.66d
Minjar	53.917bc	95.00ef	35.17cd	4.46a-d	27.92a	30.40a	1.07a	873.79a
Dalota	53.833bc	92.42fg	34.10cd	3.87cd	16.53b	14.67bc	0.88a-c	583.16b
Dimtu	51.50cd	90.50g	34.63cd	3.57d	16.10b	16.30b	1.03ab	484.03c
Mean	55.046	99.08	37.88	4.64	15.568	14.337	0.90	418.82
Range	49.667-60.00	90.5-106.08	33.3-50.06	5.37-3.57	27.91-9.67	30.4-7.93	1.07-0.72	873.79-226.57

Means with the same letters in the same columns are not significantly different, FD= days to flowering, GY (kg/ha) = Grain yield in kilogram per hectare, MD= days to maturity, PH (cm) = plant height in centimetre, NPB= number of primary branch, SPPnt= seed per plant, Spp = seeds per pod, PPP= pods per plant

Table 7: Pooled Mean values of yield and yield related traits of 9 Varieties of Chickpea tested at Abaya and B/ hora in 2010E.C and 2011 cropping season

Variety	FD	MD	Pht	NPB
Dhera	64.63a	113.375a	51.933a	5.183a
Areri	61.33bc	109.667bc	36.183e	4.683ab
Hora	62.04b	110.583b	40.033c	4.650ab
Ejere	59.38cd	107.958c	39.233cd	4.267bc
Habru	54.71e	108.708bc	43.767b	4.617ab
Natoli	62.42ab	104.625d	36.583de	4.00bc
Minjar	58.67d	102.292e	40.533c	4.517a-c
Dalota	59.25cd	101.292ef	37.917c-e	4.567ab
Dimtu	56.29e	99.750f	38.217c-e	3.767c
Means	59.85	106.47	40.49	4.47

Means with the same letters in the same columns are not significantly different FD= flowering date, MD= Maturity date, PH= plant height, NPB= number of primary branch.

CONCLUSIONS AND RECOMMENDATIONS

The results of this investigation showed significant variation among varieties for all traits as well as significant effect of varieties by location interaction for grain yield and most yield related traits, which indicated the differential performance of varieties across environments. The highest mean grain yield was exhibited by Minjar (1087.5kg ha-1) and Natoli (1030.94kg ha-1) at Bule hora and Minjar had significantly highest mean grain yield (873.79kg ha-1) at Abaya with About four varieties gave mean grain yield greater than grand mean at Bule hora and and Abaya. Minjar variety is significantly high yielding variety at both locations with yield advantage of 26.13% and 52.07% over variety mean at Bule hora and Abaya respectively. The prominent chickpea varieties Minjar and Natoli are promising varieties due to their relatively higher yield and some considerable traits at Bule hora and similar agro-ecologies while Minjar is promising variety at Abaya. Therefore, farmers and chickpea producers around study areas and similar agro ecologies can use those varieties for chick pea production.

REFERANCES

Anbessa, Y., and G. Bejiga. 2002. Evaluation of Ethiopian chickpea landraces for tolerance to drought. *Genetic Resources and Crop Evolution* 49 (6):557-564.

Bejiga, G. 1994. Forty years of research experience. Debre Zeit Agricultural Research Center(1955-1994). Debrezeit, Ethiopia: Debrezeit Agricultural Research Center.

Bulti Merga and Jema Haji, 2019. Economic importance of chickpea: Production, value, and world trade. Cogent Food & Agriculture. 5: 1615718

Central Statistical Agency (CSA). 2017. Federal Democratic Republic of Ethiopia, Agricultural sample survey, Vol. I. Report on Area and production of Major crops. Private peasant holdings, in 2016/17 Meher season. Statistical bulletin 584. Addis Ababa, Ethiopia.

Dan Singh Jakhar1, M.S. Kamble, Abhishek Singh and Saket Kumar. 2016. Performance of Chickpea (Cicer arietinum L.) Genotypes in Kolhapur Region. International Journal of Agriculture, Environment and Biotechnology: Vol 9(2) pp 283-289.

Desai Kamla, C.J. Tank , R.A. Gami and A.M. Patel. 2016. G X E Interaction and stability analysis in chickpea (Cicer arietinum L.). *International Journal of Agriculture, Environment and Biotechnology.Vol* 9(4): pp 479-484

Desalegn Negasa and Pichiah Gomathi Nayagam.2019. Genotype and environment interaction effect on yield and yield components in Desi-type Chickpea [Cicer arietinum (L.). African Journal of Agricultural Research:Vol. 14(25), pp. 1073-1080

Duke, J.A. 1981. Handbook of legumes of world economic importance. Plenum Press, New York. p. 52-57.

Ercan Ceyhan, Ali Kahraman, Hasan Dalgıç, 2013. Determination of Some Agricultural Characters of Chickpea (*Cicer arietinum* L.) Genotypes. World Academy of Science, Engineering and Technology. International Journal of Agricultural and Biosystems Engineering Vol:7(11). PP. 1092-1095

Food and Agricultural Organizations of the United States Statistics (FAOSTAT), 2019 http://www.fao.org/faostat/en/#home

Fox, P. N., B. Skovmand, B. K. Thomson, H. J. Braun and R. Cormier. 1990. Yield adaptation and hexaploid spring triticale. *Euphytica,* 47:57-64.

Getachew Tilahun, Firew Mekbib, Asnake Fikre and Million Eshete, 2015. Genotype x environment interaction and stability analysis for yield and yield related traits of Kabuli-type Chickpea (*Cicer arietinum* L.) in Ethiopia. *African Journal of Biotechnology*. Vol. 14(18), pp. 1564-1575.

Gomez KA, Gomez AA (1984). Statistical Procedures for AgriculturalResearch. 2nd edition. John Willey & Sons Ltd., New York, USA.680p.

Hulse, J.H. 1991. Nature, composition and utilization of grain legumes. p. 11-27. In: Uses of tropical Legumes: Proceedings of a Consultants' Meeting, 27-30 March 1989, ICRISAT Center. ICRISAT, Patancheru, A.P. 502 324, India.

Redden B. and Berger J. 2007. History and origin of chickpea. In: Yadav SS, Redden B, Chen W, Sharma B (eds) Chickpea breeding and management. CAB International, Wallingford, pp 1–13

Rozina Gul , Ghayour Ahmad , Shuja Abbas Khan ,Habib Ullah ,Khadim Shah , Muhammad Iqbal Safi , Arsalan Kakakhel , Shah Hussain , Yousaf Khan and Abid Ali. 2015. Effect of Seeds Size on Yield and Yield Components of Chickpea (Cicer arietinum). Journal of Bio-Molecular Sciences (JBMS) (2015) 3(2): 56-65

Saxena MC (1990) Problems and potential of chickpea production in nineties. In: Chickpea in the nineties: proceedings of the second international workshop on chickpea improvement, 4–8 Dec 1989, ICRISAT Center, Patancheru, India

Sheleme Beyene, Berhanu Abate, Walelign Worku, Endalkachew W/Meskal, Molla Assefa, Legesse Hidoto, Wondwosen Tena, Tussa Dedefo, Regassa Ayana. 2015. CHICKPEA (Cicer arietinum L.) PRODUCTION in the Southern Nations, Nationalities, and Peoples' Region of Ethiopia.

Singh KB, Bejiga G, Malhotra RS (1990). Associations of some characters with seed yield in chickpea collections. Euphytica 49:83-88

Singh, K.B. 1987. Chickpea breeding. p.127-162. In: M.C. Saxena and K.B. Singh (eds.), The Chickpea. CAB International, UK.

USDA, 2015. Foods Product Information Sheet, 101020: Beans, Garbanzo, Dry. Retrieved 4/12/2017 from: https://www.fns.usda.gov/

Van der Maesen, L.J.G. 1987. *Cicer* L. Origin, history and taxonomy of chickpea. p.11-34. In: M.C. Saxena and K.B. Singh (ed.), The Chickpea. C.A.b. International Cambrian News Ltd, Aberystwyth, UK

Van der Maesen, L.J.G., 1972. A monograph of the genus with special reference to the chickpea (*Cicer arietinum* L.), Its ecology and cultivation. Commun. Agric. University, Wageningen, Dordrecht, The Netherlands.

Adaptability Studyof Early Maturing Ground nut Variety in West Guji lowland, Southern Oromia

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Abstract

Groundnut is an important oil seed crop, grown throughout the tropics and sub tropics worldwide. It is one of the three economically important oilseed crops grown in Ethiopia.

Groundnut is commonly produced by small scale farmers as food and cash crops in the study area. The area has potential for the production of ground nut for food and nutrition security as well as export commodity. However, lack of improved varieties that are suitable for the areas is one of the major ground nut production constraints in the area. Therefore, this experiment was initiated to evaluate five ground nut varieties and to select early maturing varieties with considerable yield and agronomic traits. The field experiment was conducted in 2017 and 2018 cropping season at Abaya and varieties were planted in Randomized Complete Block Design (RCBD)in three replications. Data were collected on yield and important agronomic traits. The analysis of variance revealed significant variations among varieties for days to maturity, number of primary branches, number of pegs per plants, grain yield and shelling percentage.The result of pooled over years grain yield mean of varieties indicated ,Tole- 1 variety (Check) is high yielding with mean grain yield of 4174.7kg followed by variety Sedi (3552.5kg/ha) and Babile local (3550.4kg/ha). Variety Sedi has special merit in terms of earliness and therefore recommended for moisture stress areas of Abaya and location with similar agro ecologies while Tole -1 (Standard check) is high yielding varieties and should be used in production until new varieties is developed through selection/breeding program.

Key words: *Early maturity, Grain yield, related traits*.

INTRODUCTION

The word A. hypogaea has been derived from two Greek words *Arachis* meaning a legume and *hypogaea* meaning below ground (referring to the formation of pods in the soil). It is an annual legume which is also known as peanuts, earthnut, monkey-nut and goobers. It is the 13th most important food crop and 4th most important oil seed crop of the world. Groundnut seeds (kernels) contain 48-50% oil, 26-28 % protein and are a rich source of dietary fibre, minerals and vitamins. Groundnut kernels are consumed directly as raw, roasted or boiled kernels while the oil extracted from the kernel is used as culinary oil. It is also used as animal feed and industrial raw material (Garko et al, 2016). Groundnut or peanut is an important oil seed crop, grown throughout the tropics between 40° South and 40° North of the equator where the annual rainfall ranges between 500 to 1200 mm and with average daily temperature higher than 20°C. The crop is grown in tropical and subtropical regions of the world. It is grown in six continents, but mainly in Asia, Africa and America in over 100 countries with a world production of 37.10 million metric tons from an area of 23.11 million hectares. Groundnut is one of the three economically important oilseed crops including noug, and sesame in Ethiopia and is largely produced in the eastern part of the country (Mastewal et al 2017). The annual world groundnut production was around 38.2 million tons from 26.4 million ha of production area. Developing countries constitute 97% of the global area and 94% of the global production of this crop. The average national yield of groundnut is about 1.1 ton ha-1 (CSA, 2015), which is significantly lower than the World's average of about 1.49 t ha-1 (FAOSTAT, 2010). The major groundnut producer region in Ethiopia is Oromia region (41,089 ha), followed by Benshangul- Gumuz (14,759 ha) and Amhara (3,161 ha) regional states (Musa*et al*.,2016). Groundnut is planted both during the "Belg" season (March) and also during the main season (June), in some parts of western Ethiopia. With regard to final utilization, groundnut varieties are categorized into two major groups: oil types and confectionery ones. Confectionery groundnut varieties are those with large seeds and are mostly used for various food types (roasted seeds, peanut butter, candies, cookies and other snacks). A great amount of the groundnut produce in Ethiopia is consumed locally for confectionery purposes (Amele work *et al.*, 2007). Therefore, this study was undertaken with the objective of selecting early mature and high yielder Ground nut Variety for the study area.

MATERIAL AND METHODS

Description of the experimental site

The experiment was conducted at Abaya during 2017 and 2018 main cropping season. The experimental area is located in the Southern part of the country in the Oromia Regional State. Abaya is the sub-site of Yabello Pastoral and Dryland Agriculture Research Center and located at 365 km far from Addis Ababa cite. The detail description of the study area is presented in the Table 1.

Table 12: Description of the study area

Variables	
Soil type	Sandy clay loam
Altitude (m.a.s.l.)	1442
Latitude	06º43'520"N
Longitude	038º25'425"E
Annual Temperature ^{0}C	
Minimum	12.6
Maximum	29.9
Annual rainfall (mm)	
Minimum	500
Maximum	1100

Experimental Materials

For this study, four released ground nut varieties were obtained from Haramaya University and evaluated along with one standard check for adaptability study.

Experimental Design and Managements

The experiment was laid out in Randomized Complete Block Design. Each entry was planted in a plot having 6 rows of 3 meter length. Four rows were harvested and two border rows were left to exclude border effect. The row and plant spacing was kept at 40 cm and 10 cm, respectively. Individual plot size was 2.4 m x 3m=7.2 m^2 and 1.5m between each block. All other agronomic managements were applied uniformly in all experimental plots as per national recommendation for the crop.

Data Collection: The following data were collected during the experimentation period both from the net plot and sampled plants by random selection method from the middle of the four rows of each plot.

Data recorded on plant basis

Plant height at harvest (cm): Height of five randomly taken plants during harvest period from each experimental plot was measured in centimeter from the ground level to top of the plants and the average height was recorded.

Number of primary branches: Number of productive branches extending from the main stem was recorded from five randomly selected plants and average branch number was taken.

Number of pods per plant: this was recorded as average total number of pods of five randomly selected plants from each experimental plot at harvest.

Number of seeds per pod: This was recorded as average total number of seeds of five randomly selected plants from each experimental plot divided by total number of pod of the same plants at harvest.

Seeds per plant: Average number of seeds counted from five randomly selected plants.

Data recorded on plot basis

Days to Flowering: The numbers of days from the date of emergence to the date on which about 50% of the plants in each plot produce flowers.

Days to maturity: The number of days from planting to maturity period

Stand count at harvest: This was recorded by counting the total number of plants from the four middle rows of each plot at harvest.

Grain yield (g/plot): Grain yield in grams obtained from the central four harvestable rows of each plot was harvested, threshed and weighted using sensitive balance

Grain yield (kg/ha): Grain yield obtained from each plot was used to estimate grain yield (kg) per hectare.

Data Analysis

Analysis of variance

Analysis of variance (ANOVA) was computed for grain yield and other traits as per the methods described by Gomez and Gomez (1984) using SAS computer software (Version 9) for randomized complete block design. Comparison of treatment means was made using Least Significant Difference (LSD) at 5% level of significance test. ANOVA was computed using the following mathematical model:

$$Yij = \mu + rj + gi + \varepsilon ijl$$

Where: Yij =the observed value of the trait Y for the i^{th} variety in j^{th}replication, μ= the general mean of trait Y, rj = the effect of j^{th} replication, gi= the effect of i^{th}variety and εij= the experimental error

Results and Discussions

Analysis of variance

Analysis of variance computed for each location revealed that variation among varieties were highly significant (P<0.01) for all traits except for number of primary branches which showed significant (P<0.05) differences while number of pods per plants are not significant (Table 2). The presence of variations among varieties under the experiment for traits studied indicated the presence of sufficient variability among ground nut varieties that would be exploited. Similar results were also reported by (Chavadhari *et al.,* 2017 and Izge *et al*., 2007) in ground nuts**.** The year effect was highly significant (P<0.01) for maturity dates, pods per plants and grain yield indicated that the performance of varieties are different in different year for these traits.

In Ethiopia, Biru and Dereje (2014) reported the presence of highly significant variation among twelve ground nut varieties evaluated in two environments. They also reported the existence of significant variation for days to flowering, days to maturity, plant height, hundred seed weight and grain yield. Chavadhari *et al.,* 2017 and Izge *et al*., 2007) also reported highly significant variation for plant height, pods per plant, seeds per plant, hundred seed weight and grain yield in ground nut which is in line with this current finding.

Mean performance of varieties

Crop phenology: Flowering duration of five varieties of ground nut ranges from 45.17-50.5 while the maturity duration of varieties ranges from 145.33-157.67. The mean performances of these traits are presented in Tables 3. The earliest flowering and maturing varieties was Sedi (145.33 days) while the late maturing variety was Baha gidu (157.67 days) followed by Babile local (156.33 days) (Table 3). Similar result was reported by Biru and Daraje 2014.

Growth traits, Yield and yield components: Mean performances of varieties for plant height ranged from 39.33 cm to 45.13cm. Baha guddo is significantly shorter than the other varieties while Sedi was significantly taller. Varieties showed considerable variations for number of primary branches that ranged from 8.33 for Sedi to 13.87 for Tole 1 (table 3). Variation for plant height and branches in Ground nut is also reported by other author (Izge*et al*., 2007; Chavadhari*et al.*, 2017; Biru and Daraje 2014). Shelling percentage was calculated by dividing shelled yield weight to total pods weight (unshelled pod) and multiplying by hundred (Emmanuel *et al*., 2017**)**. In this experiment, the mean of shelling percentage ranged from 54.015% to 78.077%. The Highest shelling present was recorded by variety Tole- 1 (78.077%) followed by Sedi (67.105%). According to Jeyaramraja and Fantahun 2014, higher shelling percent indicates less seed case (pod) weight and more seed weight and so, it is preferable in ground nut. Other authors also reported similar results in shelling percentage of ground nuts (Mulatu*et al*., 2017; Jeyaramraja and Fantahun 2014; Chavadhari*et al.*, 2017).

The variation of varieties for pods number per plant ranged from 24.83 (Baha giddu) to 29.0(Tole-1). The mean shelled grain yield of varieties ranged from 2878.0 kg to 4174.7kg; (table 3). Significantly highest mean grain yield was recorded from Tole-1 (4174.7kg/ha) followed by Sedi (3552.5kg/ha) and Bablile local (3550.4kg/ha). The high yielding capacity of these three varieties may be due to high pods per plant, number of primary branches in Varity Tole-1 while short maturity periods and relatively higher shelling percentage in Sedi varieties. A wide range of variation in ground nuts varieties for grain yield was also reported by (Jeyaramraja and Fantahun 2014; WedajoGebre and WondewosenShiferaw, 2017) which is in line with this finding.

Table 2: Mean squares from combined analyses of variance over two years for 8 traits of Ground nut varieties grown at Abaya in 2017 and 2018 E.C

Sources of variation	**DF**	**FD**	**MD**	**PH (cm)**	**NPB**	**PPP**	**GY (kg /ha) (with shell)**	**GY(kg/ ha) (shelled)**	**SP (%)**
Year	1	4.03	448.53**	2.7	25.03	1068.03**	6373048.66*	3400797.949*	59.36
variety	4	24.12**	144.78**	23.95**	28.62*	17.30	448765.16	1959362.38*	594.269*
Rep within year	2	21.23	6.43	3.43	16.78	98.23	1713251.1	31295.10	293.33
Rep*variety	8	1.225	35.43	1.23	3.24	23.53	593381.88	313206.98	146.22
Year*variety	4	0.95	102.78*	1.12	13.99	163.53	1515385.29	1365636.03	254.47
Error	10	17.27	33.43	0.76	9.9	46.13	919478.68	526073.55	169.971
CV (%)		8.65	3.74	1.78	28.31	25.69	17.75	21.42	20.69
LSD		5.05	7.438	0.318	4.05	8.737	1233.5	933.05	16.76

ns, *, **&***, non-significant, significant, highly significant and very highly significant at $P<0.05$, $P<0.01$ and $P<0.001$, respectively. DF= degrees of freedom, FD= Flowering date, MD= days to maturity, PH=Plant Height, NPB= number of primary branch, PPP= pods per plant, SP (%) =Shelling Percentage, GY (Kg/ha) = Grain yield in Kilogram per hectare.

Table 3**:** Pooled Mean value of yield and yield related traits of 5 Varieties of Ground nut tested at Abaya for two consecutive years (2017 and 2018)

Varieties	FD	MD	PH (cm)	NPB	PPP	*GY(kg /ha)	SP (%)	GY(kg/ ha) (shelled)
Tole 1	50.5a	155.67a	42.93c	13.87a	29.a	5398.1a	78.077a	4174.7a
Baha gidu	49.0b	157.67a	43.07b	11.63ab	24.83a	5108.4a	54.788b	2776.6b
Sedi	45.17d	145.33b	45.13a	8.33b	26.33a	5307.9a	67.105ab	3552.5ab
Baha guddo	48.0bc	155.67a	39.33e	12.17ab	27.0a	5339.7a	54.015b	2878.0b
Babile local	47.17c	156.33a	40.27d	9.57ab	25.00a	5849.5a	61.035ab	3550.4ab
CV (%)	8.65	3.74	0.59	28.31	25.7	17.75	20.68	21.42
LSD	5.05	7.438	0.20	2.55	ns	ns	16.764	933.05

CV = Coefficient of variations,FD= Flowering date, MD= days to maturity, PH=Plant Height, NPB= number of primary branch, PPP= pod per plant, SP (%) =Shelling Percentage, ShGY (Kg/ha) = Grain yield in Kilogram per hectare, LSD= Least significant diffirence. *= grain yield with shell.

Conclusion and Recommendations

The results of experiment conducted at Abaya exhibited significant variation among varieties for all traits except pods per plants and unshelled grain yields. Significant variations among varieties for phenological traits also point out that the possibility of selecting early maturing varieties for the study areas. Regardless of this, Sedi variety was significantly early maturing variety in the study area. The mean of shelling percentage in this experiment ranged from 54.015% to 78.077%. The highest shelling percentage was recorded by variety Tole- 1 (78.077%) followed by Sedi (67.105%). The highest mean grain yield was exhibited by Tole-1 (4174.7kg ha-1) followed by Sedi (3552.5kg ha-1) and Babile local (3550.4 ha-1). The high yielding capacity of these three varieties may be due to presence of high pods per plant, number of primary branches in Tole-1 Varity while short maturity periods and relatively higher shelling percentage in Sedi varieties. In this experiment, Tole-1 variety is identified as high yielding variety while Sedi variety is recommended as early maturing varieties. Therefore, farmers and ground nut producers around the study area and similar agro ecologies can use those varieties.

References

AmeleworkBeyene, Temesgen Alene, AleminewTagele and AemiroBezabih. Groundnut variety evaluation in the lowlands of Abergelle, Wag-himra. 2007. Proceedings of the 2nd annual regional conference on completed crop research activities Sekota Dry land Agricultural Research centre, Sekota

Biru Alemu1 and DarajeAbera. 2014. Adaptation Study Of Improved groundnut (Arachishypogaea L) Varieties At KellemWollega Zone, HaroSabu, Ethiopia. *Journal of Biology, Agriculture and Healthcare*. Vol.4 (23)

Chavadhari R. M., V. H. Kachhadia, J. H. Vachhani* and M. B. Virani.2017. Genetic variability studies in groundnut (*Arachishypogaea*L.).*Electronic Journal of Plant Breeding*. vol8(4): 1288-1292

CSA (central statistical authority), 2015. Area and production of crops volume 1 statistical bulletins. Central Statistical Authority. Addis Ababa, Ethiopia. pp. 446.

Emmanuel Zuza Jnr, AmadeMuitia, Manuel I.V. Amane, Rick L. Brandenburg and Ana M. Mondjana. 2017. Effect of harvesting time on groundnut yield and yield components in Northern Mozambique. *Journal of Postharvest Technology*. Vol. 05(2): 55-63

FAOSTAT. 2010. Available at http://faostat.fao.org/. Accessed date october 2, 2019.

Garko M.S., I.B Mohammed, A.I. Yakubu, Z. Y. Muhammad. 2016. Performance of Groundnut [ArachisHypogaea (L.)] Varieties As Influenced By Weed Control Treatments. *International Journal of Scientific & Technology Research*. Volume 5(03)

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research. 2nd edition. John Willey & Sons Ltd., New York, USA.680p.

Izge A. U, Z. H. Mohammed and A. Goni.2007 Levels of variability in groundnut (Arachishypogaea L.) to cercospora leaf spot disease – implication for selection. *African Journal of Agricultural Research.* Vol. 2 (4), pp. 182-186.

Jeyaramraja P R and FantahunWoldesenbet. 2014. Characterization of yield components in certain groundnut (*Arachishypogaea* L.) Varieties of ethiopia. *Journal of Experimental Biology and Agricultural Sciences*. Vol. 2(6).Pp 593-596.

MastewalAlehegn, Sakhuja PK and Mashilla D. 2017. Evaluation of Released and Local Groundnut Varieties against Groundnut Rust (PucciniaArachidis) at Babile, Eastern Ethiopia. *Journal of Agriculture Research*. 2017. Vol 2(1): 000123.

Mulatu Gabisa, Tamado Tana and Elias Urage 2017. Effect of planting density on yield components and yield of Groundnut (Arachishypogaea L.) varieties at Abeya, Borena Zone. *International Journal of Scientific Engineering and Applied Science (IJSEAS). Vol. 3 (3).*

Musa H. Ahmed, Hiwot M. Mesfin ,SelteneAbady , WendmagegnMesfin and Amare Kebede. 2016. Adoption of improved groundnut seed and its impact on rural households' welfare in Eastern Ethiopia. *Cogent Economics & Finance*. Vol 4: pp 1-13

Wedajo Gebre and Wondewosen Shiferaw. 2017. Performance Evaluation of Ground Nut Varieties in Lowland Areas of South Omo, Southern Ethiopia. *International Journal of Research Studies in Science, Engineering and Technology*.Vol 4 (2) .PP 6-8

Performance evaluation of sesame varieties at Abaya, Southern Oromia

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***Abstract**: Sesame (Sesamum indicum L.) is an ancient oil crop that has been referred to as the 'Queen of oilseeds' by virtue of its high quality oil. It is an important oil seed crop grown throughout the tropics and sub tropics worldwide. In southern part of Oromia, where agriculture investors are engaged, the production of sesame is still low. Moreover, there is a need for selecting high yielding and adaptable sesame varieties for the study areas. Therefore, this experiment was conducted to evaluate thirteen sesame varieties and select adaptable varieties with considerable yield and agronomic traits. The field experiment was conducted in 2017 and 2018 at Abaya and varieties were planted in Randomized Complete Block Design (RCBD). Data were collected on yield and important agronomic traits and analyzed using SAS software. The analysis of variance revealed significant variations among varieties for days to flowering, plant height, number of primary branches and Grain yield. The pooled over years mean of varieties showed Dicho variety is identified as the high yielding variety with mean grain yield of 542.81kg/ha followed by variety Obsa (527.71kg/ha) and Chalasa (515.38 kg/ha) and therefore recommended for moisture stress areas of Abaya and location with similar agro ecologies.*

Key words: Adaptability, Grain yield, Sesame,

1. INTRODUCTION

Sesame (*Sesamum indicum* L.), a conventional oilseed crop from Pedaliaceae family (Zeb et al. 2017) and Tubeflorae order (Nayar, 1976), is grown well in tropical and subtropical areas of the world (Gandhi, 2009). It is widely cultivated in the tropical parts of Africa and Asia and about 36 species are said to be existent (Saydut et al., 2008). It is the most ancient oil seed known and used by man (Kafiriti and Deckers, 2001). Sesame has a small, oval and flat seed with diverse colors (black, white, grey, yellow, brown and red) depending on the cultivar (Nagendra Prasad et al. 2012). Due to its very valuable phytochemical content, it is one of the most resistant vegetable oil to oxidative rancidity. Therefore, it is known as queen of the oilseed crops (Zeb et al. 2017). It is also stable due to the natural anti-oxidants sesamol and sesamolinol that reduce the rate of oxidation (Terefe *et al*., 2012). The chemical composition of sesame seed shows that the seed is a good source of carbohydrate (13.5%), protein (18-25), ash (5%) (Borchani *et al*., 2010) and about 50% high quality oil (Roy *et al*., 2009).

Sesame is important oil crop grown in Ethiopia and occurs both as cultivated and wild species (Zerihun, 2012). It is thought to have originated in Africa, and there is a great weight of evidence indicating that Ethiopian lowland area is the origin of cultivated sesame (Mahajan et al 2007). It is the major oil seed in terms of exports, accounting for over 90% of the values of oil seeds exports of Ethiopia. It is the second largest source of foreign exchange earnings after coffee (Abadi, 2018).

Sesame (*Sesamum indicum)* is grown in areas with annual rainfall of 625-1100mm and temperature less than $27C^0$. The crop is tolerant to drought, but not to water logging and excessive rainfall. Sesame is well adapted to a wide range of soils, but requires deep, well-drained, fertile sandy loams (Geremew et al 2012**)**. In Ethiopia, sesame grows well in the semiarid areas of Amhara, Tigray, Benshangul Gumuz, and Somali Regions. Lowlands of Oromiya and Southern Nations nationalities and Peoples Regions also grow a significant amount**.** Though variations in climatic and edaphic conditions affect sesame yields and performance (Muhamman and Gungula 2008), the major constraints identified in growing sesame in most countries are instability in yield, lack of wider adaptability, drought, non-synchronous maturity, poor stand establishment, lack of response to fertilizer application, profuse branching, lack of seed retention, low harvest index and susceptibility to insect pests and pathogens (Rajani Bisen et al., 2014).Ethiopian Sesame has good demand in the world market and known for its top quality and therefore used as a reference for grading in the international market. There is an enormous potential to expand sesame seed production in Ethiopia through cultivation of additional new land (EPOSPEA, 2019). In southern part of Oromia, where agriculture investors are highly engaged, the production of Sesame is still very low. Moreover, there is a need for selecting high yielding and adaptable varieties and capacitating farmers and agricultural investors in the study areas. This experiment was therefore conducted by Yabello Pastoral and Dryland Agriculture Research Center with the following objective to select and recommend adaptable sesame varieties for the study area.

MATERIALS AND METHODS

Descriptions of the study area

The experiment was conducted at Abaya during 2017 and 2018 main cropping season. The experimental area is located in the Southern part of the country in the Oromia Regional State. Abaya is sub-site of the Yabello Pastoral and Dryland Agriculture Research Center and located at 365 km far from Addis Ababa city. The detail description of the study area is presented in the table 1

Table 13: Description of the study area

Variables	
Soil type	Sandy clay loam
Altitude (m.a.s.l.)	1442
Latitude	06^{o}43’520"N
Longitude	038^{o}25’425"E
Annual Temperature ^{0}C	
Minimum	12.6
Maximum	29.9
Annual rainfall (mm)	
Minimum	500
Maximum	1100

Experimental Materials

A total of thirteen sesame varieties were collected from Melka Werar and Bako Agriculture research Centers and evaluated at Abaya for two consecutive years (2017 and 2018).

Table 2: List of Sesame varieties used in this experiment

S.No	Variety	Year of release	Breeder/ Maintainer
1	Serkamo	1993	WARC/EIAR
2	E	1978	WARC/EIAR
3	Dicho	2010	BARC/OARI
4	Argane	1993	WARC/EIAR
5	Tate	1989	WARC/EIAR
6	Mehado-80	1989	WARC/EIAR
7	S	1978	WARC/EIAR
8	T-85	1976	WARC/EIAR
9	Kalifo-74	1976	WARC/EIAR
10	Abasena	1990	WARC/EIAR
11	Chalasa-EW023 (2)	2013	BARC/OARI
12	Obsa	2010	BARC/OARI
13	Adi	1993	WARC/EIAR

Experimental Design and Managements

The experiment was laid out in Randomized Complete Block Design. Each entry was planted in a plot having 6 rows of 3 meter length. Four rows were harvested and two border rows were left to exclude border effect. National seed rate recommendation (5kg/ha) was calculated for each plot and drilled uniformly to plot. Individual plot size was 2.4 m x 3m=7.2 m^2 and 1.5m between each block. All other agronomic managements were applied uniformly in all experimental plots as per national recommendation for the crop.

Data Collection

Data recorded on plant basis

Plant height at harvest (cm): Height of five randomly taken plants during harvest period from each experimental plot was measured in centimeter from the ground level to top of the plants and the average height was recorded.

Number of primary branches: Number of productive branches extending from the main stem was recorded from five randomly selected plants and average branch number was taken.

Data recorded on plot basis

Days to Flowering: The numbers of days from the date of emergence to the date on which about 50% of the plants in each plot produce flowers.

Days to maturity: The number of days from planting to maturity period

Stand count at harvest: This was recorded by counting the total number of plants from the four middle rows of each plot at harvest.

Grain yield (g/plot): Grain yield in grams obtained from the central four harvestable rows of each plot was harvested, threshed and weighted by using sensitive balance

Grain yield (kg/ha): Grain yield obtained from each plot was used to estimate grain yield (kg) per hectare.

Data Analysis

Analysis of variance

Analysis of variance (ANOVA) was computed for grain yield and other traits as per the methods described by Gomez and Gomez (1984) using SAS computer software (Version 9) for Randomized complete block design. Comparison of treatment means was made by using Least Significant Difference (LSD) at 5% level of significance test. Analyses of variance (ANOVA) was computed using the following mathematical model:

$$Yijk = \mu + Gi + yj + Bk + Gyij + \varepsilon ijk$$

Where: $Yijk$ = is the observed mean of the i^{th} variety (G_i) in the j^{th} year (y_j), in the k^{th} block (B_k)

μ= General mean of trait Y

Gi = Effect of the i^{th} variety

yj= Effect of the j^{th} year

Bk =Block effect of the i^{th} variety in the j^{th} year, Gyij =The interaction effects of the i^{th} variety and the j^{th} year, and εijk= The error term

Results and Discussions

Analysis of variance

The combined over two years Analysis of variance (ANOVA) computed shown that variation among varieties were highly significant (P<0.01) for all traits except dates to maturity (Table 3). The presence of variations among varieties under experiment for traits studied indicated the presence of sufficient variability among Sesame varieties. The presence of highly significant variation in sesame varieties for grain yield, Number of primery branch, plant height, days to flowering and days to maturity was also reported by Fiseha *et al*., 2016 and Bharathi et al., 2014**.** Highly significant variation of year effect (P<0.01) for flowering and maturity dates were observed indicatingthe presence of variability in both year. The interaction effect of variety by year was not significant indicating similar performance of varieties in different year for these traits. Okello-Anyanga *et al*., 2016 also reported similar findings in sesame.

Table 3: Mean squares from combined analyses of variance over two years for 5 traits of Sesame varieties grown at Abaya in 2017 and 2018

Sources of variation	**DF**	**FD**	**MD**	**PH (cm)**	**NPB**	**GY (kg/ha)**
Year	1	184.615**	1041.346**	250.743	0.461	275011.34*
Rep(Year)	4	3.564	14.717	214.672	1.641	43301.332
Variety	12	22.510**	27.517	1081.493**	2.467*	200871.199**
Year* Varieties	12	0.532	55.679	117.708	1.211	40642.835
Error	48	8.05	22.829	114.069	0.849	27182.255
CV (%)		4.295%	3.559%	12.095%	25.311	69.712%

ns, ,**&***,non-significant, significant and highlysignificant at P<0.05, P<0.01 and P<0.001, respectively. DF= degree of freedom, FD= days to flowering, MD= days to maturity, PH (cm) = plant height in centimeter, NPB= number of primary branch, GY (kg/ha) = Grain yield in kilogram per hectare.*

Mean performance of varieties

Crop phenology: Flowering duration of 13 sesame varieties ranges from 62.5-70.0 while the maturity duration of varieties ranges from 129.833-138.167. The mean performances of these traits are presented in Tables 4. The earliest flowering variety was Dicho (62.5days) while the late flowering variety were Mahado-80 (70.0 days). Varieties also showed variation in maturity date which ranged from 129.833days to 138.167days.

Growth traits, Yield and yield components: Considerable variation was shown in 13 sesame varieties for plant height. Mean performances of varieties for plant height ranged from 71.867 cm to 111.10cm. About 53.85% of varieties were taller than the grand mean. Adi variety was relatively taller followed by Dicho, chalasa and Obsa wile Variety Kalifo-74, S, E and Mahado-80 were relatively short. Varieties showed considerable variations for number of primary branches that ranged from 2.833 to 4.833 (table 4). Daniel et al., 2017 also reported a presence of wide range of variability for plant height (54.2 to 163.9cm), days to maturity (82 to 113days), days to flowering (29 to 66 days) and number of primary branches (1 to 8.3) in sesame varieties.

Table 4: Mean value of yield and yield related traits of 13 Varieties of Sesame tested at Abaya in 2017 and 2018 cropping season

Variety	FD	MD	PH (cm)	NPB	Gy/ha (kg)
Serkamo	65.167bcd	133.833a	94.333bc	4abcd	96.69c
E	66.167bcd	136.333a	72.767d	2.833d	81.51c
Dicho	66.000bcd	134.000a	101.500ab	4.667ab	542.81a
Argane	66.833abc	134.000a	81.567cd	3.50bcd	114.85bc
Tate	66.667abc	138.167a	88.667bc	3.833abcd	242.04bc
Mehado-80	70.000a	135.500a	73.367d	3.333cd	82.98c
S	66.667abc	133.000a	72.633d	3.333cd	69.80c
T-85	68.833ab	135.833a	82.008cd	3.00d	111.58bc
Kalifo-74	66.000bcd	134.167a	71.867d	3.167cd	125.44bc
Abasena	62.500d	132.500a	99.033ab	3.167cd	239.86bc
Chalasa	64.000cd	129.833a	99.733ab	4.333abc	515.38a
Obsa	64.667cd	135.833a	99.333ab	4.833a	527.71a
Adi	65.167bcd	132.167ab	111.100a	3.333cd	323.88b
Mean	66.12508	134.27	87.798	3.611	248.153
Range	62.5-70	129.833-138.167	71.867-111.1	2.833-4.833	69.8-542.81

Means with the same letters in the same columns are not significantly different

FD= flowering date, MD= Maturity date, PH= plant height in centimetre, NPB= number of primary branch, GY= Grain yield per hectare

Significantly highest mean grain yield was recorded from Dicho (542.81kg/ha) followed by Obsa (527.71kg/ha) and Chalasa (515.38kg/ha). The high yielding capacity of these three varieties may be due to inherent characteristics of those varieties in bearing high number of primary branches and possessing relatively higher plant height

CONCLUSIONS AND RECOMMENDATIONS

The experiment was conducted at Abaya during 2017 and 2018 cropping season with the objective to select and recommend adaptable sesame varieties for the study areas. The results of experiment exhibited significant variation among varieties for all traits except Maturity dates. Significant variation among varieties for those traits indicated that the possibility of selecting varieties for the study areas. The mean of flowering and maturity date in this experiment ranged from 62 to 70 days and 129 to 138 days respectively. The early maturing varieties was Chalasa with 129.83 days to mature while the late maturing varieties are Tate with 138.167 days to mature. The mean seed yield ranged from 69.80 kg to 542. 81kg. The highest mean grain yield were exhibited by Dicho (542.81kg ha-1) followed by Obsa (527.71 kg ha-1) and Chalasa (515.38kg ha-1). The high yielding capacity of these three varieties may be due to presence of high number of primary branches and plant height. Therefore, farmers and Sesame producers around the study area and similar agro ecologies can use those varieties

REFERENCES

Abadi Berhanu, 2018. Sesame Production, Challenges and Opportunities in Ethiopia. Agri Res & Tech: Open Access Journal. Vol. 15 (5)

Bharathi D., V.Thirumala Rao*, Y.Chandra Mohan, D.Bhadru and V.Venkanna 2014. Genetic variability studies in sesame (Sesamum indicum L.). International Journal of Applied Biology and Pharmaceutical Technology.Vol. 5(4), pp. 31-33

Borchani, C., S. Besbes, C.H Blecker and H. Attia. 2010. Chemical characteristics and oxidative stability of sesame seed, sesame paste and olive oils. J. Agri. Sci. Technol. 12: 585-596.

Daniel Endale 2017. Sesame (Sesamum indicum L.)Breeding in Ethiopia. International Journal of Novel Research in Life Sciences Vol. 4(1). pp: (1-11)

Ethiopian pulses, Oilseeds and spice processors-Exporters Associations. http://www.epospeaeth.org/index.php/ethiopian-sesame-and-oilseeds. Accessed date October 4, 2019

Fiseha Baraki, Yemane Tsehaye and Fetien Abay 2016. Analysis of genotype x environment interaction and seed yield stability of sesame in Northern Ethiopia. Journal of Plant Breeding and Crop Science. Vol. 8(11), pp. 240-249

Gandhi, A.P. 2009. Simplified process for the production of sesame seed (Sesamum indicum L.) butter and its nutritional profile. Asian J. Food. Agro-indust. 2: 24-27.

Geremew Terefe, Adugna Wakjira Muez Berhe and Hagos Tadesse. 2012.Sesame Production Manual. ISBN: 978-99944-53-80-8

Gomez KA, Gomez AA (1984). Statistical Procedures for Agricultural Research. 2nd edition. John Willey & Sons Ltd., New York, USA.680p.

Kafiriti E, Deckers J (2001) Sesame (Sesamum indicum L.). In: RH Raemaekers, Crop Production in Tropical Africa (pp. 797-804). Brussels, Belgium: Directorate General for Inernational Co-operation.

Mahajan, R.K., I.S. Bisht, and B.S. Dhillon. 2007. Establishment of a core collection of world sesame (Sesamum indicum L.) germplasm accessions. *Sabrao Journal of Breeding and Genetics*. Vol.39 (1): 53–64.

Muhamman, M. A. and Gungula, D. T. 2008. Growth parameters of sesame (Sesamum indicum L.) as affected by nitrogen and phosphorous levels in Mubi. Nigeria. J. of Sustainable Development in Agriculture & Environment. 3(2): 80-86.

Nagendra Prasad MN, Sanjay KR, Prasad DS, Vijay N, Kothari R, Nanjunda Swamy S (2012). A review on nutritional and nutraceuticals properties of sesame. *Journal of Nutrition and Food Science*. Vol. 2(2):1–6.

Nayar, N.M. 1976. In: Sesame: Evolution of crop plants, Simmonds, N.W. (Ed.). Longman, London and New York, pp. 231-233.

Okello-Anyanga Walter, Patrick Rubaihayo , Paul Gibson and Patrick Okori. 2016. Genotype by environment interaction in sesame (Sesamum indicum L.) cultivars in Uganda. *African Journal of Plant Science.* Vol. 10(10), pp. 189-202.

Rajani Bisen, Anjay Tripathi, Ravindra P. Ahirwal, Seema Paroha, Roshni Sahu and A. R. G. Ranganatha. 2014. Study on genetic divergence in sesame (sesamumindicum L.) germplasm based on morphological and quality traits. The Bioscan. International Quarterly Journal of Live sciences. Vol. 8(4). Pg 1387-1391.

Roy, N., S.M. Abdullah and M.S. Jahan. 2009. Yield performance of sesame (*Sesamum indicum*L.). varieties at varying levels of row spacing. Res. J. Agri. Biol. Sci 5: 823-827.

Saydut A, Duz MZ, Kaya C, Kafadar AB, Hamamci C (2008) Transesterified sesame (Sesamum indicum L.) seed oil as a biodiesel fuel. Bioresour Technol 99: 6656-6660

Terefe G, Wakjira A, Berhe M, Tadesse H (2012) Sesame Production Manual. EIAR. 6. Monitor Group (2012) The Business Case for Investing in a Sesame Hulling Plant in Ethiopia.

Zeb A, Muhammad B, Ullah F (2017). Characterization of sesame (Sesamum indicum L.) seed oil from Pakistan for phenolic composition, quality characteristics and potential beneficial properties. *Journal of Food Measurement and Characterization*. Vol. 11(3):1362–1369

Zerihun J. Sesame Sesame indicum L. Crop Production in Ethiopia: Trends, Challenges and Future Prospects. Sci. Technol. 2012; 1(3):01-07.

Evaluation and Identification of Adaptable Processing Tomato Varieties with High Yield and Standard Qualities at Adami Tulu Jido Kombolcha Woreda, East Shoa Zone.

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Abstract

Experiment on evaluation and identification of adaptable processing tomato varieties with high yield and standard qualities at Adami Tulu Jido Kombolcha Woreda of east Shoa zone was initiated with objective to identify adaptable and most preferable processing tomato varieties with high yield and required qualities. Nine processing tomato varieties viz., Melkasalsa, Gelilema, Melkashola, Chali, Cochoro, Sire, Gelila, Venus F1 and Roma Vf were evaluated on field at two locations (ATARC and Abosa) for two consecutive years in 2018 and 2019 under irrigation in Randomized Complete Block Design with three replications. Among these varieties, there was highly significant variations for days to flowering, plant height at fruit harvest, cluster per plant, floret per clusters, fruit per clusters, primary branch, secondary branch, total soluble solids and titrable acids. Besides, significant variation was also observed among test varieties for marketable fruit yield while non significant variation was observed for traits such as unmarketable fruit yield, total fruit yield and potential acidity. The combined mean performances of phenological, growth, yield related and quality traits of nine processing tomato varieties was also analyzed for yield and quality standard. Based on overall performance for these above mentioned traits across year, three varieties namely Gelila, Gelilema and Melkasalsa were recommended for Adami Tulu Jido Kombolcha Woreda and similar agro ecologies.

Key Words: Evaluation, Processing type, Quality, Tomato, Yield

INTRODUCTION

Tomato is one of the most important and widely grown vegetables in the World. It is important in a variety of dishes as raw, cooked or processed products more than any other vegetables (Lemma Desalegne, 2002). In Ethiopia, it is an important cash crop widely produced by smallholder farmers and commercial growers under irrigated conditions. Processing types of tomato are mainly produced in large-scale commercial horticultural farms. It is an important cash-earning crop to small-scale farmers and provides employment in the production and processing industries. The processed products such as tomato paste, tomato juice, tomato ketchup and whole peel-tomato are produced for local market and export. It is extensively produced in the Rift Valley and lakes region both for fresh market and processing industries (Selamawit and Lemma, 2008). It is one of the most popular & important vegetables for fresh consumption as well as for processing.

Currently, tomato is one of the major regional export vegetables of the country. In Ethiopia, the crop is produced in the altitude ranging from 700 to 2200 meter above sea level, with about 700 to over 1400 mm annual rain fall, in different areas and seasons, in different soils, under different weather conditions, but also at different levels of technology (e.g. with furrow, drip or spate irrigation) and yields (Birhanu and Ketema, 2010). The plant requires a warm and dry climate. The optimum mean temperature for growth of tomato lies between 21^{0}c and 26^{0}C.Tomato should be cultivated at an altitude below 2000 m. Soils for tomato cultivation are loamy sand to silty loam. Soils with medium organic matter content have better yield than soils with a low organic content. Good soil drainage is important. Optimum pH ranges from 5.5 to 7.0. The first fruits are produced 80-100 days from transplanting. Lack of processing type of tomato varieties with high yield, stable performance and acceptable qualities for small scale farmers in the study area is the major bottle neck for production and productivity of tomato. Currently, the opening of Bulbula agro-processing industry is one of the potential market for the farmers in the area who are engaging on production of these tomato varieties. Hence, the current experiment was initiated with objective to identify adaptable and most preferable processing tomato varieties with high yield and required quality for the study area.

MATERIALS AND METHODS

This chapter introduces the description of the study area, plant materials and experimental design, method of data collection and data analysis.

Description of the Study Area

The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC) and Abosa under irrigation (from February to June) of 2018 and 2019. Both Abosa and ATARC are located in Adami Tulu Jido Kombolcha District, East Shoa Zone of Oromia, and it is located in the mid Rift Valley of Ethiopia.

Experimental Materials, Design and Management

In this experiment nine nationally released and registered processing tomato varieties were used. Of these nine varieties, six varieties viz. Melkasalsa, Gelilema, Melkashola, Chali and Cochoro were collected from Melkassa Agricultural Research center, while one variety, Sire was obtained from Bako Agricultural Research center. The three remaining test varieties viz. Gelila, Venus F1 and Roma Vf were collected from private farms who introduced from abroad and actually registered in the country for production. The planting materials were laid out in Randomized Complete Block Design (RCBD) with three replications. These varieties were grown under irrigation during the months of February to June of the years 2018 and 2019. The gross plot size was 16 m^2 (4m x 4 m) arranged in 4 rows of 100 cm spacing between rows and 30 cm between plants. The net plot size was 2 m * 3 m (6 m^2) . A spacing o f 1.5 m and 1 m between blocks and plots was maintained, respectively. Seedlings which failed to establish were replaced by replanting within a week of transplanting to maintain the appropriate plant population. Inorganic fertilizer, NPS-150 Kg/ha at planting while UREA-200 Kg/ha was applied in 10 cm band from root collar in two splits viz., ½ at transplanting and ½ at 1 month after transplanting (Lemma Deselegne, 2002). All cultural practices were done according to the tomato production technique developed and recommended by Melkassa Agricultural Research Centre (MARC) for Mid Rift Valley region of Ethiopia (Lemma Desalegne, 2002).

Table 1: Description of processing tomato varieties used in an experiment

No	Variety	Year of registration	Responsible company
1	Melkasalsa	1997/98	MARC/EIAR
2	Gelilema	2015	MARC/EIAR
3	Melkashola	1997/98	MARC/EIAR
4	Chali	2007	MARC/EIAR
5	Cochoro	2007	MARC/EIAR
6	Sire	2015	Bako ARC/OARI
7	Gelila	2011	Axum Green life
8	Venus F1	2015	MARKOS PLC
9	Roma Vf		

Data Collection and Measurement

Crop phenological, growth, yield and yield components, and quality parameters were considered in this study. All parameters considered in this study are listed below with their detail descriptions.

2.3.1. Phenological data

Data on days to 50% flowering and days to 50% maturity were recorded on a plot basis, while others i.e. number of flowers per cluster, number of fruits per cluster and fruit set were collected and recorded from 10 randomly selected plants of the two middle rows of each plot.

Days to 50% flowering: were recorded as the number of days from transplanting to the time when 50% of plants in each plot flowered.

Days to maturity: were recorded as the numbers of days from the date of transplanting to the date when 50% of the plants in each plot reached physiologically maturity of fruits for the first time. In other words, days to maturity were recorded when approximately 50% of plants per plot attained their first crop harvest.

2.3.2. Growth parameters

Plant height: height of the plants was measured from the ground level to the tip of upper most part of 10 randomly selected plants at first harvest.

Number of clusters per plant: this was recorded by counting the total number of clusters per plant from 10 randomly selected plants at full maturity.

Number of flowers per cluster (FlC):this was recorded by counting the total number of flowers per cluster from 10 randomly selected clusters at bloom.

Number of primary branches: Number of branches extended from the main stem were counted and recorded on 10 randomly selected plants in harvestable rows at flowering stage.

Number of secondary branches: Number of branches extended from the primary brancheswas recorded on 10 randomly selected plants in harvestable rows at flowering stage.

2.3.3. Yield and yield related parameters

Two inner rows leaving one plant from the boarder at each side were used to asses yieldrelated traits. All parameters to be considered were listed below with descriptions.

Marketable fruit yield (qtl ha-1): was recorded by weighing all harvests of marketable fruitsfrom the three inner rows of each plot and calculated in quintals per hectare.

Unmarketable fruit yield (qtl ha-1): was recorded by weighing all harvests of unmarketablefruits from the three inner rows of each plot and calculated in quintals per hectare.

Total fruit yield (TFY) (qtl ha-1): was recorded as the sum of the weight of marketable andunmarketable fruit yields and converted to quintal per hectare.

2.3.4. Chemical quality attributes

Total soluble solids (TSS) (0Brix): The total soluble solid were determined following theprocedure described by Acedo et al. (2008). Aliquot of juice were extracted using HighPerformance Commercial Blender. A Palette digital refractometer ATAGO®PR-32α with arange ofoBrix 0 to 32% was used to determine the TSS by placing two drops of clear juice onthe prism. Between samples, the prism of the refractometerwas washed with distilled water and dried with tissue paper before it is used for another reading. The refractometer wascalibrated against distilled water at 0 percent TSS.

pH: Aliquot of clear juice filtered with cheesecloth was used for pH measurement and the pHvalue of each plot tomato juice was measured by a pH meter with a model of AD1020 pH/mv/ISE and Tometer calibrated with standard pH buffer 4 and 7.

Titratable acidity: Extracted tomato juice was filtered through cheesecloth and decants clear juice were used for titration. Ten ml of the tomato juice sample were titrated gradually with 0.1N NaOH using burette to pink end point (persisted for 15 seconds).

2.4. Data Analysis: Data were subjected to ANOVA by using the GLM Procedure of SAS software (SAS Institute, 2002). Mean separation was performed at ($P \leq 0.05$) using the Least Significant Difference (LSD).

RESULT AND DISCUSSIONS

Analysis of Variance: Analysis of variance by General Linear Model for 14 characters (2 phenological, 6 growth, 3 yield related and 3 quality parameters) are presented in Table 2. The result showed the existence of highly significant ($P\leq 0.01$) variation among the years for days to flowering, days to maturity, plant height at fruit harvest, cluster per plant, floret per plant, fruit per cluster, unmarketable fruit yield, pH and titrable acidity. Across the locations there was highly significant variation for days to maturity, plant height at fruit harvest, cluster per plant, floret per clusters, fruit per clusters, marketable fruit yield, unmarketable fruit yield, total fruit yield, total soluble solid and titrable acidity. Among each varieties there was highly significant variations among days to flowering, plant height at fruit harvest, cluster per plant, floret per clusters, fruit per clusters, primary branch, secondary branch, total soluble solids and titrable acids where as significant difference for marketable fruit yield and no significant variation for unmarketable fruit yield, total fruit yield and pH.The presence of appreciable differences among varieties for most of the characters studied makes the possibility to carry out demonstration and scaling up.

Mean Performance of Varieties

Phenological Parameters

The combined mean values of phenological traits of 9 processing tomato varieties evaluated at Adami Tulu Jido Kombolcha were shown in table 3. The variation with respect to days to heading and days to maturity ranged from 35 to 42.5 and 95.33 to 102.33 with mean values of 38.26 and 97.55, and the coefficient of variation of 8.51 and 7.06, respectively (Table 3).This result is in close agreement with the finding of Tesfa et al., 2016. Among the varieties the variety Venus F1 was early flowering which took 35 days followed by Sire(35.08), Chali (35.75) and Gelila (38.58). Among the varieties the variety Melkasalsa was late maturing with 102.33 days followed by Chali(98.42) and Roma Vf(98.25).This indicates genotypes with shorter days to flowering and days to maturity showed shorter fruit setting than those with longer days to flowering and days to maturity.

Growth parameters

The combined mean values of growth characters of 9 processing tomato varieties evaluated at Adami TuluJido Kombolcha were shown in table 4. The variation with respect to plant height at fruit harvest, clusters per plant, floret per clusters, fruits per cluster, primary branch and secondary branches were ranged from 66.02 to 88.33, 15.97 to 24.57, 4.36 to 5.07, 3.53 to 4.43, 2.67 to 3.83 and 15.71 to 19.40, with mean values of 82.51, 19.37, 4.54, 3.94, 3.37 and 17.01, with coefficient of variation of 13.72, 11.74, 13.85, 8.42, 16.70 and 10.11 respectively.

The maximum plant height at fruit harvests were recorded in varieties Roma Vf(88.33cm), Venus F1 (87.22cm) and Melkashola (86.92cm), while varieties Chali (66.02cm), Cochoro (77.45cm) and Gelilema (80.73cm) were recorded minimum plant height at fruit harvest.The result is in close agreement with the finding of Fiseha (2014)who reported the plant height at fruit harvest from 96.8 to 106.8. The the maximum number of clusters per plant were recorded in varieties Melkashola (24.57) and Roma Vf(24.17), while varieties Venus F1(15.97) and sire (16.33) were recorded minimum number of clusters per plant. The maximum number of florets per cluster were recorded in Roma Vf (5.07) and Melkasalsa (4.90), while Cochoro (3.73) and sire (4.36) recorded minimum number of florets per cluster. The maximum number of fruit per cluster was recorded in Roma Vf(4.43) and Melkasalsa(4.20),while Cochoro(3.53) and Venus F1(3.73) were recorded the lowest number of fruit per clusters. According to Tesfa *et al.,* 2016, the number of fruits per cluster ranged from 3.1 to 7.3. The maximum primary branches were recorded in Roma

Vf(3.83) and Melkasalsa(3.50),while Chali(2.67) and Venus F1(3.30) were recorded lowest primary branches per plant. The highest secondary branches were recorded in Melkasalsa (19.40) and Roma Vf(18.57), while Chali(15.71) and Gelilema(15.84) were recorded the minimum number of secondary branches per plant. Over all the variety Roma Vf recorded the highest mean values of all the studied growth parameters.

Table 2: Combined analyses (ANOVA) of phenological, growth, yield and quality parameters of processing tomato varieties tested over two locations (ATARC & Abosa) for two years (2018 and 2019)

Source of variation	Mean squares													
	Phonological parameters			**Growth parameters**						Yield parameters			Quality Parameters		
	Df	**DF**	**DM**	**PHFrHa**	**CP**	**FlCl**	**FrPc**	**PBr**	**SBr**	**MFY**	**UnMFY**	**TFY**	**pH**	**TSS**	**TA**
Year	1	133.33***	1401.12**	2342.67***	243.00***	1.08ns	1.08***	1.08ns	1.68ns	10576.17ns	22012.76***	2072.65ns	2.072**	0.107ns	33.745***
Location	1	0.037 ns	51.91***	2930.72**	54.04***	1.82**	0.85***	0.01ns	7.84ns	585208.33***	27293.14***	865263.63***	0.560ns	22.595***	6.283*
Replication	2	18.89 ns	134.23ns	27.57ns	22.09*	0.96ns	0.10ns	0.36ns	20.34***	24735.26ns	441.13ns	24169.50ns	0.140ns	0.140ns	0.184ns
Variety	8	80.09***	2552.08ns	604.47***	128.67***	2.13**	0.84***	1.12**	15.69***	13612.55*	960.46ns	11089.36ns	0.106ns	0.4513***	11.305**
Loc*variety	8	2.53ns	9.77ns	58.73ns	23.95***	0.76ns	0.34*	1.083*	7.20**	6933.79ns	231.58ns	7134.64ns	0.069**	0.34***	1.79**
Year*loc	1	56.33*	2455.78***	6332.67***	27.00*	0.00ns	0.00ns	0.00ns	0.067ns	362413.55**	1467.62*	410006.54***	10.09***	0.03ns	0.29**
Year*variety	8	26.95**	36.84ns	117.83*	0.00ns	0.00ns	0.00ns	0.00ns	0.00ns	12643.02*	501.57ns	9328.60ns	0.15ns	0.59***	3.64***
Year*loc*variety	8	5.54ns	9.34ns	79.55ns	0.00ns	0.00ns	0.00ns	0.00ns	0.00ns	9608.99ns	519.50503ns	10901.7253ns	0.05ns	0.28***	7.31***

Where : **Df:** Degree of freedom, **DF**: Days to 50% flowering and **DM**: Days to maturity, **PHFrHa**: Plant height at first harvest (cm).**CP**: Number of cluster per plant, **FlCl**: Number of flower per cluster; **FrPc** : Number of fruit per cluster;**PBr**: number of primary branch , **SBr**: Number of Secondary branch, **MFY** = Marketable fruit yield (qtls/ha); **UnMFY**= Unmarketable fruit yield (qtls/ha) , **TFY** = Total fruit yield (qtls/ha), **pH**: potential acidity (power of Hydrogen),**TSS**: Total soluble solid (^{0} Brix), and **TA**: Titrable acidity

Table 3: Combined mean of Phenological parameters of processing tomato varieties tested over

two locations (ATARC & Abosa) for two years (2018 and 2019)

S.N	Variety	Phenological parameters	
		DF	**DM**
1	Melkasalsa	39.00^{b}	102.33a
2	Gelilema	39.50^{b}	95.67^{b}
3	Melkashola	42.50^{a}	97.17^{ab}
4	Chali	35.75^{cd}	98.42^{ab}
5	Cochoro	38.17^{bc}	96.50^{b}
6	Sire	35.08^{d}	97.58^{ab}
7	Gelila	38.58^{b}	95.33^{b}
8	Venus F1	35.00^{d}	96.67^{b}
9	Roma Vf	40.75^{ab}	98.25^{b}
Mean		**38.26**	**97.55**
CV (%)		**8.51**	**7.06**
LSD (5%)		**2.64**	**5.58**

Where: **Df:** Degree of freedom, **DF**: Days to 50% flowering and **DM**: Days to maturity

Table 4: Combined mean of growth parameters of processing tomato varieties tested over two locations (ATARC & Abosa) for two years (2018 and 2019)

S.N	Variety	Growth parameters					
		PHFrHa	**CP**	**FlCl**	**FrPc**	**PBr**	**SBr**
1	**Melkasalsa**	85.95^{b}	21.33^{b}	4.90^{a}	4.20^{b}	3.50^{ab}	19.40^{a}
2	**Gelilema**	80.73^{ab}	18.13^{cd}	4.43^{bc}	3.96^{bcd}	3.37^{b}	15.84^{e}
3	**Melkashola**	86.92^{a}	24.57^{a}	4.87^{abc}	4.03^{bc}	3.43^{ab}	17.24^{bcd}
4	**Chali**	66.02^{c}	17.13^{de}	4.50^{bc}	3.90^{cd}	2.67^{c}	15.71^{e}
5	**Cochoro**	77.45^{b}	19.50^{bc}	3.73^{d}	3.53^{e}	3.43^{ab}	15.91^{de}
6	**Sire**	86.13^{ab}	16.33^{de}	4.36^{c}	3.80^{cde}	3.33^{b}	16.71^{cde}
7	**Gelila**	83.83^{ab}	17.23^{de}	4.46^{bc}	3.83^{cd}	3.46^{ab}	17.51^{bc}
8	**Venus F1**	87.22^{a}	15.97^{e}	4.50^{bc}	3.73^{de}	3.30^{b}	16.17^{cde}
9	**Roma Vf**	88.33^{a}	24.17^{a}	5.07^{a}	4.43^{a}	3.83^{a}	18.58a^{b}
Mean		82.51	19.37	4.54	3.94	3.37	17.01
CV (%)		13.72	11.74	13.85	8.42	16.70	10.11
LSD (5%)		9.1731	1.8435	0.5094	0.2688	0.4564	1.394

Yield and yield related parameters

The combined mean values of growth parameters of 9 processing tomato varieties evaluated at Adami TuluJido Kombolcha were shown in table 5. The variation with respect to marketable fruit yield, unmarketable fruit yield and total fruit yields were ranged from 319.79 to 477.6, 43.7 to 64.84 and 373.96 to 533.07 quintals, with mean values of 400.46, 53.92 and 454.38 quintals, coefficient of variation of 25.80, 34.25 and 24 respectively.

The maximum marketable yield in quintals were recorded in varieties Gelila(477.60) and Gelilema(441.15), whileSire (319.79) and Venus Vf1 (369.79) were recorded minimum marketable fruit yield. The highest total fruit yields in quintals were recorded in Gelila(533.07), Gelilema(484.90) and Melkasalsa (474.22), while the varieties Sire (373.96), Venus F1 (427.34) and Melkashola(446.72) were recorded the minimum total fruit yield in quintals per hectare.This result is in close agreement with the finding of Tesfa et al, 2016 who reported that mean total yield from 46.8 to 87.1 ton per ha for different hybrid tomato varieties.

Table 5: Combined mean of Yield parameters of processing tomato varieties tested over two locations (ATARC & Abosa) for two years (2018 and 2019)

S.N	Variety	**MFY**	**UnMFY**	**TFY**
1	Melkasalsa	409.38^{ab}	64.84^{a}	474.22^{ab}
2	Gelilema	441.15^{b}	43.7^{b}	484.90^{ab}
3	Melkashola	389.32^{bc}	57.40^{ab}	446.72^{abc}
4	Chali	418.23^{ab}	53.91^{ab}	472.14^{ab}
5	Cochoro	407.81^{ab}	46.87^{b}	454.69^{abc}
6	Sire	319.79^{c}	54.17^{ab}	373.96^{c}
7	Gelila	477.60^{a}	55.47^{ab}	533.07^{a}
8	Venus F1	369.79^{bc}	56.25^{ab}	427.34^{bc}
9	Roma Vf	371.09^{bc}	52.60^{ab}	422.40^{bc}
Mean		400.46	53.92	454.38
CV (%)		25.80	34.25	24.00
LSD (5%)		83.742	14.969	88.389

Chemical quality attributes

The combined mean values of quality attributes of processing tomato varieties tested at Adami TuluJido Kombolcha were shown in table 6. The variation with respect to pH (power of hydrogen), total soluble solids and titrable acids were ranged from 4.1 to 4.39, 3.62 to 4.21 and 5.45 to 8.5 with the mean values of 4.22, 3.82 and 6.77, coefficient of variation of 9.23, 10.36 and 15.86 respectively. The maximum pH was recorded in varieties Melkasalsa (4.39) and Gelilema (4.31), while the varieties Gelila(4.10) and Venus F1(4.13) recorded the minimum pH values. The average pH range for most tomato fruit lies between 4.3 and 4.4 (Jones, 2008). However there was no significant difference among the varieties by pH. The maximum total soluble solids were recorded in varieties Sire (4.21), Gelila(4.20) and Melkasalsa(4.02), while Venus Vf1(3.62), Gelilema(3.65) and Chali(3.72) were recorded the lower total soluble solids. It is in line with the finding of Fiseha (2014), who reported the total soluble solid ranges from 4.10 to 4.36. Similarly Tesfa *et al.*, 2016 reported the total soluble solids with the range from 3 to 4 for different hybrid tomato varieties. The maximum titrable acidity was recorded in varieties Melkasalsa (8.50), Gelila(7.82) and Sire (7.75), while the lowest titrable acidity was recorded in the varieties Gelilema (5.45), Chali (6.01) and Melkashola (6.25). Over all the varieties Gelila, Melkasalsa and Sire fulfills the quality standards for processing, however the yield and fruit size of Sire was very low as compared to all the others.

Table 6: Combined mean of Quality parameters of processing tomato varieties tested over two locations (ATARC & Abosa) for two years (2018 and 2019)

S.N	Variety	Chemical quality parameters		
		pH	**TSS**	**TA**
1	Melkasalsa	4.39[a]	4.02[ab]	8.50[a]
2	Gelilema	4.31[a]	3.65[c]	5.45[f]
3	Melkashola	4.25[a]	3.75[bc]	6.25[def]
4	Chali	4.23[a]	3.72[c]	6.01[def]
5	Cochoro	4.12[a]	3.90[bc]	6.68[cde]
6	Sire	4.20[a]	4.21[a]	7.75[b]
7	Gelila	4.10[a]	4.20[a]	7.82[ab]
8	Venus F1	4.13[a]	3.62[c]	7.12[bc]
9	Roma Vf	4.22[a]	3.82b[c]	6.77[cd]

Mean	**4.22**	**3.82**	**6.71**
CV (%)	**9.23**	**10.36**	**15.86**
LSD (5%)	**Ns**	**0.2874**	**0.8622**

Where: **pH**: potential acidity (power of Hydrogen), **TSS**: Total soluble solid (^{0}Brix), and **TA**: Titrable acidity

4. CONCLUSIONS AND RECOMMENDATIONS

Adami Tulu Jido Kombolcha is one of the districts in East Shoa zone of mid rift valley of Oromia where tomato is widely produced with limited knowledge on fresh market type and processing type tomato varieties. The current study was conducted to identify adaptable and most preferable processing tomato varieties with high yield and required qualities of 9 processing type tomato varieties. Data recorded for 14 characters were subjected to analysis of variance and the results showed the presence of significant differences (P≤0.01/0.05) among the tested varieties for almost all traits indicating the presence of variations among the tested 9processing tomato varieties.The mean performance of each varieties for different traits were obtained, most of the traits studied showed a wide range of variations in days to flowering (35-42.5), days to maturity (95.67-102.33), plant height at fruit harvest in centimeters (66.02-88.33), number of cluster per plants (15.97-24,17), Number of florets per clusters 3.73-5.07), number of fruits per clusters (3.53-4.43), number of primary branches (2.67-3.83), number of secondary branches (15.71-19.40), marketable fruit yield in quintals(319.79-477.60), unmarketable fruit yield in quintals (46.87-64.84), total fruit yield in quintals (373.96-533.07), pH 4.10-4.39), total soluble solids (3.62-4.21) and titrable acids (5.45-8.50).

The present study showed the presence of considerable variations among the evaluated varieties. Processing tomato varieties Gelila, Gelilema and Melkasalsa have given higher combined mean yield and quality over the other varieties across years and locations studied. Therefore, Gelila, Gelilema and Melkasalsa were identified and selected as the best for different merits to be demonstrated and popularized in the studied areas. Furthermore, production packages of these varieties should be studied so as to increase the production and productivity of processing tomato in mid rift valley thereby to justify food security of farming community and to supply for the tomato processing agro-industry in the industrial zone.

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5. REFERENCES

Birhanu K, Ketema T .2010. Fruit yield and quality of drip-irrigated tomato under deficit irrigation. Afr. J. Food, *Agric*, *Nutr. Dev.*

Fiseha Tadesse, 2014. Growth, Yield, and Quality Response of Tomato (*Lycopersicon Esculentum* Mill.) Varieties to Nitrogen fertilizer at Adami Tulu, Central Rift Valley, Ethiopia. An MSc Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia.

Jones, J. B. 2008. Tomato plant culture: in the field, greenhouse, and home garden (2nded.). CRC Press Tylor and Francis Group.

Lemma D. 2002. Tomatoes research experiences and production prospects. Research Report No. 43. Ethiopian Agricultural Research Organization, Addis Ababa, Ethiopia. Pp. 811.

Selamawit K. and Lemma D. 2008. Evaluation of tomato Genotypes for salt tolerance at seed germination. In: Ethiopian Horticulture Science Society (EHSS). 2008. Volume I. Proceedings of the first conference 23-24 March 2006, Addis Ababa, Ethiopia. pp. 99-102.

Tesfa B., Yosef A., Jibicho G. Gebeyehu W and Melkamu H.2016. Performance of Introduced Hybrid Tomato (Solanumlycopersicum Mill.) Cultivars in the Rift Valley, Ethiopia.PP 25-28

Evaluation of Improved Exotic Head Cabbage (*Brassica Oleracea* Var *Capitata* L.) Varieties at Adola Rede Areas, Southern Oromia, Ethiopia

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Abstract

Evaluation of exotic varieties of head cabbage was carried out to select the most adaptable and high yielding improved cultivars suitable for the study area. Field experiments were conducted during the 2017 and 2018 short rainy season at three locations with supplemental irrigation. Randomized Complete Block Design (RCBD) with three replications was used. Four improved exotic cabbage varieties: Olsen, Royal, *Monarch and DSA Copenhagen market were used for the study. A widely cultivated variety (Gloria) was included as check. Results revealed that for each seasons and locations days to head initiation, days to 80% maturity, plant height, number of expanded true leaves, diameter of head, untrimmed head mass, trimmed head mass, head yield with wrapper, head yield without wrapper and total head yield had significant differences (P < 0.05) among the varieties. But there was non-significance difference (P > 0.05) for mean of head height of the varieties. The maximum day to head initiation (72 days) was recorded for variety Gloria whereas lower (63.83, 64.25, 65.08 and 65.91 days) duration was observed for Olsen, Royal, DSA and Monarch varieties, respectively. The maximum days (100.5 days) to maturity was recorded for variety Gloria and the minimum days (93 days) were recorded for variety Olsen. The highest plant height (30.74 cm) was attained by Monarch variety and the minimum (21.93 cm) was recorded for Gloria variety. As combined analysis of improved varieties over locations and years revealed that the highest number of expanded true leaves (17) were obtained from Monarch variety whereas lower number of true leaves (8, 9, and 10) were recorded from Royal, Olsen and DSA varieties. Similarly the highest diameter of head (21.16 cm) was recorded for variety Royal. There was non-significant difference among varieties with respect to height of head. The maximum untrimmed head mass (4735 g) was recorded from variety Royal whereas the minimum (2180 g) was recorded from DSA Copenhagen variety. Regarding the trimmed economic head mass the maximum (3960 g) was recorded by Royal variety and the minimum (1310.3 g) was by DSA Copenhagen variety. The highest yield without wrapper (78.69 t ha-1) was recorded from Royal while the lowest yield without wrapper (53.39 t ha-1) was recorded from DSA Copenhagen variety. Similarly, the highest total yield (164.14 t ha-1) was attained from Royal variety and the lowest (129.49 t ha-1) was from DSA Copenhagen variety. Generally, as a conclusion and recommendation, for head cabbage growers in Adola Rede and similar agro ecologies improved varieties of Royal and Monarch were selected and recommended for better early maturing, maximum head yield, head shape, head size, and low incidence of loose heads.*

Key words: Improved cabbage varieties, growth, head yield, yield components

Introduction

Cabbage *(Brassica oleracea* L. var. *capitata)* is a member of the Brassicaceae (Mustard) family. This family includes broccoli, Brussels sprouts, cauliflower, kale, mustard (greens), and collards. Collectively, these crops are referred to as cole crops or crucifers. Cabbage and many of the cole crops are cultivated throughout the world for use fresh and in processed products. Nutritionally, one cup of raw cabbage contains 93 percent water and is a good source of dietary fiber as well as vitamins A and C. Worldwide, China is the leading producer and consumer of cabbage. In the United States, 80,000 acres of cabbage valued at almost $280 million was harvested in 1997 [1].

Cabbage (*Brassica oleraceae* var. *capitata*) is one of the most important leafy vegetables worldwide [6]. It originated in Northern Europe, the Baltic Sea coast [3] and the Mediterranean region [6], where it has been grown for more than 3000 years and is adapted to cool moist conditions [7, 8]. Cabbage is cultivated for its head, which consists of water (92.8%), protein (1 .4 mg), calcium (55.0 mg) and iron (0.8 mg); the leaves are eaten raw in salads or cooked. The optimum mean temperature for growth and quality head development is 1 5 - 1 8°C, with a minimum temperature of 4°C and a maximum of 24°C. Cabbage grows well on a range of soils with adequate moisture and fertility. It tolerates a soil pH range of 5.5 - 6.8 and it is a heavy feeder.

The importance of head cabbage in tropical and subtropical regions has increased considerably in recent decades. Recent estimates indicate Africa has about 100,000 ha planted to head cabbage [9]. Based on sales of commercial seed, at least 40,000 ha of white-headed cabbage is grown in Kenya, Uganda and Tanzania; 10,000 ha in Malawi, Zambia and Zimbabwe; 4000 ha in Ethiopia; and 3000 ha in Cameroon. Vegetables can be planted throughout the year provided there is reliable soil moisture.

Prior to cultivation and use as food, cabbage was mainly used for medicinal purposes. In addition to the fresh market, cabbage is now processed into Kraut, egg rolls and cole slaws and there is the potential for other specialty markets for the various types including red, savoy and mini cabbage. Cabbage is an excellent source of Vitamin C. In addition to containing some B vitamins, cabbage supplies some potassium and calcium to the diet. 250 mL of raw cabbage contains 21 kilocalories and cooked 58 [3].

Most farmers in the area (Adola and Shakiso) especially those having land along the river valleys grow cabbages. The importance of head cabbage in Guji areas has increased considerably in recent years. The cultivars grown so far have less acceptability by the consumers due different factors. Choice of inappropriate varieties has led to low yields due to diseases and related constraints. The area offers high potential for the production of such vegetables. Most of the farmers produce head cabbage widely using unknown variety and source. As a result the production is characterized by low yield. Therefore variety development and promoting is important in order to help farmers attain better yield and markets.

Materials and Methods

Description of the Study Sites

The field trials were conducted during 2017 and 2018 main cropping season at Shakiso Boke, Dole and Odabuta areas of Adola Rede district. The average climatic condition of the area is sub humid and moist condition, with relatively short growing season. Adola district falls in the agro-ecological classification of hot to warm sub-moist mid-lands. The experimental area is situated at an altitude of 1768 meters above sea level and is located 469 km south of Addis Ababa along the Hawassa road. The district was characterized by three agro-climatic zones, namely high land, mid land and low land with different coverage. The main rainy season is from May to October. The mean annual rain fall and temperature of the district are about 978 mm and 12-34 ^{0}c, respectively.

Treatments and Experimental Design

Field experiments were conducted in April main cropping season having relatively short rainy season. A randomized complete block design with three replications was used; each plot consisted of five rows and eight plants per row having spacing of 40cm*50cm on a plot size of 2.5 m* 2.8 m. Cabbage seedlings was raised on flat bed for four weeks and then transplanted to the sides of the ridges with 0.50 m space between plants. Cabbage varieties commercially available on the market Olsen, Royal, Monarch and DSA Copenhagen market were used for the study. A widely cultivated variety (Gloria) was included as check. Weeding was carried out manually and frequently to maintain weed free plots. Fertilizer NPS was applied during transplanting and also after transplanting. Urea was applied at the rate of 138 kg ha^{-1} in a split application at transplanting and 30 days after transplanting.

Data Management and Statistical Analysis

Measurements of plant height, number of expanded true leaves (leaves with a clearly visible petiole before head initiation), average head mass as untrimmed head mass and trimmed head mass, diameter of head, head height, days to 50% head initiation, days to 90 % maturity and total fresh marketable yield were recorded from samples of each treatments. At harvest, total mass (with and without wrapper leaves) was recorded. The diameter and height of the head was obtained by cutting the head longitudinally.

Statistical Analysis

Analysis of variance procedures were used on every measured parameter to determine the significance of differences between means of treatments using the SAS software for each parameters and separated using Least Significant Difference (LSD).Yield and yield related data were statistically analyzed using the Proc Glm function of SAS and means were compared using LSD at a probability level of 5 % [5].

Results and Discussions

Days to 80% head initiation, maturity, plant height, head diameter, head height, trimmed and untrimmed head mass, yield with wrapper and without wrapper and total yield of the plot were measured and converted to hectare basis.

Phenological and growth variables of cabbage

Results of combined ANOVA over locations and seasons indicated that different cultivars had significantly varying ($P < 0.05$) days to head initiation, days to 80% maturity, plant height and number of expanded true leaves (Table 1). The maximum days to head initiation (72) was attained from variety Gloria whereas lower durations for head initiation (63.83, 64.25, 65.08 and 65.91) were recorded from Olsen, Royal, DSA Copenhagen and Monarch varieties, respectively (Table 1). Similarly the maximum duration to maturity (100.5) was recorded from Gloria variety while the minimum (93) was recorded from Olsen variety. The highest plant height (30.74 cm) was observed for variety Monarch and the least (21.93 cm) was recorded from variety Gloria (Figure 1).

Yield component and yield variables of head cabbage

Results of combined ANOVA over locations and seasons also indicated that different cultivars had significantly ($P < 0.05$) varying diameter of head, untrimmed and trimmed head mass and yield of head cabbage (Table 2). On the other hand, the varieties showed non-significant ($p > 0.05$) variations for head height (Table 2). The longest head diameter (21.16 cm) was recorded from variety Royal while the rest of the varieties had lower head diameter (Table 2). These results suggest wide genetic variability among head cabbage cultivars and that environmental variables also influence the expression of crop growth parameters. This however, did not hold true for the height of the head. There was a highly significant variation ($p < 0.01$) among the cultivars for untrimmed and trimmed head mass. The maximum untrimmed head mass (4735 g) was recorded from variety Royal followed by Monarch (3309.2 g) variety whereas the lowest untrimmed head mass (2180 g) was recorded from DSA Copenhagen variety (Table 2). The highest trimmed economic head mass (3960 g) was likewise recorded from variety Royal and the least trimmed head mass was (1310.3 g) was recorded from DSA Copenhagen variety (Figure 2). Combined ANOVA also showed that the highest yield with wrapper (86.52 t ha^{-1}) was attained from variety Monarch whereas the lowest (63.71 t ha^{-1}) was recorded from variety DSA Copenhagen (Table 2). Similarly the maximum yield without wrapper (78.69 t ha^{-1}) was recorded from Royal variety followed by variety Monarch (68.84 t ha^{-1}) whereas the least (53.39 t ha^{-1}) was recorded from DSA Copenhagen variety (Figure 3). The highest total yield (164.14 t ha^{-1}) was recorded from variety Royal whereas the lowest (129.49 t ha^{-1}) was recorded from DSA Copenhagen variety. However Gloria and DSA Copenhagen varieties showed yield reduction, indicating their unsuitability for cultivation during the short rainy season. This is because the area is characterized by inconsistent rainfall and high temperatures that often reach 34 °C. The adaptation of Royal and Monarch to the short rainy season was evident in the head yields (Table 3).

Table 1. Mean value of varieties for different variables across locations and years

Treatments	DHI	DM	ETLV	PH
Olsen	63.83^{b}	93.58^{b}	9.41^{b}	25.44^{b}
Royal	64.25^{b}	98.50^{ab}	8.58^{b}	22.10^{cd}
Monarch	65.91^{b}	96.75^{ab}	17.08^{a}	30.74^{a}
DSA	65.08^{b}	96.58^{ab}	10^{b}	23.88^{bc}
Gloria	72.25^{a}	100.50^{a}	9.41^{b}	21.93^{d}
Mean	66.26	97.18	10.90	24.82
Lsd	4.08	6.86	1.63	1.93
CV (%)	7.52	8.63	18.33	9.52

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; LSD = Least Significant difference; NS= Not significant; CV= Coefficient of Variation; DHI=days to head initiation, DM=days to maturity, ETLV=average expanded leaves, PH=plant height

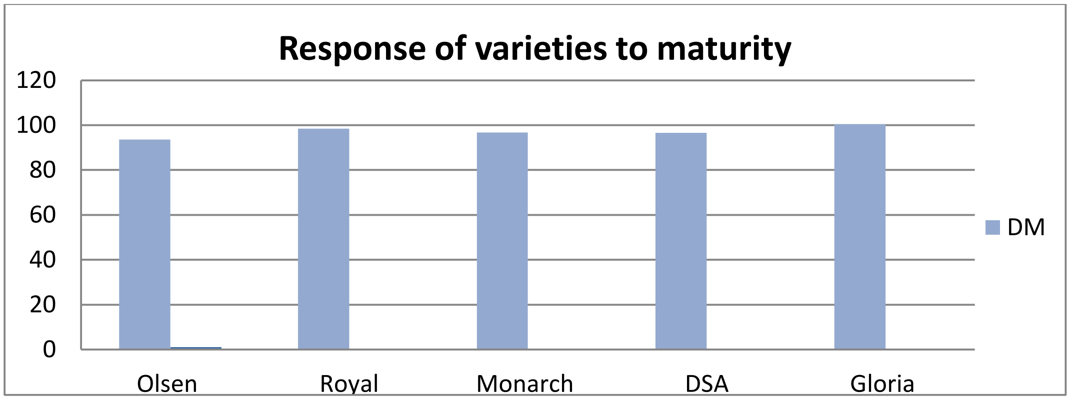

Figure 1. Response of varieties to days to maturity

The study showed that cabbage production in Adola areas and the cultivation of Royal and Monarch varieties evaluated during the short rainy season with supplemental irrigation could provide considerable maximum head yield.

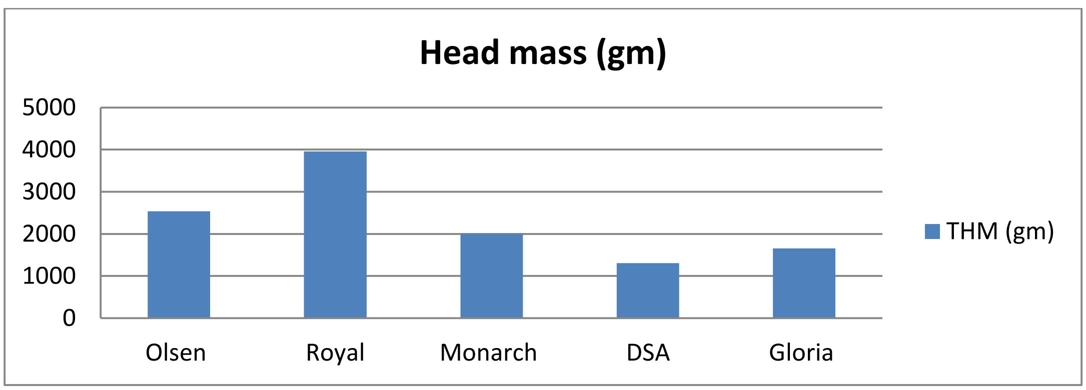

Figure 2. Response of varieties to average head weight

Table 2. Mean value of diameter of head, and height of head, untrimmed head mass, trimmed head mass.

Treatments	DH	HH	UTHM	THM
Olsen	18.91[b]	17.20	2746.7[bc]	2540[b]
Royal	21.16[a]	18.54	4735[a]	3960[a]
Monarch	18.88[b]	17.65	3309.2[b]	2007.4[c]
DSA	18.72[b]	17.63	2180[c]	1310.3[d]
Gloria	17.60[b]	16.38	2717.5[bc]	1658.1[cd]
Mean	19.06	17.48	3137.66	2295.16
Lsd	1.96	NS	594.88	483.95
CV (%)	12.57	15.90	23.17	25.77

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; LSD = Least Significant difference; NS= Not significant; CV= Coefficient of Variation; DH=diameter of head, HH=height of head, UTHM=untrimmed head mass, THM=trimmed head mass.

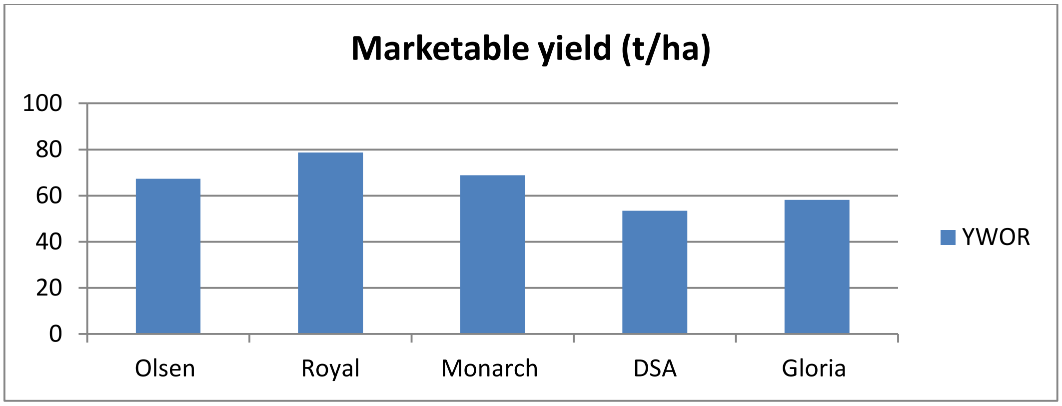

Figure 3. Response of varieties to yield without wrapper

Table 3. Mean value of yield with wrapper, yield without wrapper and total yield

Treatments	YWR	YWOR	TYLD
Olsen	73.94abc	67.36ab	141.31bc
Royal	85.44ab	78.69a	164.14a
Monarch	86.52a	68.84ab	155.37ab
DSA	63.71c	53.39c	117.11d
Gloria	71.36bc	58.13bc	129.49cd
Mean	76.19	65.28	141.48
Lsd	14.56	11.55	20.86
CV (%)	23.36	21.62	25.50

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; LSD = Least Significant difference; NS= Not significant; CV= Coefficient of Variation; YWR=yield with wrapper, YWOR=yield without wrapper, TYLD=total yield.

Summary and Conclusion

The importance of head cabbage in tropical and subtropical regions has increased considerably in recent decades. Lack of improved varieties and management recommendations call for introduction and adaptation studies of high yielding varieties with all agronomic management practices.

Generally results of the study showed that head cabbage varieties Royal and Monarch were found to be better adaptable than the rest of the varieties. Therefore as a recommendation, head cabbage growers at Adola Rede and similar agro-ecologies can grow head cabbage varieties of Royal and Monarch for early maturity, better head yield, good head shape, firmness, marketable head size and low incidence of loose heads.

References

[1] Alabama and Auburn University (1999). Guide to commercial cabbage production. Access at www.aces.edu.

[2] Haque KMF. 2006. Yield and nutritional quality of cabbage as affected by nitrogen and phosphorus fertilization. Bangladesh J Sci Ind Res.41:41-46.
[3] Monteiro A, Lunn T. (1998). Trends and perspectives of vegetable brassica breeding. World Conference on Horticultural Research. 17-20 June 1998. Rome, Italy.
[4] Mwasha A.M. (2000). Status of vegetable production in Tanzania In: Chada ML, Nono-Womdim R, Swai I, eds. Proceedings of the Second National Vegetable Research and Development Planning Workshop held at HORTI-Tengeru, Arusha, Tanzania, and 25-26 June 1998. AVRDC. pp. 22-27.
[5] Statistical Analytical System, (2003). SAS/STAT users Guide for Personal Computers Version 9.1.3: SAS-Institute. Cary, North Carolina.
[6] Talekar N.S. (2000). Chinese cabbage. Proceedings of the 1st International Symposium on Chinese Cabbages. AVRDC, Shanhua, Tainan, Taiwan. pp. 67-69.
[7] Thompson J.K. (2002). Yield evaluation of cabbage varieties. J. Agric. Technol., 5:15-19.
[8] Tindall H.D. (1993). Vegetables in the Tropics Macmillan International College. 3rd Edition, London, UK. pp. 354-356.
[9] Van der Vossen HAM, Seif A A. (2004). *Brassica oleracea* L. (headed cabbage) In: Grubben GJH, Denton OA, eds. PROTA 2: Vegetables/Légumes. [CD-Rom]. PROTA, Wageningen, Netherlands.
[10] Vural H, Esiyok D, Duman I. (2000). The culture of vegetables (Vegetable growing). Izmir, Turkey. PP: 440.

Adaptation trial of Market Types Common Bean(*Phaseolus Vulgaris* L.) Varieties in Eastern Hararghe Zone, Oromia

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Abstract

Common bean has tremendous importance in the country's economy interms of home consumption,export and soil fertility restoration. However,in Ethiopia.its improvement is highly hampered by diseases, insect pests, and prolonged drought. This calls for searching varieties that can withstand these stresses. Therefore, the experiment was conducted to identify high yielding, biotic and abiotic stress-resistant or tolerant varietiesthat are also high yielder and early maturing.The study was conducted at Fedis for two consecutive years of 2017 and 2018 during the rainy season. Analysis of variance revealed the presence of significant ($P \leq 0.05$) differences in seed yield and podsperplant among the cultivars. The maximum and minimum number of podsper plant of (20.22) and (11.33) were recorded for varieties Awash-2 and Awash Melkasa, respectively. The *highest grain yield of 1711kg/ha was recorded for variety Awash-2 and the least grain yield of (1410kg/ha) was for the SER125. Generally, Awash-2, KATB1, SAB736 and Awash-1which gave higher yield than the standard check interims of number of pods per plant and grain yield. Therefore, Awash-2, KATB1, SAB736 and Awash-1 were recommended for production in Eastern Hararghe and other areas with similar agro-ecology.*

Key words*: Common bean, early maturing, stress-resistance/tolerance*

Introduction

Common bean (*Phaseolus vulgaris* L.) is the most important pulse crops grown in central southern, eastern and Western lowland and mid altitudes of Ethiopia. It is grown predominantly in low land areasof altitudinal range 300-1100masl and some mid highland areas of altitudinal range 1400-2000masl. Besides, its use as a readily available source of protein for smallholders, it is also an important cash crop and export commodity that generatessignificant amount of foreign exchange for the country. It is predominantly grown for cash in the central rift valley, but in other parts, it is a major staple food supplementing the protein source for the poor farmers who cannot afford to buy other sources of protein such as animal products.

Common bean is mainly grown in Eastern, Southern, South Western and the Rift valley areas of Ethiopia (Habte E. *et al*., 2014).Nationally, area under common bean production is estimated at about 300-500 thousand hectares (IAR, 1995; EARO, 2001). However, according to the official statistical data of the country, common bean was grown on about 166 thousand hectares of land in 1999/2000 and ranked third next to horse bean and chick peas and the average common bean productivity was about 8 quintals per hectare(CSA, 2000). However, the experience from experimental plots indicates that yield level of up to 25-30 quintal per hectare can be attained (EARO, 2001). 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 (PABRA, 2014). It ranks third as an export commodity in Ethiopia, contributing about 9.5% of total export value from agriculture. It is often grown as cash crop by small scale farmers. The majority of common bean producers in Ethiopia are small scale farmers, and it is used as a major food legume in many parts of the country where it is consumed in different types of traditional dishes (Habtu A., *et al*., 1996).

Common bean seeds contain 20-25% proteins, much of which is made up of the storage protein phaseolin (Ma Y., and Bliss F.A, 1978). Phaseolin is a major determinant of both quantity and nutritional quality of proteins in bean seeds (Gepts P, 1984). In addition to this, it is also very important in providing fodder for livestock and it contributes to soil fertility improvement through atmospheric nitrogen fixation during the cropping season (Asfaw A, 2014). Common bean adds not only diversity to production systems on resource poor farmers' fields, but also it contributes to the stability of farming systems in Ethiopia (Asfaw A, 2014). Pulses covered 10.38% (about 2,671,843.040 tons) of the grain production. Out of this, common beans (red), and common beans (white) were planted to, 1.95% (about 244,049.94 ha) and 0.91% (about 113,249.95 ha) of the grain crop area, respectively. The production obtained from common bean (red) and common bean (white) were 1.43% (380,499.453 tons) and 0.60% (159,739.484 tons) of the grain production, respectively. Therefore the total area devoted for common bean crop production and the yield obtained in Ethiopia are 357,299.89 ha and 540,238.94 tons, respectively (CSA, 2016).

Even though the crop has tremendous importance in country's economy, such as for home consumption, soil fertility improvement etc., its improvement is highly challenged by diseases, insect pests, and prolonged drought in Ethiopia. In spite of this challenge, the crop is crucial primarily for home consumption, for foreign exchange earnings, soil fertility improvement by changing unavailable atmospheric nitrogen into available form and it has high protein content. The current study was initiated with the objective to identify high yielding, early maturing and stress (biotic and abiotic) resistant/tolerant common bean variety/ies that are adaptable to Eastern Hararghe areas among the varieties domestically released for different parts of the country.

Materials and Methods

The study was conducted at Fedis for two consecutive years of 2017 and 2018 during the rainy season. Important data like plant height, pods per plant, seed per pod, number of branches per plant and yielded were collected.Six common bean varieties with one standard check were evaluated. The collected data were subjected to statical analysis using softwares(SAS 2009 and GenStat 18th edition).

Results and discussion

Analysis of variance revealed the presence of significant ($P \leq 0.05$) difference in grain yield, and pods/plant among common bean varieties tested at Fedis. This indicated the presence of performance variation among the tested varieties for yield, which is supported by the earlier works of Negash(2006)Kefelegn (2012) and Rezene*et al*(2011) who noticed a large variation in yield performance among different bean varieties.The maximum and minimum number of pods/ plant of (20.22) and (11.33) were recorded from varieties Awash-2 and Awash melkasa, respectively (Table 1). In this study, days to maturity, and number of seeds/ pod was not significantly affected due to varieties (Table 1). The maximum and minimum number of seeds /pod of (4.88) and (3.50) were noted for the varieties Awash-2 and Awash melkasa, respectively (Table 1). The findings revealed that the maximum number of pods per plant and the highest number of seeds per pod resulted in the maximum grain yield of (1711kg/ ha) for the common bean variety Awash-2 which agree with the finding of Misgana M and Tadesse (2017)that stated the maximumnumber of pods per plant and the highest number of seeds per pod resulted in the maximum grain yield of (2.1478t/ha) for common bean variety Dinkinesh. In this experiment, grain yield of common bean was significantly different at ($P < 0.05$) (Table1) and affected by the tested varieties. This finding agrees with the previous findings reported by Fekadu (2013). The highest grain yield of 1711kg/ha was recorded for the variety Awash-2 and the least grain yield of (1410kg/ha) was noted for SER125.

Table-2. Combined mean of grain yield and yield related parameters over two year at Fedis station

Treatment	Days to maturity	Podsperplant	Seedsperpod	Grain yield(kg/ha)
Awash-1	84.67	13.66^{b}	3.39	1505^{ab}
Awash-2	85.50	20.22a	4.88	1711a
Awash-Melkasa	92.50	11.33b	3.50	1455b
KATB1	84.17	17.89a	4.22	1682a
SAB632	82.67	16.00ab	4.23	1485b
SAB736	87.17	18.22a	4.87	1602ab
SER125	84.67	13.17b	4.22	1410b
LSD (5%)	NS	4.50	NS	2.035
CV (%)	18.6	16.9	25.1	17.9

Recommendation

Analysis of variance showed that significant variations were recorded for Awash-2, KATB1, SAB736 and Awash-1which gave high yield than the standard check interims of number of pods per plant and grain yield. Therefore**,** Awash-2, KATB1, SAB736 and Awash-1were recommended for production under the agro-clamitic conditions of East Hararghe and other areaswith similar agro-ecologies.

References

Abuhay, T. and A. Teshale, 1995. Review of Tef Research in the Marginal Rainfall Areas of Ethiopia: Past and future Prospects. *In*: Proceeding of the 25th Anniversary of Nazareth Agricultural Research Center: 25 years of experience in lowland crops research, 20-23 September. Nazareth, Ethiopia.

Ma Y, Bliss FA (1978). Seed proteins of common bean. Crop Sci 17: 431–437.

Gepts P, Bliss FA (1984) Enhanced available methionine concentration associated with higher phaseolin levels in common bean seeds. Heor Appl Genet 69: 47–53.

Asfaw A, Blair MW (2014) Quantification of drought tolerance in Ethiopian common bean varieties. Agricultural Sciences 5: 124-139.

CSA (Central Statistics Agency of Ethiopia) (2016) Report on area and crop production of major crops for 2016 Meher season, 1: 125.

Habte E, Gebeyehu S, Tumsa S, Negash K (2014) Decentralized common bean seed production and delivery system. Melkassa agricultural research center, Ethiopian institute of agricultural research, Ethiopia.

Misgana M, Tadesse M. Performance Evaluation of Common Bean (Phaseolus vulgaris (L.)) Varieties at Benatsemay Woreda of South Omo Zone, SNNPR, Ethiopia. Agri Res & Tech: Open Access J. 2017; 12(3): 555846. DOI: 10.19080/ARTOAJ.2017.12.555846

AleligneKefyalew, 1990. Farm Surveys and Onfarm Research in Haricot Bean in the Middle Rift Valley of Ethiopia. Procs. of National Workshop held in Addis Ababa, 1-3.

AsnakewWoldeab, 1991. Soil Fertility and Management in the Dry land. pp.70-81, In: Procs. of the First National Workshop on Dry land Farming System in Ethiopia. 26-28 November. Nazareth, Ethiopia. *Adv. Environ. Biol., 3(3): 302-307, 2009* 307.

Central Agricultural Census Commission (CACC), 2002. Ethiopian Agricultural Sample Enumeration, 2001/2002: Report on the primary results of area, production and yield of temporary crops (*Meher*season private peasant holding) part I. Addis Ababa.

Fekadu G (2013) Assessment of Farmers' Criteria for Common Bean Variety Selection: The case of Umbullo Watershed in Sidama Zone of the Southern Region of Ethiopia. Ethiopian journal for research and innovation foresight 5(2): 4-13.

Habtu A, Sache I, Zadoks JC (1996) A survey of cropping practices and foliar diseases of common bean in ethiopia. Crop Protection 15: 179-186.

Kefelegn N (2012) Genotype x environment interaction of released common bean (Phaseolus vulgaris l.) varieties, in eastern Amhara region, Ethiopia. An MSc Hesis Presented to the School of Graduate Studies of Haramaya University.

Kidane Georgis, 1987. A Review of Haricot Bean Agronomy Research in the Semi-Arid Regions of Ethiopia. Procs. of National work shop held in Addis Ababa, l-3.

Negash K (2006) Studies on genetic divergence in common bean (Phaseolus vulgaris L.) introduction of Ethiopia. An MSc Hesis presented to the School of Graduate Studies of Addis Ababa University.

PABRA (Pan Africa Bean Research Alliance) (2014) Phase report and partnership in research for impact: case of common beans in Ethiopia. Nairobi, Kenya.

Rezene Y, Gebeyehu S, Zelleke H (2011) Genetic variation for drought resistance in small red seeded common bean genotypes. African Crop Science Journal 19: 303-311

Tadele, G.S. and GermewEticha, 1977. Haricot Bean Fertilizer Trial. pp: 87-88, In : IAR, Progress Report for 1981/82.

TamirieHawando, 1986. Increasing Agricultural Production in Ethiopia through improved soil water and crop management practices. 243-275.

TilahunMulatu and Teshome Regassa, 1987. Nazareth Mixed Farming Zone Diagnostic Survey Report, Shoa Region. Research Report No. 2. Institute of Agricultural Research, Department of Agricultural Economics, Addis Ababa.

Tolessa, D., B. Tesfa, N. Wakene, w. Tenaw, L. Minale, M. Tewodros, M. Burtukan and M. Waga, 2001. A Review of Fertilizer Management Research on Maize in Ethiopia. Enhancing the Contribution of Maize to Food Security in Ethiopia. *In* Proceedings of the Second National Maize Workshop of Ethiopia, 12-16, Addis

Agronomy

Effect of Cassava Intercropping with Legume Crops Followed by Sorghum on Growth, Yield and Yield Parameters of Cassava-Based Double Cropping System in Fedis and Babile District, Eastern Hareghe Zone

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Abstract

Some farmers of eastern Hareghe in the lowland area survive with food aid from government and different NGOs due to shortage of rainfall and prevalence of recurrent drought. In Hareghe, intercropping is a popular farming practice where most of farmers intercrop Chat with sorghum and groundnut in a growing season. The experiment was initated and conducted under rainfed conditions at Fedis Agricultural Research Center of Oromia Agricultural Research Institute (OARI), at Boko sub-site to determine the compatibility of crops in double cropping system and efficient land uses for the component crops. The experiment was conducted in two phases: cassava with legumes (soybean, haricot bean and cowpea) and cassava based sorghum varieties (Hormat, Gedo and Birhan) in one cropping season. The treatments were arranged as intercropping and sole cropping. A total of 7 treatments for preceding and 7 treatments for cassava-based succeeding treatments were arranged in Completely Randomized Block Design with three replications. Variety Kello was used for the experiment. The results revealed that there were significant (P < 0.05) differences for cassava average root weight, number of roots per plant, root diameter and root yield due to cassava-legumes intercropping. Soybean-cassava intercropping increased average root weight, root numbers and root enlargement of cassava by 39, 33.6 and 27.7 % as compared to cassava- cowpea intercropping. Cowpea intercropping in cassava significantly affected cassava root yield as compared to other legumes intercropping. Cassava-soybean intercropping was found to increase root yield by 41.7 and 21.3 % as compared to cassava-cowpea and cassava-haricot bean, respectively. Cassava-soybean intercropping improved land use efficiency by 16.4 and 19.3 % as compared to cassava-cowpea and cassava-haricot bean intercropping, respectively. Accordingly, sole stands could require 74, 40 and 46 % more land i.e. the mixture cropping gives 74, 40 and 46 % yield advantage, for soybean, haricot bean and cowpea, respectively as intercropped in cassava than the pure stand. Following the harvest of legumes, sorghum was sown as double crop for *additional yield advantage. Therefore, from this result, cassava-soybean intercropping following cassava-based early maturing sorghum was recommended for the study area and similar agro ecologies.*

Key words: *Cassava, Cowpea, Haricot bean, Intercropping, Sorghum, Soybean*

Introduction

Cassava (*Mahinot esculenta* Cratzy) is a perennial crop native to tropical America with its center of origin in north-eastern and central Brazil (Allem, 2002). It is one of the most important energy sources in many tropical countries (Cock, 1985). It is cultivated mainly for its enlarged starchy roots and one of the most important food staples in the tropics, where it is the fourth most important energy source (Alves, 2002). Its roots are the main source of calories to approximately 600 million people in Africa, Asia, Latin America and Oceania. Globally it ranks the sixth most important source of calories in the human diet (FAO, 1999). Given the crop's tolerance to poor soil and harsh climatic conditions, it is generally cultivated by small-scale farmers as a subsistence crop in a diverse range of agricultural and food systems. Roots can be left in the ground without harvesting for a long period of time, making it a useful crop as security against famine.

Cropping system aims at making efficient use of growth resources so that high and /or stable productivity can be achieved (Papendick *et al*., 1976; Okigbo, 1982). Multiple cropping is the most common traditional cropping system in tropical Africa. It provides the farmer with a variety of returns from the land, often increases the efficiency of resource utilization by combining variety of crops and reduces the risk of dependence on a single crop which may suffer from environmental or economic fluctuations. It also gives scope for increased labour use efficiency and provides early income (Prabhakar and Pillai, 1984).

Cropping system involving cassava is the most common throughout the humid and sub-humid regions of Africa. Cassava is well suited to intercropping with short duration crops because of its initial slow growth as well as its length of stay in the field (12 to 18 months). In some countrys of Africa, it is commonly grown in association with crops like maize which exploits the micro-environment early in the growing season and melon a low canopy crop that serves a dual purpose of protecting the soil against erosion and for weed control. The crops are selected on the basis of differences in growth habits and can be combined in either simple or complex mixtures. Complex mixtures consisting of three or more crop species are known to give higher financial and caloric returns (IITA, 1990). Cassava is often left scattered in the field to mature after the other crops have been harvested (Edje, 1982). However, it has been observed that the fields become very weedy and, while a few farmers carry out weeding after harvesting the early season crops, some plant a few stands of okra and other vegetables in the cassava farm in the late season (Isola. 1998). Cropping could possibly be intensified with appropriate plant arrangement on the field and by modifying cassava canopy in order to introduce a late season crop like cowpea and beans. This will not only increase the productivity of the land, but will also prevent weed from taking over. Results from Nyabyenda (1983) and Neuman (1984) showed that higher cassava yield was attained when intercropped with soybean and other beans than as a sole crop. Other reports, however, disagree with this finding (Mason *et al*., 1986; Balasubramanian and Sekayange, 1990; Keating *et al.*, 1982). However, legume crops as a source of rich protein are particularly important if incorporated into the diets of cassava-consuming populations.

Limited availability of additional land for crop production, decreased soil fertility and declining yield for major food crops have been cited as the major concerns for agriculture's ability to provide nourishment for the increasing population (Sinclair and Gardner, 1998). An advantage commonly claimed for intercropping systems is that, they offer greater yield stability than sole cropping (Mead and Willey, 1980). The system of intercropping is to a great extent practiced in various ways based on the extent of spatial arrangement of the crops on the field (Oguzor, 2007). For subsistence farmers, greater stability in the production of food crops in inter-cropping systems is particularly meaningful since this characteristic of the production system tends to better insure their sustainability and substantially reduces the risk of total crop loss.

In Harerghe, intercropping is well practiced and most farmers intercrop *Chat* with sorghum and groundnut, but single production per year. Some lowlands of eastern part of Harerghe survive with some grain support from government and different NGOs due to shortage of rainfall and prevalence of recurrent drought. To such areas it is important to adapt some technologies that can tolerate the agro-ecology and increase production per unit land, especially through intercropping and double cropping using early maturing crops by adjusting with the agro-ecology of the area. Therefore, intercropping of cassava with legumes crops following early maturing sorghum is an important method in increasing production per unit land area.

The limitations of these agricultural inputs and rising pressure on the supply of arable land of the Harerghe regions may lead to more intensive mono cropping of sorghum. Currently, farmers are developing different farming systems. The only way to increase agricultural production in the small or marginal units of farming is to increase the productivity per unit time and area. Cropping system and practices in turn could help combat pests. Understanding the association of disease intensity with cropping systems, crop combinations and management practices will help to identify the most important variables and focus efforts in developing an integrated and sustainable management packages. Therefore, this study was aimed to determine the compatibility of crops in double cropping system and efficient land use for the crops.

Materials and Method

Description of the Experimental Site

The study was conducted under rainfed conditions at Fedis Agricultural Research Center of Oromia Agricultural Research Institute (OARI) at Boko sub-site, which is located at the latitude of 9^{o} 07' north and longitude of 42^{o} 04' east, in the middle and lowland areas and at altitude of 1702 meter above sea level. The area is situated at the distance of about 24 km from Harar town in the southern direction.

The soil of the experimental site is black with surface soil texture of sand clay loam that contains 8.20% organic matter; 0.13 % total nitrogen, available phosphorus of 4.99 ppm, soil exchangeable potassium of 1.68 cmol(+)/kg and a pH value of 8.26 (Table 1). The experimental area is characterized as lowland climate. The mean rainfall is about 859.8 mm for the last ten years and has a bimodal distribution pattern with heavy rains received often from April to June and long and erratic rains from August to October. The mean maximum and minimum annual temperature are 27.7 and 11.3^{o}C, respectively for the last five years (Fedis Agriculture Research Center Metrological Station).

The total rainfall distribution during the cropping seasons were 883.8, 1022.2 and 728.7mm in the years 2016, 2017 and 2018, respectively (fig 1). The first rain set is from March to May and the second is from August to September. The preceding crops (Cassava + legumes) were planted in the first week of April during the onset of rainfall and cassava based intercropped legumes were harvested in the last week of July in the first two years. The succeeding crops (cassava + sorghum), sorghum was planted with the shower of rainfall, after one week of legumes harvested in the beginning of August in the first two years.

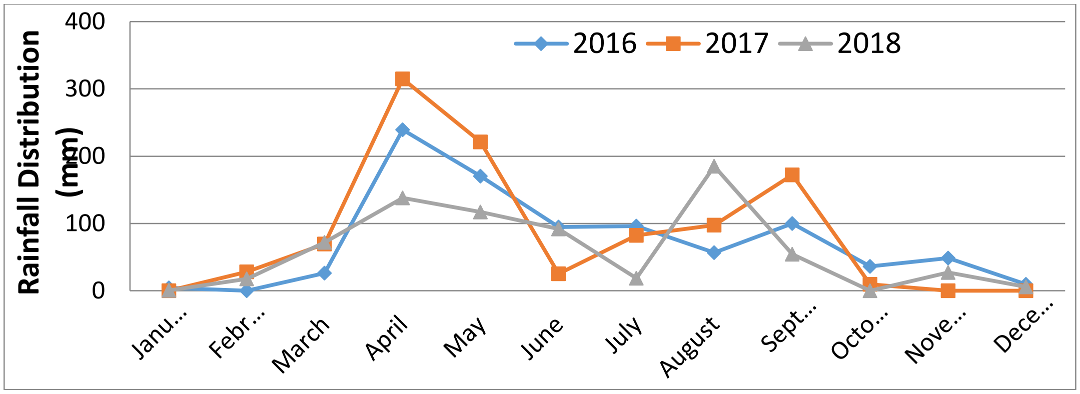

Figure 1. Rainfall distribution during the three years of cropping seasons

Experimental Treatments and Design

The experiment had two phases: intercropping cassava with legumes and Cassava-based intercropping of early maturing and striga tolerant sorghum varieties (Gedo, Hormat and Birhan). Field experiment was conducted using seven treatments for each phase and laid out in Randomized Complete Block Design in three replications. Cassava cuttings were planted at 1 m and 1.2 m between plants and rows, respectively. Two rows of legume crops were planted at 40 cm apart from cassava plant rows. Seeds of legumes (haricot bean, soy bean and cow pea) were planted at 10, 5 and 10 cm, respectively. Both crops were planted at a time during the first shower of rainfall. In the second phase after legumes were harvested, sorghum varieties were sawn between cassava in two rows as in the case of legumes. Sorghum was planted 30 cm apart from the two rows of cassava plants and 40 cm spacing between the two rows of sorghum.

The experiment had two cropping cycles.

First cropping cycle: Cassava + Legumes

1. Cassava +Haricot bean
2. Cassava + Soybean
3. Cassava + Cowpea
4. Sole Cassava
5. Sole Haricot bean
6. Sole Soybean
7. Sole Cowpea

Second cropping cycle: Cassava + sorghum

1. Cassava + Gedo
2. Cassava + Hormat
3. Cassava + Birhan
4. Sole Cassava
5. Sole Gedo
6. Sole Hormat
7. Sole Birhan

Data Management and Statistical Analysis

Data of each crop were taken randomly from taged plants per experimental unit (plots). The following data were collected for each crop.

Cassava data: Field stand count, plant height, number of branches, canopy diameter, root length, root diameter, number of root per plant, average root weight and root yield.

Legumes data: seed per pod, pod per plant, hundred seed weight and yield

Sorghum data: field stand count, plant height, panicle length, thousand seed weight, grain yield

Root yield of cassava was weighed using digital balance after harvest, and grain yield of haricot bean and sorghum were also weighed using ordinary balance. The collected data were subjected to ANOVA using GenSTAT Software version 15^{th} edition.

Land use efficiency was determined by calculating Land Equivalent Ratio (LER) using (Mead and Willey 1980) method. Land equivalent ratio of cassava is calculated as intercrop yield of cassava/sole stand yield of cassava and that of haricot bean and sorghum is calculated as intercrop yield of haricot bean and/or sorghum/sole stand yield of haricot bean and/or sorghum. The competitive value was determined by calculating the ratio of the individual LER's of the three crops.

Results and Discussions

Cassava-Legumes Intercropping on Root Yield Parameters

The experiment was conducted to evaluate cassava-based double cropping of different component crops. The results revealed that all growth and yield parameters of cassava were significantly ($P \leq 0.05$) affected due to intercropping except number of branches and root length. Parameters like average root weight, number of roots per plant and root diameter were statistically paired for the treatments, except for cassava-cowpea intercropping that was the lowest value for the parameters (Table 1). Cassava-cowpea intercropping significantly affected average root weight, root numbers and root diameter. Soybean-cassava intercropping increased average root weight, root numbers and root enlargement of cassava by 39, 33.6 and 27.7 % as compared to cassava-cowpea intercropping. Cassava-soybean intercropping increased root yield by 41.7**%** and 21.3**%** as compared to cassava-cowpea and cassava-haricot bean, respectively (Table 2).

Cassava-cowpea intercropping was significantly decreased cassava root yield as compared to other legumes intercrop as cowpea had greater leaf canopy that the other legumes and better competitor for resources as compared to other legumes. This study was in line with Polthanee, *et al*., (2007) who reported that cassava inter-cropped with cowpea decreased root yield by 11 to 17%.

Table 1. Effect of cassava based-legumes-sorghum double cropping on root yield parameters of cassava.

Treatments	ARW (g)	NBPP	NRPP	RD (cm)	RL(cm)
Cassava + Soybean	914.70a	3.13	9.80a	5.91a	46.43
Cassava + Haricot bean	816.50ab	2.60	9.40a	5.32ab	51.93
Cassava + Cowpea	557.80b	3.20	6.51b	4.27b	50.40
Sole Cassava	862.70ab	2.53	8.47a	5.61a	49.10
LSD(0.05)	294.700	NS	1.935	1.190	NS
CV (%)	18.7	23.5	11.3	11.3	14.9

ARW=Average Root Weight, NBPP=Number of Branches Per Plant, NRPP=Number of Roots Per Plant, RD=Root Diameter, RL=Root Length.

Cassava - Legumes Intercropping

The result indicated that pure stand of haricot bean was significantly different in grain yield from intercropping of the same crop. Pure stand of haricot bean provided grain yield of 33.5% over the intercrop of the same crop. However, the grain yield of legumes intercropped with cassava was additional benefit for the cassava production land. Intercropping of soybean and cowpea with cassava did not significantly affected grain yield of same crops as compared to pure stand.

Table 2. Effect of cassava-based legumes and sorghum double intercropping on root (tons ha^{-1}) and grain yields (kg ha^{-1}) of component crops over the two years.

		Preceding crop	Succeeding crop
Treatments	Cassava Root yield	Legumes Grain yield	Sorghum grain yield
Cassava + Soybean + Hormat	51.36^{a}	1618^{ab}	804^{b}
Cassava + Cowpea + Birhan	29.94^{c}	1446^{b}	882^{b}
Cassava + Haricot bean + Gedo	40.40^{b}	1406^{b}	820^{b}
Sole Cassava	54.28^{a}	--	--
Sole Haricot bean	--	2114^{a}	--
Sole Soybean	--	2018^{ab}	--
Sole Cowpea	--	1589^{ab}	--
Sole Gedo	--	--	1292^{a}
Sole Hormat	--	--	1059^{ab}
Sole Birhan	--	--	1034^{ab}
LSD (0.05)	9.5	453	254.1
CV(%)	17.8	26.5	25.7

Cassava based-Sorghum Intercropping

In cassava based double cropping, sorghum varieties were followed by legumes and significant differences were observed between pure stand and intercrops. Pure stand of Gedo sorghum variety was significantly different from intercrop of the same crop for grain yield. However, the yield of sorghum varieties intercropped with cassava was low; it might be the competition of cassava with sorghum for moisture and or soil nutrients because of the shortage of rainfall distribution (241.8mm and 279.7mm, total rainfall for four months of sorghum growing life) in 2016 and 2017 cropping season, respectively. Sorghum yield was declined due to shortage of rainfall after September in both years in 2016 and 2017. However, the intercrops were significantly efficient in land use economy. In other way, aboveground sorghum stalk was also used for cattle feed as farmers' of Harerghe need different forage crops for fattening.

Land Equivalent Ratio (LER)

The land area and yield advantage obtained due to mixed cropping was calculated as land equivalent ratio (LER). This study showed that intercropping legumes with cassava recorded land equivalent ratio of more than 1 and was beneficial in land productivity as compared to pure stand. Accordingly, pure stands could required 74, 40 and 46 % more land i.e. the mixture cropping gives 76, 51 and 15% yield advantage for soybean, haricot bean and cowpea, respectively intercropped in cassava than pure stand of these crops. Cassava-soybean intercropping improved land use efficiency by 16.4 and 19.3 % as compared to cassava-cowpea and cassava-haricot bean intercropping, respectively. Intercropping led to greater LER compared with sole cropping. Despite individual yields of component crops being lower under intercropping compared with sole cropping, the overall land productivity was greater under intercropping. Similar results have been reported across diverse environments and cropping systems (Dapaah *et al*., 2003; Okonji *et al*., 2007; Ennin and Dapaah, 2008).

Sorghum was cassava-based double cropped following legume crops. Intercropping cassava based double cropping was advantageous than pure stand of cassava. Sorghum grain yield was also additional benefit as it was intercropped in cassava following the legume crops. The result showed that sorghum intercropping in cassava following legume crops was advisable. Because sorghum benefited additional income from the bare space in cassava and even used as forage.

Table 3. Land equivalent ratio of legume crops and cassava intercropped in the first cropping cycle

Legumes	**Sole crop**	**Intercrop**	**Partial LER_L**	**Partial LER_C**	**LER**
Soybean	2018	1618	0.802	0.946	1.748
Haricot bean	2114	1406	0.665	0.744	1.409
Cowpea	1589	1446	0.910	0.551	1.461

LER_L= Land Equivalent Ratio of Legumes, LER_C = Land Equivalent Ratio of Cassava

Table 4. Land equivalent ratio of sorghum varieties and cassava intercropped in the second cropping cycle

Sorghum	Sole crop	Intercrop	Partial LER_S	Partial LER_C	LER
Hormat	1058.5	803.7	0.759	0.946	1.705
Gedo	1292.3	820	0.634	0.744	1.378
Birhan	1033.8	881.5	0.852	0.551	1.403

LER_S= Land Equivalent Ratio of Sorghum, LER_C = Land Equivalent Ratio of Cassava

Soil Fertility Improvement

Mixture cropping lead to the competition of moisture and nutrients in the soil among the crops. However, cropping of non-nitrogen fixing crops with nitrogen fixing legume crops can improve soil fertility. The highest Organic matter and total nitrogen was recorded for the pure stand plot of cassava followed by cassava-soybean intercropping. Accordingly, the soil of these two plots had good structural conditions and high structural stability (Emerson, 1991) that might increased root yield of cassava. According to this study the highest competitor for nutrients was cowpea intercropped in cassava following haricot bean. This result was in line with the study of Ogola *et al* (2013) who reported that cassava-cowpea intercropping was better competitor for resources compared as to other legumes. The phosphorous was very low across all plots according to the range of Holford and Cullis (1985) and high exchangeable potassium (Abbott, 1989).

Table 5. Plots based soil chemical analysis

S/N	Sampling plots	EC	OM	pH	TN	Avail. P	Exch. K
1	Cassava + Soybean	0.17	4.01	7.10	0.24	2.72	129.00
2	Cassava + Haricot bean	0.14	3.01	8.30	0.15	4.52	125.50
3	Cassava + Cowpea	0.19	2.53	8.15	0.13	9.00	123.00
4	Sole Cassava	0.17	4.37	8.18	0.25	5.52	129.50
5	Sole Soybean	0.14	4.18	8.30	0.16	1.08	125.00
6	Sole Haricot bean	0.15	3.82	8.10	0.17	1.28	127.00
7	Sole Cowpea	0.15	2.73	7.88	0.13	1.72	127.00

pH (soil to water ratio 1:25) by pH meter, EC (soil to water ratio 1:25) by electro conductivity meter, OM(Organic Matter by %), Exch. K (cmol (+) kg^{-1} soil), Avail. P (mg kg^{-1} soil), TN (Total Nitrogen by %).

Conclusion and Recommendation

Incorporation of grain legumes into the cassava-based cropping systems could enhance overall productivity of the systems in this dry environment of east Harerghe zone. In this study, soybean intercropped with cassava did not affect the root yield of cassava. Intercropping soybean in cassava advanced about 74% yield advantage, that means the pure stand could required 74% more land as compared to the mixture. Cassava also did not significantly affected grain yield of soybean intercropped in cassava as compared to pure stand of soybean. Because of the long duration of cassava roots maturity, drought and disease problems, intercropping grain and legumes in cassava should be developed. Producing cassava for dual-purpose as root yields and hay offers a good source of fodder for dairy cows. Cassava tuber is very low in protein content and inclusion of a pulse crop is quite significant from the point of view of balanced nutrition in Hararghe. Therefore, from this result, cassava-soybean intercropping following early maturing sorghum was recommended for the study area and similar agro- ecologies.

REFERENCES

Abbott, T. S. (Ed.) (1989). BCRI soil testing methods and interpretation. NSW Agriculture and Fisheries, Rydalmere, NSW.

Allem, A.C. 2002. The origin and taxonomy of cassava. *In*: R.J. Hillocks, M.J. Boulder (Eds.). CO, USA, p. 191.

Alves, A.A.A. 2002. Cassava botany and physiology. *In*: R.J. Hillock, J.M. Thresh, A.C. Bellotti (Eds). Cassava: Biology, Production and Utilization, CABI International Oxford, pp. 67-89.

Balasubramanian, V. and Sekayange, L. 1990. Area harvest equivalency ratio for measuring efficiency in multi-season intercropping. *Journal of Agronomy,* 82: 519-522.

Cock, J.H. 1985. Cassava: New potential for a neglected crop. West view Press, R.J. Hillock, J.M. Thresh, A.C. Bellotti (Eds). Cassava: Biology, Production and Utilization, CABI International, Oxford, pp. 1-16.

Dapaah, H.K., Asafu-Agyei, J.N., Ennin, S.A., Yamoah, C., 2003. Yield stability of cassava, maize, soya bean and cowpea intercrops. J. Agric. Sci. 140, 73–82.

Edje, O.T. 1982. Comparative development and yield and other agronomic characteristics of maize and groundnut in monoculture and association. *In*: Proceedings of the 2nd symposium on intercropping in semi-arid areas. Keswani, C. I. and Ndurguru, B.J. (eds), PP. 401. Morongoro, Tanzania.

Emerson, W. W. (1991). Structural decline of soil, assessment and prevention. *Australian Journal of Soil Research* 29, 905–922.

Ennin, S.A., Dapaah, H.K., 2008. Legumes in sustainable maize and cassava cropping systems in Ghana. Agric. Food Sci. J. Ghana 7, 519–540.

Food and Agricultural Organization (FAO). 1999. Crops and products and domain. Available online at: www.apps.fao.org/lim500/nph-wrap.pl?FS.

Holford, I. C. R., and Cullis, B. R.1985. Effects of phosphate buffer capacity on yield response curvature and fertiliser requirements of wheat in relation to soil phosphate tests. *Australian Journal of Soil Research* **23**, 417–427.

IITA. 1990. Cassava in Tropical Africa. A References Manual International Institute of Tropical Agriculture. Ibadan, Nigeria, 176 PP.

Isola. O.T. 1998. Effects of cassava planting patterns, pruning regimes and fertilizers on growth and yield of cassava/maize/melon and relayed cowpea. A PhD Thesis. Department of Agronomy, University of Ibadan, Nigeria: 189 pp.

Keating, B.A., Evenson, J.P., and Fukai, S. 1982. Environmental effects on growth and development of cassava *(Manihot esculenta* Crantz). III. Assimilated distribution and storage organ yield. *Field Crops Res.* 5: 293-303.

Mead, R. and Willey, R.W. 1980. The concept of a ‘land equivalent ratio’ and advantages in yield from intercropping. Experimental Agriculture, 16, 217 – 218.

Mason, S.C., Leihner, D.E., and Vorst, J.J. 1986. Cassava with cowpea; and cassava with peanut intercropping. I. Yield and land use efficiency. *Journal of Agronomy*. 78:43-46.

Neumann, I.F. 1984. La promotion des cultures associees au projet. *Etudes et Experiences,* No. 4: 80 pp.

Nyabyenda, P. 1983. Association de patate douce et du manioc avec d'autrea cultures. In *Culture et Selection du Manioc et de Patate Douce au Rwanda, 1983,* Ndamage, G. *et al.,* eds. Compterendu, Rwanda, Institut des Sciences Agronomiques du Rwanda, pp. 66-67.

Ogola , .B. O., Mathews , C. and Magongwa, S.M. 2013. The productivity of cassava - legume intercropping system in a dry environment in Nelspruit, South Africa. African Crop Science Conference Proceedings, Vol. 11. pp. 61 - 65.
Oguzor, N.S. 2007. Effect of planting methods on growth of cassava. Research Journals of Biological Sciences 2: 590-592.
Okigbo, B.N. 1982. Shifting cultivation in tropical Africa: Definition and Description. In: Proceedingof International Workshop on shifting cultivation. Bunting, A.H. and Bunting. E.(eds). PP: 18 – 36. FAO, Rome.
Okonji, C.J., Okeleye, K.A., Olowe, V.I.O. & Ajayi, E.O. 2007. Potentials of intercropping rice (*Orysa sativa* L.) and cassava (*Manihot esculent*a Crantz.) of different morphotypes in the transition zone of South West Nigeria. *International* Journal of Agricultural Research **2 (5),** 476-482.
Papendick, R.I, Sanchez, P.A., Triplett, G.B. and Stelly, M. 1976. Multiple cropping. ASA, Special publication Madison, Wisconsin, USA, 376 PP.
Polthanee, A., Wanapat, S., Wanapat, M. and Wachirapokorn, C. 2007. Cassava-Legumes inter-cropping: A potential food-feed system for dairy farmers. Use of Cassava as Animal Feed, *Khon Kaen University, Thailand.* http://www.mekarn.org/procKK/polt.htm
Prabhakar, M. and Pillai, N.G. 1984. Multiple cropping systems with tuber crops. *Indian Farming*, 33: 25 - 28
Sinclair, T.R. and Gardner, F.P. 1998. Principles of ecology in plant production. CAB ternational, Wallingford, UK.

Effects of Seed Rate, Row Spacing and Phosphorous fertilizer on yield and yield components of fenugreek (*Trigonella foenum-graecum L.)* in Bale mid lands, Oromia

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ABSTRACT

Soil nutrient depletion and poor agronomic practices are the major production constraints of fenugreek in mid-land of Bale Zone in Oromia. Therefore, a field experiment was conducted with the objectives of assessing the effect of phosphorous fertilizer rates, seed rates and row spacing on yield components and seed yield of fenugreek. The treatments consisted of factorial combinations of four levels of P_2O_5 *fertilizer application (75, 90, 105 and 120 kg* P_2O_5 ha^{-1}*), three seed rates (25, 30, and 35 kg* $ha^{-1)}$ *and three row spacing (20, 25, and 30 cm) in Randomized Complete Block Design (RCBD) with three replications. The main effects of phosphorus application significantly affected days to 50% flowering, days to 90% physiological maturity, number of pod per plant, above ground dry biomass and harvest index, while plant height was affected by seed rate and row spacing. The shortest (54.43) days to 50% flowering and days to 90% physiological maturity (117.7) were recorded from phosphorus application at 120 kg* P_2O_5 ha^{-1}*rate. The highest number of pod per plant (14.49) and harvest index (26.82%) were obtained from (120, 105 and 25, 35) kg* P_2O_5 ha^{-1}*and kg* ha^{-1} *seed rate, respectively. The* *tallest plant height (44.18 cm) was recorded from 25 kg ha^{-1} seed rate and 30 cm row spacing. The highest biomass yields (7550, 6661 and 6561 kg ha^{-1}) were obtained from 120 kg P_2O_5 ha^{-1}, 25 kg ha^{-1} seed rate and 25 cm row spacing, respectively. The interaction of P_2O_5 fertilizer, seed rate and row spacing significantly affect number of primary branches and seed yield while days to 90% physiological maturity and number seed per pod did not affected by P_2O_5 fertilizer, seed rate and row spacing nor by their interaction. The highest number of primary branches per plant (3.95) was recorded from 90 kg ha^{-1} P_2O_5 fertilizer, 25 kg ha^{-1} seed rate and 25 cm row spacing while the highest seed yield (1966 kg ha^{-1}) was obtained from 120 kg P_2O_5 fertilizer ha^{-1}, 25 kg ha^{-1} seed rate and 25 cm row spacing. The partial budget analysis also revealed that the highest net return (39164.17 Birr ha^{-1}) with MRR 10971.43% was obtained from application of 120 kg P_2O_5 ha^{-1} treated under 25 cm row spacing and 25 kg ha^{-1} seed rate. Based on the result, it can be tentatively concluded that 120 kg P_2O_5 ha^{-1}coupled with 25 kg ha^{-1} seed rate and 25 cm row spacing to be appropriate for fenugreek production in study areas.*

Key words: fenugreek, seed rate, row spacing, seed yield, Phosphorus

INTRODUCTION

Fenugreek (*Trigonella foenum-graecum* L.) belongs to the genus Trigonella and family Fabaceae. The genus consists of approximately 70 species that are annuals and native to Southern Europe (Engles *et al*., 1991). In Ethiopia, fenugreek is consumed by nursing mothers, who consume large quantities of pulses to maintain the supply of breast milk (Smart, 1976). There is a large genetic diversity of the fenugreek in Ethiopia (Feysal, 2006). Asfaw *et al.* (1981) reported that, fenugreek is found in nearly every market in Ethiopia and has been cultivated in Ethiopia since ancient times for use as a food, spices and medicinal purpose. In Ethiopia, fenugreek-growing regions are the high plateaus (1800-2300 m a.s.l.) characterized by subtropical climate of wet and dry seasons (Westphal, 1974). Fenugreek is grown on wide range of soils but flourishes on well drained loams or sandy loam.

Plant density varies according to the cultivar, yield capacity of the soil, irrigation condition and cultivation objectives. Optimum row spacing and seed rate play an important role in contributing to the high yield, because, thick plant population do not get proper light for photosynthesis and can easily be attacked by diseases and other pests on the other hand, very small population will also reduce the yield. Fenugreek is very important spice crop but the productivity of this crop is very low. Not only for maximizing the productivity but also for securing the highest net returns from a unit area, maintaining optimum plant population per unit area, which depends on best possible fertilizer, seed rate and spacing, is considered very essential (Miah*et al*., 1990). However, very little research work has been done on P_2O_5 fertilizer, seed rate and spacing of fenugreek. Hence, there is a considerable scope of increasing the productivity of this commercial crop by adopting the improved management practices along with optimum seed rate and spacing. Therefore, the objectives of this study were:

i) To assess the effects of seed rate, row spacing and P fertilizer rates on seed yield and yield components and of fenugreek; and
ii) To identify economically feasible seed rate, row spacing and P fertilizer for fenugreek production.

MATERIALS AND METHODS

2.1. Description of Study area: the experiment was conducted at Ginir and Goro during 'Bona' main cropping season under rain fed condition for three years (2015-2017). Ginir is located 519 km away from Addis Ababa to South eastern, 86 km away from the zonal capital town, Robe. It is located at 07^{o} 15′ N latitude and 40° 66′ E longitude at 1972 m above sea level (Wubishet *et al.*, 2016). Goro is located in Bale zone at $7^{0}8$'N and $40^{0}11$' E, at 2396 meter above sea level (m.a.sl) and 473 km Southeast of Addis Ababa. It receives an annual average rain fall of 325.78 mm during the Bona cropping season. Both areas have bimodal rainfall patterns. Based on this, there are two separate crop growing seasons locally called *bona* and *gana*. The main season *bona* extends from September to November and *gana* from March to May. The soil type for both area is *Vertiso*ls. The major crops grown widely in the area are cereals (wheat, barley, maize and *tef*) pulses (chickpea, field pea, faba bean, and lentil), seed spices (black cumin, coriander and fenugreek) and vegetables (onion, garlic, potato and tomato) under rain fed and irrigation.

2.2. Treatments and Experimental Design

The treatments consisted of factorial combination of four P_2O_5 fertilizer rates (75, 90, 105 and 120 kg ha^{-1}), three seed rates (25, 30 and 35 kg ha^{-1}) and three row spacing (20, 25 and 30 cm) in factorial combinations. The experiment was laid out in a randomized complete block design in three replications. The fenugreek variety Ebisa which was released by Sinana Agricultural Research Centre (SARC) in 2006 was used as planting material while TSP is used as the source of fertilizer.

2.3. Experimental Procedure and Field Management

The experimental field was ploughed and disked by tractor and pulverized to a fine by hand digging. Blocking and the required number of rows were marked in each plot according to the spacing proposed and rows were made to plant the seeds. The gross plot size of 1.2 m × 2 m (2.4

m^2) which contains four rows and the seeds were seeded at required spacing. The two middle rows were used for data collection. Weeding and other agronomic practices were applied as required by the crop.

2.4. Data Collected and Measurement

2.4.1. Crop phenology and growth parameters

Days to 50% of flowering (DF): it was recorded as the number of days from date of emergence to the appearance of first flower in 50% of the plants based on visual observation.

Days to 90% maturity (DM): days to maturity was recorded by counting days from emergence to days on which about 90% of the plant on plot attained physiological maturity (leaves and capsules turned to yellowish-green colour) based on visual observation.

Plant height (PH): Height of five randomly taken plants during physiological maturity period from each net plot was measured from ground to top of the plant by centimeters (cm).

Number of primary branches per plants: the number of primary branches in five randomly selected pre tagged plants was recorded at physiological maturity and their average was expressed as number of primary branches per plant.

2.4.2. Yield components and yield

Number of pod per plant: Number of pods was counted on five randomly taken plants from each of the net plot at harvest and the mean was expressed as number of pod per plant.

Number of seeds per pod: Total number of pods from five randomly taken plants was threshed and number of seeds was counted and total number of seeds was divided by total number of pods to compute average number of seeds per pod.

Aboveground dry biomass yield (kg ha^{-1}): At physiological maturity, plants from the central two rows of net plot size 0.6 x 2 m (1.2 m^2) were manually harvested close to the ground surface. The harvested plants were sun-dried in an open air, weighed to determine above ground plant biomass yield.

Seed yield: The central two rows were harvested and threshed to determine seed yield and the yield was adjusted to moisture level of 10% and yield per plot was converted to per hectare.

Harvest index: Harvest index was recorded as the ratio of dry seed yield to the aboveground biomass yield per plot.

2.5. Statistical Data Analysis

All crop data collected were subjected to analysis of variance (ANOVA) procedure using GenStat 16th edition software (Gen Stat, 2013). Comparisons among treatment means with significant difference for measured characters were done by using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

2.6. Economic Analysis

Yield from experimental plots was adjusted downward by 10% for management difference, to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. Accordingly, the mean seed yields for the treatments were subjected to a discrete economic analysis using the procedure recommended by CIMMYT (1988). Total variable cost (TVC) (ETB ha^{-1}) was calculated by summing up the costs that vary, including the cost of TSP, seed rate, row planting and the application costs of TSP. Based on partial budget procedure described by CIMMYT (1998), the variable costs including the TSP fertilizer price (39 ETB kg^{-1}), fenugreek seed (25 ETB kg^{-1}) and Labor cost involved for application of TSP fertilizer (4 persons ha^{-1} for 75 and 90 kg P_2O_5 ha^{-1}, 5 persons ha^{-1} for 105 and 120 kg P_2O_5 ha^{-1} each 35 ETB day^{-1}), for row planting (4 persons ha^{-1} for 20 x 10 cm), (3 persons ha^{-1} for 25 x 10 cm) and (2 persons ha^{-1} for 30 x 10 cm) and for seeding (3 persons ha^{-1} for 25 kg), (4 persons ha^{-1} for 30 kg) and (5 persons ha^{-1} for 35 kg) each 35 ETB day^{-1}) for each treatment was recorded and used also for this analysis. The costs of other inputs and production practices such as labor cost for land preparation, planting, weeding, harvesting and threshing were considered the same for all treatments or plots.

RESULTS AND DISCUSSION

3.1. Crop phenology and Growth Parameters

3.1.1. Days to 50% flowering

Number of days to 50% flowering was highly significantly ($p<0.01$) affected by the main effects of P_20_5 fertilizer, while, the main effects of seed rate, row spacing and the interaction of P_2O_5 fertilizer, row spacing and seed rate were not influenced this parameter. Increasing the rate of P_2O_5 fertilizer from nil to 120 kg ha^{-1} significantly decreased the number of days required to reach 50% flowering rate from 55.57 days to 54.43 days (Table 1).The decrease in days to flowering at the highest P_2O_5 fertilizer might be due to the fact that phosphorus enhances reproductive phase through fastened flowering. In line with this result, Gifole *et al*. (2011)

reported that phosphorus application to haricot bean significantly reduced days to flowering. Similarly, Acharya *et al*. (2007) reported that P is important for flowering and seed formation and fastening crop maturity.

3.1.2. Days to 90% physiological maturity

The analysis of variance showed that main effect of P_2O_5 fertilizer was highly significantly ($p< 0.01$) influenced the number of days required to reach physiological maturity. However, significant variation was not observed due to the seed rate, row spacing, two and three way interactions. Increasing the rate of P_2O_5 fertilizer significantly decreased the duration required to reach physiological maturity. Thus, plants with low application of the P_2O_5 fertilizer required the longest number of days (117.7 days) to reach physiological maturity, whereas those treated with the highest rate of P_2O_5 fertilizer (120 kg ha^{-1}) required the lowest days (112.1 days) to reach physiological maturity (Table 1). The decreased number of days required to reach physiological maturity in response to increased rates of P_2O_5 fertilizer may be attributed to the enhanced availability of the nutrient in the soil and its increased uptake by the fenugreek plants, which might have resulted in a more luxurious vegetative growth that resulted in delayed maturity. This result is in line with that of Abera (2015), who reported that days to 90% physiological maturity of chickpea was highly significantly ($p<0.01$) affected by application of P fertilizer rate, where, the longest time to maturity (114 days) was recorded for the application of 20 kg P_2O_5 ha^{-1}. Similar effects were also reported earlier where inoculation and P application delayed maturity time of common bean (Buttery *et al.*, 1987) and chickpea (Gan *et al.*, 2009).

3.1.3. Plant height

The analysis of variance showed that the main effect of row spacing was highly significant ($p<0.01$) on plant height. Similarly, significant variation ($p<0.05$) was observed due to seed rate. However, the interaction between P_2O_5 fertilizer, row spacing and seed rate did not significantly affect this parameter (Table 1). The highest plant height (44.18cm) and (43.65 cm) were recorded from row spacing of 30 cm and seed rate of 25 kg ha^{-1}, respectively while the lowest plant height (41.41 cm) and (42.17 cm) were recorded from 20 cm row spacing and 35 kg ha^{-1} seed rate, respectively. Plant height increased with increasing row spacing. On the other hand, plant height decreased assed rate increasing. This might be due to intra-specific competition for the sunlight resulting in shorter plants. This trend explains that as the number of plants increased in a given area, the competition among the plants for nutrients uptake and sunlight interception also increases. Similarly, Baswana and Pandita (1989) reported that plant height decreased with increased row spacing in fenugreek. Singh et al. (2005) reported higher plant heights in 22.5 cm row spacing while Halesh et al. (2000) and Gowda *et al*. (2006) obtained the highest plant heights from the 30 cm row spacing for fenugreek. The sparsely sown crop spreads more than the closely spaced which tends to grow in up right direction (Singh *et al*., 2012).Moniruzzaman *et al*. (2013) reported the plant height and number of leaves/plant was found to be the highest in lower seed rate 30 kg ha^{-1} (19.34 cm) and lower in the maximum seed rate 50 kg ha^{-1} (19.16 cm) in coriander.

Table 1. Main effects of P_2O_5fertilizer, seed rate and row spacingon days to 50% flowering, days to 90% maturity, and plant height of fenugreek

Treatment	Days to 50% flowering	Days to 90% maturity	Plant Height
Rate of P_2O_5(kg ha^{-1})			
75	55.57a	117.7 a	42.95
90	55.13 ab	116.1 b	43.44
105	54.52 bc	113.9 c	43.38
120	54.43 c	112.1 d	42.67
LSD	0.6	0.4	NS
Seed Rate (kg ha^{-1})			
25	54.75	115.1	43.65a
30	55.10	114.9	43.51a
35	54.89	114.9	42.17b
LSD	NS	NS	4.31
Row spacing (cm)			
20	55.07	114.8	41.41b
25	54.83	115.0	43.73a
30	54.83	115.0	44.18a
LSD	NS	NS	2.15
CV (%)	3.0	0.8	8.8

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; LSD=Least significance difference at 5% probability level; CV=Coefficient of variation.

3.1.4. Number of primary branches per plant

The main effect of seed rate was highly significant ($p<0.01$) and the interaction of P_2O_5, seed rate and row spacing were significant ($p<0.05$) on the number of primary branches produced per plant. However, the main effect of row spacing and P_20_5 fertilizer didn't influenced this parameter. The highest number of primary branches per plant (3.95) was recorded from 90 kg ha^{-1} P_2O_5 fertilizer,25 kg ha^{-1}seed rate and 25 cm row spacing while the lowest number of primary branches per plant (2.82) was recorded from 75 kg ha^{-1} of P_2O_5 fertilizer, 35 kg ha^{-1} seed rate and 30 cm row spacing (Table 2).The above result can be attributed to reduced competition among plants for growth factors due to wider spacing between plants and medium seed rate. These results were confirmed with the findings of Brar *et al.* (1993a) who also registered the highest number of branches per plant with a seed rate of 15kg/ha. Similarly, Brar *et al*. (2005) and Singh *et al.* (2005) recorded that sowing of fenugreek seed at a row spacing of 22.5 cm gave significantly higher number of branches per plant. Low competition among plants for growth factors such as moisture, nutrients, and light, coupled with genetic potential of fenugreek plants produced more branches. According to Khan *et al*. (2017) higher number of branch plant^{-1} might have also been possible due to vigorousity and strength of the plants that were attained as a result of better photosynthetic activities with sufficient availability of growth factors due to reduced competition. Similar, results were reported by Mohamed (1990), Halesh *et al*. (2000) and Gowda *et al*. (2006) for the number of branches in fenugreek.

Table 2. The interaction effect of P_2O_5 fertilizer rate, row spacing and seed rate on number of primary branch of fenugreek

P_2O_5 rate (kg ha^{-1})	**Row spacing (cm)**	**Seed rate (kg ha^{-1})**	**25**	**30**	**35**
75	20		3.5 abcde	3.57 abcde	3.60 abcde
	25		3.65 abcde	3.68 abcde	3.52 abcde
	30		3.73 abcde	3.73 abcde	2.82 f
90	20		3.62 abcde	3.88 ab	3.42 bcde
	25		3.95 a	3.90 ab	3.35 cde
	30		3.32 de	3.85 abc	3.47 abcde
105	20		3.68 abcde	3.40 bcde	3.35 cde
	25		3.58 abcde	3.52 abcde	3.33 de
	30		3.62 abcde	3.58 abcde	3.62 abcde
120	20		3.82 abcd	3.53 abcde	3.32 de
	25		3.75 abcde	3.77 abcde	3.60 abcde
	30		3.67 abcde	3.53 abcde	3.28 e
$LSD_{0.05}$	P x RS x SR= 0.41CV (%) = 10.0				

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; P= P_2O_5 fertilizer rate; LSD=Least significance difference at 5% probability level and CV=Coefficient of variation.

3.2. Yield Components and Seed Yield

3.2.1. Number of pods per plant

The analysis of variance showed the main effect of P_2O_5fertilizer and seed rate were highly significant ($p<0.01$) affect the number of pods per plant while the main effect of row spacing and the interaction among P_2O_5fertilizer, seed rate and row spacing did not show significant effect. The highest number of pods per plant (14.49) was obtained from 120 kg P_2O_5 ha^{-1}, however; it was statistically at par with P_2O_5 rates of 105 and 95 kg ha^{-1} while the lowest number of pod number per plant (12.80) was obtained from 75kg ha^{-1} of P_2O_5fertilizer (Table 3). This might be due to adequate availability of N and P which might have facilitated the production of more primary and secondary branches and plant height, which might, in turn, have contributed for the production of higher number of total pods. This result is in line with the findings Ali *et al.* (2004) who reported that increased number of pods per plant of chickpea by seed inoculation and P fertilization. Zafar *et al.* (2003) have also reported that phosphorus fertilization showed significant increase in number of pods per plant of lentil due to the cumulative effect of phosphorus in the processes of cell division and balanced nutrition. On the other hand, the highest (14.99) number of pod per plant was due to seed rate of 25 kg ha^{-1}, while the lowest (12.56) was from 35 kg ha^{-1}(Table 3).The number of pod $plant^{-1}$ produced under low seed rate was significantly higher than that grown under high seed rate. Low seed rate allows wider spacing to produce a large number of pods per plant due to enough access of plants to nutrients, sunlight, water and other growth requirements. Brar et al. (1993a) received significantly higher number of pod per plant (31.47) with a seed rate of 15 kg ha^{-1}, which was statistically at par with a seed rate of 20 (28.67) and 25 kg ha^{-1} (26.22).

3.2.2. Number of seeds per pod

The main effects of P_2O_5fertilizer, seed rate and row spacing and their interaction effects werenot significant on number of seeds per pod (Table 3)

3.2.3. Above ground biomass

The analysis of variance showed that the main effect of P_2O_5 fertilizer was highly significant ($p<0.01$) on aboveground biomass. Similarly, significant variation ($p<0.05$) were observed due to seed rate and row spacing. However, the interaction among P_2O_5 fertilizer, seed rate and row spacing did not significantly affect this parameter. The highest biomass yields (7550, 6661 and 6561 kg ha^{-1}) were obtained from 120 kg P_2O_5 ha^{-1}, 25 kg ha^{-1} seed rate and 25 cm row spacing, respectively (Table 3). The increase in biomass yield at maximum rate of P_2O_5 fertilizer may indicate that these nutrients play synergistic role in metabolism, chlorophyll formation, and photosynthesis of the plant which in turn increases the biological yield (Fageria, 2009). This result is in agreement with that of Alemu (2009) who reported that highest biomass yield (6508.9 kg ha^{-1}) of fenugreek was obtained from 26 kg P ha^{-1}. Similar effects of seed rate on biological yield of fenugreek observed by Taneja *et al*. (1985). Fenugreek crop was sown at a spacing of 30.0 x 10.0 cm increased stover yield by 6.4% over crop sown at a spacing of 22.5 x 13.3 cm observed by Chaudhary (2006).

Table 3. Main effects of P_2O_5fertilizer, seed rate and row spacingon number of pod per plant, number of seeds per pod and above ground biomass of fenugreek

Treatments	**Number of pod plant^{-1}**	**number of seeds per pod**	**Above ground biomass (kg ha^{-1})**
Rate of P_2O_5(kg ha^{-1})			
75	12.80 b	15.86	5103 d
90	13.95 a	16.42	5946 c
105	14.14 a	16.15	6888 b
120	14.49 a	15.72	7550 a
LSD	0.80	NS	526.0
Seed Rate (kg ha^{-1})			
25	14.99 a	16.29	6661 a
30	13.98 b	13.98	6393 ab
35	12.56 c	12.56	6060 b
LSD	0.70	NS	455.5
Row spacing (cm)			
20	13.43	16.04	6525 a
25	14.24	16.21	6561 a
30	13.87	15.86	6028 b
LSD	NS	NS	455.5
CV (%)	15.3	10.3	21.7

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; P= P_2O_5 fertilizer rate; LSD=Least significance difference at 5% probability level and CV=Coefficient of variation.

3.2.4. Seed yield

The analysis of variance showed that the main effect of P_2O_5fertilizer and row spacing were highly significant ($p<0.01$) and the interaction among P_2O_5fertilizer, seed rate and row spacing significantly ($p<0.05$) influenced the seed yield. However, there was no significant variation among the seed rate of P_2O_5 fertilizeron the seed yield. The highest seed yield (1966 kg ha^{-1}) was recorded from 120 kg P_2O_5fertilizer ha^{-1}, 25kg ha^{-1} seed rate and 25 cm row spacing while the lowest seed yield (1092 kg ha^{-1}) was recorded from 90 kg P_2O_5fertilizer ha^{-1}, 35 kg ha^{-1} seed rate and 30 cm row spacing (Table 4). The yield increase with increased rate of P_2O_5fertilizerrate might be due to cumulative effect of more grain filling percentage and more number of seeds per pod due to the increased nutrient uptake by the plants might have stimulated the rate of various physiological processes like growth and assimilation of nutrients. In line with this result, Tolanur and Badnur (2003) reported the highest seed yield (2379 kg ha^{-1}) in chick pea by application of mineral and organic fertilization. Chaudhary (2006) reported that the maximum seed yield was recorded with a seed rate of 25 kg ha^{-1}in fenugreek. The increase in seed yield due to population might be related to contribution of P to profound branching, better fruiting, increased number of seeds pod^{-1} and heavier grains that contributed to increased seed yield (Ahmad*et al.*, 2015).Sharma (2000) reported that the highest seed yield in fenugreek was obtained when seed is sown at spacing of 30 x 7.5 cm.

Table 4. The interaction effect of P_2O_5 fertilizer rate, row spacing and seed rate on seed yield (kg ha^{-1}) of fenugreek

P_2O_5 rate (kg ha^{-1})	**Row spacing (cm)**	**Seed rate (kg ha^{-1})** 25	30	35
75	20	1094 n	1199 mn	1186 n
	25	1105 n	1359 jklm	1389 ijk
	30	1253 klmn	1250 klmn	1206 lmn
90	20	1551fghi	1574 fgh	1494ghij
	25	1366 jkl	1461 hij	1520 fghij
	30	1400 ijk	1189 n	1092 n
105	20	1598 efgh	1428 hij	1443 hij
	25	1639 defg	1653 cdefg	1596 efgh
	30	1586 efgh	1507 ghij	1494ghij
120	20	1810 abc	1850 ab	1836 ab
	25	1966 a	1820 abc	1767 bcd
	30	1794 bcd	1750 bcde	1686 bcdef
$LSD_{0.05}$	P x RS x SR= 145.94 CV (%) = 8.6			

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; P= P_2O_5 fertilizer rate; LSD=Least significance difference at 5% probability level and CV=Coefficient of variation.

3.2.5. Harvest index

The analysis of variance showed that the interaction of P_2O_5fertilizer and seed rate were significantly ($p<0.05$) affect the harvest index while the main effect of P_2O_5fertilizer, seed rate and row spacing did not influence this parameter. The highest harvest index (26.82%) was observed from 105 kg P_2O_5 ha^{-1}fertilizer and 35 kg ha^{-1}seed rate while the lowest harvest index (21.84%) was observed from 75 kg P_2O_5 ha^{-1}fertilizer and 25 kg ha^{-1} seed rate(Table 5).The increased HI of fenugreek at application of 105 kg P_2O_5 ha^{-1} with 35 kg ha^{-1}seed rate might be due to increased seed yield, number of branch per plant, number of pod per plant and thousand seed weight applied with these treatment combinations that improved fenugreek production. In line with this result Zafar *et al*. (2003) found that calculated values of harvest index showed an increasing trend in the harvest index values with application of P on lentil and minimum harvest index from the control plot. Similarly, Mavai *et al.* (2000) noticed that harvest index is significantly affected by the seed rate, which was found maximum with a seed rate of 20 kg ha^{-1} in fenugreek.

Table 5. The interaction effect of P_2O_5 fertilizer and Seed rate on harvest index of fenugreek

	P_2O_5 rate (kg ha^{-1})			
Seed rate (kg ha^{-1})	75	90	105	120
25	22.30 b	26.11 ab	25.87 ab	24.19 ab
30	22.76 ab	23.69 ab	26.68 a	26.12 ab
35	21.84 b	23.91 ab	26.82 a	24.76 ab
$LSD_{0.05}$	P_2O_5 x SR =3.640CV (%) = 22.5			

Means followed by the same letter(s) in the table are not significantly different at 5% level of significance; P= P_2O_5 fertilizer rate; LSD=Least significance difference at 5% probability level and CV=Coefficient of variation.

3.3. Economic Evaluation

Partial budget analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 6. The partial budget analysis showed that the highest net benefit (39164.17 ETB ha^{-1}) was recorded from the application of 120 kg P_2O_5 ha^{-1} treated under 25 cm row spacing and 25 kg ha^{-1} seed rate followed by (35324.17 ETB ha^{-1}) due to same P_2O_5 and seed rate and 30 row spacing. The lowest net returns (27262.92 ETB ha^{-1}) was obtained from 75 kg P_2O_5 ha^{-1}, 25row spacing and 30 kg ha^{-1} seed rate. The results in this study indicated that the use of higher dose phosphorus fertilizer resulted in higher net benefits than the lower dose phosphorus fertilizer (Table 6). According to CIMMYT (1988) suggestion, the minimum acceptable marginal rate of return should be more than 100%. In this study, the combination of 120 kg P_2O_5 ha^{-1} with 25 cm row spacing and 25 kg ha^{-1}seed rate had marginal rate of return (MRR) of 10971.43% which is above the acceptable minimum MRR of 100% and suggests for fenugreek production. Therefore, on economic grounds, applications of 120 kg P_2O_5 ha^{-1}coupled with 25kg ha^{-1} seed rate and 25 cm row spacing would be best and economical for production of fenugreek in the study area and other areas with similar agro-ecological conditions.

Table 6. Summary of economic analysis of the effects of phosphorus application, seed rate and row spacing.

Treatments			USY (kg ha^{-1})	ASY (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
P_2O_5 (kg ha^{-1})	Seed rate	Row spacing						
75	25	30	1253.24	1127.92	28197.92	3240	24957.92	
75	25	25	1104.63	994.17	24854.17	3275	21579.17	D
75	30	30	1250.46	1125.42	28135.42	3275	24860.42	D
75	25	20	1093.52	984.17	24604.17	3310	21294.17	D
75	30	25	1358.80	1222.92	30572.92	3310	27262.92	3292.86

Treatments			USY (kg ha^{-1})	ASY (kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
75	35	30	1205.56	1085.00	27125	3310	23815	D
75	30	20	1198.61	1078.75	26968.75	3345	23623.75	D
75	35	25	1396.30	1256.67	31416.67	3345	28071.67	2310.21
75	35	20	1185.65	1067.08	26677.08	3380	23297.08	D
90	25	30	1400.00	1260.00	31500	3825	27675	D
90	25	25	1338.43	1204.58	30114.58	3860	26254.58	D
90	30	30	1188.89	1070.00	26750	3860	22890	D
90	25	20	1551.39	1396.25	34906.25	3895	31011.25	534.47
90	30	25	1460.65	1314.58	32864.58	3895	28969.58	D
90	35	30	1114.35	1002.92	25072.92	3895	21177.92	D
90	30	20	1573.61	1416.25	35406.25	3930	31476.25	1328.57
90	35	25	1519.91	1367.92	34197.92	3930	30267.92	D
90	35	20	1493.52	1344.17	33604.17	3965	29639.17	D
105	25	30	1585.65	1427.08	35677.08	4445	31232.08	D
105	25	25	1638.89	1475.00	36875	4480	32395	167.05
105	30	30	1506.94	1356.25	33906.25	4480	29426.25	D
105	25	20	1597.69	1437.92	35947.92	4515	31432.92	D
105	30	25	1652.78	1487.50	37187.5	4515	32672.5	792.86
105	35	30	1494.44	1345.00	33625	4515	29110	D
105	30	20	1470.83	1323.75	33093.75	4550	28543.75	D
105	35	25	1595.83	1436.25	35906.25	4550	31356.25	D
105	35	20	1442.59	1298.33	32458.33	4585	27873.33	D
120	25	30	1793.52	1614.17	40354.17	5030	35324.17	514.89
120	25	25	1965.74	1769.17	44229.17	5065	39164.17	10971.43
120	30	30	1750.46	1575.42	39385.42	5065	34320.42	D
120	20	20	1810.19	1629.17	40729.17	5100	35629.17	D
120	30	25	1819.91	1637.92	40947.92	5100	35847.92	D
120	35	30	1685.65	1517.08	37927.08	5100	32827.08	D
120	30	20	1850.00	1665.00	41625	5135	36490	D
120	35	25	1766.67	1590.00	39750	5135	34615	D
120	35	20	1836.11	1652.50	41312.5	5170	36142.5	D

Where, P=Phosphorus (P_2O_5) rate (kg ha^{-1}); USY = Unadjusted seed yield; ASY = adjusted seed yield; GFB = gross field benefit; NB = net benefit; MRR = marginal rate of return; D = dominated treatments; Cost of P_2O_5 3900.00 Birr 100 kg^{-1}; cost for row sale price of fenugreek seed 2500 Birr per 100 kg during harvest on farm.

SUMMARY AND CONCLUSION

The productivity of fenugreek is low because of several constraints. Among the production constraints, imbalanced and inadequate soil nutrition and poor agronomic practices is considered to be the important limiting factors. One of the alternatives to address such problem is supplying well-balanced nutrients and adequate agronomic practices to meet the crop nutrient requirements. Therefore, an experiment was conducted with the objectives of assessing the effect of P_2O_5 fertilizer rates, seed rates and row spacing on yield components and seed yield of fenugreek. The treatments consisted of factorial combinations of fourP_2O_5 fertilizer application rates (75,90, 105 and 120 kg P_2O_5ha^{-1}), three seed rates (25, 30, and 35 kg ha$^{-1)}$ and three row spacing (20, 25, and 30 cm) in Randomized complete block design with three replications. Data was collected on days to 50% flowering, days to 90% physiological maturity, plant height, number of primary branches per plant, number of pods per plant, number of seeds per pod, seed yield, above ground biomass yield and harvest index. The main effects of phosphorus application significantly affected on days to 50% flowering, days to 90% physiological maturity, number of pod per plant, above ground dry biomass and harvest index while plant height was affected by seed rate and row spacing. On the other hand, the interaction of P_2O_5 fertilizer, seed rate and row spacing significantly affect number of primary branches and seed yield while days to 90% physiological maturity and number seed per pod did not affected by P_2O_5 fertilizer, seed rate and row spacing nor by their interaction. The shortest (54.43) and longest (55.57) days to 50% flowering were recorded from phosphorus application at 120 kg P_2O_5 ha^{-1} and 75 kg P_2O_5 ha^{-1} rate, respectively. The highest number of pod per plant and harvest index was obtained from (102, 105 and 25, 35) kg P_2O_5 ha^{-1}rate and kg ha^{-1}seed rate, respectively. The tallest plant height (44.18 cm) was recorded from 25 kg ha^{-1} seed rate and 30 cm row spacing. The highest biomass yields (7550, 6661 and 6561 kg ha^{-1}) were obtained from 120 kg P_2O_5 ha^{-1}, 25 kg ha^{-1} seed rate and 25 cm row spacing, respectively. The highest number of primary branches per plant (3.95) was recorded from 90 kg ha^{-1} P_2O_5 fertilizer, 25 kg ha^{-1} seed rate and 25 cm row spacing while the lowest number of primary branches per plant (2.82) was recorded from 75 kg ha^{-1} of P_2O_5 fertilizer, 35 kg ha^{-1} seed rate and 30 cm row spacing. The highest seed yield (1966 kg ha^{-1}) was obtained from 120 kg P_2O_5 fertilizer ha^{-1}, 25 kg ha^{-1} seed rate and 25 cm row spacing while the lowest seed yield (1092 kg ha^{-1}) was recorded from 90 kg P_2O_5 fertilizer ha^{-1}, 35 kg ha^{-1} seed rate and 30 cm row spacing.

The economic analysis also indicated that the highest net benefit/return (39164.17 ETB ha^{-1}) was recorded from combined application of 120 kg P_2O_5 ha^{-1}treated under 25 cm row spacing and 25 kg ha^{-1} seed rate with marginal rate of return (MRR) of 10971.43%. This is above the acceptable minimum MRR of 100% while the lowest net returns (27262.92 ETB ha^{-1}) was recorded from 75 kg P_2O_5 ha^{-1} with 30 kg ha^{-1} seed rate and 25 cm row spacing. Hence, it can be concluded that application of 120 kg P_2O_5 ha^{-1}coupled with 25 kg ha^{-1} seed rate and 25 cm row spacing is the most appropriate combination for fenugreek production in the study area and similar agro ecology.

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REFERENCE

Abera Sisay. 2015. Effect of *Rhizobium* inoculation and phosphorus rate on nodulation, yield and yield related traits of chickpea (*Cicer arietinum* L.) at Kobo, Northern Ethiopia. MSc. Thesis, Haramaya University, Haramaya, Ethiopia.

Acharya, S.N., Thomas, J.E., and Basu, S.K. 2007. Fenugreek an "Old world" crop for the "New World". *Journal of Biodiversity,* 7(3-4): 27-30.

Alemu Dessa, 2009. Effects of phosphorus application and *Rhizobium* inoculation on nodulation yield and yield related traits of fenugreek (*Trigonella foenum*-graecum) in Sinana, south eastern Ethiopia. An MSc thesis presented to the school of graduate studies of Haramaya University. 72p.

Ali, A., 1993. Effects of different planting methods and phosphorus levels on the performance of Vigna radiate L. *Pakistan Journal of Agriculture Research,* 14:162-168.

Ali, H., Khan,M.A. and Randhawa, S.A. 2004. Interactive effect of seed inoculation and phosphorus application on growth and yield of chickpea (*Cicer arietinum* L.). *International Journal of Agriculture and Biology,* 6 (1):110-112.

Ahmad, S., Khan, A. A., Ali, S., Imran I. M. and Habibullah, M. 2015. Impact of Phosphorus Levels on Yield and Yield Attributes of Mung Bean Cultivars under Peshawar Valley Conditions. *Journal of Environment and Earth Science,* 5(1).326-332.

Asfaw Tilaye, Tarekegn Melesse and I.V. Lewis, 1981. Research on Pulse Crops in Ethiopia 1970-1973 E.C. 1977/78-1980/81 G.C. Institute of Agricultural Research (IAR) Addis Ababa.

Baswana, K.S. and Pandita, M.L. (1989). Effect of time of sowing and row spacing on seed yield offenugreek.*Seed Research*, **17**: 109-112.

Brar, D.S., Singh, S.P., Buttar,G.S. and Singh, Sudeep (2005). Effect of different date of sowing and row spacing on yield of fenugreek (*Trigonella foenum-graecum* L.). *Journal of Medical andAromatic Plant Sciences*, **27**(4): 629-630.

Brar, R.S., Yadav, B.D. and Joon, R.K. (1993a). Effect of row spacing and seed rate on growth andseed yield of fenugreek (*Trigonella foenum-graecum*). *Forage Research*, 19(1):104-106.

Buttery, B., Park, S. and Findlay, W. 1987. Growth and yield of white bean (*Phaseolus vulgaris* L.) in response to nitrogen, phosphorus and potassium fertilizer and inoculation with *Rhizobium*. *Canadian Journal of Plant Science*, 67(2):425-432.

Chaudhary, P.D. (2006). Effect of crop geometry, balanced fertilization and agro-chemicals on the yield attributes and yield of fenugreek (*Trigonella foenum-graecum* L.). *Indian Journal ofAgricultural Sciences*, **76**(8): 503-505.

CIMMYT (International Maize and Wheat Improvement Center). 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, DF. 79p.

Engles, J.M., J. G. Hauwkes and Melaku Worede, 1991. Plant Genetic Resources of Ethiopia. Ethiopia. M.Sc. Thesis Presented to the School of Graduate Studies of Alemaya University.

Fageria, N.K., 2009. *The use of nutrients in crop plants.* CRC, Press Taylor and Francis group, Printed in U.S.A. 430pp.

Feysal Bushira, 2006. Genetic divergence and association among seed yield, yield related traits and protein content of some fenugreek (*Trigonella foenum-graecum* L.) landraces in Alemaya. Msc. Thesis Presented to the School of Graduate Studies of Alemaya University.

Gan, Y., Zentner, R.P. and McDonald, C.L. 2009. Adaptability and maturity response of chickpea in northern high latitude areas. *Agriculture and Forest Meteorology,* 149:711-720.

GenStat. 2013. GenStat Procedure Library Release. 16th edition. VSN International Ltd.

Gifole Gidago, Sheleme Beyene and Walelign Worku. 2011. The Response of haricot bean (*Phaseolus vulgaris* L.) to phosphorus application on *Ultisols* at Areka, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare,* 1(3):38-49.

Gowda, M. C., D. P. Halesh, A. A. Farooqi, 2006. Effect of dates of sowing and spacing on growth of fenugreek (*Trigonella foenum-graecum* L.). *Biomed,* 1 (2): 141-146.

Halesh, D. P., M. C. Gowda, A. A. Forooqi, M. Vasundhara, K. N. Srinivasappa, 2000. Influence of nitrogen and phosphorus on growth, yield and nutrient content of fenugreek (*Trigonella foenum-graecum* L.). Spices and aromatic plants: Challenges and opportunities in the new century. Contributory papers. *Centennial conference on spices and aromatic plants,* 20-23 September, Calicut, Kerala, India. 191-194.

Khan, M.M.S., Singh, V.P. and Kumar, A. 2017. Studies on Effect of Phosphorous Levels on Growth and Yield of Kharif Mung bean (*Vigna radiata* L. wilczek), *International Journal of Pure and Applied Biological sci*ences 5(4): 800-808.

Mavai, D., Lal, S., Singh, A., Baswana, K.S. and Singh, N. (2000). Response of fenugreek (Trigonella *foenum-graecum* L.) to seed rate, nitrogen and phosphorus fertilizer. *Haryana Journal of Horticultural Sciences*, 29(3-4): 244-246.

Mohamed, M. A., 1990. Differences in growth, seed yield and chemical constituents of fenugreek plants (*Trigonella foenum graecum* L.) due to some agricultural treatments. *Egyptian Journal of Agronomy*, 15 (1-2): 117-123.

Moniruzzaman, M., M. M. Rehman, M. M. Hossain, A. J. M. Sirajul Karim and Q. A. Khaliq (2013).Effect of seed rate and sowing method on foliage production of different genotypes ofcoriander (*Coriandrum sativum* L.). *Bangladesh J. Agri. Res.* 38 (3): 435-445.

Sharma H.R., Chauhan G.S. 2000. Physico-chemical and rheological quality characteristics of fenugreek (*Trigonella foenum-graecum* L.) supplemented wheat flour. *Journal of Food Science and Technology-Mysore*, 37:87-90.

Singh, S., G. S. Buttar, S. P. Singh, D. S. Brar, 2005. Effect of different dates of sowing and row spacings on yield of fenugreek (*Trigonella foenum-graecum*). *Journal of Medicinal and Aromatic Plant Sciences*, 27 (4): 629-630.

Singh, S. P., S.K. Sandhu, L.K. Dhaliwal and Inderjeet Singh. 2012. Effect of Planting Geometry on Microclimate, Growth and Yield of Mung bean (*Vigna radiata* L.). *Journal of Agricultural Physics.*12 (1):70-77.

Smart, J., 1976. *Tropical Pulses*. Longman Group Limited London.

Taneja, K.D., Gill, P.S. and Rana, D.S. (1985). Effect of sowing time, row spacing and seed rate onseed production of metha (*Trigonella foenum-graecum* L.).*Forage Research*, 11 (1): 33 36.

Tolanur, S.I. and Badnur, V. 2003. Effect of integrated use of organic manure, green manure and fertilizer nitrogen on sustaining productivity of rabi sorghum chick pea system and fertility of vertisol. *Journal of the Indian Society of SoilScience*, 51: 41-44.
Westphal, E., 1974. Pulses in Ethiopia: their taxonomy and agricultural significance. Center for Agricultural Publishing and Documentation. Wageningen, the Netherlands.
Wubishet Alemu and Chemeda Fininsa, 2016. Effects of Environment on Wheat Varieties' Yellow RustResistance, Yield and Yield Related Traits in South-Eastern Ethiopia. *Plant*, *4* (3):14-22.
Zafar, M., M. Maqsood, R. Anser and Z. Ali, 2003. Growth and yield of lentil as affected by phosphorus. *International Journal of Agricultural and Biological Sciences*, 1560-8530.

Effects of Climate Variability on Wheat Rust *(PucciniaSpp.)* and Climatic Condition Conducive for Rust at Highlands of Bale, Southeastern Ethiopia

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ABSTRACT

Rainfall, temperature and relative humidity are the most important climatic parameters for agricultural practices and more conducive for disease and insect developments. In this study, effects of climate variability on wheat rust diseases and climatic condition conducive for rust were analyzed. Cropping season weather data obtained from nearby stations were used to analysis impacts on rust disease occurrence. The result of historical data analysis suggested that, annual rainfall amount was increased by 9.1 mm/yr and 2.8 mm/yr at Sinana and Robe respectively. On the other hand, the seasonal Kiremt rain was increased by 6.1 mm/yr at Sinana station and 2.9 mm/yr at Robe station. The study results revealed that climate variability has played a great role in agricultural practices, which in turn influences crop diseases occurrence. In particular, it has induced wheat rust diseases over the study areas that significantly affect the quality and quantity of the yield. The correlation between monthly rainfalls and disease severity about -0.86, while for relative humidity and diseases severity reached 0.74 at (p= 0.05). This condition was also true for maximum and minimum temperature with rust diseases, the correlation analysis indicated 0.61 and 0.79 respectively (p=0.05). From weekly analysis during *cropping season, the climatic condition conducive for rust diseases occurrence were identified. Therefore, the development and spread of rust is highly enhanced with maximum temperature and minimum temperature ranges 20.8 °C to 28 °C and 8.2 °C to 11.7 °C, while relative humidity was more than 70 % across the highland regions. In view of this condition, early warning can be well practiced by acquiring appropriate lead-time climate-based forecasting of on the possible occurrence of both climates and diseases on varieties of wheat crops across the Bale highlands.*

Key words: Climate variability, disease, wheat rust, variety.

Back ground and justification

Ethiopia located between 30N-150N and 330E-480E within the tropical region of horn Africa. The annual rainfall distribution in the western part of the country has one maximum during July or August. In Ethiopia there are some regions which experiences three seasons with two rainfall peak (one peak is more dominant than the other), while some regions have four seasons with two distinct rainfall peaks (Bimodal type), there are still some regions with two seasons having single rainfall peak (mono modal type). The area has bimodal rainfall pattern with the first rainy season starting in March and taper off in July; it is locally named “Ganna” while the second rains falls between August and December, locally known as “Bona” (Olkeba, 2011). According to Degefu (1987), 85 to 95% of the food crop of the Ethiopia is produced during June to September period. Kiremt rain, that falls during June–September months (JJAS) accounts for 50%–80% (Sisay, 2009). Thus, the most severe droughts are usually related to a failure of the JJAS rainfall to meet Ethiopia’s agricultural and water resources needs, (Korecha and Barnston, 2007).

Agriculture is the most vulnerable and sensitive sector that is seriously affected by the impact of climate variability and change (Gizachew, 2012). Due to climate variability, most of Ethiopian economies varied from year-to-year (Sisay, 2009). The impacts of climate change on crop yields occurring more in developing countries, compared to developed countries (World Bank 2012).The impacts of increased temperature and changes in rainfall patterns resulting to reduce agricultural production (Valizadeh*et al.*, 2013).Weather are one of the key components that control agricultural production. In some cases, it has been stated that as much as 80% of the variability of agricultural production is due to the variability in weather conditions, especially for rain fed production systems (Petr, 1991; Fageria, 1992). Weather has a major impact on plants as well as pests and diseases. In Ethiopia, wheat has been among the major cereals of choice dominating the food habit and known to be a major source of energy and protein for the highland population (Dereje and Chemeda, 2007). According to Geletu*et al*., (2012) Ethiopia is the second largest wheat producer in Sub-Saharan Africa and has good wheat growing conditions. However, In addition to moisture stress, heat stress, frost, and salinity, wheat production is hindered by three different types of rust diseases (EATA Group, 2012). The stem rust reduce the wheat yield up to 100%.Yellow rust can losses the wheat yield by 50-100%.whereas Leaf rust reduce <10% (ICARDA,2011). Wheat diseases not only reduce yield but also affect the qualities of grains (Dereje and Chemeda 2007).

Using information on the effect of weather and climatic factors on agricultural productivity can not only reduce the damage but can also make it possible to enhance agricultural productivity (Gizachew,2012).The most important climatic parameters influencing agriculture are: Seasonal rainfall (onset, end date…), temperature ,relative humidity and sunshine. But, apart suffering from climatic variability, there is no attention and/or efforts to solve the rising problems due to climate variability particularly in our study area. However, in this paper I was analyzed meteorological data for Bale highlands to quantify climatic conditions that influence the development and spreading of rusts on wheat varieties. Therefore this study is initiated to fill the knowledge gap between problems of climatic variability and professionals so that attention could be given to alleviate this problem.

Objectives:

To analysis climate variability of study areas

To evaluate and identify the most climatic conditions suitable for wheat rust

MATERIALS AND METHODS

Description of the Study Area

Experiment was conducted at Sinana Agricultural Research Center (SARC) on-station Adaba, Robe area and Agarfa sub-site at Bona season in 2013/14 – 2015/16. SARC is located at 07º 06' 12'' to 07º 07' 29'' N and 40º 12' 40'' to 40º 13' 52'' E with altitude 2400 masl. The area receives annual rainfall of 750 to 1100 mm. The monthly average values of maximum and minimum temperatures are 21ºC and 9 ºC respectively. Whereas, Agarfa is located 07º 26'N and

39^o 87'E with altitude 2514 meter asl. Its annual rainfall ranges from 1000 to 1100mm.The monthly average values of maximum and minimum temperatures are 22.8 ^oC and 7.3^oC, respectively.Adaba is located 07^o 01'N and 39^o 24' E with altitude 2365 meter asl. The mean annual rain fall range from 600mm to 750mm and it has a mean monthly temperature varying from 4.5 to 9.6 ^oC for the min temperature and 22.6 ^oC to 26.4 ^oC for the maximum temperature. The average annual maximum and minimum temperature is 25.9 ^oC and -1.21 ^oC respectively. Robe is located 7^o 06'44''N and 40^o 01'33''E with altitude 2464 masl.

Data Collection

Meteorological data : Daily, Monthly and Decadal Meteorological data such as rainfall in (mm), Relative humidity in (%) and temperature (max, min and mean ^oC), which were obtained from nearby station.

Observed rainfall: Thirty three years of rainfall data were used to characterize the seasonal and annual rainfall variability and trends using time series data for which stations had long term data. Mann-Kendall's test: Mann- Kendall trend test was employed to detect the trend of climate variability. The Mann-Kendall's test statistic was given as:

$$s = \sum_{i=1}^{N-1} \sum_{j=1+i}^{N} sgn(xj - xi)$$

Where S is the Mann-Kendal's test statistics; xi and xj are the sequential data values of the time series in the years i and j (j> i) and N is the length of the time series. A positive S value indicates an increasing trend and a negative value indicates a decreasing trend in the data series. The sign function is given as:

$$sgn(xj - xi) = \begin{cases} +1\ if(xj - x_{\mathrm{i}}) > 01 \\ 0\ if(xj - x_{\mathrm{i}}) = 0 \\ -1\ if(xj - x_{\mathrm{i}}) < 0 \end{cases}$$

For n larger than 10, ZMK approximates the standard normal distribution was computed as follows:

$$ZMK = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} if\ S > 0 \\ 0\ if\ S = 0 \\ \frac{S+1}{\sqrt{Var(S)}}\ if\ S < 0 \end{cases}$$

Where, S is variance and the presence of a statistically significant trend is evaluated using the ZMK value.

The Sen's estimator of slope: This test was applied when the trend supposes to be linear, describing the quantification of changes per unit time. The slope (change per unit time) was estimated above procedure of Sen (1968).

The coefficient of variation of seasonal rainfall variability was analyzed by:

$CV = (\frac{SD}{\bar{X}})$*100, Where$\bar{x} = \sum \frac{xi}{N}$ and $SD = \sqrt{\frac{(xi-\bar{x})^2}{N-1}}$

And seasonal rainfall anomaly during kiremt season can be analyzed by:

$$Rainfall\ Anomally\ Index(RAI) = \frac{xi - \bar{x}}{SD}$$

Where $\bar{x}$ is long year mean and N is total number of year during observations were held for specific site, SD is standard deviation, Xi is rainfall of each month and RAI is rainfall anomaly of each month. If RAI is more than 0.5, between -0.5 and 0.5, less than -0.5 is meteorologically the month is wet, normal and dry respectively.

Treatments and Experimental Design

Six bread wheat varieties (MaddaWalabu, Digalu, Sofumar, Kubsa, Danda'a and Tussie) and two bread wheat differential cultivars (Morocco and PBW343) were planted in RCBD with three replications. The plot size was plots of 1.2m x 2m having total experimental area of 16.6 m x 9 m with between row, plot and block spacing of 0.2 m, 1 m and 1.5 m, respectively. All cultural practices were done as per the agronomic recommendation for the crop.

Disease data: Disease data collected at different times from SARC wheat experiments and which were documented as progress report was used. Relationships of each weather factor with three rust diseases were determined through correlation and regression.

Agronomic data: Data on crop parameters (all necessary agronomic data) were collected throughout the cropping season. At crop maturity, the four middle rows were harvested for the determination of grain yield.

Data Management and Statistical Analysis: All collected data were subjected to the analysis ofStata andInstat software respectively. A simple correlation and regression analysis was employed to test the relationship between weather observations and rust diseases occurrence.

RESULTS AND DISCUSSIONS

Characterization of climate variability under Bale highlands

The analysis of temperature and precipitation revealed changes in extreme values during 1984–2016 in the study area. The analysis of past rainfall variability and trend was conducted after the quality control was done, missed data was filled.

Start of rainy Seasons

Start of rainy season analysis of long term 1984 to 2016 rainfall data showed that the rainy season started in minimum on average during the February forBelg season at Sinana and Robe. The start of the Kiremt season also depicted that the rain begun raining at least in the 2nd decade of July at Sinana while 2nd decade of June at Robe. Earlier planting before 3rddecades of July were possible in Sinana and Robe in one out of four years for Kiremt season. Also, planting before 1st decades of August at Sinana and 3rd decades of July at Robe were possible in three out of four years' time of the Kiremt. The start of the Kiremt season CV was 5.3 % for Sinana and 10.2 % for Robe area. From this point of view, the start of Kiremt season was less predictable at Robe, thus, decisions pertaining to crop sowing activities would be with risk. The standard deviation for mean start of the season showed high deviations about 11.2 days and 20.2 days at Sinana and Robe respectively.

End of Seasons

The end of Belg season could be extended to a maximum of 1st decades of May for Sinana and 2nd decades of May for Robe, while for theKiremt season ranged between 1st decade of October to 1st decade of November at Sinana and 1st decades of October to 2nd decades of October at Robe. There was 75% probability to end before 1st decades of November at Sinana while there was 75% probability that the end of season before 2nd decades of October at Robe. The end of the season CV was 5.9% for Sinana area while end of the season CV was 4.6 % at Robe area.

Length of Growing Seasons (LGS)

The length of growing season in Belg season ranged from 2nd decades of February to 1st decades of May for Sinana and 3rd decade of February to 2nd decades of May for Robe whereas the length of growing season for Kiremt season ranged from 40 days to 132 days at Sinana and 29 days to 131days at Robe area. The probability that the area could be supported a variety with LGS greater than 73 days was 25% at Sinana and 58 days was 25% at Robe while the probability that the area had recorded LGS less than 99 days was 75% at Sinana and 84 days was 75% at Robe for Kiremt season. Hence crops that require LGS of up to 132 days and 131 days could be produced with less risk of water shortage in Sinana and Robe areas respectively in Kiremt season. The issue of LGS requires further due attention in that one needs to know the type and level of risks of yield loss associated with cultivars of different maturity categories, requiring different amounts of water during a sequence of growth stages. The LGS of the season CV was 25.1 % for Sinana and 28.9 % for Robe areas. Therefore, the length of growing season in the area had high annual variability at Robe (Table 1).

Number of Rainy Days

The average numbers of Kiremt rainy days were 136 days and 114 days with CV value of 18.4 % and 10.6 % at Sinana and Robe stations respectively. The standard deviation of rainy days was 25.1 days and 12.1 days at Sinana and Robe stations respectively. The study also depicted that the number of rainy days was less than 119 days and 109 days once in four years, less than 156 days and 121 days for three times in four years, it was less than 127 days and 115 days twice in four years at Sinana and Robe station respectively. The minimum and maximum number of rainy days was 90 days and 189 days for Sinana station and 81 days and 135 days for Robe station. This indicates that the amount of rainfall achieved depend on the number of rainy days that could be available to plants which in turn depends on the rainy season's onset, length, temporal distribution and cessation and can indirectly indicate the climatic suitability of the crop and its success or failure in a season (Ngetich*et al.*,2008).

Table 1. Descriptive statistics of Kiremt season rainfall characteristics from 1984-2016 on

SARC station

Rainfall features	Min	1st Quartile (25%)	Median (50%)	3rd Quartile (75%)	Max	Mean	StdDev (±)	CV (%)
SOS(DOY)	195	199	208	219	235	210	11.2	5.3
EOS(DOY)	275	276	287	305	334	293	17.26	5.9
LGS(Days)	40	72.5	79	99	132	83.3	20.9	25.1
NRD(days)	90	119	127	156	189	136	25.06	18.4
TKRF(mm)	194.9	284.3	355	488.2	819	402.5	158.4	39.4
2. Robe station								
SOS(DOY)	167	197	201	206	246	196.5	20.1	10.2
EOS(DOY)	275	275	281	289	321	285.3	13	4.6
LGS(Days)	29	58	73	84	131	74	21.4	28.9
NRD(days)	81	109	115	121	135	113.7	12.1	10.6
TKRF(mm)	214.	296.6	377.9	422.9	538.2	367.3	83.2	22.7

Note: SOS, start of season; EOS, end of season; LGS, length of growing Season; NRD, number of rainy days; TKRF, Total Kiremt season rainfall; SD, standard deviation; CV, coefficient of variation.

Additionally, the Mann–Kendall trend test showed a decreasing trend of start of season, end of season and annual number of rainy days at Sinana and end of season and length of growing season at Robe stations; however, it is not statistically significant (Table 2).

Table 2.Trend analysis of rainfall features for Sinana and Robe areas (1984-2016)

Station	SOS			EOS			LGS			NRD		
	ZMK	p.	S	ZMK	p.	S	ZMK	p.	S	ZMK	p.	S
Sinana	-0.43	0.67	-0.1	-0.35	0.73	-0.1	0.78	0.44	0.1	-0.15	0.88	-0.2

Robe	0.75	0.45	0.3	-0.21	0.84	-0.2	-1.43	0.15	-0.5	0.76	0.44	0.3

ZMK, Mann–Kendall trend test, S: Sen‟s slope, P: p-value

Probability of maximum dry spells length

Probability of dry spells exceeding 5,7,10 and 15 days length at two stations in the Sinana district during 1984-2016 was depicted in Figure 3. The graphs in Figure 3 also demonstrate how the probability of 15 days of dry spell curves stays at their maximum value of near to 80% during the earlier and later months relative to the growing seasons. When looked in to the probability of dry spell occurrence of 5 days length, it was at more than 95% over Sinana and 80% over Robe areas for Kiremt season.

The probability of occurrence of dry spells greater than 5 and 7 days length were observed being near to 0% at Robe and Sinana for Kiremt season (Figure 1).There was no chance for the occurrence of dry spell at greater than 7, 10 and 15 days lengths during the peak months of Kiremt season for Sinana and Robe areas. As the length of dry spell thresholdbecomes short, the probability of dry spells occurrence increases and conversely, as the dry spells threshold becomes longer, the probability of dry spells occurrence decreases with-in the growing seasons in both locations.

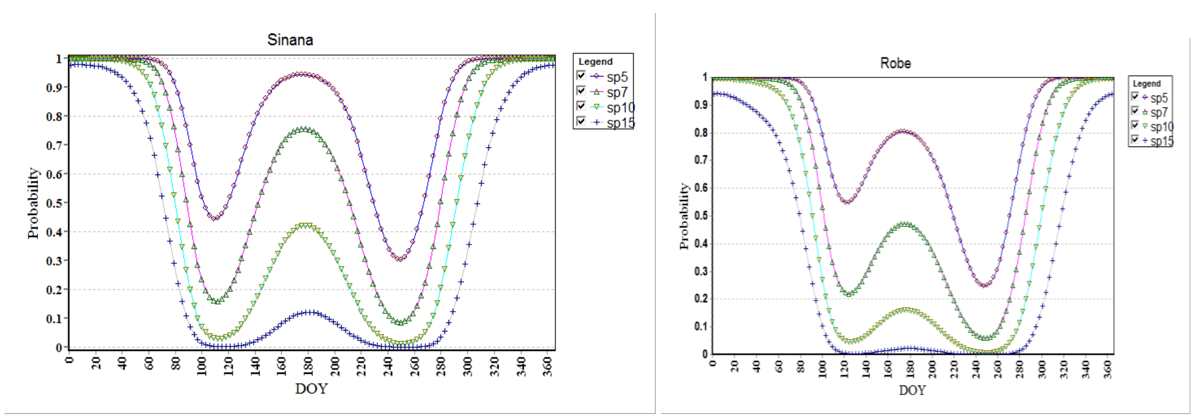


Figure 1.Probabilities of maximum dry spells exceeding 5, 7, 10 and 15 days length within 30 days after starting date at two stations in Sinana district during 1984-2016

Generally, at both locations, curves of probability of dry spells attain minimum during months of peak rainfall periods and turn upward again from the 2nd decades of November, signaling end of the growing season. This suggests that as the probability of dry spell increased, the standing crops faced with risk of water shortage.

Trends and Relationship between Rainfall Features

Total annual and Kiremt seasonal rainfall data for the period 1984 to 2016 in Sinana district was presented in figure2. Total annual and seasonal time series for Sinana and Robe stations revealed increasing trends after the year of 2006 while more increment was shown at Sinana in near decade figures 2. There was an observed slightly variability trends of seasons before a decade at Sinana and Robe stations. Total annual rainfall had shown upward slope which indicated increasing for historical in trend at Sinana and Robe stations. The result of historical data analysis suggested that, annual rainfall amount was increased by 9.1 mm/yr and 2.8 mm/yr at Sinana and Robe respectively. On the other hand, the seasonal kiremt rain was increased by 6.1 mm/yr at Sinana station and 2.9 mm/yr at Robe station.From this point of view, it was possible to confidentially advise the farmers of the area in a way that they could have information like when to plant and the variety to be used in agriculture practices.

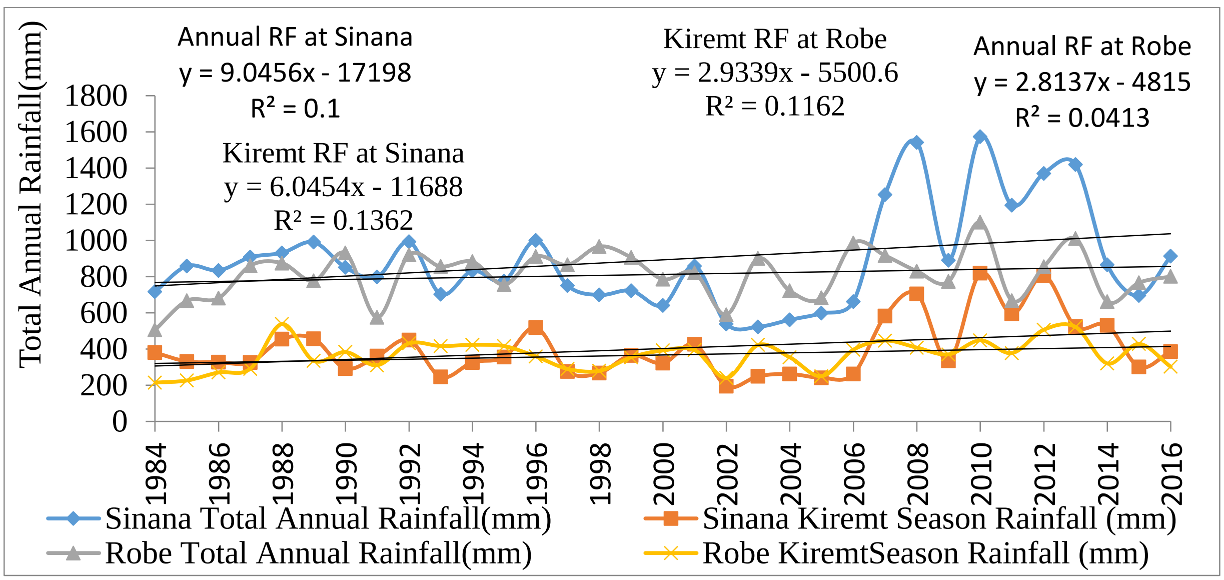


Figure 2.Time series of total annual rainfall and Kiremt season total raifall based on the data of 1984-2016 at Sinana and Robe

Annual and seasonal rainfall totals

Trends of annual and seasonal rainfall amount at Sinana and Robe are presented in Table 3. The result indicated that rainfall total of the rainy and dry seasons as well as the annual totals increased slightly, but trends were not statistically significant for the period 1984-2016. During the study period, the area received considerable amount of annual rainfall that ranged from 538 mm to 1586 mm at Sinana and 506.2 mm to 1101 mm at Robe (Table 3).

The Kiremtseason contributed more annual rainfall totals compared to another seasons for both stations. The coefficient of variation also showed that more variable at Sinana and less variable at Robe when compared all seasonal rainfall (Table 3). Furthermore, the results of seasonal climate data analysis revealed that the mean of the main rainy (Kiremt season) season was 367.3 mm with CV value of 22.7 % which was the least as compared to the CV values of small rainy season (Belg season) 36.1 % at Sinana and 34.1 % at Robe while dry period (Bega season) 41.2 % at Sinana and 43.7 % at Robe. This indicates that Belgrain was less variable than KiremtandBegarains at Sinana while Kiremt rain was less variable than BelgandBegarains at Robe.

Table 3. Descriptive statistics of rainfall of annual and seasonal rainfall totals of Sinana and Robe areas during the period of 1984-2016

		Sinana station							
		Descriptive statistics				Trends			
Parameters	Mean	Min	Max	Media	SDE	CV (%)	ZMK	p-values	Slope
Annual RF	905.1	537.9	1586.3	863.9	277.6	30.67	0.92	0.356	9.05
Kiremt RF	402.5	194.9	819.0	355.0	158.4	39.35	1.36	0.169	6.05
Belg RF	339.0	160.0	716.2	337.4	122.5	36.14	-0.20	0.843	1.10
Bega RF	163.7	51.1	383.8	156.6	67.7	41.36	1.47	0.140	2.0
		Robe station							
Annual RF	812.4	506.2	1101	830.5	133.8	16.47	0.60	0.549	2.8
Kiremt RF	367.3	214.3	538.2	377.9	83.22	22.66	1.91	0.056	2.9
Belg RF	259.1	140.6	545.1	232.7	88.38	34.11	-1.04	0.298	-1.03
Bega RF	186.0	36.4	454.4	199.6	81.34	43.73	0.72	0.470	0.91

ZMK Mann–Kendall trend test, Slope: Sen‟s slope

Annual and seasonal rainfall anomalies

There was high seasonal and annual rainfall variability in the study area over 1984-2016. There were wet (0 to +0.5) and dry (0 to -0.5) periods over the study area for both annual and seasonal rainfall. Similarly, annual rainfall anomalies wet (above +0.5) and dry periods (above -0.5) were observed in certain years. The years of 2007, 2008, 2010, 2011, 2012 and 2013 experienced extreme wet condition, while the years 2000, 2002, 2003, 2004, 2005and 2006 were extreme dry at Sinana station. Similarly, extreme wet condition showed in the years of 1998, 2006, 2010 and 2013 while the years of 1984, 1985, 1991, 2002, 2011 and2014 extreme dry period at Robe station. The main rainy(Kiremt) season for the years 2007, 2008, 2010, 2011 and 2012 at Sinana station and the years 1988, 2012 and 2013 at Robe station were experienced extreme wet condition and the other years 1993, 2002and 2005 at Sinana and the years 1984, 1985, 2002 and 2005 were extreme dry period at Robe. This result implies that the production of crops could be affected severely in these periods either due to deficit or excess of rainfall required for agricultural activities at Sinana and Robe areas (Figures 3-4).

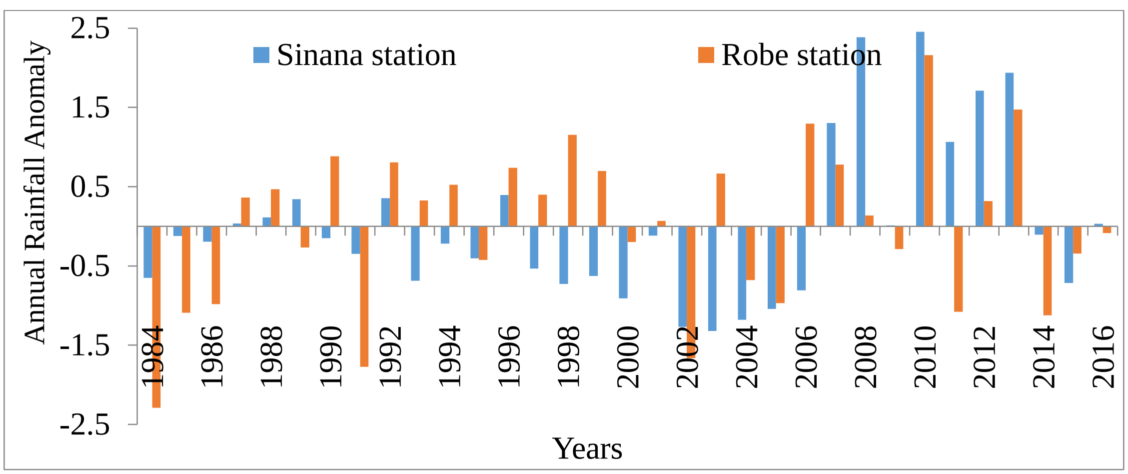


Figure 3.Annual rainfall anomalies for Sinana and Robe areas for the period (1984-2016)

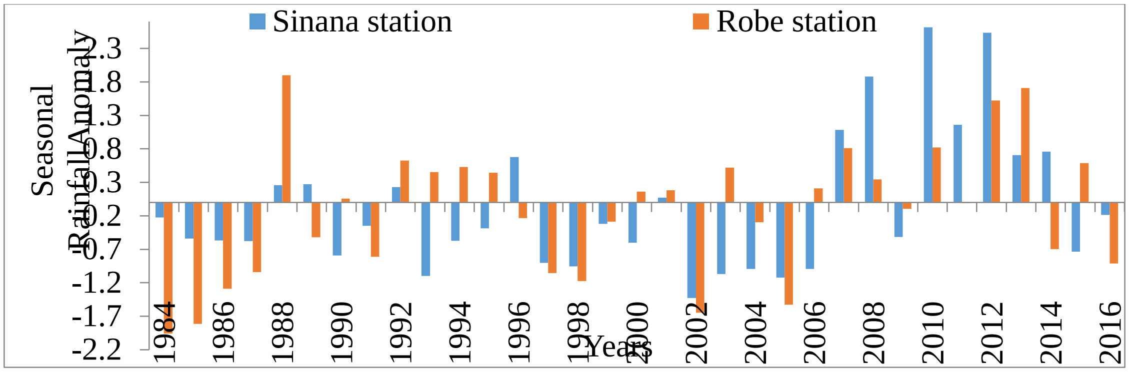


Figure 4.Kiremt season rainfall anomaly for Sinana area for the period 1984-2016

Trend analysis of annual maximum and minimum temperature

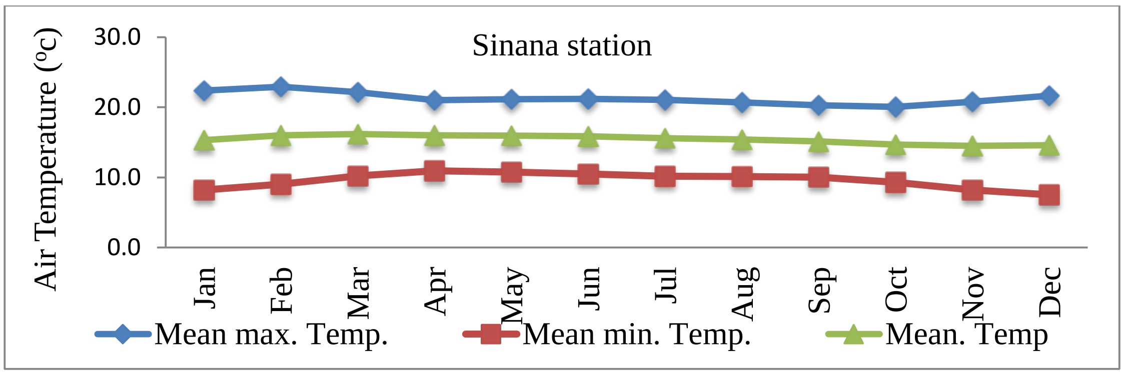
The temporal variability of average maximum and minimum temperatures had been examined at inter annual time scale for the period 1984-2016 at Sinana and Robe. The result indicated that annual maximum temperature had decreased by -0.15°C while annual minimum temperature has increased 1.5°C at Sinana respectively in the last three decades. Similarly, annual maximum and minimum temperature had increased trend 0.28 ^{0}C and 0.41 ^{0}C respectively in the last three decades at Robe. This was due to high variability of climate aspects in the southeastern highland of the country. The probability of occurrence of dry spell caused due to high heat stress the study area was increased the impact of temperature variability on agricultural activities would be with high risk.Mean annual trends of maximum and minimum temperatures at Sinana and Robe stations for the historical was indicated in (Table 4). The result showed that annual maximum and minimum temperature at Robe and minimum temperature at Sinanawas increased and statistically significant in the last three decades for ($p<0.01$). On the other hand, decreasing annual maximum temperature at Sinana was not statistically significant ($p<0.05$).

Table 14.Trends of annual Max.andMin.temperature in Sinana and Robe areas for 1984-2016

Stations	Minimum Temperature				Maximum Temperature			
	Mean	ZMK	P-value	S(°C/yr)	Mean	ZMK	P-value	S(°C/yr)
Sinana	9.6	5.11**	0.000	0.15	20.2	-1.82	0.069	-0.02
Robe	8.1	4.21**	0.000	0.04	21.6	3.54**	0.000	0.03

Note: ZMK: Mann–Kendall trend test, S: Slope (Sen"s slope) is the change (^{0}C/year) ** indicates significant trend at less than 1% p-values

Mean monthly temperature clearly showed that the area experience the highest mean recorded in March, while the month of November showed that the lowest air temperature was observed which could reach up to 16.2 ^{0}C and 14.5 ^{0}C respectively showed the mean monthly maximum and minimum temperature at Sinana area for the period 1984-2016 (Figure 5).Similarly, the highest mean monthly temperature was recorded in May and July up to 15.8 ^{0}C, while the month of November showed that the lowest air temperature was observed which could reach up to 13.4 ^{0}C at Robe station. As the result showed that, the highest mean maximum temperature was recorded in March at Sinana station and in May and July at Robe station, while in the month of November mean minimum temperature was received for both areas.



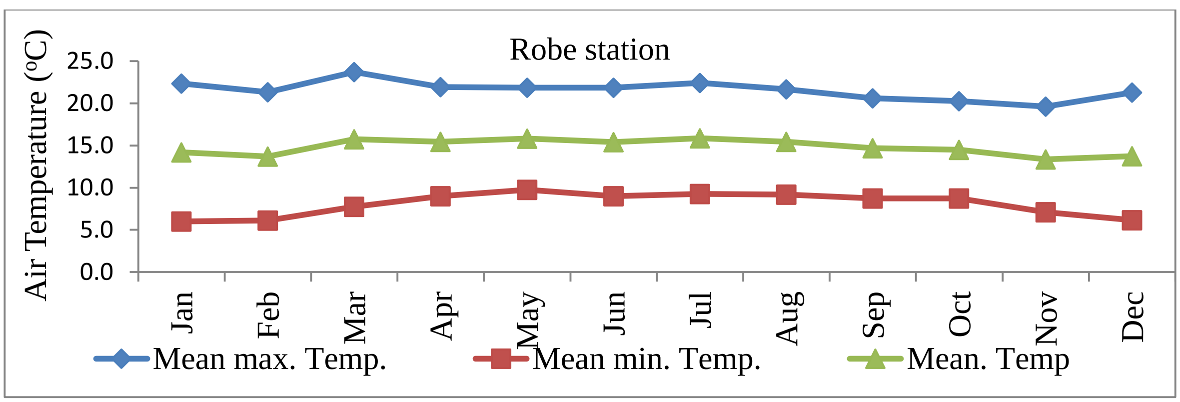


Figure 5.Mean maximum, mean minimum and mean monthly air temperature for the period 1984-2016 at Sinana and Robe station

Wheat rust severity and average yield loss values for 6-wheat cultivar’s and 2-local check

Rust diseaseseverity data was collected from all succeed sitesand patch into Excel in the order of recorded time and its reaction with all varieties trials. Diseases severity and host response data are combined into a single value called coefficient of infection. The coefficient of infection is calculated by multiplying the severity times a constant for host response (i.e. R=0.2, MR =0.4, MS =0.8 and S =1). The yield loss due to diseases severity calculated by Cobb scale (i.e. 1% terminal severity is equivalent to a 0.54 % loss in yield). Some of the cultivars such as Madda-walabu, Digalu and Danda'a were resistance for yellow and leaf rust, while moderately susceptible to stem rust. Kubsa was moderately susceptible for leaf and susceptible to yellow and stem rust disease. Tussie and Sofumer were susceptible for this climatic condition during the study periods.

Table.5 Reaction of Bale highland wheat crop to yellow, leaf and stem rust diseases basedon modified Cobb scale (Peterson et al. 1948)

	Degree of infection (reaction) to			Yield loss (%) due to		
Variety	yellow rust	stem rust	leaf rust	yellow rust	stem rust	leaf rust
PBW343	S	S	S	31.6	21.6	21.5
Maddawalabu	R	MS	R	1.7	2.9	2.2
Morocco	S	S	S	32.1	26.1	27.9
Kubsa	S	S	MS	25.0	20.7	16.6
Sofumer	S	MS	R	11.0	8.7	8.8
Digalu	R	S	R	15.0	25.9	10.2
Tussie	S	S	MR	12.8	10.8	8.2
Danda'a	R	MS	R	10.4	16.6	9.4

S= Susceptible, MS= Moderately Susceptible, MR= moderately resistant and R= Resistance.

Wheat rust disease over study area in relation to some climate parameters

During study years, wheat rust disease requiresoptimum climate variability for its development and infection. However, at Bale highlands the minimumthe favoring temperature was 4.5^{o}C to 15.6^{o}C while the maximum temperaturewas ranged from 20^{o}C to 28^{o}C. The results have shown that the correlation value between monthlyrainfall withleaf rust, yellow rust and stem rust were indicated -0.76, -0.94 and -0.57 while positively correlated with relative humidity and temperature, which is statistically good and so facilitates its development and infection on main cropping season. Therefore, yellow rust diseases has decreased and disfavored by high rainfall with a correlation value coefficient -0.94(Table 6). This is because the condition is not favorable for the spreading of yellow rust over wheat fields during the cropping season. The correlation between minimum temperatureand stem rust diseases was indicated 0.89, which is statistically significant. In fact, the correlation values between maximum temperature and yellow rust is 0.59, which is not good.This study has shown that whenever the climatic conditions are favorable, wheat crop is highly affected by climate related disease. The stem rust diseases mostly affectat vegetative and flowering stages. From the analysis, the correlation between minimum temperature and stem rust is 0.89 and statistically significant.

The correlation values existed between relative humidity and leaf rust diseases development in the main croppingseason over thewheat fieldsrevealed 0.88, which was extremely high. The series of annual diseases severity in the four locations of Bale highlands showed stronginter-annual fluctuation, without visually apparent association with climate variability as shown in table 6. This analysis showed that there was a climate impact onwheat rustdiseases occurrence.This indicated that the development of rust diseases mostly depends on temperatures,rainfall and relative humidity for development and spreading.

Table.6. Correlation between climatic parameters with stem rust, yellow and leaf rust intensity over Bale highlands.

Parameter	Correlation coefficient (r)		
	Leaf Rust	Yellow Rust	Stem Rust
Seasonal rainfall	-0.76*	-0.94**	-0.57*
Relative Humidity	0.88*	0.72*	0.63*
Minimum temperature	0.66*	0.84*	0.89*
Maximumtemperature	0.69*	0.59*	0.57*

Note **= highlysignificant,*=significant and ns=non-significant', (p =*0.05)*

Severity of rust disease versus mean local climate patterns over Bale highlands

The computed correlation values for cropping season rainfall and diseases severity showed strong associations among the parameters. For instance, the correlation between monthly rainfalls and disease severity about -0.86, while for relative humidity and diseases severity reached 0.74. This condition was also true for maximum and minimum temperature with rust diseases, the correlation analysis indicated 0.61 and 0.79 respectively.The results hence revealed that the rust diseases severity is highly favored by cropping season rainfall than the relative humidity as shown in table 7. It is found that cropping season rainfall and wheat rust diseases had indirect relation, while maximum temperature, minimum temperature and relative humidity had direct relation withwheat rust diseases as table 7. Generally, wheat rust development and severity follows climate parameters such as rainfall, relative humidity and temperature.

Table 7.Correlation between climatic parameters and wheat rust wheat rust intensity

Parameters	Correlation coefficient (r)
Seasonal rainfall	-0.86
Relative humidity	0.74
Maximum temperature	0.61
Minimum temperature	0.79

Generally, wheat rust development and severity follows local climate variability, since the relationship between the rust, relative humidity and temperature are directly related to the rust diseases as shown in table 7. From weekly analysis during cropping season, theclimatic condition conducive for rust diseases occurrence were identified.Therefore, the development and spread of rust is highly enhanced with maximum temperature and minimum temperature ranges 20.8 ^oC to 28^oC and 8.2 ^oC to 11.7 ^oC, while relative humidity was more than 70 % across the highland regions. In the warm and humid climate the wheat rust development and infection was severe and requires long period dew point (RH) at least 6 to 8 hrs. Rust attains maximum infection at 8 to 12hrs of dew at 18^oC. Moreover, the impact of local climatic parameters on rust diseases over Bale highlands during development and spreading periods summarized in the table 8.

Table 8.The impact of local climatic on wheat rust diseases based on Pearson's correlation value

Met-parameters	Impacts on rust diseases of wheat
Rainfall	Atincreasing rainfall, decreases spore development by cleaning the spores from the leaf and stem. In cropping season, if rainfall amount increases, the infectiondecreases by scrubbing the spores from the plant and increases RH.

Maximum temperature	An average ranges of temperature from 20.8 ^{o}C to 28 ^{o}C increases rust spreading during cropping season and favors for spore development.
Minimum temperature	An average ranges between 8.2 ^{o}C to 11.7 ^{o}C minimum temperature has positive effect on spore development and below 8.2 ^{o}C eliminates rust injuries.
RH (moisture)	A function of moisture in the cropping season used to spread wheat rust onfield, initiate germination within 1 to 3hrs of contact with moisture, health of the spores rapidly increases at moisture contents more than 70%.

Conclusions and Recommendations

Climate variability was believed to cause the most damaging impacts on agricultural practices in developing countries like Ethiopia. The study tried to investigate the impact of climate variability on wheat rust disease development. The results of this study showed that wheat yield variability over Bale highland determined by fluctuation of rainfall, temperature and relative humidity for developing and spreading of rust diseases mainly during main season. Results from the analysis of average wheat yield loss showed that the current levels of 6-cultivers and two check of wheat yield widely responding to yellow, leaf and stem rust diseases. The studies made on the relationship between short-term meteorological variations and diseases development and their spatial spread across the Bale highland has not yet well assessed. Such studies could be used for predicting wheat rust diseases development and infection during the main seasons. The potential impacts of local climate variability on the rust diseases and wheat production were also investigated using various statistical techniques. Moreover, the average relative humidity, rainfall and temperature observed during cropping season created conducive conditions for the rust infection on wheat crop across the Bale highlands. Being rust diseases are one of the most natural factors that affect wheat crops; they reach maximum infection stage in main season. Generally, rust disease directly relied on the level of climatic conducive prevailing during main season to temperature, relative humidity and rainfall. The overall results as generated based on local climatic factors and rust diseases as well as wheat yields can be utilized in the provision of optimizing climatic information for monitoring wheat crop performances over Bale highlands and demonstrate these techniques over regions having similar climatic conditions.

As stated above, we identified some climatic factors as precursor indicators for the severity of rust diseases and wheat yield losses over the highland of Bale. This is due to the fact that farmers are always operate under uncertainty by avoiding some external inputs such as weather forecasts for their early planning. Therefore, there is a need to establish a system that enables to use available climatic information towards the optimization of wheat productivity across the Bale highlands. This in fact requires coordinated efforts among the meteorological institutes, agricultural research institutes and farmers training centers. Finally, there is a need to design and expand multi-sectoral researches particularly focusing on microclimates and rust diseases, frosts, and insect's pests that are responsible for year-toyearcrop yield variations.

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References

Dereje Hailu and Chemeda Fininsa, 2007. Relationship between stripe rust (Puccinia striiformis) and grain quality of bread wheat (Triticum aestivum) in the highlands of Bale, southeastern Ethiopia.

Diriba Korecha and Tony Barnston, 2007. Predictability of June–September Rainfall in Ethiopia, National Meteorological Agency of Ethiopia, Addis Ababa, Ethiopia and International Research Institute for Climate and Society, Palisades, New York.

EATA Group, 2012. Discussion on Establishment of Early Warning System through Rust Trap Nurseries for the Prevention Rust Wheat Diseases Outbreaks.

Fageria, N.K., 1992. Maximizing Crop Yields. Marcel Dekker,New York.

Geletu Bejiga, Firdissa Eticha, Abebe Atilaw, Zewdie Bishaw, Asnake Fikre and LijalemKorbu, 2012. Progress report of the project entitled "Rapid deployment of high yielding and rust resistant wheat varieties for achieving food security in Ethiopia" - financed by USAID and implemented by EIAR and ICARDA.

Gerrit Hoogenboom, 2000. Contribution of agrometeorology to the simulation of crop production and its applications.

Gizachew Legesse, 2012. Application of best-bet agronomic practices in response to seasonal weather forecast.

ICARDA ,2012. Synthesis of a dialog between policy makers and scientists from 31 countries at:International Wheat Stripe Rust Symposium, Aleppo, Syria, April 2011.

Ngetich, K.F., Mugwe, J.N., Mucheru-Muna, M., Shisanya, C.A., Diels, J. and Mugendi, D.N. 2008. Determination of seasonal length and rainfall onset and cessation dates in the Kenyan highlands. Kenyatta University. Nairobi, Kenya. p11.

Olkeba Birru, 2011. Efects of surface management practices on soil, water & Nutrient conservation & Yield of Whea t(Triticum aestivum L.) at Bale Highlands, Southeastern Ethiopia.

Petr, J., 1991. Weather and Yield. Elsevier, Amsterdam,Netherlands
Sisay Eshetu, 2009. Assessing &Modeling the impact of climate variability on severity of rust diseases & Wheat production over Arsi Highlands, Ethiopia.
Valizadeh, J., Ziaei, S.M. and Mazloumzadeh,S.M. 2013. Assessing climate change impacts on wheat production (a case study). *Journal of the Saudi Society of Agricultural Sciences, Vol. 13 (2) pp: 107-115.*
World Bank. 2012. Turn down the Heat, why a 4 .C warmer world must be avoided. A report for the world bank by the Potsdam Institute for Climate Impact Research and World scientists' warning to Humanity. Washington, DC: World Bank.
Workneh Degefu, 1987. Some aspects of Meteorological Drought in Ethiopia. Drought and Hunger in Africa, Edited by Michael H. Glartz Cambridge University, press, London, pp 21- 36.

Effect of NPS Rate on Yield and Yield Components of Upland Rice (*Oryza sativa* L.) In Western Ethiopia

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Abstract
The key elements that contributed to low rice productivity is such biotic, abiotic factors and inappropriate crop management practices. Moreover, application of balanced fertilizers is the basis to produce more crop yield from existing land under cultivation and nutrient needs of crops is according to their physiological requirements and expected yields. Thus, a field experiment was conducted in 2016-2018 main cropping season from the end of May to end November at western Oromiya on Bako and Chewaka locations to improve soil fertility and increase yield of Rice in East Wollega and West Showa and to determine optimum level of NPS fertilizer for growth, economically feasible rates that maximize the yield of Rice in the area. The treatments were factorial combination of seven rates of fertilizer (0, 25, 50, 75, 100, 125 kg/ha NPS) and one previous recommendation (100 kg/ha DAP) with two Rice varieties (Chewaka and Nerika-4) and with uniform application 23 N kg/ha in randomized complete block design and replicated three times. The pre soil analysis indicates that the soil of experimental area is acidic (pH = 5.4) and medium in available Phosphorus (13 ppm). The main effect of plant height, panicle length and number of effective tillers were not influenced by NPS rate but significantly (P<0.01) different due to variety both at Bako and Chewaka locations. But the main effect of above ground biomass and grain yield were significantly different at Chewaka site. Though the other parameters were non-significantly affected, grain yield of Chewaka variety was significantly influenced due to the interaction effect of NPS rates and varieties at Bako. Thus, economic analysis revealed that 125 kg/ha NPS (47.5 P2O5, 23.75 N and 8.75 kg/ha S) rate on Chewaka variety gave grain yield (6454.8kg/ha) with the net benefit (61160.5 birr/ha) and the highest Marginal Rate of Return (MRR) (787.69%) were economically feasible alternative to the other treatments. Therefore, it is recommended to use 125kg/ha NPS rate on Chewaka variety since it is economically feasible.
Keyword: *Economic analysis, biotic and a biotic factors,NPS rates, yield and yield components*

Introduction

Rice (*Oryza sativa* L.*)* is widely grown in tropical and subtropical regions (Bijay and Singh, 2017). In Ethiopia field crops cover the largest cultivated land area from which cereals covered nearly 80.7% and rice covered 0.51% from cereal land coverage and accounting 2844kg/ha grain yield (CSA, 2018). A latest report of Central Statistical Authority (CSA) indicates that area covered by major cereals namely, Tef, Maize, Sorghum and Wheat were 23%, 17%, 16% and 13% respectively, in main crop season of 2010. During the same season, national yield averages obtained from the same cereals were 1.26, 2.25, 2.00 and 1.86 t/ha, respectively. Rice is also one of cereal crops which is cultivated in most regions of the country even if specific to a few locations of the regions. It is said a newcrop to the country. This crop also faces different challenges like other cereal crops in the country (Helufand Mulugeta, 2006). Despitethe fact that numbers of farmers' as well as area coverage are increasing from time to time, crop yields are generally found in declining trends (CSA, 2009).

Although, low yields of these crops were attributes of several biotic and a biotic factors, inappropriate crop management practices that mainly include; sowing periods, seeding methods, weeding practice, and lack of farmers awareness on uses of cropping systems and different soil fertilization methods are found the key elements that contributed to low crop productivity in the country. Rice is the high yielding crop in different countries of the world and stable food in some countries (Riaz *et al*., 2007). In Ethiopia the productivity is very low then the attainable yield and not Exide 35 kuntal per hectare due to the challenges mentioned above. Improvement of its production has not been possible due to low soil fertility and inadequate nutrient management among other factors (Helufand Mulugeta, 2006). Therefore, to alleviate the aforementioned persistent problems of crop production, there has been a growing interest to increase the productivity through improved agronomic practices. Consequently, some crop management research activities with objectives to identify agronomical optimum and economical maximum crop management practices are proposed to conduct on various crops in different agro-ecologies of the country. But the growth and yield of rice is influenced by different nutrients management and other factors during their production in a field (Riaz *et al.,* 2007). Despite its importance and increased production, crop productivity, in many parts of the world, is low due to genetic and environmental factors affecting its yield and yield related traits (Nonnecke, 1989). In many crop producing areas lack of available nutrients is frequently the limiting factor next to the soil water as their uptake and liberation of N, P and S from soil organic matter depends upon availability of water (FAO, 2003). Research work has been done on the base of NP in different soil types and in various climatic conditions, but very limited work has been reported on various sources of fertilizers for a certain nutrient. Application of only N and P containing fertilizers causes reduction of the quantity of K and S in most of the soils as there is also evidence of fixation of potassium and leaching of sulphur in different types of soils in addition to mining by different crops as result of continues cultivation of land (Murashkina*et al*., 2006).Under P deficient conditions, rice does not respond to application of N, K, and other nutrients (Bijay and Singh, 2017). Therefore, the application of K and S and other micronutrients to soils having even fair amounts of K and S contents may still show its effect on plants.In rice, number of panicles and panicle length may be adversely affected by S deficiency (Fageria*et.al.*2003).Phosphorus management must focus on the buildup and maintenance of adequate available P levels in the soil to ensure that P supply does not limit crop growth and N-use efficiency (Fairhurst *et.al.,*2007). The recently cultivated crop(upland rice) in the country also full of these challenges such as, soil fertility problem, pests(weed, disease, insects) & a biotic factors .Therefore, improving the productivity of the crop, soil fertility improvement will be the mandatory & this can be improved by different mechanisms. Thus, the research aimed to investigate different optimum and economically feasible rate of fertilizers to the rice crop. Therefore, the experiment is initiated with the objective of determining optimum level of NPS fertilizer for growth, economically feasible and high productivity of upland rice in the research area.

Materials and Methods

The trial was conducted at Bako Agricultural research center on station and sub- station of Chewaka site during 2016-2018 main cropping seasons. The treatments were consisted of different level of NPS compound fertilizer and control treatment without fertilizer application. The recommended fertilizer rate 46 P_2O_5 (100kg kg/ha DAP) was used as check in comparison with different levels of fertilizers. Uniform application of 23 kg/ha Nitrogen (50kg/ha Urea) was used in split at sowing and tillering. The constituent of Nitrogen, phosphorus and sulfur in 100 kg/ha NPS is 38 kg P_2O_5, 19 kg N and 7 kg S respectively. Two upland rice varieties (Chewaka and Nerica-4) were used as tested crop in the trial. Thus, fourteen treatment combinations consisting seven rates (0, 25, 50, 75, 100 & 125 kg/ha NPS with one recommended rate of 46 kg/ha P_2O_5) fertilizer and two rice varieties (Chewaka and Nerica-4) combined factorially were arranged in a randomized complete block design in three replications.

Data Collection and Measurements

Growth, Yield and Yield Component

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

Results and Discussions

Soil Physico-Chemical Properties of Experimental Site

The soil textural classes consisted proportion of 38% sand, 50% clay and 12% silt indicating sandy clay at Bako which is ideal for rice production. pH of the soil was 5.4 categorized as acidic according to rating described by Landon (1991). According to Tekalign (1991) rating, the organic carbon of the soil showed medium at Bako (2.88%). Total N of the soil (0.23%) was medium; as rated by Havlin et al., (1999) who rated total N between 0.15 to 0.25% as medium. Available phosphorus indicated that there was medium (11 mg/kg) phosphorus content of the soil at Bako site which was in line with (Jones, 2003).

Growth, Yield and Yield Components

From the analysis of variance plant height, panicle length, number of effective tiller, number of filled grain, Above ground biomass and harvest index were not influenced by main effect of NPS rate ($p>0.05$) but highly influenced ($p<0.01$) due to variety at Bako locations and Chewaka except non-significance difference on number of filled grain and harvest index at Chewaka. However, none of their interaction effects were significantly different at both locations during the main growing season of 2016-2018 cropping calendar (appendix Table 1). In all parameters the highest values were recorded at Chewaka variety than Nerika-4 (Table 1). The lower values of Nerika-4 when compared with Chewaka variety were probably associated with the severity of head blast disease to Nerika-4 especially at Bako location.

Table 1. The main effect of rates of NPS on Plant height, Panicle length, Number effective tiller, Number of filled grains, Above ground biomass and Harvest Index of rice at Bako

NPS rates (kg/ha)	PH	PL	NET	NFG	AGBM	HI
0	100.51	20.78	12.83	85.1	12838	34.58
25	104.58	21.13	13.72	93.7	13927	30.5
50	101.36	20.73	13.14	83.3	13154	31.02
75	103.67	21.03	12.54	82.8	13065	31.71
100	103.39	20.82	12.4	84.7	12672	31.69
125	103.43	21.43	12.22	84.7	13867	33.43
100 DAP	101.69	20.94	12.48	81.1	12536	30.37
LSD	NS	NS	NS	NS	NS	NS
Variety						
Chewaka	118.1	21.37	14.13	90.4	16030	38.36
Nerika-4	87.22	20.59	11.39	79.7	10273	25.44
LSD	3.81	0.42	0.9	6.84	1030.4	2.37
Cv	10.5	5.7	19.8	22.7	22.1	21.0

LSD (0.05) = Least significance difference at 5% probably level, CV = Coefficient of variation, NS = non-significant at 5% probability level. PH=Plant height, PL=Panicle length, NET= Number effective tiller, NFG=Number of filled grains AGBM=Above ground biomass and HI=Harvest Index.

On the other hand, even if the other traits except panicle length and number of effective tiller showed non-significant difference due to the main effect of NPS, Plant height, Grain yield and Above ground biomass were highly (P>0.01) influenced due to the main effect of NPS rates and rice varieties but all of the parameters were not significantly affected (P>0.05) due to their interactions at Chewaka location (Appendix Table 2). This result was in line with Increase in the magnitude of yield attributes is associated with better root growth and increased uptake of nutrients favoring better growth of the crop (Helufand Mulugeta, 2006). Except number of filled grain and harvest index all parameters were significantly different due to the main effect of Variety at Chewaka location and the highest values were also observed at Chewaka variety when treated with Nerika-4 on the site (Table 2).

Table 2. The main effect of rates of NPS on Plant height, Panicle length, Number effective tiller, Number of filled grain, Grain yield, Above ground biomass and Harvest Index of rice at Chewaka

NPS rates	Traits						
(Kg/ha)	GY(kg/ha)	AGBM(kg/ha)	HI	NET	NFG	PH (cm)	PL (cm)
0	2517c	5645c	45.492	6.056	54.95	91.17b	20.422
25	2939b	6784bc	43.528	6.489	57.68	95.28b	20.267
50	3243ab	7988a	46.368	6.233	54.53	92.72b	20.922
75	3291a	7096ab	49.291	6.422	61.8	95.56ab	20.889
100	3263ab	7373ab	46.263	6.467	56.02	96.5ab	20.789
125	3318a	7677ab	44.77	6.322	56.89	96.5a	21.58
100 DAP	3108ab	7276ab	45.787	5.9	58.89	95.78ab	21.544
LSD(0.05)	344.16	1194.9	NS	NS	NS	5.66	NS
Varieties							

Chewaka	4032a	9528a	46.87	6.91a	58.49	109.6a	21.61a
Nerika -4	2199b	4712b	44.98	5.63b	56.01	81.25b	20.22b
LSD	183.96	638.69	NS	0.51	NS	3.03	0.56
CV	16.7	25.3	12.8	22.8	18.0	8.9	7.5

LSD (0.05) = Least significance difference at 5% probably level, CV = Coefficient of variation, NS = non-significant at 5% probability level. PH=Plant height, PL=Panicle length, NET= Number effective tiller, NFG=Number of filled grains AGBM=Above ground biomass GY= grain yield and HI=Harvest Index.

From analysis variance showed non-significant difference, except grain yield was significantly affected due the main effect of NPS rate and variety as well as their interactions at Bako location (Appendix Table 1). The highest grain yield (7172 kg/ha) was recorded from 125 kg/ha NPS (47.5 P_2O_5, 23.75 N and 8.75 kg/ha S) on Chewaka variety at Bako location (Table 3). This was in line with Fageria*et.al* (2003) suggesting the above-ground P uptake by high-yielding rice varieties commonly ranges from 25 to 50 kg P/ ha with 60–75% of the total plant P contained in the panicles at maturity. Comparative result was also statedas application of phosphorus fertilizer had significantly increased the grain yield of rice up to the applied level of 46 kg P_2O_5 /ha on baby trial (Getahun*et.al.*, 2017). Generally, the grain yield obtained from Nerika-4 variety was by far smaller than Chewaka variety on Bako station as well as Chewaka location over years due to increased number of unfilled grains that had positive correlation for lower total grain yield in Nerika-4 which might be connected with rice head blast.

Table 3. Interaction effects of rates of NPS and Variety on Grain yield (Kg/ha) of rice varieties (Chewaka and Nerika-4) at Bako

NPS (kg/ha)	Chewaka	Nerika-4
0	6048bc	2929d
25	6202bc	2635de
50	6314bc	2211ef
75	6523b	2307ef
100	6192bc	2393def
125	7172a	2606de
100 DAP	5742c	1896f
LCD	611.8	
CV	14.9	

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

Economic Analysis

The partial budget analysis was done on the basis of total variable cost considering the costs of different NPS rates, variety, and transport as well as application costs.The economic analysis was done on the basis of adjusting 10% yield downward for that fact it closest to the farmer yield.The result of partial budget analysis showed that five NPS rates were non-dominated with an associated MRR greater than 100% (Table 4). An additional income of 7.87 Ethiopian Birr per unit Birr invested was obtained from 125 kg/ha NPS rate on Chewaka variety compared to the other treatments. This analysis revealed that 125 kg/ha NPS rate on Chewaka variety gave (6454.8kg/ha) with the net benefit (61160.5 birr/ha) and the highest marginal rate of return (787.69%) are economically feasible alternative to the other treatments (Table 4). Therefore, it is advisable to use 125kg/ha NPS rate on Chewaka variety since economically feasible to the farmers.

Table 4. Results of partial budget analysis for NPS fertilizer rates and Rice varieties (Chewka and Nerika-4).

NPS (kg/ha)	Variety	Gross yield	Adjusted yield (10%)	Gross benefit	TVC	NB	Dominance	MC	MB	MRR (%)
0	Nerika-4	5229	4706.1	53061	1667.5	52400.5		0	0	
0	Chewaka	6048	5443.2	54432	1767.5	52664.5		100	264	264.00
25	Nerika-4	2635	2371.5	23715	1986.5	21728.5	D			
25	Chewaka	6202	5581.8	55818	2086.5	53731.5		319	1067	334.48
50	Nerika-4	2211	1989.9	19899	2310.5	17588.5	D			
50	Chewaka	6314	5682.6	56826	2410.5	54415.5		324	684	211.11
75	Nerika-4	2307	2076.3	20763	2629.5	18133.5	D			
75	Chewaka	6523	5870.7	58707	2729.5	55977.5		319	1562	489.66
100DAP	Nerika-4	1896	1706.4	17064	2868.5	14195.5	D			
100	Nerika-4	2393	2153.7	21537	2968.5	18568.5	D			
100DAP	Chewaka	5742	5167.8	51678	2968.5	48709.5	D			
100	Chewaka	6192	5572.8	55728	3068.5	52659.5	D			
125	Nerika-4	2606	2345.4	23454	3287.5	20166.5	D			
125	Chewaka	7172	6454.8	64548	3387.5	61160.5		658	5183	787.69

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

Conclusion

Even though the experiment was conducted at Chewaka and Bako locations over years the yield obtained at Chewaka was relatively lower than Bako location which might be connected with severity of rice head blasts. From different NPS rate and rice varieties(Chewaka and Nerika-4) tested, economic analysis showed that 125 kg/ha NPS rate on Chewaka variety gave grain yield (6454.8kg/ha) with the net benefit (61160.5 birr/ha) with the highest marginal rate of return (787.69%) are economically feasible alternative to the other treatments. Therefore, it is advisable to use 125kg/ha NPS rate on Chewaka variety since economically feasible to the farmers. There would be the need of further NPS rate investigation beyond the highest rate of this recommendation (125kg/ha NPS rate) to assess the maximum potential of rice and reach its turning (peak points) to give general conclusion.

References

Bijay-Singh and V.K. Singh, 2017. Fertilizer Management in Rice. Pp. 232-233, In: B.S. Chauhan *et al*. (eds.) Rice Production Worldwide. Indian Agricultural Research Institute, New Delhi,India

CSA (Central Statistical Authority), 20018. Agricultural sample survey, 2018 (2010 E.C) report on area and production for major crops (private peasant holdings, main season), statistical bulletin 586, Addis Ababa, Ethiopia.

Fageria NK, Slaton NA, Baligar VC, 2003. Nutrient management for improving lowland rice productivity and sustainability. Adv Agron 80:63–152.

Fairhurst TH, Dobermann A, Quijano-Guerta C, Balasubramanian V, 2007. Mineral deficiencies and toxicities. In: Fairhurst TH, Witt C, Buresh RJ, Dobermann A, editors. Rice: a practical guide to nutrient management, 2nd ed. International Rice Research Institute, Los Banos; International Plant Nutrition Institute, Norcross; International Potash Institute, Berne, pp.46–86.

Food and Agriculture Organization (FAO), 2003. *World agriculture: towards 2015/2030. An FAO perspective*, edited by J. Bruinsma.Rome, FAO and London, Earthscan.

Getahun D, BogaleW, Assefa G, Solomon H, Hagos A, *et al*., 2017. Participatory Evaluation and Determination of N and P Fertilizer Application Rate on Yield and Yield Components of Upland Rice (NERICA-4) at Bambasi District, Benishangul-Gumuz Regional State. Adv Crop Sci Tech 5: 303. doi:10.4172/2329-8863.1000303.

He Havlin, J.L., Beaton, J.D., Tisdale, S.L and Nelson, W.L.(1999). Functions and forms of N in plants. *In Soil Fertility and Fertilizers*. (6th ed) Prentice Hall, New Jersey. DOI: http://dx.doi. org/10.1097/00010694-195704000-00019.

HelufGebrekidan and MulugetaSeyoum, 2006. Effects of Mineral N and P Fertilizers on Yield and Yield Components of Flooded Lowland Rice on Vertisols of Fogera Plain, Ethiopia, *Journal of Agriculture and Rural Development in the Tropics and Subtropics* , 107(2) : 161–176.

Jones, J.B., 2003. Agronomic handbook: Management of crops, soils, and their fertility. CRC Press LLC, Boca Raton, FL, USA. 450p.

Landon, J. R., 1991. Tropical soil manual: a handbook for soil survey and agricultural land evaluation in the tropics and sub tropics. Longman Scientific and Technical, Longman Group, UK Ltd

Murashkina, M., Southard R.J., Pettygrove, G.S. (2006). Potassium Fixation in Silt, Sand and Clay Fractions of Soils Derived from Granitic Alluvium of the San Joaquin Valley, California. The 18th World Congress of Soil Science (July 9-15, 2006) at Philadelphia, Pennsylvania, USA.

Tekalign, T., (1991). Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document NO 13. International Livestock Research Center for Africa (ILCA), Addis Ababa

Effect of Yam Tuber Size Cutting on Its Yield in Western Oromia, Ethiopia

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Abstract

Yams (Dioscorea spp.) are an annual tuber and monocotyledonous crop. The plant Genus comprises of over 600 species with only 10 species producing edible tuber. A field experiment was conducted at Western Oromia to recommend appropriate tuber weight of yam cutting for the farming and its economic feasibility for communities in western Oromia for two consecutive years during the main cropping season of 2017 and 2018 at Bako Agricultural Research Center (BARC) on station and subsite of Gute. Yam variety Bulcha, which is adapted to the agro-ecology of the area, was used for the study appropriate tuber weight of yam cutting. Planting was done on April and yam tubers cutting at different gram were planted at a spacing of 80 cm between rows and 30 cm between plants. After cutting up the tuber into mini-setts, takes ash and rub ash onto the freshly cut fresh that are exposed. Nitrogen fertilizer was used 100kg ha^{-1}in two splits and 100kg ha^{-1}NPS which were used.NPS 100 kg ha^{-1}and half Nitrogen fertilizer applied after emergence and the remaining half a month after first application along the rows of each plot to ensure that N is evenly distributed. The treatment consist of factorial combination of one variety (Bulch) with six treatment ((50-100g/ha), (101-150g/ha), (151-200g/ha), (201-250g/ha), (2501-300g/ha) and (whole size as control)) yam tuber cutting different weight size. The treatments were arranged in randomized complete block design (RCBD) with three replications. Each plot will be 4.8m long and 3m wide (6 rows). Finally, yam tuber plant in the central net plot area (9.6 m^2) was harvested at normal physiological maturity. Therefore, the result of the economic analysis (partial budget) show that best promising yam tuber cutting size weight 201-

250g (78874.3 birr) followed by 151-200g (73096.3birr) and 251-300g (70936.3 birr) and tuber yield tone hectare (57.95 tone/ha, 56.42 tone/ha and 54.45 tone/ha respectively were recommended for farmer or end user in western Oromia of yam production area and similar agroecology.

***Key words**: Yam tuber cutting, mini-setts*

Introduction

Yams (*Dioscorea*spp.) are an annual tuber and monocotyledonous crop. The plant Genus comprises of over 600 species with only 10 species producing edible tuber. Six of these edible species are cultivated in Africa, West Indies, Asia, South and Central America (Amusa,2000; Tamirou et al., 2008; Bousalem et al., 2010; Elsie, 2011; Petro et al, 2011; Ibitoye et al., 2013) and only three (3) of them are available in Gabon. The primary species cultivated are the white yam (*Dioscorearotundata),* yellow yam (*Dioscoreacayenensis)* and water yam (*Diosoreaalata), D. rotundata*and *D. cayenensis* may have been first domesticated in the forest-savannah ecotone of West Africa (Hamon et al., 1995; Tostain et al., 2003).Yam tubers are important in different domains. Nutritionally, yams are a major source of nourishment to many populations in the world (Craufurd et al., 2006). Pharmaceutically, some species of *Dioscorea*, particularly *Dioscoreazingiberensis*, produces high concentration of diosgenin, a chemical used for the commercial synthesis of sex hormones and corticosteroids (Chen et al., 2003; Yuan et al., 2005; Islam et al., 2008). Agriculturally, yams tubers are used as planting material (Odjugo, 2008; Zannou, 2009). Yam also plays vital roles in traditional culture, rituals and religion as well as local commerce of African people (Izekor and Olumese, 2010). The conventional multiplication of *Dioscorea*species is by tuber seeds, a tuber fragment that grows and develops into a new tuber. The farmers of the area unknowingly cut and use of yam planting materials without recommendation that causes rotting and desiccation for the majority of planting materials which leads to yield reduction. Then it is very essential to recommend appropriate yam tuber size cutting for optimum yield production in the farming communities.

Objective: To recommend appropriate tuber weight of yam cutting for the farming and its Economic feasibility for communities in western Oromia

Materials and method

A field experiment was conducted at Western Oromia to recommend appropriate tuber weight of yam cutting for the farming and its economic feasibility for communities in western Oromia for two consecutive years during the main cropping season of 2017 and 2018 at Bako Agricultural Research Center (BARC) on station and subsite of Gute.

Plant materials: Yam variety Bulcha, which is adapted to the agro-ecology of the area, was used for the study appropriate tuber weight of yam cutting. Variety Bulcha is the most successful variety released by Bako Agricultural Research Centre in 2012. Bulcha variety performed tuber yields of 66.45 t/ha

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 on April and yam tuber cutting at different gram was planted at a spacing of 80 cm between rows and 30 cm between plants. After cutting up the tuber into mini-setts, takes ash and rub ash onto the freshly cut fresh that are exposed. Allow the mini-setts to dry out for one day in cool dry place before placing them in a nursery. This prevents the flesh from being infected whilst in the nursery. The animal manure (in order to conserve moisture inside tuber cutting) was applied along the rows before planting and mixed with soil then placement yam tubers at recommended spacing was done in hole prepared in the field. Nitrogen fertilizer was used 100kg/ha in two splits and 100kg/ha NPS which were used.100kg/ha NPS and half Nitrogen fertilizer appliedafter emergence and the remaining half a month after first application along the rows of each plot to ensure that N is evenly distributed.

The treatment consist of factorial combination of one variety (Bulcha) with six treatment ((50-100g/ha), (101-150g/ha), (151-200g/ha), (201-250g/ha), (2501-300g/ha) and (whole size as control)) yam tuber cutting different weight size. The treatments were arranged in randomized complete block design (RCBD) with three replications. Each plot was 4.8m long and 3m wide (6 rows). The inside four 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, yam tuber plant in the central net plot area (9.6 m^2) was harvested at normal physiological maturity. The yam tubers were harvested manually using by hoeing and hand picking.

Procedure of yam tuber cutting

Five Yam tuber sample randomly taken and measured their average weight (500g+1000g+1500g+ 2000g+ 4000g =9000g/5=1800, 9kg/5=1.8kg) of tuber used to calculated amount of cutting for each treatment and about 50,000 cutting required for a hectare (Table1).

Table.1. Yam tuber cutting in different size in gram and the amount of cutting per hectare.

	Treatment	Number Cutting	1kg/cutting	Kg/ha	Quintal/ha
1	50-100g	24	13.33	3751	37.51
2	101-150g	14	9.44	5297	52.97
3	151-200g	10	5.56	8993	89.93
4	201-250g	9	5	10000	100
5	251-300g	7	3.89	12853	128.53
6	whole size/control	1.8kg	1.8kg	25000	250

Figure 1. Yam tuber cutting, their measurement and placement of tuber on appropriate space

Economics analysis

Net return (NR ha^{-1}) and benefit: cost ratio (B: C) was calculated by considering the sale prices of yam tuber (1kg = 6 birr) and labor 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 yam tubers for economic analysis. Hence, following the CIMMYT partial budget analysis methodology, total variable costs (TVC), gross benefits (GB) and net benefits (NB) will be calculated (CIMMYT, 1988).

Collected Data: Plant height/Vine length (cm), Tuber number per plant, Tuber length per plant (cm), Tuber diameter per plant (cm), Tuber weight per plant in gram, Tuber weight per plot in kilo gram and Tuber yield per ha in tone were collected.

Results and Discussions

Yam tuber tons per hectare, tuber weight per plant in kg and tuber weight per plot in kg

The combination analysis main effect yam tuber tone per hectare, tuber weight kilo gram per plant and tuber weight per plot in kilo gram were showing significant ($P<0.05$) different between yam cutting tuber of Bulch of variety. Similarly, the interaction effect of tuber cutting size weight of yield parameter tuber kilo gram per plant, tuber weight per plot in kilo gram and tuber tone per hectare were significant influenced by location and years. The maximum yam tuber yield was obtained by whole tuber size/ control (66.12 tons per hectare) and followed by 251-300g (57.95 tons per hectare), 201-250g (56.42 tons per hectare) and 1051-200g (54.4 tons per hectare) (Table.2.).

Table 2. Main effect of yield component parameter of yam tuber

Treatment	TWPkg	TWplkg	TTONha
50-100g	2.42d	39.88d	41.54d
101-150g	2.74cd	46.56c	48.5c
151-200g	3.21bc	52.28bc	54.45bc
201-250g	3.15bcd	54.16b	56.42b
251-300g	3.54b	55.63b	57.95b
whole size	5.44a	73.08a	66.12a
Mean	3.41	53.6	55.83
CV%	27.84	13.25	13.25
Year			
2017	2.96b	72.27a	75.28a
2018	3.87a	34.92b	36.37b
Location			
Bako	2.68b	52.28a	54.46a
Gute	4.14a	54.91a	57.2a
TRT	**	**	**
Yr	**	**	**
TRT*yr	**	*	*
TRT*Loc	**	**	**
yr*Loc	**	**	**

Clue: *TRT= treatment, g = gram, CV%= coefficient of variation in percentage, Yr = year, Loc = location, TTONha= Tuber tone per hectare, TWpkg = tuber weight kilo gram per plant and TWPlkg = tuber weight per plot in kilo gram*

Figure.2. Yam tuber harvesting and their storage

Yam growth parameter

The combination analysis main effect yam growth parameter such as plant height in cm, vine number per plant, tuber number per plant, tuber length per plant were significantly influenced by yam cutting size weight ($P < 0.05$) but tuber diameter per plant not significantly affected by yam tuber cutting size weight. The vigorously of yam vegetative were increasing as tuber cutting size weight in gram increases (figare.3) and the maximum plant height, vine number per plant, tuber

Table.3. Main effect of yam growth parameter

Treatment	PHcm	VNP	TNP	TLPcm	TDPcm
50-100g	2.69 c	3.05d	2.98b	18.03c	8.27ab
101-150g	2.74 c	3.13cd	3.63ab	20.04bc	8.41ab
151-200g	3.17 a	3.87a	3.32ab	18.95bc	8.07ab
201-250g	2.99 c	3.8ab	4.03a	19.41bc	7.79b
251-300g	3.06 b	3.27bcd	3.63ab	21.12b	8.33ab
whole size	3.39 a	3.68abc	4.05a	20.63a	8.85a
Mean	3.01	3.47	3.61	20.2	8.28
CV%	12.48	19.45	25.77	14.61	15.04
Year					
2017	3.22a	3.05b	3.33b	25.42a	9.47a
2018	2.79b	3.88a	3.89a	14.97b	7.1b
Location					
Bako	3.21a	3.69a	4.12a	20.83a	8.2a
Gute	2.80b	3.24	3.1b	19.56a	8.37a
TRT	**	*	*	**	Ns
Yr	**	**	*	**	**
Loc	**	**	**	ns	Ns
Rep	Ns	Ns	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	Ns

Clue: TRT= treatment, g = gram, CV%= coefficient of variation in percentage, Yr = year, Loc = location, phcm= plant height in cm, VNP= vine number per plant, TNP= Tuber number per plant, tlpcm= Tuber length per plant in cm, tdpcm= tuber diameter per plant

number per plant, tuber length per plant and tuber diameter per plant were obtained by yam whole size/ control and followed by 251-300g (Table.3)

Figure .2. Yam vegetative performance

Economic analysis

Table 4. Partial budget analysis

Treatment	Tuber yield toneha^{-1}	Gross return (Birr ha^{-1})	Cost ofProduction (Birr ha^{-1}) or Total Cost vary birr ha^{-1}	Net benefit birr/ha or Net return (GR – PC) (Birr ha^{-1})	Benefit:cost ratio(GR/PC Eth. Birr	Return/Birr Investment (NR/PC) ETB	Net return (Eth. Birr ha^{-1})
50-100g	41.54	249240	219605	29635	1.134947	0.134947	
101-150g	48.5	291000	231427.7	59572.3	1.257412	0.257412	
151-200g	54.45	326700	253603.7	73096.3	1.28823	0.28823	73096.3
201-250g	56.42	338520	259645.7	78874.3	1.303777	0.303777	78874.3
251-300g	57.95	347700	276763.7	70936.3	1.256306	0.256306	70936.3
whole size	66.12	396720	341543.8	55176.2	1.161549	0.161549	

The result of the economic analysis (partial budget) for different yam tuber cutting size presented on (Table. 4.) indicated that the treatment of (50-100g, 101-150g, 151-200g, 201-250g, 251-300g and whole size/control) the best ideal yam tuber cutting size were obtained highest net return (Ethiopia Birr) per hectare from 201-250g (78874.3 birr) followed by 151-200g (73096.3birr) and 251-300g (70936.3 birr). The result of the economic analysis (partial budget) for different yam tuber cutting size presented indicated that the treatment of the best ideal yam tuber cutting size were obtained highest net return (Ethiopia Birr) per hectare from 201-250g (78874.3 birr) followed by 151-200g (73096.3birr) and 251-300g (70936.3 birr). Therefore, the best promising yam tuber cutting size weight 201-250g (78874.3 birr) followed by 151-200g (73096.3birr) and 251-300g (70936.3 birr) and tuber yield tone hectare (57.95 tone/ha, 56.42 tone/ha and 54.45 tone/ha respectively were recommended for farmer or end user in western Oromia of yam production area and similar agroecology.

Reference

Amusa NA (2000). Screening cassava and yam cultivars for resistance to anthracnose using toxic metabolic of collectorichim species. Mycopathologia 150: 137-142.

Bousalem M, Viader V, Mariac C, Gomez R, Hochu I, Santoni S, David J (2010). Evidence of diploidy in the wild Amerindian yam, a putative progenitor of the endangered species Dioscoreatrifida (Dioscoreaceae). Genome, 53: 371-383.

Chen Y, Fan J, Yi F, Luo Z, Fu Y (2003). Rapid clonal propagation of *Dioscoreazingiberensis*. Plant Cell. Tiss. Organ Cult. 73: 75-80.

Craufurd PQ, Battley NH, Ile EL, Asiedu R (2006). Phase of dormancy in yam tubers (*Dioscorearotundata*). Ann. Bot. 97: 497-504.

Hamon P, Dumont R, Zoundjihékpon J, Tio-Touré B, Hamon S (1995). Les IgnamesSauvagesd’Afrique de l’Ouest/ Wild Yam in Africa. Morphological Characteristics. Ed. Orstom, collection Didactiques, 84pp.

Ibitoye SJ, Onimisi JA (2013). Economic assessment of yam production in Kabba-Bunu Local Government Area of Kogi State, Nigeria. J. Dev. Agric. Econ. 5: 470-475

Islam MT, Keller ERJ, Philibert D (2008). Effects of growth regulators on in vitro propagation and tuberization for four Dioscorea species. Plant Tissue Culture and Biotechnology18 (1):25-35.

Izekor OB, Olumese MI (2010). Determinants of yam production and profitability in Edo State, Negeria. Afr. J. General. Agric. 6: 30-35.

Odjugo PAO (2008). The effect of taillage systems and mulching on soil microclimate, growth and yield of yellow yam (Dioscoreacayenensis) in Midwestern Nigeria. Afr. J. Biotechnol. 7(24): 4500-4507.

Petro D, Onyeka TJ, Etienne S, Rubens S (2011). An intraspecific genetic map of water yam (Dioscoreaalata L.) based on AFLP markers and QTL analysis for anthracnose resistance. Euphytica 179: 405-416.

Tamiru M, Becker HC, Mass BL (2008). Diversity, distribution, and management of yam landraces (Dioscorea spp.) in Southern Ethiopia. Genet. Resource. Crop. Evol. 55: 115-131.

Tostain S, Okry FK, Baco NM, Mongbo RL, Agbangla C, Daïnou O (2003). La domestication des ignames*Dioscoreaabyssinica*dans les sous- préfectures de Sinendé et de Banté au Bénin (Afrique de l'Ouest). Ann. Sci. Agron. Bénin 4: 33-54

Zannou A (2009). Economic assessment of seed-tuber practices of yam Dioscoreacayenensis and Dioscorearotundata planting materials. Afr. J. Agric. Res. 4(3): 200-207.

Integrated Management of Barley Shootfly on the Highlands of Guji Zone, Southern Oromia

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ABSTRACT

This study was initiated to assess the effect of Integrated Management of Barley Shoot flyon yield and yield componenst of Barley (Hordeum vulgare L.). Afield experiment was conducted during the 2017-18 main cropping season at Bore Agricultural Research Center to evaluate the effect of integrated barley shoot fly management on yield and yield components of barely and to determine an economically feasible optionshoot fly management for barley production. The treatments consisted of five levels of insecticides (Apron star, Dynamic, Procid plus, Joint and Torpido and four levels of planting dates. The experiment was laid out in Randomized Complete Block Design (RCBD) in a factorial arrangement with three replications. Analysis of variance revealed that interaction of the two factors (chemicals and planting dates) significantly affect most parameters except thousand kernels weight, number of tillers per plant and number of productive tillers per plant. Generally, all parameters recorded over all treated plots were significantly higher than untreated/control plots. Thus using insecticides and adjusting planting date can help to improve yield andyield components byreducing the degree of barley shoot fly infestation. The highest grain yield (4403 kg h^{-1}) and lower shoot flyinfestation wereachieved from combined application of Torpido + first planting date. The partial budget analysis, however, revealed that combined applications of Torpido insecticide and planting in the last week of Julygave the best economic benefit 26941.78 Birr ha^{-1}. Therefore, based on this study it can be concluded that the use of Torpido insecticide and planting in the late Julycan be recommended for production of barley in the study area and other areas with similar agro-ecological conditions.

Key words: Insecticides, interaction effect, main effect, shoot fly, sowing date

Introduction

In Ethiopia, cereal crops are majorly produced for several purposes where they are greatly contributing towards sustaining food security. Farmers in different parts of the country are growing different types of cereal crops based on their agro-ecological suitability to address their family food demand. Particularly, farmers in high land parts of the country are producing barley for home consumption and income generation. As a result, it's commonly called as a poor man's crop that is able to give yield in marginal environments that is unsuitable to other crops at higher elevation (Zerihun*et al*., 2007). It ranks 5th in terms of area (993,918.89 ha) and production (19,533,847.83) next to wheat and followed by finger millet (CSA, 2016).

The crop grows well at altitudes ranging between 1500–3500 masl but is predominantly grown at altitudes ranging between 2000–3000 masl (MoA, 1998). The highlands of Guji Zone are also found within most suited agro-ecological adaptation for barley crop production. Farmers in the area are usually producing barley as major crop for home consumption as well as for cash generation. It ranks second next to maize both in area (17,969.07 ha) and production (315,115.09). However, the production and productivity of the crop remains lower (17.54qt/ha) in relation to the national average (19.65qt/ha) and regional average (22.52qt/ha) productivity (CSA, 2016). This may be due to several production constraints like in insect pests, diseases low level of soil fertility, lack of improved varieties and others.

Barley shoot fly is one of the major biotic constraints to barley production on Guji highlands. A survey of *Barley shoot fly* incidence and damage level conducted in 2014 and 2015 indicated that there is high infestation which can cause high yield loss in susceptible varieties.However there is no known management practices used by farmers so far. Therefore, there is a need to evaluate and recommend different management options such integrated management which can be economically and environmentally most viable and sustainable.The objective of the study was to evaluate integrated approaches in barley shoot fly management and recommend the best option.

Materials and Methods

Description of the study area

The experiment was conducted at two locations of Bore district which represents highland agro-ecology of Guji Zone.Bore district is located at 385 km from Finfinnee to the South. The climatic conditions of the district comprise an annual rain fall of 1250mm, mean temperature of 17.5-28

Degree Celsius. Bore district was selected for this experiment as it represents the hotspot areas for barley shoot fly infestation.

Experimental design and treatments

For this experiment five insecticides namely Joint, Torpido, Dynamic, Proced Plus and Apronstarand four planting datesat seven days interval were used.The experiment was laid out in RCBD with three replications. Each experimental plot has 2.5 m long and 1.2 m wide, with six rows 20 cm apart, giving a gross plot area of 3 m^2. Spacing for adjacent blocks was 1.5 m and 1 m between plots. Sowing was done by hand drilling and covered lightly with soil. Seed and fertilizer were applied as per the recommendation ratesfor barley production.All other agronomic practices were also applied as recommended for barley production.

Data collection

Data were collected from a net plot of four rows and selected plants. Collected data includedays to heading (DTH), days to 90% maturity (DTM), grain filling period (GFP), plant height (PH), spike length (SL), total number of tillers/plant, total number of fertile tillers/plant, 1000-kernel weight (TKW), grain yield/ha (Gy kg/ha) and shoot fly infestation.

Data analysis

The recorded data were subjected to Analysis of Variance (ANOVA) as suggested by Gomez and Gomez (1984) using GenStat 18thVersion. Mean separation was carried out using Least Significant Difference (LSD) at 5 percent levels of significance.

Results and Discussion

Days to heading: The Analysis of Variance revealed that the main effect of planting date was highly significant (P < 0.01) on days to heading of barley while the two-factor interactions of Chemical × planting datessignificantly (P<0.05) influenced days to 50% heading. However, the main effect of insecticide did not significantly affect days to 50% heading of the crop. The highest prolonged duration to reach 50% heading was observed in response to the combination of planting date one and two across all pesticides. However, the minimum duration to 50% heading was observed in the application of Apronsarat fourth planting date (Table 1).

Table 15. Interaction effect of chemical and planting date on days to heading of barley

Insecticides	Days to heading				Days to maturity			
	Planting dates				Planting dates			
	P1	P2	P3	P4	P1	P2	P3	P4
Control	83^{a}	83.33^{a}	79.33^{bc}	75^{e}	146^{a}	139.7^{c}	134.3^{d}	127.3^{e}

Insecticides	Days to heading				Days to maturity			
	Planting dates				Planting dates			
	P1	P2	P3	P4	P1	P2	P3	P4
Apronstar	83^{a}	83^{a}	79.67^{b}	73.33^{f}	144^{b}	139.7^{c}	133^{d}	127.3^{e}
Dynamic	83^{a}	83^{a}	78.33^{d}	75^{e}	144^{b}	139^{c}	133^{d}	127.3^{e}
Proced	83^{a}	83^{a}	79^{bcd}	74.67^{e}	144^{b}	139.3^{c}	133.3^{d}	126.3^{e}
Joint	83^{a}	83^{a}	79^{bcd}	74.67^{e}	144^{b}	139.7^{c}	133.7^{d}	126^{e}
Torpido	83^{a}	83^{a}	78.67^{cd}	75^{e}	144^{b}	139.3^{c}	133^{d}	127.3^{e}
LSD(0.05)	0.91				1.55			
CV (%)	0.7				0.7			

Means with the same letter(s) in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, NS= non - significant, LSD = Least Significant Difference at 5% level

Days to physiological maturity: The main effect of planting dateand interaction of the factors highly significantly (P < 0.01) influenced days to physiological maturity of barley. But the main effect ofinsecticidesdid not significantly affect days to physiological maturity.

The longest physiological maturity (168.7 days) was recorded forthe first planting date with control/untreated whereas the shortest days to physiological maturity (126 days) was recorded from combination of Joint and the fourth planting date. The increase in days to maturity of barleyfor the controltreatment might be due to rejuvenation of the crop though the level of infestation wasthe highest.

Plant height: The two factor interaction and main effect of insecticides significantly (P < 0.05) influenced plant height. On the other hand, the main effect of planting date had no significant effect on this same parameter.The result indicated that height of barley plants increased as infestation was decreased (Table 2). The highest plant height (115.8cm) was recorded for insecticide Joint coupled with the second planting date while the shortest plant height (101.9cm) was recordedfor the controlcombined with third planting date of the two factors.

Spike length

The Analysis of Variance revealed significant (P < 0.05) interaction of the two factorsand main effect of planting date on the spike length whereas the main effect of chemical did not have significant effect on this parameter. Thus, the longest spikes (9.00 cm) were obtained fortreatment combination of insecticide Joint and the first planting date whereas the shortest spikes were produced for the combination of the Procedplus and first planting date(Table 2). The highest spike length of the treated plotsin relation to the untreated control might have resulted from improved root growth and increased uptake of nutrients and better growth favouredbyreduced shoot fly infestation.

Table 16. Main effect of chemicals and planting date on plant height and spike length of Barley

Insecticides	Plant height (cm)				Spike length (cm)			
	Planting dates				Planting dates			
	P1	P2	P3	P4	P1	P2	P3	P4
Control	103.6^{cd}	102.5^{d}	101.9^{d}	102.7^{d}	$7.778^{c\text{-}f}$	8.944^{ab}	8.944^{ab}	8.611^{abc}
Aprstar	113.7^{ab}	115.1^{a}	$110.6^{a\text{-}d}$	102.6^{d}	$7.5\ 0^{def}$	8.500^{abc}	$7.889^{c\text{-}f}$	$7.944^{c\text{-}f}$
Dynamics	$111.0^{a\text{-}d}$	105.1^{bcd}	$111.2^{a\text{-}d}$	113.8^{ab}	$7.833^{c\text{-}f}$	$8.222^{a\text{-}d}$	$8.00^{b\text{-}e}$	$8.278^{a\text{-}d}$
Proced	$110.2^{a\text{-}d}$	$109.4^{a\text{-}d}$	113.1^{ab}	114.6^{a}	$7\ .00^{f}$	8.944^{ab}	8.611^{abc}	$8.5\ 00^{abc}$
Joint	112.8^{abc}	115.8^{a}	$109.7^{a\text{-}d}$	$107.8^{a\text{-}d}$	9.00^{a}	8.667^{abc}	$8.167^{a\text{-}d}$	$8.111^{a\text{-}d}$
Torpido	$107.6^{a\text{-}d}$	114.2^{ab}	$109.1^{a\text{-}d}$	115.1^{a}	7.111^{ef}	8.611^{abc}	$7.889^{c\text{-}f}$	$8.444^{a\text{-}d}$
LSD(0.05)	9.33				0.98			
CV (%)	5.2				7.3			

Yield and Yield Components

Number of tillers per plant

The main effect of chemical and planting date did not significantly (P<0.05) influence the number of tillers of barley. Similarly the two-factor interaction (chemical × planting date) also did not significantly affect this parameter. This finding agrees with that of Wakene*et el* (2014).

Table 17. Interaction effect of chemical and planting date on number of tillers and number of productive tiller per plant of barley

Insecticides	Number of tiller/plant				Number of fertile tiller/plant			
	Planting dates				Planting dates			
	P1	P2	P3	P4	P1	P2	P3	
Control	3.222	3.667	3.722	3.611	2.833	3.167	3.278	
Apr	3.667	3.056	3.556	3.389	3.222	2.833	3.056	
Dyn	3.50	3.444	3.389	3.278	3.111	3.00	3.00	
Pro	3.722	3.50	3.389	3.722	3.167	3.111	3.056	
Join	3.389	3.389	3.50	3.389	2.889	2.944	3.056	
Torp	3.778	3.278	3.444	3.722	3.222	2.722	3.056	
LSD(0.05)	NS				NS			
CV (%)	9.9				11.2			

Means with the same letter(s) in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, LSD= Least Significant Difference at 5% level

Number of productive tillers

The main effect of insecticide and planting date did not significantly (P<0.05) influence the number of productive tillers of barley. Similarly the two-factor interaction (insecticide × planting date) also did not significantly affect this parameter.

Thousand kernels weight

The main effect of insecticide and planting date did not significantly (P< 0.05) influence thousand kernels weight of barley. Similarly the two-factor interactions did not significantly affect thousand kernels weight.The highest thousand kernels weight (60.42 g) was recorded forcombined application of Torpidowiththe first planting date whereas the minimum thousand kernel weight (32.11 g) was observed for application of Torpidocombined with fourth planting dateeven though there were not statistically significant differences.

Table 18. Interaction effect of chemicals and planting date on number of kernels per spike of barley

	Grain yield (kg/ha)				TKW (g)			
Chem.	Planting date				Planting date			
	P1	P2	P3	P4	P1	P2	P3	P4
Control	2296 de	2724 b-e	2185 e	2352 de	36.69	37.47	40.41	48.71
Apr	3961 ab	2719 b-e	3543 a-d	2667 b-e	42.11	36.38	36.82	37.7
Dyn	3331 a-e	2728 b-e	2886 b-e	3277 a-e	60.42	39.17	40.54	46.07
Pro	3894 ab	2468 cde	3967 ab	3962 ab	44.42	36.27	35.73	38.98
Join	3853 ab	3108 a-e	2880 b-e	2721 b-e	36.22	42	36.32	50.64
Torp	4403 a	3727 abc	3231 a-e	2877 b-e	48.53	36.17	36.19	32.11
LSD(0.05)	1327.15				NS			
CV (%)	25.6				17.8			

Means with the same letter in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, LSD=Least Significant Difference at 5% level

Grain yield

The main effects of insecticide and planting date and their interactions significantly (P< 0.05) affected grain yield of barley.Late sowing significantly decreased grain yields. Thus, the highest grain yield (4403 kg ha^{-1}) was obtained from combined application of Torpidoand first planting date and it was statistically at par with Procedeplus at first planting date and Joint applied for the first planting date whereas the lowest grain yield (2185 kg ha^{-1}) was recorded from the combinations of control of third planting date (Table 4). The highest grain yield at the Torpido and first planting date might have resulted from better growth favouredbydecreased shoot fly infestation which enhanced yield components and yield.In general, grain yield obtained from the treated plots exceeded the grain yield from the untreated/control plots by about 33.13%.

Barley shoot fly Infestation

The main effects of insecticide and their interactions significantly (P< 0.0) affected the barley shoot fly infestation. The highest infestation (62.84) was obtained from combination of control and third planting date whereas the lowest barley shoot fly infestation recorded from application of Torpido at first planting date (Table 5).This indicated that grain yield is correlated with infestation level.

Partial Budget Analysis

Analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 5 below. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation by farmers. The studies 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. As indicated in table below, the partial budget analysis showed that the highest net benefit (Birr 26941.78 ha^{-1}) was recorded at the combination of Torpido and first planting date and lowest was from control treatment. To use the marginal rate of return (MRR%) as basis of recommendation, the minimum acceptable rate of return should be between 50 to 100% (CIMMYT, 1988). In this study application of Torpido at first planting date gave the maximum economic benefit (26941.78 ha^{-1}). Therefore, on economic grounds, application of Torpido at 250ml/100kg seed as seed dressing and sowing at late Julywould be best and recommended for production of barley in the study area and other areas with similar agro-ecological conditions.

Table 19. Partial budget and marginal rate of return analysis for management of barley shoot fly through chemical and planting date

Treatments		**AGY by 10%**	**GB (Birr ha^{-1})**	**TVC**	**NR (Birr ha^{-1})**
Insecticidesplanting date					
Control	P2	2451.82	17162.76	0	17162.76
Control	P3	1966.87	13768.08	0	13768.08
Control	P4	2116.47	14815.32	0	14815.32
Control	P1	2066.61	14466.24	0	14466.24
Dynamic	P2	2455.61	17189.28	475	16714.28
Dynamic	P1	2997.69	20983.86	475	20508.86
Dynamic	P3	2597.48	18182.34	475	17707.34
Dynamic	P4	2949.21	20644.44	475	20169.44
Apron Star	P2	2447.40	17131.80	550	16581.80
Apron Star	P1	3565.01	24955.08	550	24405.08
Apron Star	P3	3188.26	22317.84	550	21767.84
Apron Star	P4	2400.05	16800.36	550	16250.36
Procideplus	P1	3504.43	24531.00	690	23841.00
Procideplus	P4	3565.73	24960.12	690	24270.12
Procideplus	P3	3570.14	24990.96	690	24300.96
Procideplus	P2	2221.41	15549.84	690	14859.84
Joint	P2	2796.98	19578.88	800	18778.88
Joint	P4	2448.54	17139.78	800	16339.78
Joint	P3	2592.44	18147.06	800	17347.06
Joint	P1	3467.49	24272.40	800	23472.40

Torpido	P1	3963.11	27741.78	800	26941.78
Torpido	P4	2589.70	18127.92	800	17327.92
Torpido	P3	2908.05	20356.32	800	19556.32
Torpido	P2	3353.99	23477.94	800	22677.94

AGY:adjusted grain yield, GB:groth benefitTVC:total variable cost, NR: net return

Conclusion

Analysis of the results revealed that interaction of the two factors (insecticides and planting dates) significantly affected almost all parameters except thousand kernels weight, number of tiller per plant and number of productive tiller per plant. Generally, all parameters recorded over all treated plots were significantly higher than untreated/control plot. Thus using of insecticide and adjusting planting date improved yield and yield components anddecreaseed barley shoot fly infestation. The highest grain yield (4403 kg h^{-1}) was obtained from combined application of Torpidoand first planting date whereas the lowest barley shoot fly infestation recorded from combined application of Torpidoand first planting date. The partial budget analysis revealed that combined applications of Torpido insecticide and planting in the last week of Julygave the best economic benefit 26941.78 Birr ha^{-1}. Therefore, based this study it can be concluded that combined application of this chemical and planting date can be recommended for farmers for production of barley in the study area and other areas with similar agro-ecological conditions.

References

CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo/International Maize and Wheat Improvement Center). 1988. From Agronomic data to Farmer Recommendations: An Economic work Book. Mexico, D.F.: CIMMYT.

CSA (Ethiopian Central Statistical Agency). 2016. Agricultural sample survey Report on area and production for major crops 1: 1-118

MoA (Ministry of Agriculture), 1998. National Livestock Development Project (NLDP) Working Paper 1-4. AddisAbaba, Ethiopia.

Shegaw Derbew,2017.Adaptations of Exotic Barley Genotypes to Low moistureEnvironments in Southern Ethiopia.Greener Journal of Agricultural Science. *DOI: http://doi.org/10.15580/GJAS.2017.6.071617088)* Vol. 7 (6):126-131

Zerihun J., 2007. Variability and Association of yield and yield-related traits in some barley (*Hordeum Vulgare* L.) landraces and Crosses. An M.Sc. Thesis presented to the school of Graduate Studies of Haramaya University.

Effect of Blended NPS and N Fertilizer Rates on Yield, Yield Components, and Grain Protein Content of Bread Wheat (*Triticum aestivum*L.) in Bore District, Guji Zone, Southern Ethiopia

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Abstract

Bread wheat is a major cereal crop in Ethiopia and in the study area, but its yield is limited due to minimum use of improved varieties, diseases, weeds, low soil fertility and lack of location specific fertilizer recommendation. Therefore, a field experiment was conducted during the 2017/18 main cropping season at Bore Agricultural Research Center to evaluate the effect of blended NPS and N fertilizer rates on yield components, yield and grain protein content; and to determine economically appropriate rates of blended NPS and N fertilizers for bread wheat production. The treatments consisted of four levels of NPS (50, 100, 150 and 200 kg NPS ha^{-1}) and four levels of N (23, 46, 69 and 92 kg N ha^{-1}) including one control (0 NPS and 0N). The experiment was laid out as a RCBD in a factorial arrangement with three replications. Analysis of the results revealed that interaction of the two fertilizers significantly affect grain yield, above ground dry biomass, date to heading, number productive tillers, plant height, spike length, straw yield, harvest index, hectoliter and grain protein content of bread wheat while date to maturity and thousand kernels weight affected only by main effect of NPS and N. Generally, all parameters recorded over all treated plots were significantly higher than unfertilized/control plot except date to mature, number of tiller per plant and number of kernels per spike. Thus using of NPS and N fertilizers improve yield components, yield and quality parameters of bread wheat. The highest grain yield (6.416 t h^{-1}) was obtained from combined application of 150 kg NPS ha^{-1} + 46 kg N ha^{-1}whereas the highest grain protein content was recorded from application of 200 kg NPS ha^{-1} + 92 kg N ha^{-1} .The result of economic analysis showed that combined application of 150 kg NPS and 46 kg N ha^{-1} gave economic benefit of 93319.68 Birr ha^{-1} with the marginal rate of return 32876.5%. Therefore, use of 150 kg NPS and 46 kg N ha^{-1} can be recommended for production and productivity of bread wheat in the study area and other areas with similar agro-ecologies.

Key words: Grain yield, interaction effect, main effect, quality, synergetic effect

Introduction

Wheat (*Triticum aestivum*L.) belongs to the grass family *Poaceae* and to the tribe *Hordeae* in which several-flowered spikelet are sessile and alternate opposite side of the rachis forming a true spike (Feldman and Sears, 1981). It is one of the most important food grain crops grown in the world. It ranks first in the world cereal crops accounting for 30% of all cereal food worldwide and is a staple food for over 10 billion people in as many as 43 countries of the world (Reddy, 2004). It provides about 20% of the total food calories for the human race (Reddy, 2004). It is cultivated in Ethiopia on about 1.66 million hectares and contributing about 4.22 million tons of grain yields, accounting for 15.81 percent of total grain output in the country during 2015/16 *meher* cropping season (CSA, 2016).

Wheat is one of the major staple crops in Ethiopia in terms of both production and consumption. In terms of caloric intake, it is the second most important food in the country next to maize (FAO, 2014). Wheat is mainly grown in the highlands of Ethiopia, which lie between 6 - 16° N and 35 - 42° E, at altitudes ranging from 1500 to 2800 meters above sea level and with mean minimum temperatures of 6°C to 11°C (Hailu, 1991; MoA, 2012). There are two types of wheat grown in Ethiopia: durum wheat, accounting for 40 percent of production, and bread wheat, accounting for the remaining 60 percent (Bergh *et al.*, 2012). Oromia region accounts for over half of national wheat production (58 percent), followed by Amhara (28 percent); Southern Nations, Nationalities and Peoples Region (SNNPR) (7.9 percent); and Tigray (4.2 percent) (CSA, 2016). Of the total wheat production area, about 75 percent is in the Arsi, Bale and Shewa wheat belts (MoA, 2012). Data from the Central Statistics Agency (CSA) indicated that the observed increase in wheat production over the last ten years can be attributed both to expansion of production area and adoption of improved technologies. For example, between 1995/96 and 2014/15 wheat production area increased from 0.8 million ha to 1.66 million ha, and yield increased from 1.20 t ha^{-1} to 2.54 t ha^{-1} (CSA, 2015). The study area (Guji Zone) is also one of wheat producing Zones of Oromia which covers an area of 4,879.92 ha with production of 11,795.435 t and yield of 2.4 t ha^{-1} in 2015/16 cropping season (CSA, 2016). Thus, wheat yield in Ethiopia and the study zone is well below the experimental yield of above 5 t ha^{-1} (Hailu , 1991, MoA, 2012).

Despite an increase in production and productivity trends, wheat is still the single most important staple food crop imported from abroad and most of the humanitarian food aid and commercial import takes in the form of wheat (Demeke and Di Marcantonio, 2013). To feed the growing human population and fill the yield gaps between wheat consumption and production in Ethiopia, increasing production of wheat is of paramount importance. Increasing wheat production in Ethiopia can be achieved by increasing productivity of smallholder producers in the mid and highlands areas and by bringing more area into wheat production in the lowlands. On the other hands, in the mid and highlands, wheat production is constrained by both biotic and abiotic factors such as diseases and pests, poor management practices, poor soil fertility and moisture stresses. Poor agronomic and soil management, inadequate level of technology generation and adoption are the most significant constraints to increase wheat production in the highlands and mid highlands of Ethiopia (Hailu *et al*., 1990;Demeke and Di Marcantonio, 2013).Thus, addition of nutrients such N, P and S to low fertile soil is important to increase wheat yield, yield components and quality of wheat whether it is for consumption or industrial purpose.

Most Ethiopian soils are deficit in nutrients, especially nitrogen and phosphorus and fertilizer application has significantly increased yields of crops (Tekalign*et al*., 2001). The causes for severe deficiency of most of the major nutrients (nitrogen and phosphorus) in Ethiopian highlands and midlands are the huge loss of soil from agricultural land, which is estimated to be 137 t ha^{-1} per year; approximately an annual loss of 10 mm soil depth (Zeleke*et al*., 2010). Annual nutrient deficit also estimated to be - 41 kg N, -6 kg P and -26 kg K ha^{-1} (Fassil and Charles, 2009). A range of environmental factors, such as low soil nitrogen and phosphorus levels, and acidic soil conditions are important constraints for wheat production in most areas where the crop is grown. Several researchers in Ethiopia have reported the role of N and P in wheat production in the highlands indicating that substantial increases in yield and yield components have been obtained with the application of N fertilizer (SchulthesIs*et al*., 1997; Amanuel*et al*., 2000; Tilahun*et al*., 2000; Muluneh and Nebyou, 2016; Lelago*et al*., 2016). According to Ethiosis (2013 and 14) and Tegbaru (2014). In addition to N and P, S is found to be low in the major Ethiopian soils. However, Ethiopian farmers used to apply only chemical fertilizers di-ammonium phosphate (DAP) and urea to increase crop yields for about five decades and this did not consider soil fertility status and crop requirements. For instance, in southern Ethiopia (study area), farmers apply 100/50 kg ha^{-1} DAP/Urea for wheat irrespective of the heterogeneity of the farm areas. In contrast to this, Tegbaru (2014); Fanuel (2015); and Okubay*et al*. (2015) reported that agricultural fields are not homogenous and soil macro nutrient status is highly variable. In addition to this, DAP and urea supply only P and N but not other nutrients such as K and S. The omission of these nutrients from the fertilizer package was due to the fact that when the fertilizer was tested (45 years ago) at the national fertilizer demonstration by Ministry of Agriculture and the Food and Agriculture Organization of the United Nations, no consistent trend was observed. In addition, a soil fertility survey conducted by Murphy (1968), found no deficiency of these nutrients in Ethiopian soils. However, in more recent studies, Abiye*et al*. (2004), and Wassie& Shiferaw *et al*. (2011) reported the deficiency of these nutrients in some Ethiopian soils. Moreover, the soil fertility mapping project in Ethiopia reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and thus recommend application of customized and balanced fertilizers (Ethiosis, 2014).

The farmers in most parts of the country in general and Bore district in particular have limited information on the impact of different types and rates of fertilizers except blanket recommendation of nitrogen (41 kg N ha^{-1}) and phosphorus (46 kg P_2O_5 ha^{-1}) *i.e.* 50 kg Urea and 100 kg DAP per ha^{-1} while according to the soil fertility map made over 150 districts, most of the Ethiopian soils lack about seven nutrients (N, P, K, S, Cu, Zn and B) (EthioSIS, 2013). Muluneh and Nebiyou (2016) reported the maximum yield (6.4 t ha^{-1}) at 50/150 kg NP ha^{-1}. Malik *et al*. (2003) also reported an increment of 25% protein content from a plot fertilized at a combination of 50/75 kg NP ha^{-1} as compared to other combinations of NP (25/50 kg ha^{-1}). Similarly, Yasir *et al*. (2015) reported the maximum grain yield of wheat (4463.5 kg ha^{-1}) at 140 kg N ha^{-1} and 20 kg S ha^{-1} at sowing and at anthesis respectively.

Except the blanket recommendation of nitrogen and phosphorus, the effect of other fertilizers on yield components, yield, and overall performance and quality of bread wheat are also unknown, even though new blended fertilizers such as NPS (19% N, 38% P_2O_5 and 7% S) are currently being used by the farmers in Ethiopia, including the study area. In addition to this, the amount of N in the blended NPS is small as compared to the requirement of wheat. Thus, there is a need to supplement with nitrogenous fertilizer in the form of urea. Moreover, the response of wheat plant to application of fertilizer varies with varieties (Fageria*et al*., 2008), rainfall (Scharf *et al.*, 1993), soils (Wissum*et al*., 2009) agronomic practices (Haile, 2011) etc. Thus, there is a need to develop location specific recommendation on the fertilizer rates to increase production and productivity as well as quality of wheat. Therefore, this study was undertaken with the following objectives: To evaluate the effect of rates of blended NPS and N fertilizers on yield components, yield and protein content of bread wheat and to determine economically appropriate rates of blended NPS and N fertilizers for bread wheat production.

3. Materials and Methods

3.1 Description of the study area

The experiment was conducted at Bore Agricultural Research Center (BoARC), Oromia Regional State in southern Ethiopia under rain-fed conditions for two cropping season. The site is located about 8 km North of the town in SongoBericha '*Kebele'* just on the side of the main road from Bore to Hawassa city. It is about 378 km far from capital Addis Ababa to south direction. Geographically, the experimental site is situated at latitude of 6^{o}26' 52" North and longitude of 38^{o}56' 21" East at an altitude of 2736 meters above sea level (masl). The research site represents highlands of Guji Zone, receiving high rainfall and characterized by a bimodal rainfall distribution. The first/major rainy season is from April up to October and the second season starts in late November and ends at the beginning of March. The major soil types of Bore are *Nitosols* (red basaltic soils) and *Orthic Aerosols* (Wakene*et al*., 2014). The soil is clay- loam in texture and strongly acidic with pH value of around 5.15 (Table 2).

3.2. Experimental Materials

3.2.1. Plant material

Bread wheat variety "Huluka (ETBW5496)" was used as planting material. The variety was released by Kulumsa Agricultural Research Center (KARC) in 2011/12 cropping season and hashas a maturity period of 133 days with the yielding potential of 3.8 – 7.0 t ha^{-1} (MoA, 2012). Variety Hulukawas selected on the basis of its adaptation and better agronomic performance in the study area.

3.2.2. Fertilizer materials

Blended NPS (19% N, 38% P_2O_5 and 7% S) and Urea (46% N) was used as the sources of fertilizers.

3.3. Treatments and Experimental Design: The treatments consisted of factorial combination of four N levels (23, 46, 69, 92 kg ha^{-1}) and four levels of blended NPS (50,100, 150, 200 kg ha^{-1}) fertilizer with one control (0 NPS and 0 N). The experiment was laid out in a randomized complete block design (RCBD) with three replications in factorial arrangement of 4 × 4 = 16 treatment combinations together with the one control treatment, making a total of 17 treatments. The gross size of each plot was 2 m × 3 m (6 m^2) consisting of ten rows and the distance between adjacent plots and blocks were 0.5 m and 1 m apart, respectively. The net plot area was 1.6 m × 2.6 m (4.16 m^2) and consisted of eight rows of 2.6 m length. The outermost row on both sides of each plot and 20 cm on both sides of each rows were considered as border plants and were not used for data collection to avoid border effects. The details of the treatment combinations and their nutrient contents are shown in Table 1.

3.4. Soil Sampling and Analysis

Soil samples were randomly taken from the experimental site following a zigzag pattern before planting at a depth of 0-30 cm across the experimental field from 15 spots using auger before planting and composited. Then, the collected samples were air-dried at room temperature under shade and submitted to laboratory where they were ground to pass through a 2 mm sieve whereas for organic carbon (OC) and nitrogen (N) determination, the soil was ground to pass through a 1 mm sieve. Working samples (1 kg) were obtained from prepared sample/composite and analysed for selected physico-chemical properties mainly for soil texture, soil pH, cation exchangeable capacity (CEC), organic carbon, total N, available P and S using standard laboratory procedures at Horticoop Ethiopia soil and water analysis laboratory.

Organic carbon was determined by the Walkley and Black oxidation method (Walkley and Black, 1934) while total nitrogen was analysed by the Kjeldhal method (Dewis and Freitas, 1970). The pH of the soil was determined at 1:2.5 (weight/ volume) soil to water dilution ratio using a glass electrode attached to digital pH meter (Page, 1982). Cation exchange capacity was measured after saturating the soil with 1N ammonium acetate (NH_4OAC) and displacing it with 1N NaOAC (Chapman, 1965) and available phosphorus was determined using the Bray method (Bray and Kurtz, 1945). Available S was determined using turbid metric method (Chesnin and Yien, 1951).

3.5. Experimental Procedures and Field Management

The experimental field was ploughed with tractor and oxen to a fine tilth four times and the plots were levelled manually. According to the design, a field layout was made and each treatment was assigned randomly to the experimental units within a block. Bread wheat seeds were sown at the recommended seed rate of 150 kg ha^{-1} in rows of 20 cm spacing manually by drilling on 27 July 2016. The whole of NPS and ½ N fertilizers was applied at sowing while the remaining ½ N was applied at mid-tillering stage as top dressing. Weeding was done as needed and harvesting and threshing were done manually.

3.6. Data Collection and Measurement

3.6.1. Crop phenology and growth parameters

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

Days to 90% physiological maturity (DTM): days to physiological maturity was determined as the number of days from sowing to the date when 90% of the peduncle turned to yellow straw colour.

Plant height (cm): plant height was measured from the soil surface to the tip of the spike (awns excluded) of 10 randomly tagged plants from the net plot area at physiological maturity.

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

Lodging percent: The degree of lodging was assessed just before the time of harvest by visual observation based on the scales of 1-5 where 1(0-15^o) indicates no lodging, 2(15-30^o) indicate 25% lodging, 3(30-45^o) indicate 50% lodging, 4(45-60^o) indicate 75% lodging and 5(60-90^o) indicate 100% lodging (Donald, 2004). The scales were determined by measuring the angle of inclination of the main stem from the vertical line to the base of the stem by visual observation. However, none of the plots indicated lodging and hence no data were recorded and reported

3.6.2. Yield components and yield

Number of tillers per plant: number of tillers per plant was determined from 10 tagged plants per net plot at physiological maturity by counting the number of tillers after removing soils surrounded the tillers.

Number of productive tillers: number of productive tillers was determined at maturity by counting all spikes bearing tillers from two rows of 0.5 m length per plot at physiological maturity.

Number of kernels per spike: the mean number of kernels per spike was computed as an average of 10 randomly taken spikes from the net plot area.

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

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

Grain yield (t ha^{-1}): grain yield was taken by harvesting and threshing the seed yield from net plot area. The yield was adjusted to 12.5% moisture content as:

$$\text{Adjusted grain yield} = \frac{(100 - MC) \times \text{unadjusted grain yield}}{100 - 12.5}$$

Where MC- is the moisture content of bread wheat seeds at the time of measurement and 12.5 is the standard moisture content of bread wheat in percent. Finally, yield per plot was converted to per hectare basis and the yield was reported in t ha^{-1}.

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

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

3.6.3. Grain quality parameters

Hectolitre weight: It is the weight of flour density produced in a hectoliter of the seed and it was measured using a standard laboratory hectoliter weight apparatus.

Grain Protein Content (GPC): Grain protein content was determined by using “MININFRA SMART GRAIN ANALYSER” equipment at Sinana Agricultural Research Center. After calibrating the equipment for bread wheat, cleaned and prepared sample of 300 g seeds were added to the equipment and waited for one minute. Then the equipment read grain protein near infrared and displayed on screen as well as printing on paper.

3.7. Statistical Data Analysis

All data collected were subjected to analysis of variance (ANOVA) procedure using GenStat (15th edition) software (GenStat, 2012). Comparisons among treatment means with significant difference for measured characters were done by using Fisher’s protected Least Significant Difference (LSD) test at 5% level of significance.

3.8. 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 ha basis in Birr. The concepts used in the partial budget analysis were the mean grain yield of each treatment, the gross benefit (GB) ha^{-1} (the mean yield for each treatment) and the field price of fertilizers (the costs of NPS and Urea and the application costs).The benefit of straw yield was not included in the calculation of the benefit since the farmers in the area do not use it. Marginal rate of return, which refers to net income obtained by incurring a unit cost of fertilizer and its application, was calculated by dividing the net increase in yield of bread wheat due to the application of each fertilizers rate. The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that vary (TCV) using the formula 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.

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

The dominance analysis procedure as described in CIMMYT (1988) was used to select potentially profitable treatments from the range that was tested. The discarded and selected treatments using this technique were referred to as dominated and undominated treatments, respectively. For each pair of ranked treatments, % marginal rate of return (MRR) was calculated using the formula 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.

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

The fertilizer cost was calculated for the cost of each fertilizer of NPS (Birr 16 kg^{-1}) and N/UREA (Birr 14 kg^{-1}) during sowing time. The cost of NPS and Urea application (Birr 525 ha^{-1}) and the average open price of bread wheat at Bore market was Birr 7 kg^{-1} in January 2017 during harvesting time.

4. RESULTS AND DISCUSSIONS

4.1. Soil Physico-Chemical Properties of the Experimental Site

The laboratory results of the analysis of the selected physico-chemical properties of the soil before sowing is presented in Table 1. The analytical results of the experimental soil indicated that the soil textural class is clay loam with a particle size distribution of 38% clay, 30% silt and 31% sand. Thus, the soil of the experimental site is suitable for wheat cropping. The pH of the soil was 4.99, which is strongly acidic according to the rating of Tekalign(1991). FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Mengel and Kirkby (1996) reported optimum pH range of 4.1 to 7.4 for wheat production. Thus, the pH of the experimental soil was within the range for productive soils.

Organic carbon content of the experimental site was 2.8% which is considered to be moderateaccording to Tekalign (1991). The analysis further indicated that the soil has medium total nitrogen (0.25%) according to the rating of Tekalign (1991). The results of the analysis also indicated that the soil has low available phosphorus content (9.03 mg/kg) according to the rating of Cottenie (1980). The analysis for available sulfur also indicated that the experimental soil had values of 18.22 mg/kg which is low according to Ethiosis (2014).

The CEC value of the soil sample is high (30.71 [Cmol (+) kg^{-1} soil] according to the rating of Landon (1991) which indicates that the soil has high capacity to hold exchangeable cations.

Table 20.Selected physico-chemical properties of the soil of the experimental site before planting

Parameter	**Result**	**Rating**	**Reference**
Soil texture			
Clay (%)	38		
Sand (%)	31		
Silt (%)	30		
Textural Class	Clay loam		
pH (1 : 2.5 H_2O)	4.99	Strongly acidic	Tekalign (1991)
Total N (%)	0.25	Medium	Tekalign (1991)
Organic Carbon (%)	2.80	Moderate	Tekalign (1991)
Cation Exchange Capacity			
[Cmol(+)kg^{-1} soil]	30.71	High	Landon (1991)
Available Phosphorus (mg/kg)	9.03	Low	Cottenie (1980)
Available Sulfur (mg/kg)	18.22	Low	Ethiosis (2014)

4.2. Phenological and Growth Parameters

4.2.1. Days to 50% heading

The analysis of variance revealed that the main effect of NPS is highly significant ($P < 0.01$) on days to 50% heading of wheat while the two-factor interactions of NPS × N significantly

($P<0.05$) influenced days to 50% heading. However, the supplemented N rate did not significantly affect days to 50% heading of the crop. The longestperiod to reach 50% heading was observed in response to the combined application of the highest rates of the two fertilizers (200 kg NPS + 92 kg N ha^{-1}) whereas the shortest duration to 50% heading was observed in the 50 kg NPS + 23 kg N ha^{-1} but it was not statistically different from 100 kg NPS + 23 kg N ha^{-1}, 150 kg NPS + 23 kg N ha^{-1} (Table 3).

The relatively delayed days to heading at the highest rates of NPS and N may be attributed to the synergic effects of the two fertilizers in promoting cell growth and prolonging vegetative growth. On the other hand, the number of days to heading did not show a consistent increasing trend with increasing NPS and N rates. Lack of trend could be attributed to the counteracting effects of P nutrition on N nutrition because N tends to increase vegetative growth while P hastens it. But mean of days to 50% heading recorded at all treated plots were not significantly different from untreated/control plots. This result is in line with the findings of Getachew (2004) who reported that time to heading was significantly delayed at the highest (120 kg ha^{-1}) N fertilizer rate compared to the lowest rate on wheat. Similarly, Manna *et al*. (2005) reported that combined application of NP and organic fertilizers promoted vegetative growth, leading to prolonged days to heading. Wakene*et al.* (2014) also reported 95.25 days to heading for barley at combined application of 120 kg N + 0 kg P ha^{-1}. In contrast to these results, Sewnet (2005) reported early flowering with an increase in the rate of N application in rice.

Table 21. Interaction effect of NPS and N fertilizers on days to 50% heading of bread wheat

NPS rate (kg ha^{-1})	N rates (kg ha^{-1})			
	23	46	69	92
50	90 d	90 d	90 d	90.67 c
100	90 d	90 d	90 d	90 d
150	90 d	90 d	90 d	92 b
200	90 d	90 d	91 c	93 a
Treated mean	90.4			
Control	89.0			
	NPS × N	Treated vs Control		
LSD (0.05)	0.48	NS		
CV (%)	0.3	0.2		

Means with the same letter(s) in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, NS= non-significant, LSD = Least Significant Difference at 5% level

4.2.2. Days to 90% physiological maturity

The main effect of NPS significantly ($P < 0.01$) influenced days to 90% physiological maturity of wheat but the main effect of N and the two-factor interactions of NPS × N did not significantly affect days to 90% physiological maturity. The results showed that increasing NPS rates increased days to physiological maturity of wheat. The longest duration to physiological maturity (168.7 days) was recorded at the highest rate of NPS (200 kg ha^{-1}) whereas the shortest duration to physiological maturity (167.00 days) was obtained from the control. But days to physiological maturity of fertilizer rates of 150 and 200 kg NPS kg ha^{-1} were not significantly different to each other. Generally, the number of days to maturity recorded at the highest rate of NPS was significantly higher than that of unfertilized plot. The increase in days to maturity of wheat at the highest rate of NPS might be due to the three nutrients interaction and their synergetic effect, especially N and S. According to Fazli*et al.* (2008), lack of S limits the efficiency of added N therefore; S addition becomes necessary to achieve maximumefficiency of applied nitrogenous fertilizer.

Table 22. Main effect of NPS and N fertilizers on days to maturity, spike length and plant height of bread wheat

Treatment	Days to maturity	Spike length (cm)	TKW (g)
NPS rate (kg ha^{-1})			
50	166.6 b	37.91 b	37.91 b
100	167.7 ab	38.53 b	38.53 b
150	168.5 a	44.13 a	44.13 a
200	168.7 a	43.09 a	43.09 a
LSD (0.05)	1.32	8.13	8.13
N rate (kg ha^{-1})			
23	167.9	39.87	39.87
46	167.7	40.43	40.43
69	167.6	39.93	39.93
92	168.2	43.43	43.43
LSD (0.05)	NS	NS	NS
CV (%)	1.4	11.9	11.9
Treated vs control			
Treated mean	169.56	40.92 A	40.92 A
Control	167.00	34.73 B	34.73 B
LSD (0.05)	NS	2.69	2.69
CV (%)	0.3	2.0	2.0

Means with the same letter (s) in the column are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, NS= non-significant, LSD= Least Significant Difference at 5% level, TKW=thousand kernels weight

4.2.3. Plant height

The two factor interaction and main effect of N significantly ($P < 0.05$) influenced plant height. On the other hand, the main effect of NPS had no significant effect on this parameter.

The result indicated that height of wheat plants increased as NPS and N rates increased (Table 3). The tallest plant (93.59 cm) was recorded at 200 kg NPS and 69 kg N ha^{-1} rate while the shortest plant (78.07 cm) was obtained at the lowest rates of the two fertilizers (50 kg NPS and 23 kg N ha^{-1}). This is because of the vital role of N and S fertilizersfor vegetative growth and resulted for significant influence on plant height. In general, mean plant height of fertilized plots exceeded control plots by around 21.11%.The result of this study agrees with that of Firehiwot (2014).

4.2.4. Spike length

The analysis of variance revealed significant ($P < 0.05$) interaction and main effect of NPS on the spike length whereas the main effect of N did not have significant influence on this parameter. The result showed that increasing NPS and N rates increased spike length. Thus, the longest spikes (8.95 cm) were obtained at the rate of 200 kg NPS and 92 kg N ha^{-1} and this was statically at par with 200 kg NPS and 46 kg N ha^{-1} whereas the shortest spikes were produced at the combination of the lowest rate of the two fertilizers(Table 4). The increase in spike length at the highest NPS and N rates might have resulted from improved root growth and increased uptake of nutrients and better growth favouredby interaction/synergetic effect of the three nutrients at the highest rates. This result agrees with the findings of Muluneh and Nebyou (2016) who reported the highest spike length (7.7cm) for wheat at the rate of 50/150 kg N/P_2O_5 ha^{-1}. Firehiwot (2014) also reported the maximum spike length (8.29 cm) at combined application of 64 kg P_2O_5 + 46 kg N ha^{-1}. Similarly, Iqbal *et al.* (2002) reported longer spikes in response to increased application of phosphorus. Generally, spike length recorded over all the treated plots was significantly higher than the unfertilized plot/control.

Table 23. Main effect of NPS and N fertilizers on plant height and spike length of bread wheat

	Plant height (cm)				**Spike length (cm)**			
NPS rate (kg ha^{-1})	**N rates (kg ha^{-1})**				**N rates (kg ha^{-1})**			
	23	46	69	92	23	46	69	92
50	78.07^{d}	81.03^{cd}	87.06^{abc}	82.86^{cd}	7.178^{c}	8.461^{ab}	8.278^{ab}	8.456^{ab}
100	84.88^{a-d}	86.67^{a-d}	89.36^{abc}	86.82^{a-d}	7.919^{bc}	8.772^{a}	8.522^{ab}	8.561^{ab}
150	86.62^{a-d}	83.7^{bcd}	88.67^{abc}	85.71^{a-d}	8.394^{ab}	8.333^{ab}	8.433^{ab}	8.567^{ab}
200	85.33^{a-d}	93.59^{a}	92.32^{ab}	93.07^{a}	8.667^{a}	8.728^{a}	8.433^{ab}	8.956^{a}
Treated	87.66A				8.76			

mean				
Control	72.38B		7.77	
	NPS × N	Treated vs Control	NPS × N	Treated vs Control
LSD (0.05)	8.75	12.85	0.74	NS
CV (%)	8.8	4.6	7.7	4.9

4.3. Yield Components and Yield

4.3.1. Number of tillers per plant

The main effect of NPS and N did not significantly ($P<0.05$) influence the number of tillers per plant. Similarly the two-factor interaction (NPS × N) did not significantly affect this parameter. This might be due to the counter act of the three nutrients and the finding agrees with that of Wakene*et el* (2014).

Table 24. Interaction effect of NPS and N fertilizers on number of tillers and number of productive tiller per plant of bread wheat

	Number of fertile tiller/plant				Number of tiller/plant			
NPS rate (kg ha^{-1})	N rates (kg ha^{-1})				N rates (kg ha^{-1})			
	23	46	69	92	23	46	69	92
50	1.417 b	2.711 a	2.611 a	2.478 a	3.194	3.183	2.99	3.65
100	2.522 a	2.628 a	2.433 a	2.783 a	3.022	2.856	2.95	3.011
150	2.633 a	2.367 a	2.7 0a	2.233 a	3.122	2.967	3.05	2.689
200	2.322 a	2.639 a	2.45 a	2.444 a	2.817	3.078	2.878	3.494
Treated mean	2.5				3.2			
Control	1.98				2.5			
	NPS × N	Treated vs Control			NPS × N	Treated vs Control		
LSD (0.05)	0.55	NS			NS	NS		
CV (%)	19.7	23			25	7.2		

Means with the same letter(s) in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, LSD= Least Significant Difference at 5% level

4.3.2. Number of productive tillers

The main effect of NPS was significant ($P < 0.05$) on thenumber ofproductive tillers produced per plant whereas the main effect of N was highly significant ($P< 0.01$) on this parameter. The two-factor interactions of NPS × N also highly significantly ($P< 0.01$) affected the number of productive tillers produced per plant.

The number of productive tillers per plant was increased significantly as the rates of the two fertilizers increased (Table 5). The NPS × N interaction effect significantly influenced tiller production of wheat. The maximum number of tillers per plant (2.78) was produced by plants treated with the combined application of the highest rates of NPS and N (100 kg NPS ha^{-1} + 92 kg N ha^{-1}) whereas the minimum number of tillers per plant (1.41) was produced at the lower rates (50 kg NPS + 23 kg N ha^{-1}). The highest number of tillers at the highest rates of NPS and N might be due to the rapid conversion of synthesized carbohydrates into protein and consequently the increase in number and size of growing cells, ultimately resulting in increased number of tillers. In other words, it might be due to the fact that plants such as wheat can increase root proliferation in high-P regions to enhance P uptake, especially during early growth stages. The improvement in the total number of tillers with NPS application might be due to the role of P found in NPS in emerging radical and seminal roots during seedling establishment in wheat (Cook and Veseth, 1991). Generally, number of tillers per plant recorded over all the treated plots was significantly higher than the unfertilized plot/control

In agreement with this result, Tilahun*et al.* (2017) reported the maximum number of wheat tillers per plant (1.97) recorded at N rate of 92 kg ha^{-1}. Firehiwot (2014) also reported higher tillers per plant (5.58) at combined application of 32 kg N and 46 kg P_2O_5 ha^{-1} in bread wheat. Similarly, Daniel *et al.* (1998) also reported enhanced number of tillers in wheat with increased rate of P application.

4.3.3. Thousand kernels weight

The main effect of NPS significantly ($P< 0.05$) influenced thousand kernels weight of wheat. However, the main effect of N and the two-factor interactions did not significantly affect thousand kernels weight of bread wheat.

Increased rate of NPS increased thousand kernels weight of bread wheat even though there was no significant difference between 200 and 150 kg NPS ha^{-1} (Table 3). The highest thousand kernels weight (44.13 g) was recorded at application of 150 kg NPS ha^{-1} followed by 200 kg ha^{-1}. On the other hand, the minimum thousand kernel weight (37.91 g) was observed at application of 50 kg N ha^{-1}. Thousand kernels weight obtained from the overall fertilized plots was significantly higher than thousand seed weight from the unfertilized plot/control. This might be due to the improvement of seed quality and size due to synergic effect of the three fertilizers (N, P and S).In agreement with this result, Nasser (2009) reported interaction of N and P on thousand kernels for bread wheat.

4.3.4. Number of kernels per spike

The analysis of variance showed that the main effects of NPS and the two factors interaction were significant ($P < 0.05$) on the number of kernels per spike. The two fertilizers interacted significantly to influence the number of kernels per spike of bread wheat (Table 6). In general, increasing the rates of both NPS and N increased the number of kernels produced per spike even though it was not consistent. Generally, the maximum numbers of kernels per spike (50.91) was produced at the combination of highest rate of NPS fertilizers (200 kg NPS ha^{-1}) and N rates of 23 92 kg ha^{-1} whereas the minimum number of kernels per spike (38.63) was produced at the lowest rates of 50 kg NPS ha^{-1} + 23 kg N ha^{-1} of the two fertilizers. These also showed the synergistic effect of the two fertilizers resulting in increased kernel number per spike and grain production.

This result also agreed with that of Tilahun*et al.* (2017) who reported higher number of kernels per spike for durum wheat (28.39) at the highest rate of N (92 kg N ha^{-1}). Dawit *et al.* (2015) also found that increasing N rates increased the number of kernels per spike. They also stated that increasing P rate from 46 to 138 kg ha^{-1} increased the number of kernels per spike by about 7.7%. Similarly, Daniel *et al*. (1998) reported readily availability of P during early season gave plants from early stresses and its higher uptake at higher levels resulted into enhanced number of grains per spike and 1000-grain weight due to its involvement in grain formation and development. Similarly, Nasser (2009) also reported the highest number of kernels per spike of 69.85 at 90/45 kg N/P_2O_5 ha^{-1} for wheat. Yasir *et al*. (2015) also reported the maximum numbers of wheat kernels per spike (56.4) at 140 kg N ha^{-1} and 20 kg S ha^{-1} at sowing and at anthesis respectively. In general, number of kernels per spike obtained from the fertilized plots exceeded the grain yield from the unfertilized/control plots by about 34.9%.

Table 25. Interaction effect of NPS and N fertilizers on number of kernels per spike of bread wheat

	N rate (kg ha^{-1})			
NPS (kg ha^{-1})	23	46	69	92
50	38.63 d	43.01 bcd	40.79 cd	45.55 abc
100	47.03 ab	48.56 ab	45.14 abc	44.94 bc
150	47.88 ab	46.25 abc	45.68 abc	47.63 ab
200	45.64 abc	46.79 ab	44.64 bc	50.91 a
Treated mean		45.61^{A}		
Control		33.80^{B}		
	NPS × N	Treated Vs Control		
LSD (0.05)	5.94	4.45		
CV (%)	11.4	3.2		

Means with the same letter in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, LSD=Least Significant Difference at 5% level

4.3.5. Above ground dry biomass

The above ground dry biomass was significantly ($P < 0.05$) affected by the main effects of NPS and N rates as well as by the interaction of the two factors.The highest above ground dry biomass (17.15 t ha^{-1}) was obtained at the combined application of 200 kg NPS + 92 kg N ha^{-1} whereas the lowest above ground dry biomass (8.47 t ha^{-1}) was produced under application of 50 kg NPS and 23 kg N ha^{-1} (Table 7). The increase in above ground dry biomass at the highest rates of NPS and N might have resulted from improved root growth and increased uptake of nutrients,favouring better growth and delayed senescence of leaves of the crop due to synergetic effect of the three nutrients (NPS).

The result is consistent with that of Teng *et al.* (1994) who found that combined application of nitrogen and phosphorus increased biological yields of wheat by up to 362% as compared to control, revealing the benefit realized by exploiting interactions. Similarly, Bekalu and Mamo (2016) also reported that increasing N rates from 23 to 69 kg ha^{-1} increased above ground dry biomass of wheat by about 22.6%. Dawit *et al.* (2015) also reported that increasing N from 0 to 184 kg ha^{-1} and P from 0 to 138 kg ha^{-1} increased the above ground dry biomass by about 70.1% and 40.6%, respectively. Similarly, Yasir *et al*. (2015) reported the maximum above ground dry biomass of wheat (14734.5 kg ha^{-1}) at 140 kg N ha^{-1} at sowing and 20 kg S ha^{-1} at anthesis.

In general, the biomass yield obtained from the fertilized plots exceeded the biomass yield from the unfertilized plot/control by about 20.64%.

Table 26. Interaction effect of NPS and N fertilizers on above ground dry biomass (AGDBM) (t ha^{-1}) and grain yield (t ha^{-1}) of bread wheat

	Grain yield (t/ha)				Above ground dry biomass (t/ha)			
NPS rate (kg ha^{-1})	N rates (kg ha^{-1})				N rates (kg ha^{-1})			
	23	46	69	92	23	46	69	92
50	2.464 e	4.724 abcd	4.038 cde	3.622 de	8.47 d	14.9 abc	11.5 bcd	11.51 bcd
100	5.447 a-d	5.304 a-d	4.268 b-e	5.322 a-d	13.26 a-d	11.84 bcd	11.95 bcd	12.3 a-d
150	4.858 a-d	6.416 a	6.017 ab	4.259 b-e	13.46 a-d	12.28 a-d	10.61 cd	10.3 cd
200	5.202 a-d	4.852 a-d	5.975 abc	4.89 a-d	13.71 abc	16.01 ab	15.81 ab	17.15 a
Treated mean	4.96A				13.27A			
Control	1.96B				10.53B			
	NPS × N	Treated vs Control			NPS × N		Treated vs Control	
LSD (0.05)	1.73	1.31			5.15		1.25	
CV (%)	21.4	10.8			24.1		3.00	

Means in columns and rows followed by the same letters are not significantly different at 5% level of Significance; LSD (0.05) = Least Significant Difference at 5% level; CV = Coefficient of variation

4.3.6. Grain yield

The main effects of NPS and N and their interactions significantly (P< 0.05) affected the grain yield of bread wheat.Increasing the rates of the two fertilizers (NPS and N) significantly increased grain yield. Thus, the highest grain yield (6.43 t ha^{-1}) was obtained at combined rates of 150 kg NPS ha^{-1} + 46 kg N ha^{-1} and it was statistically at par with 150 kg NPS ha^{-1} + 69 kg N ha^{-1} with grain yield of 6.02 t ha^{-1} whereas the lowest grain yield (2.46 t ha^{-1}) was recorded at the combinations of 50 kg NPS + 23 kg N ha^{-1} (Table 7). The highest grain yield at the highest NPS and N rates might have resulted from improved root growth and increased uptake of nutrients and better growth favouredby interaction (synergetic) effect of the three nutrients which enhanced yield components and yield.

In general, grain yield obtained from the fertilized plots exceeded the grain yield from the unfertilized/control plots by about 60.4%.In line with the result of this study, Bekalu and Mamo (2016) reported that increasing N rate increased grain yield of bread wheat where the application of 69 kg N ha^{-1} had 65.5% more grain yield than control. Similarly, Haile *et al.* (2012) found that increasing N rate up to 120 kg N ha^{-1}increased grain yield of bread wheat. Bereket *et al.* (2014) also reported that increasing P rate from 46 to 69 kg P_2O_5 ha^{-1} increased grain yield of bread wheat by about 6.8%. Kaleem *et al*. (2009) also recorded maximum yield of 3557 kg ha^{-1} by the application of 128-128 kg ha^{-1} (NP) ratio 1:1 which indicated the importance of phosphorus at its highest dose in achieving maximum wheat productivity. Erekul*et al*. (2012) also reported high grain yield (4813 kg ha^{-1}) of wheat at combined application of 210 kg N and 40 kg S $ha^{- 1}$. Likewise, Jarvan*et al*. (2009) reported that the addition of 100 kg N ha^{-1} with 10 kg S ha^{-1} to winter wheat gave yield of 5.88 t ha^{-1} while it gave 5.73 t ha^{-1} when 100 kg N ha^{-1} with 6 kg ha^{-1} S was added with increasing grain protein content. This clearly indicates the synergic effect of the three nutrients in increasing yield and quality of wheat. Similarly, Yasir *et al*. (2015) reported the maximum grain yield of wheat (4463.5 kg ha^{-1}) at 140 kg N ha^{-1} and 20 kg S ha^{-1} at sowing and at anthesis, respectively.

4.3.7. Straw yield

Analysis of variance showed that the straw yield of wheat was significantly (P < 0.05) affected by the main effects of NPS and N. Similarly, the interaction of NPS and N was significant (P < 0.05) on straw yield.Thus, the maximum straw yields (1.26 t ha^{-1}) was obtained at the combined application of the highest rates of the two fertilizers (200 kg NPS + 92 kg N ha^{-1}) whereas the lowest straw yield (4.59 t ha^{-1}) was recorded in response to the application of 150 kg NPS + 69 kg N ha^{-1} (Table 8). The significant increase in straw yield in response to the highest rate of combined application of NPS and N might be attributed to the synergic roles of the two fertilizers played in enhancing growth and development of the crop as suggested above for grain yield. In general, straw yield obtained from the fertilized/treated plots exceeded the straw yield from the unfertilized/untreated plots by about 16.34% (Table 8). The result is consistent with that of Nasser (2009) who reported increased straw yield of wheat with increase in NP fertilizers rates of up to 90/45 kg ha^{-1}. Similarly, Bereket *et al.* (2014) reported highest straw yield of bread wheat (6827 kg ha^{-1}) at phosphorus rate of 92 kg P ha^{-1} and nitrogen rate of 138 kg N ha^{-1};Tilahun*et al.* (2017) reported straw yield of 8 t ha^{-1} at 92 kg N ha^{-1} for durum wheat.

Table 27. Interaction effect of NPS and N fertilizer rates on straw yield and harvest index of bread wheat.

	Straw yield (t/ha)				**Harvest index**			
NPS rate (kg ha^{-1})	**N rates (kg ha^{-1})**				**N rates (kg ha^{-1})**			
	23	46	69	92	23	46	69	92
50	9.042 a-d	10.176 abc	7.46 b-e	4.851 e	0.214f	0.32cdef	0.35 cde	0.43bcd
100	7.814 b-e	6.539 cde	7.684 b-e	6.973 cde	0.41 cde	0.45abc	0.36cde	0.44 a-d
150	8.598 a-e	5.867 de	4.592 e	6.038 de	0.36 cde	0.57 a	0.56ab	0.41 cde
200	8.504 a-e	11.153 ab	9.838 a-d	12.262 a	0.38cde	0.31def	0.38cde	0.29ef
Treated mean	7.59A				0.46			
Control	6.3B				0.39			
	NPS × N	Treated vs Control			NPS × N		Treated vs Control	
LSD (0.05)	4.06		1.17		0.14		NS	
CV (%)	20		4.8		21.0		18	

Means with the same letter in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, NS= non-significant, LSD= Least Significant Difference at 5% level

4.3.8. Harvest index

The main effects of NPS and N, as well as the two factor interaction (NPS × N) were highly significant ($P < 0.01$) on harvest index.The maximum harvest index (0.57) was obtained at the combined application of 150 kg NPS and 46 kg N ha^{-1} whereas the lowest harvest index (0.0.214) was recorded at combined application of 50 kg NPS and 23 kg N ha^{-1} (Table 8). The increment in harvest index at medium rate of N combined with NPS might be attributed to greater photo assimilate production and its ultimate partitioning into grains compared to partitioning in to straw, *i.e.* proportionally higher grain yield than vegetative biomass yield. The result agreed with the findings of Sharer *et al*. (2003) who reported higher harvest index (0.39) under higher level of nitrogen and phosphorus (180/130 kg N/P ha^{-1}) than application of lower levels of the fertilizers for maize which could be due to the increase in grain yield more than the increase in biomass. On the other hand, Dawit *et al*. (2015) reported no significant effect of N and P rates on harvest index of bread wheat.

4.4. Grain Quality Parameters

4.4.1. Hectoliter weight

Based on analysis of variance, hectolitr weight was significantly ($P < 0.05$) affected by the main effects of NPS and N as well as the two-factor interactions. Increasing the rate of NPS and N increased hectoliter weight. Thus, maximum hectoliter weight of 81.8 kg $hl^{-1}$was recorded at combined rate of 200 kg NPS and 92 kg N ha^{-1} even though no significant difference 200 kg NPS and 69 kg N ha^{-1} while the minimum hectoliter weight (76.6 kg hl^{-1}) was recorded at lowest rate of the two fertilizers (50 kg NPS and 23 kg N ha^{-1}) (Table 9). The highest hectoliter weight at the highest NPS and N rates might be due to the role of N and S on quality of wheat such as flour yield and protein content as N and S increases the plumpness and protein content of the cereal grains (Foth and Ellis, 1988). This result was in line with that of Gooding and Davies (1997) who reported slight increase in hectoliter weight in response to N application under more favourable growing conditions. Similarly, Haile (2011) also reported 72.69 kg hl^{-1} hectoliter weight at N rate of 120 kg N ha^{-1}. On the other hand, Dawit *et al.* (2015) reported non-significant effect of N rates on hectoliter weight of bread wheat.

4.4.2. Grain protein content (GPC)

The main effect of NPS and N significantly ($P < 0.05$) affected grain protein content while two-factor interaction highly significantly ($P<0.01$) affected grain protein content. Grain protein content under different NPS and N application rates ranged from 11.23 to 13.47% (Table 9). The highest grain protein (13.47%) was obtained at the highest NPS rate at 200 kg NPS and 92 kg N ha^{-1} whereas the lowest grain protein (11.23%) was obtained at the lowest rate of NPS and N application (50 kg NPS and 23 kg N ha^{-1}). Grain protein was generally found to increase with increasing NPS and N rates.

Table 28. Main effect of NPS and N fertilizers rates on grain protein content (GPC) and hectoliter weight (HLW) of bread wheat

	Grain protein content(%)				Hectoliter weight(kg hl^{-1})			
NPS rate	N rates (kg ha^{-1})				N rates (kg ha^{-1})			
	23	46	69	92	23	46	69	92
50	11.23 c	13.13 ab	13 ab	12.97 ab	76.6 c	81.07a	79.6ab	77.67bc
100	12.93 ab	13.13 ab	13.13 ab	12.73 ab	81.73 a	80.47a	80.53a	80.73a

150	13.23 ab	13.03 ab	13 ab	12.47 b	81.47 a	79.6 ab	79.6ab	79.87ab
200	12.67 ab	12.93 ab	12.6 ab	13.47 a	80.8 a	80.47a	81.8a	81.00a
Treated mean	13.0A				82.18A			
Control	10.8B				78.20B			
	NPS × N	Treated vs Control			NPS × N		Treated vs Control	
LSD (0.05)	0.93		1.33		2.43		1.89	
CV (%)	4.4		3.2		1.8		0.7	

Means with the same letter in the column are not significantly different at 5% level of significance; CV (%) = Coefficient of variation, NS= non-significant, LSD = Least Significant Difference at 5% level

However, there were no significant differences in grain protein content at NPS and N rates of 150 + 46, 100 + 69 kg ha^{-1}. Thus, increased grain protein content with increased NPS and N rates might be due to the synergetic effect of the three nutrients (N, P and S) found in NPS fertilizers, especially N and S, which have synergic effect on yield and quality (MalleJarvan*et al*. 2012; Erekul*et al*., 2012). In similar studies,Njira and Nabwami (2015) reported that S has great role in protein synthesis as it used as an essential component of amino acids and also the balanced fertilization that lead to the general high performance of the crop including synthesis of all N containing compounds such as proteins, chlorophyll and nucleic acids. It is also a building block of protein and a key ingredient in the formation of chlorophyll (Duke and Reisenaue, 1986). Without adequate S, crops cannot reach their full potential in terms of yield or protein content (Zhao *et al.,* 1999). Similarly, Havlin*et al.* (2005)reported that phosphorus increased protein content and sugar content in crops such as wheat and maize. In agreement with the above result, Erekul*et al.* (2012) reported increased grain (16.1%) and flour (15.0%) protein content when N and S rates increased to 210/40 N/S kg ha^{-1}. Malik *et al*. (2003) also reported a maximum protein content from a plot fertilized at a combination of 50-75 kg NP ha^{-1} as compared to other combinations of N (0, 25 and 50 kg ha^{-1}) and P (0, 50, 75 and 100 kg ha^{-1}).

Similar to NPS, N rates also significantly affected grain protein content. Grain protein was generally found to increase with increasing N rates. Compared with grain protein content obtained for the control treatment, the mean value of grain protein content obtained at 92 kg N ha^{-1} was higher by about 14.3% (Table 10). Generally, grain protein content recorded over all the treated plots was significantly higher than unfertilized plot. The increase in protein content with the increase in nitrogen rates might be due to the fact that nitrogen is the building block of protein in which N increases the plumpness of the cereal grains and protein content of both seeds and foliage (Foth and Ellis, 1988). The result is in agreement with the findings of Haile (2012) who reported that increasing N rates from 30 to 120 kg ha^{-1} increased grain protein of wheat by 5.3%. Similarly, Tilahun*et al.* (2017) also recorded the maximum grain crud protein content (11.52%) for durum wheat at the highest N rate (92 kg N ha^{-1}). Garrido-Lestache*et al.* (2004) and Brian *et al.* (2007) also similarly reported that increased N levels consistently increased grain protein content.

4.5. Partial Budget Analysis

Analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 10. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation by farmers. The studies 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 results in this study indicated that the combined application of NPS and N fertilizer resulted in higher net benefits than the unfertilized/control treatments (Table 10). As indicated in Table 10, the partial budget analysis showed that the highest net benefit (Birr 42272.5 ha^{-1}) was recorded at the rate of combined application of 100 kg NPS + 92 kg N ha^{-1} followed by 100 kg NPS + 69 kg N ha^{-1} (40618.4 Birr ha^{-1}), and the lowest was from the control treatment. To use the marginal rate of return (MRR%) as basis of fertilizer recommendation, the minimum acceptable rate of return should be between 50 to 100% (CIMMYT, 1988). In this study application of 100 kg NPS ha^{-1} and 92 kg N ha^{-1} gave the maximum economic benefit (42272.5 ha^{-}) with marginal rate of return (1728.3%). Therefore, on economic grounds, combined application of 100 kg NPS ha^{-1} and 92 kg N ha^{-1} would be best and economical, and tentatively recommended for production of bread wheat in the study area and other areas with similar agro-ecological conditions. In line with this result, Bekalu and Mamo (2016) reported that N application at 69 kg ha^{-1} is effective in attaining higher grain yield and economic benefit of wheat in southern part of Ethiopia. Dawit *et al.* (2015) also recommended 92 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} for production of wheat for moist and humid midland *vertosols* areas of Arsi zone. Similarly, Bereket *et al*. (2014) recommended 46 kg N ha^{-1} and 46 kg P_2O_5 ha^{-1} for production of bread wheat on sandy soil of Hawzen district.

Table 29. Partial budget and marginal rate of return analysis for response of bread wheat to NPS and N fertilizers

Treatments						
NPS (kg ha^{-1}))	N (kg ha^{-1})	AGY by 10% (kg ha^{-1})	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NR (Birr ha^{-1})	MRR (%)
Control	Control	1762.20	29957.40	0.00	29957.40	0

Treatments NPS (kg ha^{-1}))	N (kg ha^{-1})	AGY by 10% (kg ha^{-1})	GB (Birr ha^{-1})	TVC (Birr ha^{-1})	NR (Birr ha^{-1})	MRR (%)
50	23	2217.61	37699.44	2550.00	35149.44	3.04
50	46	4251.73	72279.47	3250.00	69029.47	49.4
100	23	4902.64	83344.93	3350.00	79994.93	110.66
50	69	3634.55	61787.41	3950.00	57837.41	D
100	46	4773.53	81150.04	4050.00	77100.04	193.63
150	23	4372.07	74325.14	4150.00	70175.14	D
50	92	3260.11	55421.87	4650.00	50771.87	D
100	69	3840.77	65293.17	4750.00	60543.17	98.71
150	46	5774.69	98169.68	4850.00	93319.68	328.77
200	23	4682.12	79596.08	4950.00	74646.08	D
100	92	4790.17	81432.92	5450.00	75982.92	3.67
150	69	5415.72	92067.26	5550.00	86517.26	106.34
200	46	4366.90	74237.37	5650.00	68587.37	D
150	92	3832.68	65155.58	6250.00	58905.58	D
200	69	5377.90	91424.37	6350.00	85074.37	262.69
200	92	4400.91	74815.46	7050.00	67765.46	D

Where, NPS cost = 16 Birr kg^{-1}, UREA cost = 14 Birr kg^{-1}of N, NPS and UREA application cost= 525 Birr ha^{-1}, bread wheat grain = 17 Birr kg^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment, Control = unfertilized

5. Conclusion and Recommendation

Analysis of the results revealed that interaction of the two fertilizers significantly affected grain yield, above ground dry biomass, date to heading, number productive tillers, plant height, spike length, straw yield, harvest index, hectoliter weight and grain protein content of bread wheat while date to mature and thousand kernels weight were affected only by main effect of NPS and N. Generally, all parameters recorded over all treated plots were significantly higher than unfertilized/control plot except date to mature, number of tiller per plant and number of kernels per spike. Thus using of NPS and N fertilizers improve yield components, yield and quality parameters of bread wheat. The highest grain yield (6.416 t h^{-1}) was obtained from combined application of 150 kg NPS ha^{-1} + 46 kg N ha^{-1}whereas the highest grain protein content was recorded from application of 200 kg NPS ha^{-1} + 92 kg N ha^{-1}. The partial budget analysis revealed that combined applications of 150 kg NPS and 46 kg N ha^{-1} gave the best economic benefit 93319.68 Birr ha^{-1} with MRR of 328.765%. Therefore, based on the results of this study it can be concluded that combined application of these rates can be recommended for farmers for production of wheat in the study area and other areas with similar agro-ecological conditions.

6. References

AbiyeAstatke, Tekalign Mamo, Don Peden and Mamadou Diedhiou. 2004. Participatory on-farm conservation tillage trial in the Ethiopian highland Vertisols: The impact of potassium application on crop yields. *Experimental agriculture* 40(03): 369-379.

AmanuelGorfu, KefyalewGirmsa. Tanner, D.G. Assefa Ta'a. and Shambel Maru. 2000. Effect of crop rotation and fertilizer application on wheat yield performance across five years at two locations in South Eastern Ethiopia in the Seventh Regional Wheat Workshop for Eastern, Central and Southern Africa, Addis Ababa, Ethiopia.

Amsal Tesfaye, Tanner, D.G. Taye Tessemma. and ChanyalewMandefro. 2000. Agronomic and economic evaluation of the on farm N and P response of bread wheat grown on two contrasting soil types in Central Ethiopia. pp. 329. In: The 11th Regional wheat workshop for central, Eastern and Southern Africa. Addis Ababa, Ethiopia. CIMMYT.

Bekalu Abebe and Mamo Manchore. 2016. Effect of The Rate of N-Fertilizer Application on Growth and Yield of Wheat (*Triticum aestivum*L.) at Chencha, Southern Ethiopia. *International Journal of Plant, Animal and Environmental Sciences,* 6(3):168 – 175.

Bereket Haileselassie, Dawit Habte, MehretabHaileselassie, Gebremedhin Gebremeskel. 2014. Effects of Mineral Nitrogen and Phosphorus Fertilizer on Yield and Nutrient Utilization of Bread Wheat (*Tritcumaestivum*L.) on the Sandy Soils of Hawzen District, Northern Ethiopia.*Agriculture, Forestry and Fisheries,* 3(3): 189-198

Bray, R.H. and Kurtz, L.T. 1945. Determination of Total Organic and Available Phosphorus in soils. *Soil Science,* 59: 39-45.

Brian, N.O., Mohamed, M. and Joel, K.R. 2007. Seeding rate and nitrogen management effectson spring wheat yield and yield components. *American Journal Agronomy,* 99:1615-1621.

Chapman, H.D. 1965. Cation exchange capacity by ammonium saturation. 9: Inc 891-901.Black, C.A., Ensminger, L.E. and Clark, F.E. (Eds.). Method of soil analysis. American Society of Agronomy. Madison Wisconsin, USA

Chesnin, L. and Yien, C. H. 1951. Turbidimetric determination of available sulfates. *Soil Science Society of America Journal*, *15*(C), 149-151.

CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo/International Maize and Wheat Improvement Center). 1988. From Agronomic data to Farmer Recommendations: An Economic work Book. Mexico, D.F.: CIMMYT.

Cook R.J. and Veseth, R.J.1991. Wheat health management. The American Phytopathological Society, USA. 152.

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 (Ethiopian Central Statistical Agency). 2016. Agricultural sample survey Report on area and production for major crops 1: 1-118

Daniel, T.C., Sharpley, A.N. and Lemunyon, J.L. 1998. Agricultural phosphorus and eutropication: a symposium overview. *Journal of Environmental Quality.* 27: 251-257.

Dawit Hapte, KasuTadese, WubengedaAdmasu, TadeseDessalegn and AsratMekonen. 2015. Agronomic and Economic Evaluation of the N and P Response of Bread Wheat Grown in Moist and Humid Midhighland*Vertisols* Areas of Arsi Zone, Ethiopia. *African Journal of Agricultural Research*, 10 (3):89-99

Demeke, M. and Di Marcantonio, F. 2013. Analysis of incentives and disincentives for wheat in Ethiopia. Technical notes series, MAFAP, FAO, Rome.

Dewis, J. and Freitas, P. 1970. *Physical and chemical methods of soil analysis*. FAO Bulletin No. 10. Rome. 175p

Donald, L. S. 2004. Understanding and reducing lodging in cereals. *Advances in Agronomy*, 84: 217–271.

Duke, S.H. and Reisenaue, H.M. 1986. Roles and requirements of sulfur in plant nutrition. p. 124-168. In: Sulfur in Agriculture, M.A. Tabatabai (ed.), and Agronomy Series No. 27, American Society of Agronomy, Madison, Wisconsin, USA

Erekul, O., Gotz, K.P. and Koca, Y.O. 2012. Effect of sulphur and nitrogen fertilization on bread-making quality of wheat (Triticum aestivum L.) varieties under Mediterranean climate conditions. *Journal of Applied Botany and Food Quality*, 85(1):17-22.

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

Fageria, N.K., V.C. Baligar and Y.C. Li. 2008. The role of nutrient efficient plants in improving crop yields in the twenty first century. *Journal of Plant Nutrition.* 31: 1121-1157.

FanuelLaekemariam. 2015. Soil spatial variability analysis, fertility mapping and soil plant nutrient relations in Wolaita zone, Southern Ethiopia, Haramaya University, Ethiopia.

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

Accessed on 20 Feb, 2017

FAO (Food and Agriculture Organization). 2014b. Crop Production Data.Rome: FAO. Accessedat.http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor.Accessed on 20 Feb, 2017

FAO (food and agricultural organization). 2015. World fertilizer trends and outlook, Rome.

Fassil Kebede and Charles, Y. 2009. Soil Fertility Status and Numass Fertilizer Recommendation of Typic Hapluusterts in the Northern Highlands of Ethiopia. *World Applied Sciences Journal,* 6 (11): 1473-1480.

Fazli, I.S., Jamal, A., Ahmad, S., Masoodi, M., Khan, J.S. and Abdin, M.Z. 2008. Interactive effect of sulphur and nitrogen on nitrogen accumulation and harvest in oilseed crops differing in nitrogen assimilation potential. *Journal of Plant Nutrition,* 31: 1203-1220.

Feldman, M. and Sears, E. R. 1981. The wild gene resources of wheat. *Scientific American,* 244: 102-112.

Firehiwot Getachew. 2014. Effect of Vermicompost and Inorganic N and P Fertilizers on Growth, Yield, and Quality of Bread Wheat (*Triticum aestivum*L.) in Eastern Ethiopia, MSc Thesis, Haramaya University, Haramaya, Ethiopia.

Foth, H.D. and Ellis, B.G. 1988. *Soil Fertility. 7th Ed*. John Wiley and Sons, Inc. New York, USA, 1988.

Garrido-Lestache, E., Lo´pez-Bellido, R. J. and Lo´pez-Bellido L. 2004. Effect of N rate, timing and splitting and N type on bread-making quality in hard red spring wheat under rain fed Mediterranean conditions. *Field Crops Research,* 85: 213-236.

GenStat. 2012. GenStat Procedure Library Release. 15th edition. VSN International Ltd.

Getachew Fisseha. 2004. Soil characterization and bread wheat (*Triticum aestivum* L.) response to N and P fertilization. MSc Thesis, Alemaya University, Alemaya, Ethiopia.

Gooding,M.J. and Davies, W.P. 1997. *Wheat production and utilization: systems, quality and the environment.* Wallingford CAB International. UK.

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

Hailu Gebremariam. 1991. Wheat production and research in Ethiopia. pp. 1-15. In: Hailu G. M., Tanner, D.G., Mengistu, H. (eds.). Wheat Research in Ethiopia: A Historical Perspective. IAR/CIMMYT, Addis Ababa, Ethiopia.

Havlin, J.L., Beaton, J.D., Tisdale, S.L. and Nelson, W.L. 2005. *Soil Fertility and Fertilizers: An Introduction to Nutrient Management. 7th (ed.)*. Pearson Prentice

Iqbal, A.S., Abbasi, M.K. and Rasool, G. 2002. Integrated plant nutrition system (IPNS) in wheat under rain fed condition of Rawalkot, Azad Jammu and Kashmir. *Pakistan Journal of Soil Science*, 21: 79-86.

Jarvan, M., Edesi, L. and Adamson, A. 2009. The effect of sulphur fertilization on yield, quality of protein and baking properties of winter wheat. *Agraarteadus (Journal of Agricultural Science)*, 20: 8-15.

Landon, J.R. 1991. *Booker Tropical Soil Manual: A hand book for soil survey and Agricultural Land Evaluation in the Tropics and Subtropics*. Longman Scientific and Technical, Essex, New York. 474p.

Lelago Alemu, Mamo Tekalign, Haile Wassie and Shiferaw Hailu. 2016. Assessment and Mapping of Status and Spatial Distribution of Soil Macronutrients in KambataTembaro Zone, Southern Ethiopia. Advinces in Plants Agricultur Research 4(4):1-14.

Manna, M.C., Swarup A., Wanjari, R.H., Ravankar, H.N., Mishra, B., Saha, M.N., Singh Y.V., Sahi. D.K. and Sarap, P.A. 2005. Long-term effect of fertilizer and manure application on soil organic carbon storage, soil quality and yield sustainability under sub-humid and semi-arid tropical India. *Field Crops Research*, 93: 264-280.

Malik, M.A. Farrukh, M., Ali, A. and Mahmood, I. 2003. Effect of nitrogen and phosphorus application on growth, yield and quality of mungbean (*Vignaradiate* L.). *Pakistan Journal of Agricultural Sci*ence, 4(3): 133-136.

MalleJarvan, LiinaEdesi and Ando Adamson. 2012. The content and quality of protein in winter wheat grains depending on sulphur fertilization.*Soil & Plant Science*, 62 (7): 627-636.

Mengel, K. and Kirkby, E.A. 1996. *Principles of Plant Nutrition*. Panimo Publishing Corporation, New Delhi, India.

MoA (Ministry of Agriculture). 2012. Ministry of Agriculture. Animal and Plant Health Regulatory Directorate. Crop variety register, Issue No. 15. Addis Ababa, Ethiopia.

MulunehMenamo and NebyouMasebo. 2016.The Effect of Application of Different Rate N-P Fertilizers Rate on Yield and Yield Attributes of Bread Wheat in Case of Chancha Woreda, Southern Ethiopia. *Journal of Natural Sciences Research*, 6(5):63 – 66.

Murphy, H.F. 1968. A report on fertility status and other data on some soils of Ethiopia.

Nasser, K.h. El-Gizawy, B. 2009. Effect of Planting Date and Fertilizer Application on Yield of Wheat under No till System. *World Journal of Agricultural Sciences*, 5 (6): 777-783.

NjiraKow and Nabwami, J.A. 2015. Review of Effects of Nutrient Elements on Crop Quality. *African Journal of Food, Agriculture, Natural and Development*, 15(1): 9777-9793.

OkubayGiday, HilufGibrekidan and BerheTareke. 2015. Soil Fertility Characterization in Vertisols of Southern Tigray, Ethiopia, thiopia. *Advanced plants agricultural research* 2(1): 00034.

Olsen, S. R. and Khasawneh, F. E. 1980. Use and limitations of physical-chemical criteria for assessing the status of phosphorus in soils. *The role of phosphorus in agriculture*, (theroleofphosph), .361-410.
Page, A.L. 1982. *Methods of Soil Analysis*. Part 2. Chemical and Microbiological Properties. Madison, USA.
Reddy, S.R. 2004. *Agronomy of Field Crops*. Kalyani Publishers Ludhiana. p.143.
Sauer Jonnes and Tchale Hardwick. 2009. The economics of soil fertility management in Malawi. *Review of Agricultural Economics, 31*(3), 535-560.
Schulthesis, U. B.1997. Yield independent variation in grain nitrogen and phosphorus concentration among Ethiopian wheat. *Agronomy Journal*, 89 (3):497-506.
SewnetAshebir. 2005. Effects of nitrogen and seed rates on grain yield components and nitrogen uptake of rain-fed rice (*Oryza sativa*) in Fogera, South Gonder. MSc Thesis, Alemaya University, Alemaya, Ethiopia.
Sharer, M.S., Ayub, M., Nadeem , M.A. and Ahmad, N. 2003. Effect of Different Nitrogen and Phosphorus on Growth and Grain Yield of Maize. *Asian Journal of Plant Sciences,* 2 (3): 347-349.
TekalignTadessa. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa
TekalignMammo, TekluErkossa and BaleshTulema. 2001. Soil Fertility and Plant Nutrition Research on Tef in Ethiopia. pp. 199-200. *In:* Hailu Tefera, Getachew Belay and Mark Sorrels (eds.) *Narrowing the Rift. Tef Research and Development*, Proceedings of the International Workshop on Tef Genetics and Improvement, 16-19 October, 2000. Addis Ababa, Ethiopia, pp 167-176.
Teng, Y. and Timmer, V.R. 1994. Nitrogen and phosphorus interactions in an intensively managed nursery soil plant system. *American Journal of Soil Science Society,* 58:232-238.
Tilahun- Chibsa B, HelufGebrekidan, Kibebew- Kibret T. and Tolessa- Debele D. 2017. Effect of rate and time of nitrogen fertilizer application on durum wheat (*Triticum turgidum Var* L. durum) grown on *Vertisols* of Bale highlands, southeastern Ethiopia. *American Journal of Research Communication*, 5(1): 39 - 56.
Wakene Tigre, WalelignWorku and Wassie Haile. 2014. 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,* 2(5): 260 - 266.
Walkley, A.J. and Black, I.A. 1934. Estimation of soil organic carbon by the chromic acid titration method. *Soil Science,* 37: 29-38.
Wassie Haile and Shiferaw Boke. 2011. Response of Irish Potato (*Solanum tuberosum*) to the Application of Potassium at Acidic Soils of Chencha, Southern Ethiopia. *InternationalJournal of Agricultural Biology,* 13: 595–598.
Wassie Haile and Shifera Boke. 2011. On-farm Verification of Lime and NPK Fertilizers Effects on the Tuber Yield of Irish Potato. *Journal of the Drylands* 4(1): 283-288.
Wissum, M., Mazzola, M. and Picard, C. 2009. Novel approaches in plant breeding for Rhizosphere related traits. *Plant Soil.* 321: 409-430.
Yasir Hayat, Zahid Hussain, Shad Khan Khalil1, Zafar Hayat Khan, Ikramullah, Muhammad Ali, Tariq Shah and Farooq Shah. 2015. Effects of Nitrogen and Foliar Sulphur Applications on the Growth and Yield of Two Wheat Varieties Grown in Northern Pakistan. *ARPN Journal of Agricultural and Biological Science*, 10(4):139 – 145.

Zeleke, G., Agegnehu, G., Abera, D., Rashid, S. 2010. Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. IFPRI, Addis Ababa, Ethiopia, 63p

Zhao, F.J., Salmon, S.E., Withers, P.J.A., Monaghan, J.M., Evans, E.J., Shewry, P.R. and McGrath, S.P. 1999. Variation in the bread making quality and mineralogical properties of wheat in relation to sulfur nutrition under field conditions. *Journal of Cereal Science,* 30(1): 19-31.

Response of Common Bean (*Phaseolus vulgaris* L.) Varieties to Rates of Blended NPS Fertilizer in Adola District, Southern Ethiopia

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Abstract

Common bean is one of the most economically important pulse crops cultivated in Ethiopia. However, the national average yield is below the potential yield that could be attained. This is partly due to low soil fertility management, lack of agronomic recommendations and diseases and pest problems. Hence, this experiment was conducted to investigate the effect of blended NPS rates on growth, yield and yield components of common bean varieties and to identify economically feasible rates of blended NPS at Guji Zone Southern Ethiopia.The experiment was conducted in Adola sub-site of Bore Agricultural Research Center during 2016-2017 main cropping seasons. The factors studied were six rates of blended NPS (0, 50, 100, 150, 200 and 250 kg ha^{-1}) and three varieties of common bean (Angar, Ibado and Nasir). These were laid out in a factorial arrangement in Randomized Complete Block Design with three replications. Data on phonological, growth yield and yield related parameters were collected and analyzed using SAS software. The result showed that thehighest number of primary branches per plant (2.77) and the highest number of total pods (18.52) were recorded at the highest rate of 250 kg NPS ha^{-1} whereas the highest number of total nodules (80.47) and effective nodules per plant (35.54) were obtained from the application of 200 kg NPS ha^{-1}. Among the varieties, Angar gave significantly the highest number of primary branches per plant (2.55) and number of pods per plant (15.3). The interaction of variety and blended NPS had significant effect on almost all parameters except the number of total and effective nodules per plant, number of primary branches per plant and number of pods per plant. Variety Nasir gave the highest plant height (99.72 cm) with application of 150 kg NPS ha^{-1} while Ibado with application rate of 200 kg blended NPS ha^{-1} had the highest hundred seed weight (54.33 g). The highest grain yield (3260 kg ha^{-1}) was recorded for variety Angar when 250 kg NPS ha^{-1}was applied. However, the highest net benefit (29,825 Birr ha^{-1}) was obtained from combination of variety Ibado with application 200 kg ha^{-1} of blended NPS. Thus, it can be concluded thatapplication of 200 kg ha^{-1} of blended

NPS with variety Ibado offers aneconomically feasible package of common bean production for the farmers.

Key words: Blended fertilizer, Nitrogen, phosphorus, Sulphur

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.*)*, is herbaceous annual plant domesticated independently in ancient Mesoamerica and in the Andes, and now is grown worldwide for both dry seeds or as a green bean. Thousands of legume species exist but common bean in any form is the most consumed by human beings compared to any other legumes (Broughton *et al.,* 2003). When common bean is used for its unripe fruit, it is termed as green bean or snap bean. About 23.9 million tons of dry bean, 20.7 million tons of green bean, and 1.9 million tons of string or common bean were produced worldwide in 2012 (FAOSTAT, 2014). It is estimated that the crop meets more than 50% of dietary protein requirements of households in Sub-Saharan Africa. The annual per capita consumption of common bean is higher among low-income people who cannot afford to buy nutritious food stuff, such as meat and fish (Broughton *et al.,* 2003).

Common bean is highly preferred by Ethiopian farmers because of its short maturing characteristics that enable households to get cash income required to purchase food and other household needs when other crops have not yet matured (Legesse *et al*., 2006). It is also an important food and cash crop in Guji zone with an area of 15,850.82 ha and average productivity of 1.52 tons per hectare. Similarly, it contributesabout 39.49% for household consumption, 13.33% for seed, 44.1% for sale, 0.58% animal for feed and 2.05 other uses in the study zone (CSA, 2016).

Improved common bean production encompasses proper use of different agronomic practices which include improved variety, seed rate, spacing, fertilizer rate and pesticide application as per recommendations. However, the current national average yield of common bean (about 1.48 tons) is far less than the attainable yield (2500-3000 kg ha^{-1}) under good management conditions for most improved varieties. This low yield of common bean in Ethiopia is attributed to several production constraints, which include lack of improved varieties for the different agro-ecological zones, poor agronomic practices such as low soil fertility management, untimely and inappropriate field operations (Alemitu, 2011). A range of environmental factors, such as low soil nitrogen and phosphorus levels, and acidic soil conditions are important constraints for bean production in most areas where the crop is grown (Girma, 2009). Wortmann (2006) also reported that low soil fertility status, especially low level of N and P to be the major constraints of common bean production responsible for the loss of grain yield of nearly 1.2 million tons in Africa. In general, an increase in grain yield and other agronomic parameters of common bean were observed as the rate of nitrogen and phosphorus increased till 27 kg N ha^{-1} and 69 kg P_2O_5 ha^{-1} (150 kg DAP ha^{-1}) (Girma, 2009). This fertilizer rate also gave yield advantages of 39% over the control. Among the nutrients, nitrogen is the critical limiting element for growth of most plants including common beans due to its unavailability and poor fixation (Vance, 2001). Deficiency in N causes reduced growth, leaf yellowing, reduced branching and small trifoliate leaves in beans (CIAT, 1986). Previous surveys estimated that over 60% of the bean production areas in Central, Southern, and Eastern Africa were affected by N deficiency. This caused yield losses of up to 40% compared to the N-fertilized areas (Singh, 1999). Besides, common bean is considered to be a poor fixer of atmospheric N when compared with other legumes and generally responds poorly to inoculation of rhizobia in the field. As a result, common bean is being generally considered as more responsive than other legumes to N fertilization (Graham, 1981).

Bean N fertilizer requirement depends on soil fertility levels; for low soil nitrogen levels (below 34 kg N ha^{-1}) N fertilizer is generally recommended in order for deficiency symptoms not to manifest and for full development up to production. Moreover, up to 60 kg N ha^{-1} also promotes increased nodule number, mass and size, giving highest yields (Dwivedi*et al*., 1994). However, nitrogenous activity declines with applied nitrogen (Davis and Brick, 2009), decreasing the sink strength, and hence, reduce the quantity of photo-assimilate partitioned to nodules and grain. Early application may also result in excessive vegetative growth leading to delayed flowering, reduced pod set, lower seed yield and a greater risk of disease infection (Setegne and Leggese, 2003)

The application of inorganic phosphorus fertilizer has positive effect on the yield and yield components of common bean. Rana and Singh (1998) revealed that grain weight per plant exhibited a pronounced response to phosphorus application, mean values of grain weight per plant records of 13.0, 17.4 and 20.7 g due to phosphorus fertilization of zero, 50 and 100 kg P_2O_5 ha^{-1}, respectively. Veeresh (2003) observed significant increase in grain weight per plant (8.65 g) due to increased P application of up to 75 kg P_2O_5 ha^{-1}. Dwivedi *et al*. (1994) also reported linear increase in number of grains per pod of common bean due to increase in phosphorus fertilization from 50 to 150 kg P_2O_5 ha^{-1} but the differences were not significant beyond 100 kg

P_2O_5 ha^{-1}. Saxena and Verma (1994) reported that the mean number of grains per pod linearly increased from 5.53 to 7.50 due to increased phosphorus fertilization from zero to 120 kg P_2O_5 ha^{-1}.

Sulfur (S) is one of the essential nutrients for plant growth and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis. It is required in similar amount as that of phosphorus (Ali *etal.*, 2008). Sulphur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through development of reproductive structure and production of assimilates to fill economically important sink. Sulphur nutrition of bean and other plants is important since its application not only increases growth rate but also improves the quality of the seed (Clarkson *et al*., 1989). Total number of nodules and active nodules significantly increased with application of S up to 20 kg S ha^{-1} (Ganeshamurthy and Readly, 2000). Formation of nodules was increased due to sulphur application in blackgram (*Phaseolus mungo*) and is involved in the formation of nitrogenase enzyme known to promote nitrogen fixation in legumes (Scherer *et al.*, 2006).

Soil fertility mapping project in Ethiopia recently reported the deficiency of K, S, Zn, B and Cu in addition to N and P in major Ethiopian soils and thus recommend application of customized and balanced fertilizers (EthioSIS, 2013).To address these nutrient deficiencies, farmers in Guji zone have been using uniform blanket application of 100 kg DAP ha^{-1} (18 kg N and 46 kg P_2O_5 ha^{-1}) for all legumes including common beanto increase crop yields for about five decades and this did not consider soil fertility status and crop requirement. This emphasizes the importance of developing an alternative means to meet the demand of nutrient in plants by using blended NPS that contains S in addition to the commonly used N and P fertilizers. However, no study has been done on response of common bean (*Phaseolus vulgaris* L.) varieties to the rates of blended NPS fertilizer in Adola District, Southern Ethiopia.Thus, the objectives of this study were to investigate the effect of blended NPS rates on growth, yield and yield components of common bean varieties and to identify economically feasible rates of blended NPS at Guji Zone, Southern Ethiopia.

Materials and Methods

Description of the Study Area

The experiment was conducted at Adola sub-site of Bore Agricultural Research Center (BOARC), Guji Zone, Oromia Regional State in southern Ethiopia under rain-fed conditions during the 2016 cropping season. The site is located in Adola town in Dufa '*Kebele'* just on the

West side of the main road to Negelle town. It is located at about 463 km south from Addis Ababa, capital city of the country. Geographically, the experimental site is situated at 55°36'31" North and longitude of 38°58'91"East at an altitude of 1721 masl. The climatic condition of the area is a humid moist condition, with a relatively shorter growing season. The area receives annual rainfall of 1084 mm with a bimodal pattern extending from April to November. The mean annual minimum and maximum temperature is 15.93 ℃ and 9.89 ℃, respectively. The type of the soil is red basaltic (*Nitisols*) and *Orthic Aerosols* ((Yazachew and Kasahun, 2011). The soil is clay in texture and moderately acidic with pH of around 5.88 (Table 3).

Experimental Materials

Three **c**ommon bean varieties, namely: Angar (medium-seeded); Ibado (large-seeded); and Nasir (medium seeded) were used (Table 1).

Table 30. Description of common bean varieties used for the study

Characteristics	Varieties		
	Angar	Ibado	Nasir
Altitude (masl)	1300-2000	1400-2250	1200-1900
Annual Rainfall (mm)	1000-1300	500-850	500-800
Planting date	Mid -Late June	Mid-June-Early July	Mid June-Early July
Days of 50 flowering	41-52	43-58	40-55
Days to 95% maturity	85-96	90-120	86-88
Growth habit	Bushy	Bushy	Bushy
Seed colour	Dark red	Red	Red
Yield in research site (t ha^{-1})	2.0 - 3.2	2-2.9	2-3.2
Year of release	2005	2003	2003

Source: MoARD (2003 & 2005)

Variety Angar was released by Bako Agricultural Research Center in 2005. Ibado was released by Areka Agricultural Research Center in 2003 and Nasir by Melkasa Agricultural Research Center in 2003. Blended NPS (19% N, 38% P_2O_5,7% S) was used as sources of N, P and S, respectivelyfor the study

Soil Sampling and Analysis

Pre-planting soil samples were taken randomly in a zigzag pattern from the experimental plots at the depth of 0-30 cm before planting. Twenty soil core samples were taken by an auger from the whole experimental field and combined to form a composited sample in a bucket. Then, the collected samples were air-dried at room temperature under shade and ground to pass through a 2 mm sieve for laboratory analysis of soil pH, and available phosphorus. Small quantity of this 2 mm sieved soil material allowed to passed through 0.2 mm sieve for soil organic carbon (OC) and total nitrogen. The composite soil samples were analyzed for selected physicochemical properties mainly textural analysis (sand silt and clay), soil pH, total nitrogen (N), available sulphur (S), organic carbon (OC), available phosphorus (P), cation exchange capacity (CEC) (c mol kg^{-1}), exchangeable potassium, magnesium and calcium using an appropriate laboratory procedures at Horticoop Ethiopia (Horticultural) PLC Soil and Water Analysis Laboratory.

Soil textural class was determined by Boycous Hydrometer Method (Aderson and Ingram 1993). Organic carbon (OC) was estimated by wet digestion method (Walkey and Black, 1934) and organic matter was calculated by multiplying the OC% by a factor of 1.724. Total nitrogen was analyzed by Kjeldhal method (Jackson, 1962). The soil pH was measured potentiometrically in 1:2.5 soil-water suspensions with standard glass electrode pH meter (Van Reeuwijk, 1992). Cation Exchangeable Capacity (CEC) was determined by leaching the soil with neutral 1N ammonium acetate (FAO, 2008). Available phosphorus was determined by the Olsen's method using a spectrophotometer (Olsen *et al.*, 1954) and available sulfur (S) was measured using turbidimetric method (EthioSIS, 2014). Exchangeable potassium, magnesium, and calcium were determined by Melich-3 methods (Mehlich, 1984).

Treatments and Experimental Design

The treatments were factorial combinations of six blended NPS fertilizer rates (0, 50, 100,150, 200 and 250 kg ha^{-1}) (Table 2) and three varieties (Angar, Ibado and Nasir). The experiment was laid out as Randomized Complete Block Design (RCBD) and replicated three times per treatment in factorial combination. The gross plot size was 3.0 m × 2.8 m = 8.4 m^2. The spacing between blocks and plots was 1.0 m and 0.6 m, respectively. Each plot had 7 rows spaced 40 cm apart. One outer most row on each side of a plot and three plants (30 cm) on each end of rows were considered as border. One row next to the border rows on any side was used for destructive sampling. Thus, the net pot size was (1.6 m × 2.4 m = 3.84 m^2) having four rows each row with 24 plants.

Table 31. Rate of fertilizer and their nutrient content (kg ha^{-1}) treatments for the experiment

No	Blended NPS Fertilizer rate (kg ha^{-1})	N	P_2O_5	S
1	0 kg NPS	0	0	0
2	50 kg NPS	9.5	19	3.5
3	100 kg NPS	19	38	7
4	150 kg NPS	28.5	57	10.5
5	200 kg NPS	38	76	14
6	250 kg NPS	47.5	95	17.5

Experimental Procedure and Crop Management

The experimental field was prepared by using oxen-drawn implements (local plough maresha) according to farmers' conventional farming practices. The field was ploughed three times. The first plough was at the end of May 2016, the second in mid July and the third during the middle of August before planting the crop to fine tilth. The plots were leveled manually. All the varieties were sown on 1 October. The dried seeds were planted by hand at a specified spacing (40 cm × 10 cm) by placing two seeds per hill and later thinned to one plant per hill after emergence. All the required amount of blended NPS was applied in band during planting. Furthermore, all necessary cultural and agronomic practices were carried out uniformly for all plots as per the recommendation for the crop at all stages of growth and development. The crop was harvested manually using a sickle when 90% of the leaves and pods turned yellow on 12 December, and dried under the sun for 4 days before threshing. Threshing was done separately for each treatment manually.

Data Collected

An effect of blended NPS rate was investigated by measuring data on phonology, growth, yield and yield component parameters. Data on phonological parameters were measured through visual observation as the number of days from sowing to when 50% of plants in a net plot had reached flowering and 90% physiological maturity. Data on growth and yield component parameters were taken in each plot from ten randomly selected plants at physiological maturity and at harvest time, respectively. For hundred seed weight and grain yield the whole plant from the net plot area was harvested and the yield per hectare was determined by converting the yield per plot (kg per plot) into kg per hectare.

Data Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to SAS software 9.1 versions. Significance Difference (LSD) test at 5% probability level was used for mean comparison.

Economic Analysis

Economic analysis was performed using partial budget analysis following the procedure described by 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 ha basis in Birr. The concepts used in the partial budget analysis were the mean grain yield of each treatment, the field price of common bean grain, and the gross field benefit (GFB) ha^{-1} (the product of field price and the mean yield for each treatment. The net benefit (NB) was calculated as the difference between the gross benefit and the total cost. The average yield obtained from experimental plot was reduced by 10% to adjust with the expected farmers' yield by the same treatment. Prices of grain (Birr kg^{-1}) were obtained from local market for each variety: Ibado was 12 Birr kg^{-1} and Angar and Nasir were 8 Birr kg^{-1}, and total sale from one hectare was computed using adjusted yield. Other costs such as cost of fertilizer (1400 Birr 100 kg^{-1} blended NPS) and its application cost (350 Birr ha^{-1}) were considered as the costs that vary for treatment to treatment.

Results and Discussion

Physico-chemical Properties of the Experimental Site Soil

Soil texture is an important soil physical characteristic as it determines water intake rate (infiltration), water holding capacity of the soil, the ease of tilling, the amount of aeration, and also influences soil fertility (Gupta, 2000). It is one of the inherent soil properties less affected by management and determines nutrient status, organic matter content, air circulation and water holding capacity of a given soil. According to the soil textural class determination triangle, soil of the experimental site was found to be clay (Table 3). High clay content might indicate better water and nutrient holding capacity of the soil. According to the soil analysis test, the soil pH of the experimental site was 5.88 (Table 3). Thus, according to Landon's (1991) rating, the chemical reaction of the experimental site is moderately acidic. The available P level in the experimental site was 5.61 mg kg^{-1} (Table 3) which is very low according to the rating of (EthioSIS, 2014). This low available of phosphorus could be due to fixation in such acidic soils.

Table 32. Physico-chemical properties of the experimental site soil before planting.

Characters	Value	Rating
A. Soil texture		
Sand (%)	30	
Silt (%)	12	
Clay (%)	58	
Textural Class		Clay
B. Chemical analysis		
Soil Ph	5.88	Moderately Acidic
Organic carbon (%)	2.3	High
Total N (%)	0.19	Low
Available P (mg kg^{-1})	5.61	Very Low
Available S (mg kg^{-1})	14.50	Low
CEC [meq/100g soil)	14.9	Low

The result of laboratory analysis showed that the total nitrogen percentage (0.19%) was low as per the rating of EthioSIS (2014). Cation exchange capacity is the capacity of the soil to hold and exchange cations. It provides buffering effect to changes in pH, available nutrients, calcium levels and soil structural changes. The result showed the CEC of the experimental soil to be 14.9 meq/100 g, rated as moderate according to the rating of Landon (1991). The total carbon content in the soil was 2.3% which was rated as high as per the classification of Hazelton and Murphy (2007). Thus, the OM content of the soil was optimum as rated by EthioSIS (2014). On the other hand, the available sulphur content in the soils has values of 14.50 mg kg^{-1} which was rated as low as per the classification of EthioSIS (2014).

Phenological and Growth Parameters of Common bean

Days to flowering: Days to 50% flowering was significantly ($P<0.05$) influenced by interaction of blended NPS rates and varieties but the main effects of variety and blended NPS rate were found to be highly significant ($P <0.01$) on days to reach 50% flowering (Table 4). Significantly, highest number of days (46.67 days) to reach flowering was recorded due to application of 200 kg ha^{-1} of blended NPS for variety Nasir and for variety Angar at NPS rate of 250 kg ha^{-1} while the earliest days to flowering (38.33 days) was recorded due to application of 50 kg ha^{-1} of blended NPS for variety Ibado (Table 4). Variety Ibado was found to be early maturing as compared to the other varieties across all NPS rates. The resultsof the current study revealed that days to flowering was delayed with increment of application rate of blended NPS fertilizer which could be due to the delaying effect of nitrogen obtained from blended NPS fertilizer. This result was in line with the findings of Reta (2015) who reported that increasing the nitrogen rate from nil to 69 kg N ha^{-1} significantly prolonged the days to 50% flowering of linseed (*Linumusitatissimum* L.). This might be due to the fact that excessive supply of N promotes luxuriant and succulent vegetative growth, dominating the reproductive phase. This result is corroborated by that of Ali and Raouf (2011) who reported that the number of days from sowing to flowering increased significantly with increasing amount of nitrogen from 23 kg N to 46 kg N ha^{-1} in chickpea. On the other hand, Tesemma and Alemayehu (2015) reported the interaction of P with variety to be non-significant on common bean. This result is also in contrast to the finding of Nebret (2012) who reported non-significant interaction effects of nitrogen and sulphur.

Table 33. Mean number of days to flowering of common bean as affected by the interaction of variety and blended NPS fertilizer rates at Adola during 2016-2017 main season

Variety	**NPS rate (kg ha^{-1})**						**Mean**
	0	**50**	**100**	**150**	**200**	**250**	
Angar	45.33^{abc}	45.33^{abc}	45.33^{abc}	45.33^{abc}	46.33^{ab}	46.67^{a}	45.72
Nasir	45.67^{abc}	45.00^{bc}	45.33^{abc}	45.67^{abc}	46.67^{a}	44.67^{c}	40.50
Ibado	41.67^{d}	38.33^{e}	39.67^{e}	39.67^{e}	42.00^{d}	42.00^{d}	45.50
Mean	44.22	42.89	43.44	43.56	45.00	44.33	

LSD (0.05)	1.58
CV (%)	2.20

Means followed by the same letters are not significantly different as judged by LSD test at 5%, CV= coefficient of variation

Days to physiological maturity

Days to physiological maturity was highly significantly ($p<0.01$) influenced by interaction of varieties with blended NPS application rates but not significantly influenced by main effect of variety (Table 5). Physiological maturity of common bean was delayed with increase in blended NPS rate. The highest number of days required to physiological maturity (99.33 days) was recorded for the highest rate of blended NPS application rate (250 kg ha^{-1}) for variety Angar while the shortest days to physiological maturity (91.33 days) was recorded without the NPS application for variety Ibado (Table 5). The results indicated that days to maturity in most cases were prolonged in response to the increased levels of blended NPS which can be attributed to the role of nitrogen in the NPS that promoted vegetative growth. This is in line with the results of Gupta and Sharma (2000) who reported that nitrogen promoted vegetative and lush growth thereby delaying plant maturity of onion. This indicates that the nutrients taken up by plant roots from the soil were used for increased cell division and synthesis of carbohydrate, which will predominantly be partitioned to the vegetative sink of the plants, resulting in plants with a luxurious foliage growth (Marschner, 2012).

Table 34. Mean number of days to physiological maturity of common bean as affected by the interaction of variety and blended NPS fertilizer rates at Adola during 2016-2017 main season

Variety	NPS rate (kg ha^{-1})						Mean
	0	50	100	150	200	250	
Angar	96.00^{a-d}	93.33^{de}	98.00^{abc}	98.67^{ab}	94.00^{cde}	99.33^{a}	96.56
Nasir	96.33^{a-d}	95.67^{a-d}	94.00^{cde}	95.33^{a-d}	98.00^{abc}	93.33^{de}	95.44
Ibado	91.33^{e}	95.67^{a-d}	95.00^{b-e}	97.33^{a-d}	98.67^{ab}	98.00^{abc}	96.00
Mean	94.56	94.89	95.67	97.11	96.89	96.89	
LSD (0.05)			3.48				
CV (%)			2.2				

Means followed by the same letters are not significantly different as judged by LSD test at 5%, CV= coefficient of variation

This result is further corroborated with the finding of Huerta *et al*. (1997) who reported delayed physiological maturity due to nitrogen fertilization of up to 80 kg ha^{-1} in common bean. In contrast, Nebret (2012) reported that the application of sulphur (0-60 kg ha^{-1}) had no significant effect on days to maturity on common bean.

Plant height

The analysis of variance showed highly significant (P<0.01) effect of varieties, blended NPS rates and their interaction on plant height at physiological maturity (Table 6). Variety Nasir showed the highest plant height (99.72 cm) with application of 150 kg NPS ha^{-1} where as the shortest plants (31.08 cm) were seen for Ibado without NPS fertilizer (Table 6).

Plant height was significantly increased from 31.08 cm for variety Ibado with 0 kg NPS ha^{-1} to 99.72 cm for variety Nasir at 150 kg NPS ha^{-1}. The increase in plant height in response to the increased blended NPS application rate might be due to the maximum vegetative growth of the plants under higher N, P and S availability. Nitrogen helps in chlorophyll formation, phosphorus establishes strong root system and sulphur enhanced the formation of chlorophyll and encouraged vegetative growth (Havlin *et al*., 2003). In conformity with the current result, Moniruzzaman *et al*. (2008) found that plant height was significantly increased up to 160 kg N ha^{-1}. · Also application of phosphorus at the highest level (120 kg P_2O_5 ha^{-1}) increased plant height. The promotion effect of high P level on plant height of maize may be due to better development of the root system and nutrient absorption (Hussain *et al.*, 2006). The increase in plant height might also be ascribed in relation to better root formation due to sulphur, which in turn activated higher absorption of N, P, K and sulphur from soil and improved metabolic activity inside the plant. Similar results were reported by Jawahar *et al.* (2017) where sulphur level of 40 kg ha^{-1} was found to increase the plant height, LAI, chlorophyll content and number of branches per plant of blackgram (*Vigna mungo).* In contrast to this result, Fisseha and Yayis (2015) reported no significant main and interaction effect of N and P levels on plant height of common bean. Similarly, Meseret and Amin (2014) also reported that P rate at 0-40 kg ha^{-1} had no significant effect on plant height in common bean.

Table 35. Means of plant height (cm) of common bean as affected by the interaction of variety and blended NPS fertilizer rates at Adola during 2016-2017 main season

Variety	NPS rate (kg ha^{-1})						Mean
	0	50	100	150	200	250	
Angar	56.30^{ef}	83.44^{bc}	75.12^{cd}	85.58^{abc}	89.71^{abc}	91.97^{ab}	80.35
Nasir	63.13^{de}	57.17^{efg}	88.94^{abc}	99.72^{a}	90.69^{abc}	90.52^{abc}	81.69
Ibado	31.08^{i}	38.57^{hi}	43.33^{ghi}	45.6f^{gh}	48.96^{fgh}	48.55^{fgh}	42.83
Mean	50.17	59.73	69.13	77.27	76.45	77.01	
LSD (0.05)			13.69				
CV (%)			12.00				

Means followed by the same letters are not significantly different as judged by LSD test at 5%, CV= coefficient of variation

Number of primary branches

The analysis of variance showed highly significant ($P<0.01$) main effect of variety and blended NPS fertilizer application rates on number of primary branches, while their interaction did not significantly influence the number of primary branches (Table 7). Variety Angar recorded the highest number of primary branches per plant (2.55) while the lowest number of primary branches (2.05) was recorded for variety Ibado. This difference might be due to genetic differences in production of number of primary branches among the varieties. This difference might be due to genetic differences in production of number of primary branches among the varieties. The result was consistent with the finding of Addisu (2013) who reported that number of primary and secondary branches were highly significantly varied among chickpea varieties at Debre- Zeit with the desi variety Natoli having significantly higher number of primary (3.21) and secondary branches (6.73) than the Kabuli variety Acos Dubie (2.26) and (3.49) respectively.

The blended NPS rate had highly significant ($P<0.01$) effect on number of primary branches per plant. Increasing rates of blended NPS fertilizer from 0 to 250 kg ha^{-1} showed progressive increase in the number of primary branches per plant (Table 7). Thus, the highest number of primary branches per plant (2.77) was recorded at the highest rate of application of (250 kg NPS ha^{-1}) and it was statistically at par with NPS rates of 200, 150, and 100 kg NPS ha^{-1}, while the lowest number of primary branches per plant (1.56) was recorded for the control. The increase in number of primary branches per plant in response to increased rate of blended NPS application rates indicates higher vegetative growth of the plants under higher N, P and S availability. In line with this result, Shubhashree (2007) reported significantly higher number of branches per plant of common bean with 75 kg P_2O_5 ha^{-1} over the control.

The increment in number of branches with increased rate of P might also be due to the importance of P for cell division, leading to the increase in plant height and number of branches (Tesfaye *et al.*, 2007). In line with this result, Moniruzzaman*et al*. (2008) reported that the number of branches per plant increased significantly with the increase of N up to 120 kg ha^{-1} on common bean. The increased primary branches observed under blended fertilizer might be attributed to readily available form of S that enhanced uptake of nutrients even at the initial stage of crop growth. The result was also in agreement with the finding of Jawahar *et al.* (2017) who reported that application of 40 kg S ha^{-1} recorded the highest number of branches per plant (7.75) in blackgram (*Vigna mungo*).

Total number of nodules

The main effect of variety and interaction of variety with blended NPS rate had no significant effect on total number of nodules, but the main effect of blended NPS rate had highly significant ($P<0.01$) effect on total number of nodules (Table 7). Thus, the highest number of total nodules per plant (80.47) was obtained from the application of blended NPS rate of 200 kg NPS ha^{-1} while the lowest number of total nodules (40.94) was recorded from nil application of blended NPS fertilizer. Application of blended NPS fertilizers significantly increased the number of nodules up to 200 kg ha^{-1} which might be due to better root development with increasing levels of these nutrients. But the total nodule number decreased at 250 kg NPS ha^{-1}.The decrease in number of nodules per plant at highest rates of blended NPS might be due to increasing nitrogen application rates and thereby attributed to the negative effect of fertilizer-N on nodule formation and growth at the high rates. This result is in line with that of Chen *et al.* (1992) and Starling *et al*. (1998) who reported that high rate of nitrogen (56.58 kg N ha^{-1}), resulted in reduction of nodule number and nodule weight in soya bean. The increase in number of total nodules at 200 kg NPS ha^{-1} might also be due to phosphorus which is needed in relatively large amounts by legumes for growth and to promote leaf area, biomass, yield, nodule number and nodule mass in different legumes. Consistent with this result, Amare *et al.* (2014) reported that nodule number was significantly increased with increasing levels of phosphorus with the lowest (12.89) and the highest (31.85) numbers in common bean obtained from the control treatment and application of 20 kg P_2O_5 ha^{-1}, respectively. Yadav (2011) reported the synergistic effect of phosphorus and sulphur on number and weight of nodules per plant with the maximum number of nodules per plant recorded at the highest level of phosphorus (40 kg P_2O_5 ha^{-1}) along with sulphur (20 kg S ha^{-1}) on clusterbean(*Cyamopsis tetrogonoloba*).

Number of effective nodules

Blended NPS fertilizer application had significant ($P<0.05$) effect on number of effective nodules per plant, but main effect of variety and interaction of variety with blended NPS had no significant effect (Table 7). Number of effective nodules per plant increased with increasing rate of blended NPS application rates. Increasing of blended NPS fertilizer from 0 to 200 kg ha^{-1} enhanced the number of effective nodules per plant (Table 7). The highest number of effective nodules per plant (35.54) was recorded at the rate of 200 kg NPS ha^{-1} while the lowest number of effective nodules per plant (27.43) was recorded at the rate of 0 kg NPS ha^{-1}. The increased number of effective nodules with the increase in NPS application up to 200 kg NPS ha^{-1} might be due to the vital role of phosphorus in increasing the number and size of nodule and the amount of nitrogen assimilated per unit of nodules. In agreement with this result, Bashir *etal*. (2011) reported that phosphorus plays a vital role in increasing plant tip and root growth, decreasing the time needed for developing nodules to become active (effective) for the benefit to the host legume. Similarly, Tsai *et al*. (1993) reported that application of nitrogen in the range of 22 to 33 kg ha^{-1} enhanced both nodulation and seed yield of French bean *(Phaseolus vulgaris)*.

Table 36. Mean numbers of primary branches, total and effective nodules per plant of common bean as influenced by the main effects of variety and blended NPS fertilizer rates at Adola during 2016-2017 main cropping season

Treatments	Number of primary branches per plant	Number of total nodules per plant	Number of effective nodule per plant
Variety			
Angar	2.55^{a}	63.01	32.88
Ibado	2.28^{ab}	68.09	32.56
Nasir	2.05^{b}	61.83	30.38
LSD (0.05)	0.28	NS	NS
NSP rate (kg ha^{-1})			
0	1.56^{d}	40.94^{c}	27.43^{c}
50	2.05^{c}	61.16^{b}	30.87^{bc}
100	2.25^{ab}	58.52^{b}	31.87^{b}
150	2.55^{a}	60.36^{b}	32.51^{ab}
200	2.58^{a}	80.47^{a}	35.54^{ab}
250	2.77^{a}	64.41^{b}	33.41^{ab}
LSD (0.05)	0.38	12.0	4.07
CV (%)	17.7	20.5	14.2

Means in the same column and treatment category followed by the same letters are not significantly different as judged by LSD at 5% level of significance. NS = non- significant

Increased number of effective nodules with the application of NPS over the control might also be from increased sulphur application which might be due to the high dose of sulphur and increasing its availability along with other major nutrients. This result is in line with the finding of Ganeshamurthy and Reddy (2000) who reported significant increase in the number of active nodules of soybean with the application of sulphur up to 20 kg ha^{-1}, at which point nodule production reached a plateau and did not increase further. Scherer *et al.* (2006) also reported that formation of nodule in blackgram was increased in response to sulphur application which is involved in the formation of nitrogenous enzyme known to promote nitrogen fixation in legumes.

Yield and Yield Components

Stand count at harvest

The main effect of NPS and the interaction of varieties and blended NPS rates had highly significant ($P<0.01$) effect on stand count at harvest. But varieties had no significant effect on stand count at harvest (Table 8). The highest stand count per plot at harvest (92.67) was obtained at applied blended NPS rate of 50 kg ha^{-1} for variety Angar, whereas the lowest stand count at harvest (72.33) was recorded for variety Angar at highest rate of fertilizer application (250 kg NPS ha^{-1}). The reduction in final crop stand count at the highest NPS rate could be due to sufficient supply of nutrients which in turn favored vigorous vegetative growth, thereby resulting in higher intra-plant competition and crowding out of weaker plants by the vigorous ones.

Table 37. Mean stand count per plot at harvest of common bean as influenced by interaction of variety and blended NPS fertilizer rates at Adola during 2016-2017 main cropping season

Variety	NPS rate (kg ha^{-1})						Mean
	0	50	100	150	200	250	
Angar	88^{ab}	92.67^{a}	79.33^{cdef}	79.00^{c-f}	84.00^{bc}	72.33^{g}	82.56
Ibado	77.33^{efg}	89.33^{ab}	84.00^{bc}	73.33^{fg}	83.67^{bcd}	76.67^{efg}	80.72
Nasir	81.33^{cde}	88.67^{ab}	83.00^{bcde}	83.67^{bcd}	80.67^{cde}	83.67^{bcd}	83.50
Mean	82.22	90.22	82.11	78.67	80.67	83.67	
LSD (0.05)			5.62				
CV (%)			4.10				

Means in rows and columns followed by the same letter are not significantly different judged by LSD test at 5% level of significance, CV= coefficient of variation

Number of pods per plant

Highly significant ($P<0.01$) effects of blended NPS fertilizer application rate and varieties were observed on the number of total pods per plant while the interaction effect did not significantly influence the number of total pods (Table 9). The highest number of total pods per plant (18.52) was recorded at application rate of 250 kg NPS ha^{-1} whereas the lowest number of total pods (8.7) was obtained from the unfertilized plot (Table 9). The increase in number of pods per plant with the increased NPS rates might possibly be due to adequate availability of N, P and S which might have facilitated the production of primary branches and plant height which might in turn have contributed for the production of higher number of total pods. In conformity with this result, Moniruzzaman *et al*. (2008) reported significant effect of N fertilizers on pod production per plant of French bean with the maximum number of pods per plant (25.49) obtained at 120-120-60-20-4-1 kg of N-P_2O_5-K_2O-S-Zn-B. The increment of number of pods per plant due to application of P fertilizer confirms the fact that P fertilizer promotes the formation of nodes and pods in legumes (Buttery, 1969). In agreement with this result, Dereje *et al.* (2015) also found that the number of pods per plant of common bean significantly increased in response to increasing rate of phosphorus up-to the highest rate (92 kg P_2O_5 ha^{-1}). On the other hand, Jawahar *et al.* (2017) reported that application of 40 kg S ha^{-1} recorded the highest number of seeds per pod of blackgram. This could be due to the increasing levels of sulphur application that enhanced its availability to the crop and increase photosynthetic activity of crop

In this study, varieties also exhibited highly significant (P<0.01) difference in the number of pods per plant. Variety Angar produced the highest number of pods per plant (15.3) while the lowest number of pods per plant (10.24) was recorded for variety Ibado (Table 9). The variation in the number of pods per plant among the varieties might be related to the genotypic variation of the cultivars in producing pods. In accord with the results of the present study, different authors reported significant variations in the number of pods per plant for common bean varieties (Fageria *et al.,* 2010; Mourice and Tryphone, 2012).

Number of seeds per pod

The interaction effect of variety and blended NPS application rates and main effects of blended NPS application rates were not significant, but the main effects of varieties had highly significant (P<0.01) effect on the number of seeds per pod. (Table 9). The highest number of seeds per pod (5.35) was recorded for variety Nasir followed by Angar (5.33) whereas the least number of seeds per pod (3.18) was recorded for variety Ibado (Table 9). This indicates that the trait is mainly controlled by genetic factors than the management. Consistent with the results of this study, Mourice and Tryphonne (2012) observed significant variations in number of seeds per pod among common bean genotypes. The variation in number of seeds per pod could be attributed to the variation in the size of seeds of the cultivars where variety Ibado with highest seed size produced lower number of seeds per pod. In agreement with this result, Fageria and Santos (2008) also reported that the number of seeds per pod of different common bean genotypes varied in the range of 3.1 to 6 and attributed the difference due to the genetic variation of cultivars. However, the result of the present study was in contrast with the findings of Shubhashree (2007) who reported that the number of seeds per pod of French bean increased significantly with the levels of phosphorus added.

Hundred seed weight was highly significantly (p<0.01) influenced by varieties, blended NPS rate and their interactions (Table 10). Variety Ibado with application of 200 kg blended NPS ha^{-1} fertilizer scored significantly the highest hundred seed weight (54.33 g) while the lowest hundred seed weight (20 g) was for variety Nasir with 100 kg blended NPS ha^{-1} application rate (Table 10).

Table 38. Mean number of pods per plant and seeds per pod of common bean as influenced by varieties and blended NPS fertilizer rates at Adola during 2016-2017 main season

Treatments	Number of pods per plant	Number of seeds per pod
Variety		
Angar	15.30[a]	5.35[a]
Ibado	10.24[c]	5.33[a]
Nasir	12.63[ab]	3.18[b]
LSD (0.05)	2.21	0.22
NSP rate (kg ha^{-1})		
0	8.70[c]	4.40
50	11.82[bc]	4.54
100	12.6[ab]	4.73
150	12.51[ab]	4.54
200	14.91[ab]	4.76
250	18.52[a]	4.75
LSD (0.05)	3.14	NS
CV (%)	25.1	6.2

Means in columns and rows followed by the same letter are not significantly different judged by LSD test at 5% level of significance; ns = non significant, CV= coefficient of variation

Hundred seed weight

This might be because nutrient use efficiency by crop was enhanced at optimum level of N, P and S since grain weight indicates the amount of resource utilized during critical growth periods. The increase in 100 seed weight with fertilizer application is in agreement with the finding of Shamim and Naimat (1987) who related the increment in 100-seed weight to the influence of cell division, phosphorus content in the seeds as well as the formation of fat and albumin. The increase in hundred seed weight as a result of increased P application might be attributed to important roles the nutrient plays in regenerative growth of the crop (Zafar *et al.,* 2013), leading to increased seed size (Fageria, 2009), which in turn may improve hundred seed weight. Similarly, Amare *et al.* (2014) observed significant increase in thousand seed weights of common bean as a result of phosphorus application up to 40 kg ha^{-1}. In contrast to the results of this study, Fisseha and Yayis (2015) reported that the different levels of phosphorus (46, 69 and 92 kg P_2O_5 ha^{-1}) fertilizer used had not resulted in significant difference in 100 seed weight of common bean. Variation in hundred seed weight might have occurred due to the presence of differences in seed size among the common bean varieties as hundred seed weight increases with increase in the seed size. In line with this result, Tanaka and Fujita (1979) stated that the number of seeds per pod and weights of hundred seeds were strongly controlled genetically in field bean (*Pisum sativim*). The higher 100 seed weight for variety Ibado associated with the size of the seed is in accordance with Hawtin *et al.* (1980) who explained that the larger the seed, the higher its seed weight.

Table 39. Means of hundred seed weight (g) of common bean as influenced by interaction of variety and blended NPS fertilizer rates at Adola during 2016-2017 main season

Variety	NPS rate (kg ha^{-1})						Mean
	0	50	100	150	200	250	
Angar	23.33^{e}	23.33^{e}	38.33^{c}	20.00^{e}	21.67^{e}	42.33^{bc}	28.17
Ibado	38.33^{c}	40.00^{c}	38.33^{c}	38.33^{c}	54.33^{a}	46.67^{b}	42.67
Nasir	21.67^{e}	20.00^{e}	20.00^{e}	20.00^{e}	31.67^{d}	30.00^{d}	23.89
Mean	27.78	27.78	32.22	26.11	35.89	39.67	
LSD (0.05)			5.58				
CV (%)			10.6				

Means in columns and rows followed by the same letters are not significantly different as judged by LSD test at 5% level of significance. CV=coefficient of variation.

Above-ground dry biomass yield

The above-ground dry biomass yield was significantly ($P<0.01$) affected by the NPS fertilizer application and the interactions of fertilizer application with variety. However, the main effect of varieties had no significant effect on biomass yield (Table 11). The result generally showed an increase in biomass production with increase in the rate of blended NPS among the bean varieties. The highest above-ground dry biomass yield (10278 kg ha $^{-1}$) was recorded due to the application of highest rate of NPS fertilizer (250 kg NPS ha^{-1}) for variety Angar followed by variety Angar at 100 kg NPS ha^{-1},whereas the lowest (4045 kg ha $^{-1}$) biomass yield was obtained for variety Nasir under the control NPS rate (Table 11).The increased in biomass yield of cultivars across blended NPS rates could be attributed to the fact that the enhanced availability of N significantly increased plant height, number of pods per plant and to the overall vegetative growth of the plants that contributed to higher aboveground dry biomass yield. 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 (*Phaseolus vulgaris*). The increment in dry matter yield with application of blended NPS fertilizer might also be due to the adequate supply of P from the NPS that could be attributed to an increase in number of branches per plant, which increased photosynthetic area and the number of pods per plant. The significant increase in the aboveground dry biomass yield in response to increasing rate of phosphorus application proves that the soil of the study area is in fact deficient in available soil P and requires external P fertilizer application for enhancing cropyield. This result was in conformity with the findings of Getachew and Angaw (2006) who reported a significant linear response of above-ground dry biomass yield to phosphorus application in faba bean on acidic *Nitisols.* In contrast with this result, Nebret (2012) reported that application of sulphur up to 60 kg S ha^{-1} and interaction of nitrogen with sulphur did not result in significant effect on above-ground dry biomass of common bean.

Table 40. Means of above-ground dry biomass yield (kg ha^{-1}) of common bean as influenced by interaction of variety and blended NPS fertilizer rates at Adola during 2016-2017 main season

Variety	NPS rate (kg ha^{-1})						Mean
	0	50	100	150	200	250	
Angar	5794^{def}	$5178e^{f}$	9135^{ab}	5798^{def}	6191^{c-f}	10278^{a}	7062.33
Ibado	4129^{f}	$4936e^{f}$	5724^{def}	6527^{b-f}	8802^{abc}	7329^{b-e}	6241.17
Nasir	4045^{f}	6443^{b-f}	6640^{b-f}	5782^{def}	8073^{a-d}	9073^{ab}	6676
Mean	4656	5519	7166.33	6035.67	7688.67	8893.33	
LSD (0.05)			2421.3				
CV (%)			21.9				

Means in columns and rows followed by the same letters are not significantly different as judged by LSD test at 5% level of significance. CV= coefficient of variation

Seed yield

Seed yield was significantly ($P<0.05$) affected by the main effect of variety, and highly significantly ($P<0.01$) affected due to main effects of blended NPS fertilizer rates and the interaction of varieties with fertilizer combination (Table 12). The highest grain yield was recorded for variety Angar (3260 kg ha^{-1}) at 250 kg NPS ha^{-1} which was followed by Nasir (3079 kg ha^{-1}) at similar rate of blended NPS level while the lowest yield (1700 kg ha^{-1}) was observed for variety Ibado at control fertilizer treatment (Table 12). Differences in seed yield among the common bean varieties might be related to the genotypic variations in P use efficiency. Hence, the cultivars which produced higher grain yield might have either better ability to absorb the applied P from the soil solution or translocate and use the absorbed P for grain formation than the low yielding cultivar. In agreement with the results of this study, Gobeze and Legese (2015) and Mourice and Tryphone (2012) observed significant variations in grain yield for common bean due to genotypic variations for P use efficiency which may arise from variation in P acquisition and translocation and use of absorbed P for grain formation in common bean. The result might be attributed to the fact that applying NPS fertilizer increases crop growth and yield on soils which are naturally low in NPS and in soils that have been depleted (Mullins, 2001). Similar results were reported by Gebre- Egziabher *et al*. (2014) that P application at the rate of

46 kg P_2O_5 ha^{-1} gave higher number of pods per plant and yield as compared to unfertilized plots in common bean. In line with this result, application of S with or without P recorded significantly higher seed yield up to 40 kg S ha^{-1} on chickpea (Shivakumar, 2001); and on blackgram (Jawahar *et al.*, 2017). It might also be due to increased levels of S, its availability along with major nutrients and higher uptake of crop and influencing growth and yield components of the crop, which ultimately lead to effective, assimilate partitioning of photosynthates from source to sink in post-flowering stage and resulted in highest seed yield.

Differences in seed yield among the common bean cultivars might also be related to their response to applied N. In conformity to this result, Dwivedi *et al*. (1994) found increased yield of common bean due to increasing levels of nitrogen up to 100 kg ha^{-1} with the difference between 80 and 100 kg N ha^{-1} being not significant. Boroomanndan *et al.* (2009) also reported that seed yield of soybean increased significantly at 40 kg N ha^{-1} compared to the control treatment. However, application of 80 kg N ha^{-1} decreased seed yield, indicating that there is a limit to the maximum level of nitrogen to be supplied to avoid its detrimental effect on the plant.

Table 41. Means of seed yield (kg ha^{-1}) of common bean as influenced by interaction of variety and blended NPS fertilizer rates at Adola during 2016-2017 main season

Variety	NPS rate (kg ha^{-1})						Mean
	0	50	100	150	200	250	
Angar	2485^{cde}	2360^{e}	2582^{b-e}	3044a^{bc}	2558^{b-e}	3260^{a}	2715
Ibado	1700^{g}	2249^{ef}	2389de	2521^{b-e}	3053^{abc}	3079^{ab}	2499
Nasir	1763^{fg}	2500^{b-e}	2747^{a-e}	2250^{ef}	2956^{a-d}	2505^{b-e}	2453
Mean	1983	2370	2573	2605	2856	2948	
LSD (0.05)				497.4			
CV (%)				11.7			

Means within columns and rows followed by the same letter are not significantly different as judged by LSD test at 5% level of significance. CV= Coefficient of Variation.

Harvest Index

Harvest index was highly significantly ($P < 0.01$) affected by the interaction of variety with blended NPS rate (Table 13). The highest harvest index (0.53) and lowest harvest index (0.28) were recorded for variety Angar with application of blended NPS at 150 kg ha^{-1} and for Nasir at 250 kg ha^{-1}, respectively (Table 13). This might be due to the fact that the higher NPS fertilizers rate had higher influence on vegetative growth than nutrient translocation from plant biomass to seed. In line with this result, Singh and Kumar (1996) reported the highest harvest index of lentil was obtained when 45 kg P ha^{-1} and 30 kg S ha^{-1} were applied. The increment in harvest index with rates of fertilizer is in agreement with the findings of Dhanjal *et al*. (2001) who also reported improvement in harvest index values of 31.60%, 31.99% and 33.86% due to increasing N level zero to 60 and 120 kg N ha^{-1} respectively. However, Gifole *et al.* (2011) found no significant response of harvest index of common bean to P application.

Table 42. Means harvest index of common bean as influenced by interaction of variety and blended NPS fertilizer rates at Adola during 2016-2017 main season

Variety	NPS rate (g ha^{-1})						Mean
	0	50	100	150	200	250	
Angar	0.43^{ab}	0.46^{ab}	0.28^{d}	0.53^{a}	0.41^{ab}	0.32^{d}	0.41
Ibado	0.41^{ab}	0.46^{ab}	0.42^{ab}	0.39^{abc}	0.35^{cd}	0.41^{ab}	0.41
Nasir	0.42^{ab}	0.39^{abc}	0.41^{ab}	0.39^{abc}	0.37^{cd}	0.28^{d}	0.38
Mean	0.42	0.44	0.37	0.44	0.38	0.34	
LSD (0.05)			0.05				
CV (%)			7.30				

Means within columns and rows followed by the same letter are not significantly different as judged by LSD at 5% level of significance. CV= Coefficient of Variation

Economic Analysis

The agronomic data upon which the recommendations are based must be relevant to the farmers' own agro-ecological conditions, and the evaluation of those data must be consistent with the farmers' goals and socio-economic circumstances (CIMMYT, 1988). The net benefit was computed due to common bean varieties, application of blended NPS fertilizer and interaction of varieties with application of blended NPS fertilizer. The economic analysis revealed that the highest net benefit (29825 Birr ha^{-1}) was obtained from combination of variety Ibado with application of 200 kg NPS ha^{-1} while the lowest net benefit (12692 Birr ha^{-1}) was obtained from variety Nasir with no application of fertilizer (Table 14). Therefore, production of Ibado variety with the application of 200 kg NPS ha^{-1} was most productive variety for economical production compared to Angar and Nasir varietiesand can be recommended for the study area. Dereje *et a*l. (2015) reported that planting of the cultivar Nasir produced the highest net benefit (15903.1 Birr ha^{-1}) with acceptable marginal rate of return (3040%) compared to other cultivars at Areka. Fisseha and Yayis (2015) also reported net benefit of 21, 070 ETB ha^{-1} with marginal rate of return of 80% by the application of 69 kg P_2O_5 ha^{-1} at Areka.

Table 43. Result of economic analysis for response of common bean varieties to rates of blended NPS fertilizer rates at Adola 2016-2017 main season

Treatments	Adjusted yield (kg ha^{-1})	NPS cost (Birr ha^{-1})	NPS application cost (Birr ha^{-1})	Total Cost (Birr ha^{-1})	Total Revenue (Birr ha^{-1})	Net Benefit (Birr ha^{-1})
Angar+0	2235.4	0	0	0	17883	17883
Ibado+0	1529.8	0	0	0	18358	18358
Nasir+0	1586.5	0	0	0	12692	12692
Angar+50	2123.6	700	350	1050	16989	15939
Ibado+50	2024.4	700	350	1050	24293	23243
Nasir+50	2250.1	700	350	1050	18001	16951
Angar+100	2324.0	1400	350	1750	18592	16842
Ibado+100	2150.3	1400	350	1750	25804	24054
Nasir+100	2471.9	1400	350	1750	19775	18025
Angar+150	2739.8	2100	350	2450	21918	19468
Ibado+150	2268.8	2100	350	2450	27226	24776
Nasir+150	2024.8	2100	350	2450	16198	13748
Angar+200	2301.9	2800	350	3150	18415	15265
Ibado+200	2747.9	2800	350	3150	32975	29825
Nasir+200	2660.3	2800	350	3150	21282	18132
Angar+250	2934.2	3500	350	3850	23474	19624
Ibado+250	2771.5	3500	350	3850	33258	29408
Nasir+250	2254.9	3500	350	3850	18039	14189

Where, NPS cost=1400 Birr/100 kg, NPS application cost=350 Birr ha^{-1}, common bean grain price of Angar and Nasir = 8, Ibado=12 Birr kg^{-1}

CONCLUSIONS AND RECOMMENDATIONS

Response of common bean (*Phaseolus vulgaris* L.) varieties to rates of Blended NPS Fertilizer were investigated on *Nitisols* and *Orthic Aerosols* soils of Guji Zone, Southern Ethiopia. It was conducted during the main 2016-2017 cropping season with the objective toinvestigate the effect of blended NPS rates on growth, yield and yield components of common bean varieties and to identify economically feasible rates of blended NPS at Guji Zone Southern Ethiopia.

The result showed that the main effects of NPS rate, variety and their interaction had a significant effect on some of growth and yield component parameters. The highest level of NPS rate (200-250 kg ha^{-1}) resulted in higher values of number of primary branches per plant, number of total nodules, number of effective nodules and total number of pods, number of total pods per plant, highest number of total nodules and effective nodules. Varieties exhibited variation on the number of pods per plant, number of primary branches and number of seeds per pod. Variety Angar gave the highest number of primary branches per plant and number of pods per plant whereas the highest number of seeds per pod was recorded for variety Nasir. However, the interaction of variety and blended NPS had significant effect on almost all parameters except on the number of total and effective nodules per plant, number of primary branches per plant and number of pods per plant.The highest number of days to flowering and days to physiological maturity were recorded due to application of 200 kg ha^{-1} and 250 kg ha^{-1} of blended NPS, respectively for variety Nasir. Variety Nasir gave the highest plant height with application of 150 kg NPS ha^{-1} whereas variety Ibado with application rate of 200 kg blended NPS ha^{-1} had the highest hundred seed weight. The highest above-ground dry biomass yield was recorded due to the application of highest rate of fertilizer for variety Angar. The highest grain yield was recorded for variety Angar at 250 kg NPS ha^{-1} whereas the highest harvest index was recorded by variety Angar with application of blended NPS of 150 kg ha^{-1}.

Based on the partial budget analysis, the highest net benefit (29825 Birr ha^{-1}) was obtained from combination of variety Ibado with application of 200 kg NPS ha^{-1} whereas lowest was from variety Nasir (12692 Birr ha^{-1}) with no fertilizer application.Thus, it can be concluded and recommended that application of 200 kg ha^{-1} with variety Ibado was found to be superior and can be used for common bean production in mid-land of Adola district, Southern Oromia.

References

Addisu A (2013).Response of chickpea (*Cicer arietinum* L.) varieties torates of nitrogen and phosphorus fertilizer atDebre Zeit, central Ethiopia. M.Sc. Thesis. Haramaya University, Haramaya. p. 28.

Alemitu M (2011). Factors affecting adoption of improved haricot bean varieties and associated agronomic practices in Dale woreda, SNNPRS M.Sc. Thesis, Hawassa University, Hawassa, Ethiopia.

Ali N, Raouf SS (2011). Phenological and morphological response of chickpea (*Cicer artienium* L.) to symbiotic and mineral nitrogen fertilization. *Zemdiryste Agri.*, 2 (98): 121-130.

Ali R, Khan MJ, Khattak RA (2008). Response of rice to different sources of sulfur (S) at various levels and its residual effect on wheat in rice-wheat cropping system. Soil and Environment 27:131-137.

Amare G, Assaye D, Tuma A(2014). The Response of haricot bean varieties to different rates of phosphorus at Arba-Minch, Southern Ethiopia. *ARPN Journal ofAgricultural and Biological Science*, 9(10): 344-350.

Anderson, J.M. and Ingram, J.S. 1993. *Tropical Soil Biology and Fertility. A Handbook of Methods.2nd Edition* pp. 93-95.CAB International U.K.

Bashir, K., Ali, S. and Umari, A. 2011. Effect of different phosphorus levels on xylem sap components and their correction with growth variables of Mash bean. *SarhadJournal of Agriculture*, 27(4):10-20.

Boroomandan, P., Khoramivafa, M.Y. Haghi, and Ebrahimi, A. 2009. The effects of nitrogen starter fertilizer and plant density on yield, yield components, and oil and protein content of soybean (*Glycine max*, Merr.). *Pakistan Biological Sciences Journal*, 12(4): 378- 382.

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

Buttery B.R. 1969. Analysis of the growth of soybeans as affected by plant population and fertilizer. *Canadian Journal of PlantSciences,* 49: 675-684.

Chen, Z., Mackenzie, A.F. and Fanous, M.A. 1992. Soybean nodulation and grain yield as influenced by N fertilizer rate, plant population density, and cultivar in South Quebec. *Canadian Plant Sciences Journal*, 72: 1049-1056.

CIAT (Centro Internacional de Agricultural Tropical). 1986. The Cultivated species of Phaseolus; Study Guide to be used as a Supplement to the Audio-tutorial unit on the Same Topic. Production: Fernando Fernandez O., Cali, Colombia. CIAT 52 p.

CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo). 1988. *From Agronomic Data to Farmer Recommendations*: An Economics Work book. Mexico, D.F. CIMMYT.

Clarkson, D.T., Saker, L.R., Purves, J.V. and Lee, R.B. 1989. Depression of nitrate and ammonium transport in barley plant with diminished sulphate status: Evidence of co-regulation of nitrogen and sulphate intake. *Experimental Botany Journal*, 40: 953-963.

CSA (Central Statistical Agency). 2016. Agricultural sample survey, Area and production of temporary crops, private holdings for the 2015/16. Meher season.

Davis J.G. and Brick M.A. 2009.Fertilizing Dry Beans. Colorado State University http://www.ext.colostate.edu. Accessed on 13 February, 2017.

Dereje Shanka, Nigussie Dechassa, and Setegn Gebeyehu. 2015. Response of common bean cultivars to phosphorus application in Boloso Sore and SodoZuria Districts, Southern Ethiopia. *East African Journal of Sciences*, 9 (1): 49 – 60.

Dhanjal, R., Prakash O., and Ahlawat, I.P.S. 2001, Response of French bean *(Phaseolusvulgaris)* varieties to plant density and nitrogen application. *Indian Journal of Agronomy*, 46: 277-281

Dwivedi D.K., Singh H., Shahi, K.M. and Rai, J.N. 1994. Response of French bean (*Phaseolus vulgaris* L.) to population density and nitrogen levels under mid upland situation in north-east alluvial plains of Bihar. *Indian Journal of Agronomy*, 39:581- 583.

EthioSIS (Ethiopian Soil Information System). 2013. Soil Analysis Report. Agricultural Transformation Agency (Unpublished)

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

Fageria, N.K. and Santos, A.B. 2008. Yield physiology of dry bean. *Journal of Plant Nutrition*, 31:983–1004.

Fageria, N.K. 2009. *The Use of Nutrients in Crop Plants*. CRC Press, Boca Raton, FL

Fageria, N.K., Baligar, V.C., Moreira, A. and Portes, T.A. 2010. Dry bean genotypes evaluation for growth, yield component and phosphorus use efficiency. *Journal of Plant Nutrition*, 33(14): 2167-2181.

Fageria, N.K., Baligar, V.C. and Jones, Ch.A. 2011. *Growth and Mineral Nutrition of Field Crops*. *Third edition*, CRC Press.

FAO (Food and Agricultural Organization). 2008. Food and Agricultural Organization. Fertilizer and Plant Nutrition Bulletin. FAO, Rome, Italy.

FAOSTAT. 2014. Food and Agriculture Organizations of the United Nations. Statistics Division. http://faostat.fao.org/site/567/default.aspx. Accessed 13 February 2017.

Fisseha Negash and Yayis Rezene. 2015. Nitrogen and phosphorus fertilizers rate as affecting common bean production at Areka, Ethiopia. *Journal of Agriculture and Crops*, 1 (3):33-37.

Ganeshamurthy, A. N. and Reddy, K.S. 2000. Effect of integrated used of farmyard Manure and Sulphur in a soyabean and wheat cropping systems on nodulation dry matter production and chlorophyll content of soyabean on swell-shrink soil in central India. *Journal of Agronomy and Crop Science*, 185: 91-97.

Gebre-Egziabher Murut, Hadush Tsehaye and Fetien Abay. 2014. Agronomic performance of some haricot bean varieties (*Phaseolus vulgaris* L.) with and without phosphorus fertilizer under irrigated and rain fed conditions in the Tigray and Afar regional states, northern Ethiopia. *Momona Ethiopian Journal of Sciences*, 6(2):95-109.

Getachew Agengew and Angaw Tsige. 2006. The role of Phosphorus fertilization on growth and yield of faba bean on acidic *Nitisol* of central Ethiopia. *EthiopianJournal of Science*, 29(2):177-182.

Gifole Gidago, Sheleme Beyene, Walelign Worku. 2011. The Response of haricot bean (*Phaseolusvulgaris* L.) to phosphorus application on Ultisols at Areka, Southern Ethiopia. *Journal of Biology, Agriculture and Healthcare*, 1(3): 38 - 49.

Girma Abebe, 2009. Effect of NP fertilizer and moisture conservation on the yield and yield components of haricot bean (*Phaseolus vulgaris* L.) in the Semi-arid zones of the Central Rift Valley in Ethiopia. *Advances in Environmental Biology*, 3(3): 302-307.
Gobeze Loha and Legese Hidoto. 2015. Evaluation of common bean varieties at phosphorus deficient and sufficient condition in southern Ethiopia. *AshEse Journal of Agricultural Sciences*, 1(4):20-27.
Graham, P.H. 1981. Some problems of nodulation and symbiotic nitrogen fixation in *Phaseolus vulgaris* L.: A review. *Field Crops Research*, 4: 93–112
Gupta, P.K., 2000. *Handbook of Soil Fertilizer and Manure*. Anis Offset Press, Paryapuni, New Delhi, India. 431p.
Gupta, R.P. and Sharma, V.P. 2000. Effect of different spacing and levels of nitrogen for production of export quality onion bulbs planted on raised bed. *News Letter NationalHorticultural Research and Development Foundation*, 20 (1&4): 13-16.
Havlin, J.L., James, D.B., Samuel, L.T. and Warner, L.N., 2003. *Soil fertility and fertilizers an introduction to nutrient management, 6th Edition.* Peason Education Inc., New Delhi, India.
Hawtin, G.C., Singh, K.B. and Saxena, M. C. 1980. Some recent development in the understanding and improvement of *Cicer* and *Lens*. *Advances in legume science*, pp. 613-623.
Hazelton, P.A. and Murphy, B.W., 2007. *Interpreting Soil Test Results*: What Do All the Numbers Mean? CSIRO Publishing, Collingwood, Victoria, xiþ152 pp.160 paperback. ISBN 978- 0-643092-25-9.
Huerta, D.J., Escalante, J.A., Estarda, J.Z., Romos, J.Z., Sanchez, R.R. and Reyes, J.A.F. 1997. Biomass and grain yield production of bean (*Phaseolus vulgaris* L.) according to the nitrogenous fertilization on the inoculation with *Rhizobiummexicana leguminosarum, Bbio var Phaseoli*. *Mexicana Revista Litotecnica*, 20: 45-46.
Hussain, N.; Khan, A.Z.; Akbar, H.and Akhtar, S. 2006. Growth factors and yield of maize as influenced by phosphorus and potash fertilization. *Sarhad Journal ofAgriculture*, 22(4): 579-583.
Jackson, M.L. 1962. *Soil Chemical Analysis.* New Delhi, Prentice Hall of India Pvt. Ltd. 498p.
Jawahar, S.V., Vaiyapuri, V., Suseendran, K., Kalaiyarasan C.,and Sriramachandrasekharan, M.V. 2017. Effect of sources and levels of sulphur on growth and yield of rice fallow blackgram (*Vigna mungo*). *International Journal of Chemistry*, ISSN: 2123-2845 (online). http://irjc.petsd.org. Accessed on 8 March 2017.
Landon, J.R., 1991. *Booker Tropical Soil Manual*: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Sub-tropics. Longman Scientific and Technical, Longman Group, New York, USA. p474.
Legese Dadi, Gure Kumsa and Teshale Assefa. 2006. Production and marketing of white pea beans in Rift Valley Ethiopia. A sub-sector analysis CRS-Ethiopia Program, Addis Ababa.
Marschner, P. 2012. *Marschner's Mineral Nutrition of Higher Plants. 3rd Edition*, Academic Press, San Diego, ISBN: 9780123849052, P. 651.
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.
Meseret Turuko and Amin Mohammed. 2014. Effect of different phosphorus fertilizer rates on growth, dry matter yield and yield components of common bean (*Phaseolus vulgaris* L.). *World Journal of AgriculturalResearch*, 2 (3): 88-92.
MoARD (Ministry of Agriculture and Rural Development). 2003 & 2005. Animal and Plant Health Regulatory Directorate, Crop Variety Register. Issue No.11. Addis Ababa.
Moniruzzaman M., Islam, M. R. and Hasan, J. 2008. Effect of N, P, K, S, Zn, and B on yield attributes and yield of French bean in south eastern hilly region of Bangladesh. *Journal of Agriculture and Rural Development*, 6 (1&2): 75-82
Mourice, S.K. and Tryphone, G.M. 2012. Evaluation of common bean (*Phaseolus vulgaris* L.) genotypes for adaptation to low phosphorus. International Scholarly Research Network Agronomy. *ISRN Agronomy*, *2012*, *Research Article.*
Mullins, G. 2001. Phosphorus, Agriculture and the Environment. Virginia Cooperative Extension, Virginia state university. No: 424-029.

Nebret Tedesse. 2012. Effect of nitrogen and sulphur application on yieldcomponents and yield of common bean*Phaseolus vulgaris* L.) in Eastern Ethiopia. M.Sc. Thesis. Haramaya University of Agriculture, Haramaya. p.23-25.

Olsen, S.R., Cole, C.W., Watanabe, F.S. and Dean, L.A. 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. *Soil Sci*ence, 96: 308- 12.

Rana, N.S. and Singh, R. 1998. Effect of nitrogen and phosphorus on growth and yield of French bean (*Phaseolus vulgaris* L.*). Indian Journal of Agronomy*, 43: 367-370.

Reta Dargie. 2015. Effect of nitrogen and sulphur fertilizer levels on growth, yield, and oil content of linseed (*Linumusitatissimum* L.) in Sinana, South-Eastern Ethiopia. MSc.Thesis. Haramaya University, Haramaya. P.27.

Saxena, K. and Verma, V.S. 1994. Growth and yield of French bean (*Phaseolus vulgaris* L.) as affected by NPK fertilization. *Haryana Journal of Agronomy*, 10: 211-214

Scherer, H.W., Pacyna, S., Manthey, N. and Schulz, M. 2006. Sulphur supply to peas (*Pisum sativum* L.) influences symbiotic N_2 fixation. *Plant Soil Environment*, 52 (2): 72-77.

Setegne Gebeyehu and Leggese Daddy. 2003. Improved haricot bean production technology. Amharic version manual.

Shamim M. and Naimat. A. 1987. Effect of seed inoculation with rhyzobium and N. P. fertlizers on the yield of gram. *Pakistan Journal of Agricultural Research*, 8: 383-385.

Sharma, O.P. and Singh, G.D. 2005. Effect of sulphur in conjunction with growth substance on productivity of cluster bean (*Cyamopsis tetragonoloba*) and their residual effect on barley. *Indian Agronomy Journal*, 50(1): 16-18.

Shivakumar, B.G. 2001. Performance of chickpea (*Cicer arietinum*) varieties as influenced by sulphur with and without phosphorus.*Indian Journal of Agronomy*, 46 (2):273-276.

Shubhashree, K.S. 2007. “Response of Rajmash (*Phaseolus vulgaris* L.) to the Levels of Nitrogen, Phosphorus and Potassium during Rabi in the Northern Transition Zone. MSc Thesis, DharwadUniversity of Agricultural Science, Dharwad.

Singh, B. and Kumar, V. 1996. Effect of phosphorus and sulphur on lentil (*Lens culinaris*) under rainfed condition. *Indian Journal of Agronomy*, 41:420-423.

Starling, M.E., Wood, C.W. and Weaver, D.B. 1998. Starter nitrogen and growth habit effects on late-planted soybean. *Agronomy Journal*, 90: 658-662.

Tanaka, A. and Fujita, K. 1979. Growth, photosynthesis and yield components in relation to seed yield of the field bean. *J. Fac. Agric. Hokkaido University*, 59:145-238.

Tesfaye, M.J., Liu, D.L., Allan and Vance C.P. 2007. Genomic and genetic control of phosphate stress in legumes. *Plant Physiology*, 144. 594-603.

Tessema Tesfaye and Alemayehu Balcha. 2015. Effect of phosphorus application and varieties on grain yield andyield components of common bean (*Phaseolus vulgaris* L.). *American Journal of Plant Nutrition and Fertilization Technology,* 5 (3): 79-84.

Tsai, S.M., Bonetti, R. Agbala, S.M. and Rossetto, R. 1993. Minimizing the effect of mineral nitrogen on biological nitrogen fixation in common bean by increasing nutrient levels. *Plantand Soil*, 152: 131-138.

Van Reewijk, L.P. 1992. *Procedures for Soil Analysis (3rd edition).* International Soil Reference Center, Wageningen, Netherlands, 371p.

Vance, C.P. 2001. Symbiotic nitrogen fixation and phosphorus acquisition. Plant Nutrition in a World of Declining Renewable Resources. *Plant Physiology,* 127: 390 – 397.

Veeresh, N.K. 2003. Response of French bean (*Phaseolus vulgaris* L.) to fertilizer Levels in Northern transitional Zone of Karnataka. MSc. (Agriculture) Thesis, University Agricultural Science. Dharwad. P 37-79.

Verma, V.S. and Saxena, K.K. 1995. Response of French bean (*Phaseolus vulgaris* L.) to graded doses of nitrogen, phosphorus and potassium in silty- loam soil of central Uttar Pradesh. *Indian Agronomy Journal*, 40: 67-71.

Vidyalakshmi, R., Paranthaman R. and Bhakyaraj, R. 2009. Sulphur Oxidizing Bacteria and Pulse Nutrition - A Review. *World Journal of Agricultural Sciences*, 5(3): 270-278.

Walkley, A. and Black, C.A. 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sciences*, 37: 29-34.

Wortmann, C.S. 2006. *Phaseolus vulgaris* L. (common bean). Record from PROTA4U. Brink, M. & Getachew, Belay. (editors). PROTA (Plant Resources of Tropical Africa RessourcesVégétales de l'AfriqueTropicale), Wageningen, Netherlands

Yadav, B.K. 2011. Interaction effect of phosphorus and sulphur on yield andquality of cluster bean in Typic Haplustept. *World Journal of Agricultural Sciences,* 7(5):556-560.

Yazachew Etefa and Kasahun Dibaba. 2011. Physical and socio-economic profile of Guji zone districts. Bureau of Finance and Economic Development. The National Regional Government of Oromia, Finfinne.

Zafar, M., Abbasi, M.K. and Khaliq, A. 2013. Effect of different phosphorus sources on the growth, yield, energy content and phosphorus utilization efficiency in maize at Rawalako Azad Jammu and Kashmir, Pakistan. *Journal of Plant Nutrition*, 36:1915–1934.

Protection

Evaluation of post-emergence herbicides against major weed species in wheat in Bale highlands, South- eastern Ethiopia.

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Abstract

A field experiment on weed control in wheat was conducted at Sinana agricultural research center and Robe area during the main bona cropping season of 2016. Different post-emergence herbicides were evaluated together with the hand weeding and weedy check for weed control and yield and yield components of wheat. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Improved bread wheat variety ''Mada walabu'' with a seed rate of 150 kg ha^{-1} and different recommended agronomic practices was used in the experiment. The treatments consist of three post-emergence herbicides: Atlantis OD 37.5, Pallas 45 OD, and Topic plus and two times hand weeding and weedy check were used for comparison. The analysis result of the two locations showed that the yield and yield components of wheat were significantly responded to the applied treatments, except plant height, Biomass and HLW at Sinana on-station and plant height and spike length at Robe area. Maximum wheat grain yield was recorded (4622 kg ha^{-1}) at Sinana on-station and (4645 kg ha-1) at Robe area in plots treated with Atlantis OD 37.5.The second maximum grain yield was recorded at both locations Sinana on-station and Robe area, 4311 kg ha^{-1} and 4289 kg ha^{-1} respectively, in plots treated with Pallas 45 OD. The third maximum grain yield at both locations was recorded in plots weeded twice. The lowest grain yield was recorded in weedy check plots at both locations, Sinana on-station and Robe area, 2867 kg ha^{-1} and 2911 kg ha^{-1} respectively. The highest weed control efficacy at both locations for both grass and broad leaved weeds was recorded for Atlantis OD 37.5 followed by Pallas 45 OD. The economic analysis also revealed that Atlantis OD 37.5gave the highest net benefit. From one year result it is possible to conclude that if economically affordable and available, Atlantis OD 37.5 is the best weed management option in wheat in Bale highlands.

Key words: Broad leaved weed, Herbicide Grass weed and Wheat (*Triticum aestivum* L.)

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops worldwide in gross production and utility (Evans, 1998). Ethiopia is the major wheat producer in the sub-Saharan Africa and the southeastern highlands of Arsi and Bale are well recognized as bread basket of the country. Arsi and Bale highlands form the major wheat belt of Ethiopia accounting for the country's 30.5% of wheat production (CSA, 2008). However, the national average yield of wheat is quite low due to biotic and abiotic factors. Rusts, Insect pests and Weeds are the major biotic constraints .Weeds are one of the major constraint in wheat production as they reduce productivity due to competition, allelopathy, by providing habitats for pathogens as well as serving as alternate host for various insects and fungi and increase harvest cost. Studies indicated that crop losses due to weed competition throughout the world as a whole, are greater than those resulting from combined effect of insect pests and diseases. It causes yield reduction in wheat from 10- 65% (Genene G. and Habtamu S., 2001).

Physical methods are laborious, tiresome and expensive due to increasing cost of labor, draft animals and implements and weeds cannot effectively be managed merely due to crop mimicry especially grass weeds in cereal crops. Therefore, the use of chemical weed control has become necessary (Marwat K. B. *et al.,* 2008). However, the choice of most appropriate herbicide, proper time of application and proper dose is an important consideration for lucrative returns (Awan, I.U. *et al.,* 1990). Application of herbicides decreased dry weight of weeds significantly compared to dry weight in non-treated plots and increased yield components and grain yield (Ashrafi Z.Y. *et al.,* 2009). Therefore seeking and evaluation of herbicides is excellent option for efficient weed control.

Materials and methods

The experiment was conducted at two locations (Sinana on- station, and Robe area) for one year (2016 main cropping season) to evaluate the efficacy of herbicides on weeds and yield and yield components of wheat. The experimental design in both locations was randomized complete block design and replicated three times. The treatments were consist of two grass and broadleaved weed herbicides (Atlantis OD 37.5, and Pallas 45 OD) and One grass weeds herbicide (Topic plus) applied at 2-4 leaf stage at the rate of 1, 0.5 and 1 lit ha^{-1} respectively, two times hand wedding and weedy check (control) were used as a treatments. The test bread wheat variety (Mada walabu) was sown at the recommended seeding rate of 150 kg ha^{-1}. Seeds were sown into rows of 0.2 m apart. The size of each plot was 5 m x 5 m (25 m^2) and the distance between the plots and blocks were kept at 1 m and 1.5m apart respectively. Weed density count of the individual species were taken from each plot before and four weeks after application of herbicides by using 0.25m^2 quadrate, and the density from treated plots compared with the untreated plots. The efficacy of herbicides was calculated by the following formula (Auskalnis and Kadzys, 2006).

$$WCE\ (\%) = \frac{(NWC - NWT)}{NWC}\ x\ 100$$

Where, WCE = weed control efficacy; NWT = number of weed species in the treated plot;
NWC = number of weed species in the control plot

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.

Economic analysis

The economic analysis was done based on the procedures by CIMMYT (CIMMYT, 1988). Partial budget and net benefit analysis were performed for weed management options for selecting the profitable treatments.

Results and discussions

Weed flora

The weed community observed in the experimental fields comprised of both broad leaved and grass weeds. Out of the total weeds observed in the experimental fields, 62.5% were broad leaved while 37.5% grass weed species. Among broad leave weed species *Amaranthus hybridus, Chenopodium spp, Galensoga parviflora, Commelina benghlensis, Guizotia scabra* were the most dominant. Whereas *Avena fatua,Bromus pectinatus and Cyprus spp* were the most dominant grass weed species observed in the experimental plot at the time of treatment application.

Wheat yield and yield related traits as influenced by different weed management options

The analysis result of the two locations (Sinana on-station and Robe area) showed that the yield and yield components of wheat were significantly responded to the applied weed management options. At both locations kernels per spike, Grain yield, Harvest index and TKW were significantly influenced by applied weed management options (Table 1and3).

Kernels per spike

Kernel per spike was significantly affected by weed management methods. There was statistically significant difference ($P \leq 0.05$) between post emergence herbicides and hand weeding and weedy check. But there was no significant difference among post emergence herbicides. The highest kernel per spike was recorded from Atlantis OD 37.5 treated plots (45 and 38.2 kernels $spik^{-1}$) at Sinana on station and Robe area respectively. On the other hand the lowest kernel per spike (36.3 and32.5) was obtained from weedy check plot at Sinana on-station and Robe area, respectively (Table 1 and 3).

Thousand kernel weight

Analysis of variance indicated that there was significant variation among weed management methods regarding to thousand kernel weight at both locations Sinana on-station and Robe area. The maximum thousand kernel weight (44.7g and 36g) was recorded from plots treated with Atlantis OD 37.5 at Sinana on station and Robe area, respectively (Table 1and 3). The minimum thousand kernel weight (38.7g and 26.7g) was obtained from weedy check at both respective locations. This low thousand kernel weights may be attributed to resource competition of wheat by weed in un-treated plot. This result is supported by the findings of Ahmad *et al.* (1991) and Mason *et al.* (2006).

Grain yield

Wheat grain yield was significantly affected by weed management options at both Sinana on-station and Robe area (Table 1and 3). Result of the experiment revealed that the herbicide treatment had a noticeable effect on the grain yield of wheat. The highest grain yield (4622 kg ha^{-1} and 4645kg ha^{-1}) was recorded from plots treated with Atlantis OD 37.5 followed by Pallas 45 OD (4311 kg ha^{-1} and 4289 kg ha^{-1}) at Sinana on-station and Robe area, respectively (Table 1 and 3). Increased grain yield of treated crop may be attributed to availability of more nutrients, light, moisture and space resulting in crop growth. This finding is in agreement with the work of Arif *et al.* (2004) who reported that the applications of herbicides in fact does affect grain yield of wheat. The lowest grain yield was obtained from weedy check (2867 kg ha^{-1} and 2911 kg ha^{-1}) at both respective locations. Such a yield reduction could be due to maximum infestation of weeds in un-treated plot. This result is similar to the findings of Chaudhary *et al.* (2008) and Dalley *et al.* (2006) who reported that high weeds intensity and more competition time with crop plants causes more yield reduction in crop yield.

Economic analysis: The economic analysis was done based on the procedures by CIMMYT (CIMMYT, 1988). Partial budget and net benefit analysis were performed for weed management options for selecting the profitable treatments (Table5). The net benefit analysis indicated that Atlantis OD 37.5 resulted in the highest net benefit (55516 Birr/ha). The next highest net benefit was recorded by Pallas 45 OD (51738 Birr/ha).There fore, according to the economic analysis the best weed management options in wheat in bale highlands was Atlantis OD 37.5 and the second was Pallas 45 OD.

Conclusions and Recommendations

The analysis result of the two locations (Sinana on-station and Robe area) showed that the yield and yield components of wheat were significantly responded to the applied weed management options, except plant height, Biomass and HLW at Sinana on-station and plant height and spike length at Robe area. At both locations Atlantis OD 37.5 gave the highest seeds per spike, Grain yield, Harvest index and TKW (Table 1and3). From analysis result and visual observation if properly used Atlantis OD 37.5 efficiently can control broad and grass weeds in wheat. The next efficient herbicide was Pallas 45 OD. Efficacy test also indicated that Atlantis OD 37.5 controls major Grass and Broad leave weed species with better control efficacy than the rest weed control methods followed by Pallas 45 OD (Table 2 and 4). The economic analysis also revealed that the highest net benefit was recorded by Atlantis OD 37.5.Therefore, From one year result possible to conclude that if economically affordable and available Atlantis OD 37.5 is the best weed management option in wheat in Bale highlands.

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Table1. Effect of weed control methods on yield and yield components of Bread wheat (On-station)

Treatments	PH(cm)	SL(cm)	KPS	BM(kg)	GY(kg)	HI (%)	TKW(gm)	HLW(kghl^{-1})
Atlantis OD 37.5	87.3	8.7b	45a	7968	4622a	0.58a	44. 7a	82
Pallas 45 OD	87.7	8.8b	40.7ab	7185	4311b	O.60a	41.7ab	81.5
Topic plus	85	9.4a	39.7ab	7613	3045d	0.40b	40. 7ab	81.3
2 times HW	86.7	9.13ab	39ab	6838	3556c	0.52a	40. 7ab	82
Weedy ckeck	86.3	9.1ab	36.3b	7162	2867d	0.40b	38. 7b	81.4
LSD(P≤0.05)	ns	0.46	5.87	ns	307	0.08	5.12	ns
CV (%)	3.8	2.7	7.8	13	4.4	9.5	6.7	4.5

PH = Plant height; SL = Spike length; KPS = Kernels per spike; HI = Harvest index; BM=Bio-mass yield; TKW=Thousand kernel weight; HLW=Hectoliter weight; ns = non-significant; LSD = Least significant difference at $P \leq 0.05$; CV (%) = Coefficient of variation (%)

Table 2. Efficacy (%) of weed control options against major weed species in wheat in Bale highlands (On-station)

Trts	*Amaranthus hybridus*	*Chenopodium spp*	*Galensoga parviflora*	*Commelina benghalensis*	*Guizotia Scabra*	*Bromus pectinatus*	*Avena spp*	*Cyprus spp*
Atlantis OD 37.5	88.2	93.3	88.2	85	100	84.6	92.3	44.4
Pallas 45	82.6	80	85.7	75	100	63.6	66.7	0
Topic plus	-10	-12	0	0	0	0	76.9	0
2 times HW	83.3	81.8	75	66.7	66.7	30	0	25
Weedy ckeck	-24	-45	-50	-23.1	-60	-50	0	-33.3

Table3. Effect of weed control methods on yield and yield components of Bread wheat (Robe area)

Treatments	PH(cm)	SL(cm)	KPS	BM(kg)	GY(kg)	HI	TKW(gm)	HLW($kghl^{-1}$)
Atlantis OD 37.5	82.9	8.5	38.2a	8000	4645a	0.53a	36a	81.1a
Pallas 45 OD	81.3	7.7	32.9c	7222	4289b	0.48a	29.3bc	79.7a
Topic plus	85.7	8.5	36.5ab	7556	3089d	0.40b	30.7bc	77.1b
2 times HW	82.5	7.9	34.5bc	7000	3600c	0.40b	33.3bc	79.4a
Weedy ckeck	83.7	8.4	32.5c	7111	2911d	0.29c	26.7c	76.5b
LSD($P \leq 0.05$)	ns	ns	3.18	ns	267	0.05	6.5	1.7
CV (%)	3.6	9.1	4.8	13	3.8	7.2	11.3	1.2

PH = Plant height; SL = Spike length; KPS = Kernels per spike; HI = Harvest index; BM=Bio-mass yield; TKW=Thousand kernel weight; HLW=Hectoliter weight; ns = non-significant; LSD = Least significant difference at $P \leq 0.05$; CV (%) = Coefficient of variation (%)

Table 4. Efficacy (%) of weed control options against major weed species in wheat in Bale highlands (Robe area)

Trts	*Amaranthus spp*	*Chenopodium spp*	*Galensoga parviflora*	*Guizotia Scabra*	*Bromus pectinatus*	*Avena spp*
Atlantis OD 37.5	83.3	100	100	83.3	100	100
Pallas 45 OD	75	84.6	100	66.7	75	100
Topic plus	-17.6	0	0	0	0	80
2 times HW	75	70	86.7	80	33.3	44.4
Weedy ckeck	0	0	0	-25	0	0

Table 5: Partial budget analysis result for evaluation of post-emergence herbicides against major weed species in wheat

	Treatments (Weed management options)				
	Atlantis OD 37.5	Pallas 45 OD	Topic plus	2 times Hand weeding	Weedy check
Average yield (kg/ha)	4622	4311	3045	3556	2867
Adjusted yield (kg/ha)	4160	3880	2741	3200	2598
Gross field benefits (Birr/ha)	62400	58200	41115	48000	38970
Cost of herbicide(Birr/ha)	1800	1700	450	6000	0
Cost of labour to apply herbicide (Birr/ha)	300	300	300	0	0
Harvesting, packing and transportation (Birr/ha)	4784	4462	3152	3680	2988
Total costs that vary(Birr/ha)	6884	6462	3902	9680	2988
Net benefits (Birr/ha)	55516	51738	37213	38320	35982

Cost of Atlantis OD 37.5 1800 Birr /Liter; Cost of Pallas 45 OD 1700 Birr /0.5Liter; Cost of Topic plus 450 Birr /Liter; 2 times hand weeding 60 person @ 100 Birr/ person/day; Herbicide application 3 person@ 100 Birr/ person/day; harvesting, packing and transportation 115 Birr per 100 kg; sale price of wheat grain 1500 Birr per 100 kg.

References

Ahmad, S., Z.A. Cheema, R.M. Iqbal and F.M. Kundi, 1991. Comparative study of different weedicides for the control of broad leaf weeds in wheat. Sarhad J. Agri.7(1):1-9.

Arif,M., L. Awan and H.U.Khan, 2004. Weed management strategies in wheat (Triticum aestivam L.).Pak. J.Weed Sci.Res.10(1-2):11-16.

Ashrafi, ZY *et.al.*,2009.Analogy potential effects of planting methods and tank mixed herbicides on wheat yield and weed population. Journal of Agricultural Technology,5(2):391-403.

Awan, I.U., M. Iqbal and H.K. Ahmad,1990. Screening of different herbicides for the control of weeds in wheat crop. Gomal Univ.J.Res.10(2):77-83.

Chaudhary, S.U., M. Hussain,M.A. Ali and J.Iqbal,2008. Effect of weed competition period on yield and yield component of wheat. J.agric. Res.46(1):47-54.

CSA (Central Statistical Agency) 2008. Agricultural sample survey report on area and production of major crops. Statistical bulletin, Vol.1, Addis Ababa.

Dally,C.D., M.L.Bernards and JJ Kells,2006. Effect of weed removal timing and spacing on soil moisture in corn (Zea mays). Weed technol. 20(2):399-409.

Evans, L.T.1998. Feeding the ten billions: Plants and population growth. Cambridge University press.

Genene Gezu and Habtamu Seboka,2001. Agronomic research recommendations and seed production and maintenance techniques. Training manual for development agents. 24-30 July 2001, Bale-Goba.

Manson, H.E. and D.Spaner, 2006. Competitive ability of wheat in conventional and organic management systems: A review of a literature. Canad. J. Plant sci.86 (2):333-343.

Survey of weed flora composition in coffee (Coffea arabica L.) growing areas of East Ethiopia

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Abstract

Coffee is one of the most important cash crops and the first most traded produce in Ethiopia. Ethiopia's coffee is exclusively of the arabica type (Coffea arabica L.) which belongs to the genus Coffea and family Rubiaceae. Arabica coffee (C. arabica L.) has been threatened by various coffee weed species. Survey was conducted to assess and rank weed species for further management study in selected areas. It was done in coffee growing areas of East Ethiopia including Bedeno, Boke, Daro Labu and Habro districts. Assessment was done via counting weed species, interviewing growers for important points related to weed plants. Quadrate with size of 0.5×0.5m was used. The collected data were analyzed via quantitative measures like weed frequency, field uniformity, mean field density, dominance and relative abundance. Accordingly, a total of 46 different weed species including 31 annuals and 12 perennials grasses which comprised of 35 broadleaved weeds 7 grasses and 1sedge (Representing by 81.3%, 16.3% and 2.3% respectively, by habitat) were identified in East coffee growing areas of Ethiopia. The highest frequency value (85.34%) was recorded with Gallant soldier (Galinsoga parviflora), field uniformity was by African coach grass (Digitaria abyssinica) (68.52%), mean field density was by Salvia tiliifolia Vahl (3184.94 plants/m^2), dominance was by Salvia tiliifolia Vahl (17.33%), while relative abundance was by Salvia Tiliifolia Vahl. The most abundant weed species were ranked and prioritized using relative abundance, because, it is summation values of all quantitative measures of a single weed species. Accordingly, top ten most abundant coffee weed species in East Ethiopia were Salvia Tiliifolia Vahl (31.96), Gallant soldier (21.67), Witch weed (20.24), African coach grass (17.57), Brown top millet (15.80), Black jack (15.80), White wort (15.34), Nut grass (12.55), Congress weed (11.53), and Wandering jaw (10.83). Therefore any coffee growers should use sound and sustainable weed management practice including cultural, chemical and integrated weed management approach based on the nature of these identified weed species and growth habit and further weed management study should be conducted.

Keywords: *Coffea arabica* L., frequency, relative abundance, weed species

1. INTRODUCTION

Coffee is one of the most important cash crops and the first most traded produce in Ethiopia. Ethiopia's coffee is exclusively of the arabica type (*Coffea arabica* L.) which belongs to the genus *Coffea* and family *Rubiaceae*. The significance of coffee in the Ethiopian economy is enormous in that it accounts for about 29% of the total export earnings of the nation, where 4.7

million small-holders directly involved in producing coffee and about 25 million people directly or indirectly depends on coffee sector for their livelihoods (CSA, 2015). However, the production of Arabica coffee in Ethiopia is to a great extent limited by several factors. Among these, coffee diseases such as coffee berry disease, coffee wilt disease and Coffee leaf rust, Coffee insect pests, mainly Antestia, leaf miners and coffee berry borer, Perennial grasses and sedges cause severe crop losses (Demelash, 2017). Research experience has shown that weeds can be serious competitors (Tadesse and Tesfu, 2015 and Demelash, 2017). Perennial grasses, sedges, and annual weeds with their fast and vigorous growth can easily smother coffee, and result in extremely low yields and affect the quality of the crop (Tadesse and Tesfu, 2015).

Excluding environmental variables, yield losses in coffee are caused mainly by competition with weeds. Weed interference is a severe problem in coffee, especially in the early time of the growing years, due to slow early growth, narrow canopy and wide row spacing. Weeds compete with the coffee plants for resources such as light, nutrients, space, and moisture that influence the morphology and phenology of the crop. Furthermore, high weed infestation increases the cost of cultivation, lowers value of land, and reduces the returns of coffee growers. These factors vary across regions and influence the composition and number of predominant weeds of economic importance to coffee production (Tadesse and Tesfu, 2015). Increased cost of production has been a principle item in coffee production caused by weed species dominant and prevalent in areas where they are common, otherwise where they were previously efficiently and effectively managed.

Information on presence, composition, importance and abundance of weed species is needed to formulate appropriate weed management strategies. The distribution and nature of the weeds in coffee growing area could be different due to the different agronomic practices employed and the altitudes across the main coffee growing areas. Specific sound knowledge on the nature and extent of infestation of weed flora in the coffee growing area through weed surveys is essential for planning of their control and an indication to formulate recommendations on the standard practices as well as appropriate herbicides doses under ideal management. However, detailed information on the presence, composition, importance and abundance of weed species especially in main coffee growing areas in East Ethiopia is lacking. Therefore, the present study was undertaken to assess and rank weed species in their abundance for further management.

2. Materials and Methods

This experiment was conducted in four different Hararghe coffee growing districts namely Daro Labu, Habro, Boke and Bedeno. Four potential PAs per district and 5 to 7 fields were selected and assessed. Zigzag sampling method was used during implementation of the survey. Quadrate with 50 cm×50 cm size was used with forward throughing method. Four to five quadrates were taken depending on farm size. Each and every weed species were counted manually and recorded. A questionnaire was also used to collect information from every coffee growers. Answer and question were made with coffee growers on developed questionnaire related to coffee weed species, usual practice carried out to manage coffee weeds, coffee cropping system, about already existing weed species and newly emerged weed plants between respondents and investigators.

Data Computation and Analysis

Collected data were summarized according to the following quantitative measures as described by Thomas (1985).

Weed frequency (F)

Weed frequency was determined as the percentage of the total number of fields surveyed in which a species occurred in at least one quadrate in the following formulae;

$$\mathrm{Fk} = \frac{\sum_{i}^{n} \mathrm{Yi}}{n} \times 100$$

Where; Fk = frequency value for species k; Yi = presence (1) or absence (0) of species *k* in field *i* and *n* being the number of fields surveyed.

Field uniformity (FU)

The field uniformity was calculated as the percentage of the total number of quadrates sampled in which a species occurred, as below;

$$\mathrm{FUk} = \frac{\sum_{i}^{n} \sum_{i}^{5-10} \mathrm{Yij}}{5-10(n)} \times 100$$

Where; FUk = field uniformity value for species k, Yij = presence (1) or absence (0) of species k in quadrate j in field i and n being the number of fields surveyed.

Field density (D)

The field density of each species in the field was calculated by summing the number of plants in all the 20 quadrates per site and dividing by their area.

$$\text{Dki} = \frac{\sum_{i}^{5-10} \text{Zi}}{\text{Ai}} \times 100$$

Where; Dki = density (in numbers m^2) value of species k in field i, Zi = number of plants of a species in quadrate j and Ai being the area in m2 of 5 to 10 quadrates in field i.

Mean field density (MFD)

This value was obtained by totaling each field density (D) and dividing by the total number of fields. MFD is the mean number of plants per m2 for each species averaged over all fields sampled and it was determined as below;

$$\text{MFDk} = \frac{\sum_{i}^{n} \text{DKi}}{n}$$

Where MFDk = mean field density of species k, Dki = density (in numbers m^{-2}) of species k in field i and n being the number of fields surveyed.

Dominance (D) is the measure of mean field density of species k (MFDk) expressed as a percentage of the total mean field density of all weed species (MFDl) and was established as;

D = (MFDk) / Σ MFDl) × 100

Relative abundance (RA)

This value was used to rank the weed species in the survey and it was assumed that the frequency, field uniformity, and mean field density measures were of equal importance in describing the relative importance of a weed species. This value has no units but the value for one species in comparison to another indicates the relative abundance of the species (Thomas and Wise, 1987). Relative abundance values quantify the predominance of a given weed species in an environment by calculating the frequency, field uniformity, and density of a particular weed species relative to all other species observed. This value is an index that is calculated using a combination of frequency, field uniformity, and field density for each species, as described by Thomas (1985). Relative abundance allows for comparison of the overall abundance of one weed species versus another. The relative frequency (RF), relative field uniformity (RFU), and relative mean field density (RMFD) shall be calculated by dividing the given parameter by the sum of the values for that parameter for all species and multiplying by 100 as illustrated below.

The relative frequency for species k (RFk) as;

$$\text{RFk} = \frac{\text{Frequency value of species}}{\text{Sum of frequency values for all species}} \times 100$$

Relative field uniformity for species k (RFU*k*)as;

$$\text{RFUk} = \frac{\text{Field uniformity value for species K}}{\text{Sum of field uniformity values for all species}} \times 100$$

Relative mean field density for species k (RFU*k*)as;

$$\text{RMFDk} = \frac{\text{Mean field density value for species K}}{\text{Sum of mean field density values for all species}} \times 100$$

The relative abundance of species k (RAk**)** was calculated as the sum of relative frequency, relative field uniformity, and relative mean field density for that species as;

RAk = RFk+ RFUk+ RMFDk

3. Results and Discussions

3.1. Weed Species Taxonomy

A total of 46 different weed species including 31 annuals and 12 perennials which comprised of 35 broadleaved weeds 7 grasses and 1 sedge (Representing by 81.3%, 16.3% and 2.3% respectively, by habitat) were identified in Eastern coffee growing areas of Ethiopia (Table 1). The annual species were greater in number than perennial species and overall annual broadleaved species were more prevalent than perennial broadleaved species, grasses and sedges. The same result was obtained by G.G. MIGWI *et al*. (2017) at KIAMBU country.

The weed species represented 21 families in the surveyed area where Asteraceae family had the highest number of weed species (8), followed by Poaceae (7), Solanaceae (3), Papavaraceae (3), Amaranthaceae (2), Lamiaceae (2), Portulacaceae (2), Rubiaceae (2), Oxalidaceae (2) (Table 1). The rest of the 12 families were represented by one species each. Asteraceae, Poaceae and Papavaraceae families accounted together for 48.8% of the species established. Family Amaranthaceae, Lamiaceae, Portulacaceae, Rubiaceae and Oxalidaceae were records together about 23.3% of the species established in surveyed areas. While 1% of weed species were established by the remaining families including Acanthaceae, Commelinaceae, Convolvulaceae, Cyperaceae, Euphorbiaceae, Fabaceae, Orobanchaceae, Plantaginaceae, Polygonaceae, Primulaceae, Tiliaceae and Verbenaceae.

Table 44. Coffee weed species taxonomy surveyed around Hararghe coffee growing belts

Family	**Common name**	**Scientific name**	**Life Cycle**	**Morphology**
Acanthaceae	Prostrate wild petunia	Ruellia prostrata Poir	P	Broad leaf
Amaranthaceae	Slender amaranth	Amaranthus viridis Hook. F.	A	Broad leaf
	Devil's horsewhip	Achyranthes aspera L.	P	Broad leaf
Asteraceae	Wild lettuce	Lactuca capensis Thunb	A	Broad leaf

Family	Common name	Scientific name	Life Cycle	Morphology
	Goat weed	Ageratum conyzoides L.	A	Broad leaf
	Gallant soldier	*Galinsoqa parviflora*	A	Broad leaf
	Guizotia scabra		A	Broad leaf
	Congress weed	Parthenium hysterophorus L.	A	Broad leaf
	Bristly star bur	Acanthospermum hispidum DC.	P	Broad leaf
	False daisy	Eclipta alba L.	A	Broad leaf
	Black jack	Bidens pilosa L.	A	Broad leaf
Commelinaceae	Wandering jaw	Commelina benghalensis L.	P	Broad leaf
Convolvulaceae	Ivy leaf morning glory	Ipomoea hederacea (L.) Jacq	A	Broad leaf
Cyperaceae	Nut grass	Cyperus rotundus L.	P	Sedge
Euphorbiaceae	Wild poinsettia	Euphorbia geniculata Orteg.	A	Broad leaf
Fabaceae	Heart leaf indig	Indigofera cordifolia Heyne. ex Roth.	A	Broad leaf
Lamiaceae	White wort	Leucas martinicensis R. Br.	A	Broad leaf
	Tiliifolia	Salvia tiliifolia Vahl	A	Broad leaf
Orobanchaceae	Witch weed	Striga asiatica L.	A	Broad leaf
Oxalidaceae	Creeping wood	Oxalis corniculata L.	P	Broad leaf
	Clover	*Trifolium rueppellianum*	A	Broad leaf
Papavaraceae	Mexican poppy	Argemone mexicana L.	A	Broad leaf
	Mexican marigold	*Tagetes minuta* L	A	Broad leaf
	Pimpefnil	*Anaqallis arvensis*	A	Broad leaf
Plantaginaceae	Buckhorn Plantain	*Plantago lanceolata*	A	Broad leaf
Poaceae	Brown top millet	Brachiaria ramosa (L.) Stapf	A	Grass
	African coach grass	*Digitaria abyssinica*	P	Grass
	Crowfoot grass	Dactyloctenium aegyptium L.	A	Grass
	Bermuda grass	Cynodon dactylon (L.) Pers.	P	Grass
	Half grass.	Desmostachya bipinnata Stapf	P	Grass
	Love grass	*Setaria verticillata*	A	Grass
	Star grass	*Cynodon dactylon* (L.) Pers.	P	Grass
Polygonaceae	Double thorn	*Oxygonum sinuatum*	A	Broad leaf
Portulacaceae	Purslane	Portulaca oleracea L.	A	Broad leaf

Family	Common name	Scientific name	Life Cycle	Morphology
	Chicken weed	Portulaca quadrifida L.	A	Broad leaf
Primulaceae	Scarlet pimpernel	Anagallis arvensis L.	A	Broad leaf
Rubiaceae	Sticky willy	Galium aparine L.	A	Broad leaf
	Snowdenia	*Snowdenia polystachya*	A	Broad leaf
Solanaceae	Black nightshade	Solanum nigrum L.	A	Broad leaf
	Thorn apple	*Datura metel L.*	A	Broad leaf
	Chinese lantern	*Nicandra physalodes*	A	Broad leaf
Tiliaceae	Burbush	Triumfetta rhomboidea Jacq.	P	Broad leaf
Verbenaceae	Wild sage	Lantana camara L.	P	Broad leaf

3.2. Occurrence and Distribution of Coffee Weed Species in Eastern Ethiopia

Occurrence of weed species is vary from area to area. Among identified species 42% of them were found across surveyed areas, whereas 28% were found at one area followed by 21% which were found at three areas and 9% of them were found at two areas (Table 2). Some weed species were occurred at all agro-ecology (Boke low land, D/Labu and Habro mid land and Bedeno high land). This indicates that weed plants have wide adaptability than another plants/crops species. For example among 46 weed species 18 of them were occurred and grown well across 4 surveyed coffee growing areas/districts. All coffee weed species including broad leaves, grasses and sedges were recorded from all surveyed areas.

Table 45: Weed species with their family observed and recorded in coffee farm in Hararghe districts

Weeds Species	Bedeno	Boke	D/Labu	Habro
Prostrate wild petunia	*			
Slender amaranth		*	*	*
Devil's horsewhip		*		
Wild lettuce	*	*	*	*
Goat weed	*	*		*
Gallant soldier	*	*	*	*
Guizotia scabra	*		*	*
Congress weed	*	*	*	*
Bristly star bur	*			
False daisy	*			
Black jack	*	*	*	*
Wandering jaw	*	*	*	*
Ivy leaf morning glory	*	*	*	*
Nut grass	*	*	*	*

Weeds Species	Bedeno	Boke	D/Labu	Habro
Wild poinsettia	*	*	*	*
Heart leaf indig	*		*	*
White wort	*	*	*	*
Salvia Tiliifolia Vahl	*	*	*	*
Witch weed	*	*	*	
Creeping wood sorrel	*	*	*	*
Clover			*	
Mexican poppy				*
Mexican marigold		*		
Pimpefnil		*		
Buckhorn Plantain	*	*	*	*
Brown top millet	*		*	*
African coach grass	*	*	*	*
Crowfoot grass	*	*	*	*
Bermuda grass		*	*	
Half grass.		*	*	*
Love grass		*		
Star grass				*
Double thorn	*	*	*	*
Purslane	*	*		*
Chicken weed	*			
Scarlet pimpernel	*		*	
Sticky willy	*		*	
Snowdenia			*	
Black nightshade	*	*	*	*
Thorn apple	*		*	
Chinese lantern		*	*	*
Burbush	*	*	*	*
Wild sage	*	*	*	*

Note: * Occurrence of weed species at one area *at two areas *at three areas *at four areas

3.3. Weed Species Frequency (F)

Coffee weed species have recorded with different frequency value from place to place. Weed species frequency value in an average recorded ranges between 85.34% and 12.50% which recorded with Gallant soldier (*Galinsoqa parviflora*) and Spiney pigweed (*Amaranthus spinosus*), respectively (Table 3). The ten superior weed frequency across surveyed area an averagely were Gallant soldier (85.34%), African coach grass (81.03%), Tiliifolia (76.19%), Wandering jew (73.48%), Nut grass (68.05%), Chicken weed (66.67%), Prostrate wild petunia

(66.67%) Black jack (57.40%) and Congress weed (57.19%). Among top ten weed species 40% and 60% were perennial and annuals, respectively, while 20% of them were grasses and remaining 80% were broad leaves weed species. Perennials lives throughout the year (twelve months) with coffee plants in the coffee farm. Unless they controlled timely poor coffee production and productivity encourage parallel to increasing year. This means finally it result in yield loss, poor quality, low price and genetic erosion of coffee crop. Similar founding reported by Begum *et al*. (2008) and Begum (2006) was revealed that different frequencies of different weed species including broad leaves, grasses and sedges. Most of common weeds in all surveyed areas were found in annual nature followed by perennials. Singh *et al*. (2008) suggested that seeds of annual weeds survive in unfavorable conditions and they have able to complete their life cycle from seed to seed in a season.

3.4. Field uniformity (FU) of Weed Species in Surveyed Areas

Among 43 identified weed species high value of field uniformity was appeared with African coach grass (*Digitaria abyssinica*) (68.52%), while the lowest was recorded with Spiney big weed (*Amaranthus spinosus*) (0.48%). The top ten weed species with first-class field uniformity are African coach grass (68.52%), Gallant soldier (49.72%), Brown top millet (43.97%), Wild lettuce (42.58%), White wort (41.84%), *Salvia tiliifolia* Vahl (32.95%), Congress weed (24.78%), Nut grass (24.48), Black night shade (24.25%) and Wandering jew (23.93%) (Table 3). Whereas the remaining 33 species were recorded with field uniformity value ranges between 22.22% (Chicken weed, *Portulaca quadrifida* L.) and 0.48% (Spiney big weed, *Amaranthus spinosus*). It was vary from district to districts, even from kebele to kebele. This dissimilar may occur due to edaphic (including soil pH, soil moisture, etc) and biological (dominated by another weed species, seed dormancy, eaten by insects and micro-organisms and etc) factors (Hakim, *et al*, 2010). Similar result was reported by Hakim *et al*. (2013) in rice field.

3.5. Mean Field Density (MFD) of Weed Species per Surveyed Areas

Salvia tiliifolia Vahl weed species belongs to Lamiaceae was recorded with high field density value (3184.94 plants/m^2) among the identified weed species from surveyed areas, while Snowdenia was recorded with low field density value (18.18 plants/m^2) (Table 3). The superior ten species under different weed families recorded with field density were *Salvia tiliifolia* Vahl (3184.94), Gallant soldier (1184.20), Brown top millet (1139.69), Goat weed (714.92), Black jack (645.67), African coach grass (644.41), Chicken weed (638.10), Congress weed (379.31), Nut grass (324.35) and Creeping wood sorrel (288.90 plants/m^2). This field density was varies from district to districts and even from kebele to kebele, farm to farm. Unlike field density has developed due to some factors like weed managements practiced by growers including cultural, mechanical, chemical and so on, biological including eaten by wild animals, birds, insects, over dominated by anther weed species and etc, physically like poor germination, soil pH, soil moisture stress and etc.

3.6. Dominance (D) of Weed Species in Surveyed Areas

Across the surveyed areas the weed dominance relied between 17.33% and 0.02% which was recorded by *Salvia tiliifolia Vahl* and *Snowdenia polystachya*, respectively. Following *Salvia tiliifolia Vahl* the dominance values and in a descending order the top ten weed species were Gallant soldier (6.72), Black jack (6.13), Goat weed (4.99), African coach grass (4.37), Brown top millet (3.74), Common cocklebur (3.64), Mexican poppy (3.58), Mexican marigold (3.08), Purslane (2.85) and Nut grass (2.78) (Table 3).

3.7. Relative abundance (RA)

Value for the relative abundance of all weed species was vary from 31.96 to 1.34 which recorded by *Salvia Tiliifolia* Vahl and Snowdenia, respectively (Table 3). In this *Salvia Tiliifolia* Vahl was significantly outstanding among the forty-six weed species identified in the surveyed areas. It topped both as a broad leaf weed species as well as in the overall top eleven (11) weeds species that were established to have a relative abundance (RA) value ≥ 9.75%. In descending order, *Salvia tiliifolia* Vahl was followed by Gallant soldier (21.67), Witch weed (20.24), African coach grass (17.57), Brown top millet (15.80), Black jack (15.80), White wort (15.34), Nut grass (12.55), Congress weed (11.53), Wandering jew (10.83) and Chicken weed (9.75%). Among ten most abundant species seven of them are broad leave while 2 are grasses and remain one is sedge.

Table 46. Quantitative measures of coffee weed species across surveyed areas of East Ethiopia during 2018

S/No	**Weed Species**	**F%**	**FU%**	**MFD, plant/m2**	**D%**	**RA**
1	African coach grass	81.03	68.52	644.41	264.65	17.57
2	Asthma herb	45.00	4.69	110.48	53.39	6.44
3	Bermuda grass	37.90	7.46	118.18	54.51	6.58
4	Black jack	57.40	8.99	645.67	237.36	15.80
5	Black night shade	46.02	24.25	36.63	35.63	6.99
6	Bristly star bur	33.33	3.70	19.05	18.69	2.73
7	Brown top millet	50.80	43.97	1139.69	411.49	15.80
8	Buckhorn Plantain	24.21	1.98	43.00	23.06	6.80
9	Burbush	41.89	11.60	101.11	51.53	5.38

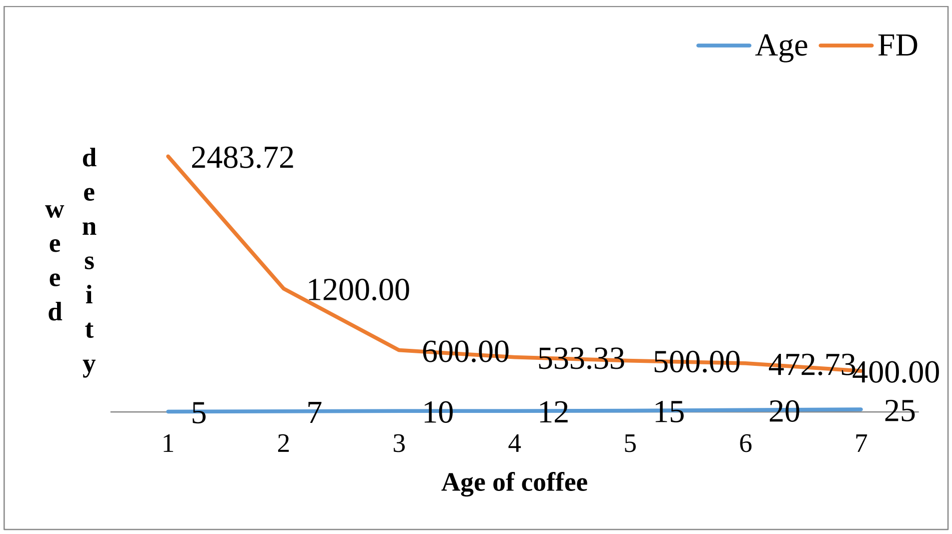
S/No	Weed Species	F%	FU%	MFD, plant/m2	D%	RA
10	Chicken weed	66.67	22.22	638.10	242.33	9.75
11	Chinese lantern	25.99	2.38	53.51	27.29	3.69
12	Common cocklebur	25.00	1.67	152.38	59.68	5.67
13	Congress weed	57.19	24.78	379.31	153.76	11.53
14	Creeping wood sorrel	35.00	5.79	288.90	109.90	4.80
15	Crowfoot grass	56.11	15.88	71.99	47.99	8.12
16	Double thorn	31.39	9.86	23.23	21.49	4.10
17	False daisy	26.49	3.70	19.05	16.41	1.95
18	Gallant soldier	85.34	49.74	1184.20	439.76	21.67
19	Goat weed	32.72	13.74	714.92	253.79	9.34
20	Guizotia scabra	25.33	2.21	126.88	51.47	4.90
21	Half grass	27.18	8.89	18.76	18.28	3.77
22	Heart leaf indig	31.05	9.21	101.30	47.19	4.27
23	Humera weed	33.33	20.00	57.14	36.83	7.07
24	Ivy leaf morning glory	30.93	6.76	68.66	35.45	3.92
25	Love grass	23.81	2.56	114.29	46.89	4.85
26	Meskel flower	12.50	3.89	168.61	61.67	5.09
27	Mexican marigold	33.88	11.64	236.77	94.10	7.83
28	Mexican poppy	33.33	6.67	152.38	64.13	6.83
29	Nut grass	68.05	24.48	324.35	138.96	12.55
30	polygonum aviculma	38.39	11.96	142.42	64.26	5.00
31	Prostrate wild petunia	66.67	15.58	114.29	65.51	6.45
32	Purslane	26.19	8.46	258.20	97.62	5.93
33	Salvia tiliifolia Vahl	76.19	32.95	3184.94	1098.03	3.15
34	Scarlet pimpernel	25.00	8.33	76.19	36.51	5.64
35	Slender amaranth	40.36	10.19	39.59	30.04	1.34
36	Snowdenia	12.50	0.48	18.18	10.39	3.93
37	Spiney pigweed	12.50	0.48	141.82	51.60	2.01
38	Sticky willy	25.00	2.08	38.10	21.73	1.73
39	Thorn apple	19.64	1.37	18.61	13.21	31.96
40	Wandering jaw	73.48	23.93	159.09	85.50	10.83
41	White jute	14.29	0.65	38.10	17.68	2.01
42	White wort	72.23	41.84	198.02	104.03	15.34
43	Wild lettuce	38.49	42.58	44.99	42.02	7.13
44	Wild poinsettia	30.73	8.13	145.60	61.49	5.10
45	Wild sage	39.24	10.01	141.45	63.56	5.09
46	Witch weed	49.55	14.26	112.12	58.65	20.24

3.8. Interaction of Important Factors and Both Weed Composition and Field Density Under Coffee Fields

3.8.1. Impact of coffee age on emergence and growth of weed species

Coffee age has play a great role on weed emergence and its composition. Different weed species compete more coffee plants at young stage rather than at elder stage. Coffee plant become shade to weed and suppresses its emergence and growth when aged. As coffee become aged, its canopy also expanded at the same time and block sun radiation from the emerged weeds underneath of it. Additionally, the shed/dropped coffee leaves cover ground and prevent weed emergence.

However, coffee plants at young stage are invaded by weed plants unless they are got an adequate management. In present study the result was revealed that high weed field density (2483.72 plants /m^2) was recorded from young coffee than the aged one (Figure 1). Weed plants grow freely without any limitation in young coffee's farms rather than in oldest coffee's farm unless coffee farms well managed.



3.8.2. Weed composition and field density in shaded and open sun coffee farm

High (12 weed kinds) weed composition was recorded under open sun coffee farm, while low (5 weed kinds) weed composition was recorded under shaded coffee farm. Similarly high field density was recorded from open sun coffee farm, whereas low field density was recorded from shaded coffee farm. Under shaded coffee farm weed grow has restricted where the shade trees' canopy always block sun radiation penetration to the weed plants which finally leads to weed suppression. In the same way leaves shed from the shade trees cover the ground and serve as mulching which result in blocking of weed seed emergence.

3.8.3. Management practice versus weed composition

Under surveyed areas coffee growers were practiced some different agronomic management in order to manage weed species in their own coffee farm. However, all growers have handled their farm equally as well as some of them were didn't. During survey different weed field density were recorded from different coffee farm and areas as well. Accordingly high (12 weed kinds) field density (2483.72 plants /m^2) was recorded from coffee farm remain with weed plant for long time. Among management practice handled by Hararghe coffee growers hoeing followed by soil mulching has critically weed field density in coffee farm.

3.8.4. Effect of coffee intercropping with annual crops on weed composition

As usual Hararghe farmers has been practiced intercropping and alley cropping system in order to win land shortage. Mainly they have been intercropped coffee with maize, sorghum, haricot bean, ground nut, barely and etc. Accordingly significant weed density was recorded from different coffee farms intercropped with different crops. For example low field density and small number of weed kinds were recorded from coffee farm intercropped with legumes (ground nut and haricot bean) and barely crops which are cover the ground and compete weed on space. According to their morphological structure crops suppresses weed plants at different degree.

4. Conclusions and Recommendations

In present study, a total of forty-six coffee weed species belongs to twenty one families were assessed and identified. Among thirty-four annuals and twelve perennials which comprised of 38 broad leaves weeds seven grasses and one sedge. Annual broad leaves weeds were over dominated and abundant than perennial broad leaves, annual and perennial grasses and sedges across surveyed areas. During previous survey relatively abundant top ten weed species in Hararghe coffee growing areas were *Salvia Tiliifolia* Vahl (31.96), Gallant soldier (21.67), Witch weed (20.24), African coach grass (17.57), Brown top millet (15.80), Black jack (15.80), White wort (15.34), Nut grass (12.55), Congress weed (11.53), Wandering jew (10.83). Therefore any coffee growers should be used a sound and sustainable weed management practice including cultural, chemical and integrated weed management approach and further weed management study should be conducted.

5. References

Begum, M. 2006. Biology and management of *Fimbristylis miliacea* (L.) Vahl. Ph.D Thesis, University Putra Malaysia, Serdang Darul Ehsan, Malaysia.

Begum, M. Juraimi, A. S Azmi, M., Syed Omar S. R. and Rajan A. 2008. Weed flora of different farm blocks in block-1 of muda rice granary inpeninsular Malaysia. J. Biosci. 19: 33–43.

CSA. 2015. Federal Republic of Ethiopia, Central Statistical Agency, Agricultural Sample Survey Report on Area and Production of Major Crops, 2014/2015, Vol. 1, Statistical Bulletin 578, May 2015, Addis Ababa, 121p.

Demelash Teferi, 2017. Coffee weed management review in South West Ethiopia. *International Journal of Agriculture and Biosciences*, 6(5): 252-257.

G. MIGWI, E.S. ARIGA and R.W. MICHIEKA. 2017. A Survey on Weed Diversity in Coffee Estates With Prolonged Use of Glyphosate In Kiambu County, Kenya. *International Journal of Scientific Research and Innovative Technology*; 4(2) : 82-94.

Hakim, M. A., Juraimi, A. S., Razi Ismail, M. Hanafi, M. and Selamat A. 2013. survey on weed diversity in coastal rice fields of sebarang perak in peninsular malaysia. *Journal of Animal & Plant Sciences*, 23(2):534 - 542.

Hakim, M. A., A. S Juraimi, M. R. Ismail, M. M. Hanafi and A. Selamat. 2010. Distribution of weed population in the coastal rice growing area of Kehah in Peninsular Malaysia. *Journal of Agronomy*, 9: 9-16.

Singh, A., Sharma, G. P. and Raghubanshi, A. S. 2008. Dynamics of the functional groups in the weed flora of dryland and irrigated agro ecosystems in the Gangetic plains of India. Weed Biolological. Manage, 8: 250–259.

Thomas, A. G. 1985. Weed survey system used in Saskatchewan for cereal and oilseed crops. Weed Science, 33: 34-43.

Thomas, A. G. and Wise , R. F. 1987. Weed survey of Saskatchewan for cereal and oilseed crops. Weed surveys series. Pub.87-1. Agri. Can. Regina, Saskatchewan. pp. 251.

Tadesse Eshetu and Tesfu Kebede. 2015. Effect of weed management methods on yield and physical quality of coffee at Gera, Jimma zone, South West Ethiopia. *Journal of resources development and management*,11: 82-89.

Efficacies of Fungicide Application Regimes Against FabaBean Gall (*Olpidium species*) Disease

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Abstract

Faba bean (Viciafaba L.) is an important pulse crop due to its high nutritive value both in terms of energy and protein contents. Ethiopia is considered as the secondary center of diversity faba bean for widely grown in the mid-altitude and highland areas. Average yield of faba bean is quite low in Ethiopia and the productivity of the crop is far below the potential because of several limiting *biotic and abiotic constraints. In recent years, the crop has become threaten under a new emerged gall forming faba bean disease. The experiment was conducted to evaluate Matico fungicide under field conditions for the management of faba bean gall disease and also to assess the yield losses. Only significant difference disease incidence recorded on at early (vegetative, flowering and pod setting) fungicide sprayed from other treatments on 4th and 5th assessments and not significant difference disease severity between fungicides sprayed and unsprayed plots of the treatments and Area under Disease Progressive Curve (AUDPC) among treatments. On the final date of disease assessment, at early vegetative and early flowering fungicide, sprayed was recorded the lowest disease severity (28.3%) whereas the highest disease severity of (35%) was recorded on faba bean gall on control plot but not significant different. Not significant difference hundred seed weight(HSW) and yield between fungicides sprayed and unsprayed plots of the treatments. Using Ridomil fungicide for the management faba bean gall not an effective.The results of the present study revealed that the novel possibility of using other management system to decreasefaba bean gall disease symptoms in HoroGuduruShambu area.*

Keywords: *Faba bean, gall disease, Fungicide, and Yield.*

Introduction

Faba bean (*Viciafaba* L.) is an important diploid (2n = 12 chromosomes) Fabaceous pulse crop with common names including broad bean, horse bean, tic bean and field bean. It is one of the earliest domesticated food legumes in the world, probably in the late Neolithic period (Metayer, 2004; Dagne*et al.*, 2016). Faba bean is one of the most important food legumes due to its high nutritive value both in terms of energy and protein contents (24-30%) and also is an excellent nitrogen fixer. According to the United Nations Food and Agriculture Organization's (FAO) the world area of faba bean production is 2.5 million ha, while common bean is 29 million, chickpea was 13.5 million ha and dry peas 6.4 million ha (FAOSTAT, 2014). However, faba bean exceeds both common bean and chickpea in terms of productivity. For instance, the world faba bean productivity in 2013 was 1.6 t ha^{-1} while that of dry bean was 0.8 t ha^{-1} and chickpea 0.9 t ha^{-1}. Faba bean production in the world is concentrated in nine major agro-ecological regions, namely; northern Europe, Mediterranean, the Nile valley, Ethiopia, Central Asia, East Asia, Oceana, Latin America, and North America (Bond *et al.*, 1985). It is cultivated in temperate and subtropical regions of the world (Torres *et al.,* 2006). China has been the main fababean producing country, followed by Ethiopia, Egypt, Italy, and Morocco (Salunkhe and Kadam, 1989).

Ethiopia is considered as the secondary center of diversity faba bean for widely grown in the mid-altitude and highland areas (1800-3000 masl)and serves as a multi-purpose crop leading the pulse category in area and production and it is a source of cash to the farmers and foreign currency to the country. It is the first among pulse crops cultivated in Ethiopia and leading protein source for the rural people and used to make various traditional dishes. The average yield of this crop under small-holder farmer below 1.8t ha^{-1} (CSA, 2014), while world average grain yield of faba bean is around 1.8 t ha^{-1} (ICARDA, 2008). Faba bean is grown on 443,087.9 hectares in Ethiopia with an annual production of about 838,943.9 tons (CSA, 2014). The crop takes the largest share of the area under pulses production in Ethiopia.The growing importance of faba bean as an export crop in Ethiopia has led to a renewed interest by farmers to increase the area under production (Samuel *et al.,* 2008).

The crop is grown in several regions of the country and production obtained from faba bean was 3.94% of the grain production (CSA, 2014). Amhara and Oromia are the two major fababean producing regions in Ethiopia. The Oromia region has the largest faba bean area (43.0%) and contributes to the highest production (48.27%) in the country followed by Amhara region that has 39.06%of the area and contributes 36.34% to national production (CSA, 2014). It is mainly produced in Tigray, Gondar, Gojjam, Wollo, Wollega, Shoa and Gamo-Gofa regions of Ethiopia. Ethiopia's faba bean export has moved north world since the year 2000 and the major destinations are Sudan, South Africa, Djibouti, Yemen, Russia and USA, though its share in the countries pulse export is small (Amanuel*et al.,* 1993; Lupwayi*et al*., 2011).

Despite its wide cultivation, the average yield of faba bean is quite low in Ethiopia and the productivity of the crop is far below the potential because of several limiting biotic and abiotic constraints (Amanuel*et al.,* 2008; EIAR, 2011). According to Samuel *et al* (2008), diseases are the most important biotic factors limiting the production of faba bean in Ethiopia. Faba bean is attacked by more than 100 pathogens. More than 17 diseases causing pathogens are reported in Ethiopia (Dereje and Tesfay, 1995). Many diseases are affecting faba bean production and productivity, but only a few of them have economic significance. Among these, fungi are the largest and perhaps the most important groups affecting all parts of the plant at all growth stages (Negussie*et al.,* 2008). Diseases such as chocolate spot (*Botrytis fabae*), rust (*Uromycesfabae*), black root rot (*Fusarium solani*), and foot rot (*Fusarium avenaceum*) are among the fungal groups that contribute to the low productivity of the crop (Berhanu*et al.*, 2003, Negussie*et al*., 2008). In recent years, the crop has become threaten under a new gall forming disease (*Olpidium species*) (Hailu *et al*., 2014).

Apparently, the newly emerged disease "*Qormid*" faba bean was first recorded in North Shoa, central Ethiopia, sometime in the early 2010s (Beyene, 2015; Beyene and Wulita, 2012; Dereje, 2012). The disease has spread to the highland faba bean-growing areas of Amhara, Tigray, and Oromia regions (Endale*et al*., 2014). These three regions cover about 89.36% of the total faba bean production of the country (CSA, 2014). This shows that the spread of the disease has been very fast and expanding from year to year in all faba bean growing areas of the country. The faba bean gall incited by the pathogen OlpidiumviciaeKusano infection leads to complete crop failure over wide areas within short period of time and aggravates the diminution of yield to maximum nationwide. Moreover, the crops threatened by this disease showed the symptom of green and sunken on the upper side of the leaf and bulged to the back side of the leaf, and finally develops light brownish color lesion, chlorotic galls, and progressively broaden to become circular or elliptical uneven spots (Dereje et al; 2012).

The newly emerged faba bean gall disease is rapidly expand in West Shewa and HoroGuduruWollega Zones. However, the management of faba bean gall disease through the effect of fungicide has not been studied so far in the area. Therefore, this study was carried out to evaluate the fungicide for management of faba bean gall disease under field conditions and also to assess the economic benefit of fungicide.

Materials and Methods

Description of the study area

The field experiment was conducted in Bako Agricultural Research Center (BARC) Shambu Sub-site in Horo District, Western Oromia, Ethiopia during the main cropping season of 2016 and 2018. Horo District is located at 302.4 km West of Addis Ababa and its geographic location is 9°34'0.01N latitude and 37°06'0.00 E longitude with an elevation of 2503 masl. The annual rain fall distribution is 1800-2000mm and the annual minimum and maximum temperature is 17-21^0C. And have clay loam to loam soil types.

Experimental materials, treatments and applications

Local faba bean cultivar was used in this experimental study. Matico (Metalaxyl 80g/kg + Mencozeb 640g/kg) fungicide was obtained from local market and used in different frequency. Total of 7 treatments were arranged in a randomized complete block design with three replications and unsprayed control. Plot size was consisted of 3m x 3.2m and an inter-row and intra-row spacing of 40 cm and 10 cm, respectively, which having 8 rows with six rows per plot harvested. The fungicides were applied as per recommendation of the manufacturers using a manually-pumped knapsack sprayer of 15liter capacity (Table 1). Agronomic practices were carried out in all the field plots as per recommendations.

Table 1: Treatment combination and frequency of fungicide application

Fungicides application	Frequency
At early vegetative	Once
AT early flowering	Once
At early vegetative and early flowering	Twice
At early vegetative and early pod setting	Twice
At early (vegetative, flowering and pod setting)	Three time
Control (no application)	Zero

Disease assessment

Disease incidence and severity

Disease incidence were made on all rows of each plot starting from the onset of the disease and continued every ten days till crop maturity. Both diseased and healthy plants were counted from the all plants in the plots and the percentage of disease incidence (PDI) was calculated according to the formula used by Wheeler (1969):

$$\text{PDI}(\%) = \frac{number\ of\ diseased\ plants}{total\ number\ of\ plants\ inspected}\ x\ 100$$

Disease severity was assessed as the percentage of the total leaf surface covered with gall spot lesions on each expanded leaflet separately at regular intervals using a 0–9 scale (Table 2) (Ding et al., 1993). The severity grades were converted into percentage severity index (PSI) according to the formula by Wheeler (1969).

$$\text{PSI}\ (\%) = \frac{\sum Individual\ numerical\ rating}{(Total\ number\ of plants\ assessed\ X\ Maximum\ scoring\ in\ the\ scale}\ X\ 100$$

Table 2: percent of infection and scale of faba bean gall

Scale	Description
0	no visible infection on leaves
1	a few dot-like accounting for less than 5% of total leaf area
3	discrete spots less than 2 mm in diameter (6–25% of leaf area)
5	numerous scattered spots with a few linkages, diameter 3–5 mm (26–50% of leaf area) with a little

	defoliation
7	confluent spot lesions (51–75% of leaf area), mild sporulation, half the leaves dead or defoliated
9	complete destruction of the larger leaves (covering more than 76% of leaf area), abundant sporulation, heavy defoliation and plants darkened and dead

Area under Disease Progress Curve (AUDPC)

The progress of faba bean gall was plotted over time using to mean percentage severity index for each treatment at each plot, and the DSI values were also used calculate apparent infection rate (r). The AUDPC values (%-day) were calculated for each variety according to the mid-point rule formula (Campbell and Madden, 1990).

$$\mathbf{AUDPC} = \sum_{i=1}^{n-1} 0.5(X_{i+1} + X_i)(t_{i+1} - t_i)$$

Where Xi is the disease severity of faba bean gall at I th assessment date, Ti is the time of the I th assessment in days from the first assessment date and n is the total number of disease assessments. Because severity was in percentage and time in days, AUDPC was express in proportion days.

Growth parameters

A. Days 50% emergence: Days from planting to the emergence of 50% plants per plot were recorded.

B. Days 50% flowering: Days to flowering were recorded for each plot when 50% of the plants in a plot flowered.

C. Days 90% maturity: Days to 90 % maturity of the crop when 90% of the pods in the plot reached physiological maturity.

D. plant height: The height of plants from the ground to the tip of the plants was measured five randomly selected plants per plot at maturity.

Yield and yield components

Number of pods per plant: The number of pods per plant was counted on eight randomly taken plants from 8 tagged plants from six central rows and the means were recorded as number of pods/plant.

Number of seeds per pod: number of seeds per pod was threshed and number of seeds were counted and the total number of seeds was divided by total number of pods to compute average number of seeds per pod. The grain yield per plot from the three central rows was recorded.

Adjusted yield per plot = (Fw (100-Amc) x)/RDW

Where: Fw = Field weight; Amc = Actual moisture content; RDW = Recommended dry weight

The grain yield in gram per plot was then calculated per hectare basis. The weight of 100 randomly taken seeds from the yield of each plot was recorded.

Data Analysis

The analysis of variance (ANOVA) was performed for the disease parameters (incidence, severity, AUDPC) and yields parameters (seed yield per pod/plant and yield loss) using GenStat software. Least significant difference (LSD) values were used to separate treatment means ($P<0.05$) among the treatments. Correlation coefficient (r) between yield and severity as well as were determined through yield components correlation analysis using GenStat 18th edition software, following analysis using the standard procedure (Gomez and Gomez, 1984).

Results and Discussions

Disease incidence

Gall disease of faba bean was first observed at on experimental field at 64 days after sowing (DAS), around the mid of September in both years (2016 and 2018) and it was recorded on the leaf of faba bean in all treatments. There was a not significant difference($P<0.05$) disease incidence between treatments forfaba bean gall disease of the treatments between the fungicide sprayed and unsprayed control form the first assessment (74DAS) and up to third assessment (94DAS) and only significant difference disease incidence recorded on at early (vegetative, flowering and pod setting) fungicide sprayed from other treatments on 4th and 5th assessments (table 3) but, there were no other significant differences($P<0.05$) between the fungicide sprayed and unsprayed control form the first assessment (74DAS) and up to last assessment (114DAS).

Table 3: Disease incidence of faba bean gall treated with fungicide against gall disease

Frequency of Fungicides application	Percentage diseases incidence % (10 interval)				
	74DAS	84DAS	94DAS	104DAS	114DAS
At early vegetative	9.0	29.3	40.3	630.	74.0
At early flowering	11.3	23.0	40.3	58.7	81.3
At early vegetative and early flowering	8.0	21.3	29.3	47.3	47.7
At early vegetative and early pod setting	6.7	32.0	33.0	55.7	59.3
At early (vegetative, flowering and pod setting)	11.0	18.3	24.0	27.7	44.0
Control (no application)	9.0	29.3	34.3	64.0	84.0
Mean	9.2	25.6	33.6	52.7	65.1
LSD(P<0.05)	ns	ns	11.04	21.23	15.04
CV %	57.2	22.5	18.1	22.1	12.7

DAS=day after sowing, LSD=least significant different, ns= non-significant, CV=coefficient variation

Disease severity

There was a not significant difference disease severity index between treatments forfaba bean gall disease of the treatments and also no significance difference disease severity between fungicides sprayed and unsprayed plots of the treatments (table 4).The analysis of variance showed that there were non-significant differences (P<0.05) on disease percentage severity index among the fungicide sprayed plots and control one form the first assessment (74DAS) and up to last assessment (114DAS).

Figure 1: Faba bean gall disease symptom on leaf and stem of faba bean plants.

Table 4: Percentage of diseases severity index of gall disease treated with fungicide

Frequency of Fungicides application	Percentage diseases severity index (10 interval)					Other diseases(1-9)	
	74DAS	84DAS	94DAS	104DAS	114DAS	Ch.st	As.bt
At early vegetative	3.67	4.3	14.0	28.3	33.0	3.3	2.3
At early flowering	3.0	6.0	15.0	30.0	33.0	3.3	3.3
At early vegetative and early flowering	3.7	4.7	14.7	24.0	28.3	2.3	3.0
At early vegetative and early pod setting	3.3	5.7	12.7	24.3	29.3	3.3	3.3
At early (vegetative, flowering and pod setting)	5.3	5.7	13.7	24.3	33.0	3.0	3.2
Control (no application)	3.3	4.7	15.7	29.3	35.0	3.3	3.3
Mean	3.7	5.17	14.28	26.7	31.9	3.11	3.08
LSD(P<0.05)	ns	ns	ns	ns	ns	ns	ns
CV %	26.7	25.5	19.8	16.1	9.7	17.3	21.1

DAS=day after sowing, LSD=least significant different, ns= non-significant, CV=coefficient variation

Yield and yield components

Data on yield parameters showed non-significant differences (P<0.01) among treatments in the number of pods per plant, seeds per pod and seed yield, as well as, no significant differences were observed in 100 seeds weight. Plots treated withMaticofoliar spray fungicide no difference yield and yield components against faba bean gall (table 5). But some literature indicate some chemicals can reduce faba bean gall.Bogale*et al*. (2017),Bayleton WP25 (Triadimefon 250 g a.i./kg) at the rate of 300g fungicide per 100 kg of faba bean used as a seed treatment can reduced faba bean gall pressure, thus minimizing farmer's losses and also Woulita*et al*. (2019), application of Triadimefon 250 g/l and Metalaxyl 8% + Mancozeb 64% WP lowered "faba bean gall" disease severity,

Table 5: Yield and Yield components of faba bean at different frequency chemical application on faba bean gall disease

Frequency of Fungicides application	Yield and Yield component parameters					
	PH	PPP	SPP	PL	HSW	YLD(kg ha^{-1})
At early vegetative	62.07	8.8	3.2	5.533	49.67	1405
At early flowering	58.87	6.8	3.07	5.6	52.33	1781
At early vegetative and early flowering	64.4	8.2	3.47	5.4	52.67	1839
At early vegetative and early pod setting	60.53	6.07	2.93	5.47	50.67	1519
At early (vegetative, flowering and pod setting)	56.47	7.87	3.13	5.13	53.33	1813
Control (no application)	54.07	5.4	3.2	5.67	51	1494
Mean	59.4	7.19	3.17	5.467	51.6	1642
LSD(P<0.05)	ns	ns	ns	ns	Ns	ns
CV %	6.9	17.8	6.1	7.4	10.3	16.4

PH= Plant height, PPP= pod per plant, SPP= seed per pod, HSW= hundred seed weight, YLD= Yield, kg ha^{-1}= kilo gram per hectare, ns=non-significant, LSD= least significant difference, CV= coefficient of variations

Conclusions

This study results showed that levels of disease incidence were no significant difference for the first three data assessments and significant difference on only fourth(104DAS) and fifth (114DAS) assessments incidence at early (vegetative, flowering and pod setting) respectively. The Matco fungicide sprayed and control (unsprayed) no difference in disease severity and yield and yield components. The results of the present study revealed that the novel possibility of using Matco foliar spray for managements of faba bean gall was not be an effective to control faba bean gall disease symptoms on faba bean in Shambu area.

Recommendations

The results of the present study revealed Matco foliar spray is not effective to manage faba bean gall disease in and around Shambu areas. Therefore, it is recommended to test other chemical fungicides and use other managements systems for control this fast spreading disease.

Reference

AmanuelGorfu, Tanner DG, Assefa Taa, DugaDebele. 1993.Observation on wheat and barley-based cropping sequences trials conducted for eight years in South-eastern Ethiopia. Paper presented at the 8th Regional Workshop for Eastern, Central and Southern Africa, 7-20 June 1993, Kampala, Uganda.

Berhanu Bekele., GetachewMuhammed., TeshomeGelano. andTemesgenBelayneh.2003. Faba bean and field pea diseases research in Ethiopia. pp. 278-287. *In:* Ali, K., Kenneni,

BeyeneBitew. and WulitaWondwosen. 2012. New faba bean disease in North Shewa-Ethiopia: ‘Faba bean leaf and stem gall’.

BeyeneBitew. 2015. Survey and identification of new faba bean disease (*Qormid*) in the highlands of North Shewa, Ethiopia. *Current Research Microbiology and Biotechnology*, 3(1): 561-563.

Bogale N., M., Setu B., Tesifaye D. and Eyeberu A. 2017,Management of faba bean gall in fababean producing area of Eastern Amhara, Ethiopi.Journal of Agriculture and Environment for International Development - JAEID - 2017, 111 (2)

Bond, D.A., D.A. Lawes, G.C. Hawtin, M.C. Saxena, and J.S. Stephens. 1985. Faba Bean (*Viciafaba* L.). p. 199-265. In: R.J. Summerfield and E.H. Roberts (eds.), Grain Legume Crops. William Collins Sons Co. Ltd. 8 Grafton Street, London, WIX 3LA, UK.

Campbell, C. L. and Madden, V. L. 1990. Introduction to Plant Disease Epidemiology. Wiley, New York, USA. 532 pp.

Central Statistical Agency (CSA), 2014. Report on area and production of major crops (privat peasant holdings, meher season). Statistical Bulletin, 1 (532): 10-14.

Dagne Kora, Temam Hussein, Seid Ahmed 2016.Oromia Agricultural ResearchInstitute, Sinana Agricultural Research Center.Department of Plant Sciences, Haramaya University.International Center of Agricultural Research in the Dry Areas, Addis Ababa, Ethiopia.

Dereje Gorfu, WendafrashMulugeta and GemechuKeneni 2012. Faba Bean Galls: A new disease of faba bean in Ethiopia. Available at *Google.doc.com*, pp 1-6.

Dereje, G. and Tesfaye, B. 1995.Faba bean diseases in Ethiopia.pp.328-345. In: Asfaw, T., Geletu, B., Saxena, M.C. and Solh M.B. (eds.), Cool-season food legumes of Ethiopia. Proceedings of the 1st National Cool-Season Food Legumes Review Conference, 16-20 December, 1993. Addis Ababa, Ethiopia.

Ding, G., Xung, L., Oifang, G., Pingxi, L., Dazaho, Y. and Ronghai, H. 1993. Evaluation and screening of faba bean germplasm in China. *Fabis Newsletter,* 32: 8–10

EARO (Ethiopian Agricultural Research Organization), 2011.A Guide for faba bean and field pea seed producers.Technical Manual No. 14, Addis Ababa, Ethiopia. 41p.

Endale H, Gezahegn G, Tadesse S, Nigussie T, Beyene B, et al. (2014) Faba bean gall: a new threat for faba bean (Viciafaba) production in Ethiopia. Advances in Crop Science and Technology 2: 1-5.

FAOSTAT. 2014. Data base. Available at: http://faostat3.fao.org/faostat-gateway

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. 2nd edition. *A Wiley Interscience Publications,* New York. 680 pp.

Hailu E, Getaneh G, Sefera T, Tadesse N, Bitew B, et al. (2014) Faba Bean Gall; a New Threat for Faba Bean (*Viciafaba*) Production in Ethiopia.Adv Crop Sci Tech 2: 144. doi:10.4172/2329-8863.1000144 ICARDA (International Center for Agricultural Research in Dry Areas).

ICARDA (International Center for Agricultural Research in the Dry Areas). 1993. International Center for Agricultural Research in the Dry Areas. Faba Bean in China: State-of-the-art Review. Special study report. Aleppo, Syria.

Lupwayi NZ, Kennedy AC and Chirwa RM. 2011. Grain legume impacts on soil biological processes in sub-Saharan Africa. African Journal of Plant Science 5: 1-7.

Metayer (2004).Viciafaba breeding for sustainable agriculture in EuropeGiefeverole.NigussieTadesse., Seid Ahmed., DerjeGorfu., Tesfaye, B., ChemedaFininsa,Adane ,A., Abiy T., Fekede, A. and Kiros, M. 2008. Review of Research on Diseases of Food Legumes.*In*: Abraham Tadesse (Eds). Increasing crop production through improved plant protection - volume I. *Proceedings of the 14th Annual Conference of Plant Protection Society of Ethiopia*, *(*PPSE), 19-22 December 2006. Addis Ababa, Ethiopia. PPSE and EIAR, Addis Ababa, Ethiopia.598 pp.

Salunkhe DK and Kadam SS.1989. Handbook of World Food Legumes: Nutrition Chemistry, Processing Technology, and Utilization. CRC press, Inc. Boca Rotan, Florida. 310p.

Samuel Sahile, Seid Ahmed, ChemedaFininsa, M.M. Abang and P.K. Sakhuja.2008b. Survey of chocolate spot (Botrytis fabae) disease of faba bean (Viciafaba L.) and assessment of factors influencing disease epidemics in northern Ethiopia.Crop Protection. 27:1457-1463.

Torres, A. M., B. Roman, C.M. Avila, Z. Satovic, D. Rubiales, J. C..Sillero,J.I. Cubero, and M.T. Moreno, 2006. Faba bean breeding for resistance against biotic stresses: towards application of marker technology. Euphytica, 147:67-80.

Wheeler, B.E.J. 1969. An Introduction to plant diseases. Wiley and Sons, London.374 pp.

Wulita W., Mashilla D., Negussie T. and Seid A. (2019), Fungicide Management of Faba Bean Gall (Olpidiumviciae) in Ethiopia, Turkish Journal of Agriculture - Food Science and Technology, 7(7): 1075-1081, 2019

Evaluation of Different Insecticide for Management of Fruit Worm (*Helicoverpaarmigera*) on Hot Pepper at Bako, Western Oromia

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Abstract

The fruit worm is a polyphagous and highly mobile insect, is a pest of economic importance on many agricultural and horticultural crops. It feeds on flowers, pods and fruits of hot pepper and it damaged fruits by making hole, ripen prematurely, or become infected with disease. This may affect the quality as well as quantity of the dry pod yield of pepper. The objectives of this study were to evaluate resistance/tolerance of different hot pepper varieties under production and to evaluate different insecticides registered to manage fruit worm pests. The result of this research indicated that, use of different variety were significantly differ in fruit worm infestation in both cropping seasons. Percent of pod infestation per plant were higher, 32.36 and 12.62 % on Marakofana variety in 2017 and 2018 cropping season respectively. Significant variations were observed between the insecticides used for fruit worm infestation. Application of Deltametrin at rate of one l ha^{-1} two times in the growing season reduced pod infestation. Percent of pod infestation was 16.01 and 8.62 % in 2017 and 2018 cropping season respectively on Deltametrin applied plots. Likewise, partial budget indicated positive net change in benefit when changing convectional practice (no treatment) to chemical fruit worm management. Switching from untreated control to use of Deltametrin for the insecticide management, the highest MRR (28.12%) was calculated. Therefore, it was recommended that production of Oda Haro and Bako local was pertinent where fruit worm infestation was high like Bako area and where Marakofana *variety production was important for market purpose application of Deltametrin was very important.*

***Key words**: Fruit worm, Hot pepper, Insectiside,*

Background and Justification

Hot pepper (*Capsicum annuum* var. *annuum L.*) is a vegetable crop grown and consumed worldwide. Hot pepper is a crop of growing significance in the economies of sub-Saharan Africa (SSA). Unfortunately, the rate of production is far from coping with the demand within and outside the SSA region. The first introduction of hot pepper to Ethiopia was by Portuguese, probably in the 17th century (Hafnagel, 1961). Nowadays the crop is adapted to different agro-ecological zones of the country. Hot pepper fruits have a high nutritional value, particularly considerable amount of vitamin C at green stage and vitamin A at matured dried fruits (Mohammed *et al.,* 1992). Pepper is consumed as a fresh vegetable or dried, whole or ground into powder alone or in combination with other flavoring agents or spices. The high nutritive and culinary value of pepper gives the crop a high demand in the market year-round (Bosland and Votava, 2003). Pepper is produced in all mid and lowlands of Ethiopia in the ranging from 1000 to 1800 meter above sea level (Hafnagel, 1961). The average national yield per hectare of red and green pepper is 2.33 and 6.16 t ha^{-1}, respectively. However, the average yields around Bako area is declining and below the national yield of 1.9-2.0 and 3.5 t ha^{-1} for red and green pepper, respectively (CSA, 2015/16).

The poor quality of the produce is largely attributed to biotic and abiotic stresses in the field and the poor quality cultivars grown by farmers (Tusiime et al., 2010). Attacks by fungal, bacterial or viral diseases, nematodes, mites and many insect pest infestations can cause significant losses in pepper production (Ochoa-Alejo and Ramirez-Malagon, 2001). These disease infections and pest infestations undoubtedly, severely reduce the production and profitability of this crop even further by reducing the period in which the crop can be harvested.

Aphids, leaf miners, cutworms, fruit fly, false codling moth, Fruit worm (*Heliothisarmigera)* and lesser armyworm are among the major insect pests that attack pepper. Infected fruits with fruit fly often contain several maggots, and usually rot and drop prematurely and substantial losses can be occurred (Ministry of Agriculture Natural Resource Sector, 2011). The tomato fruit worm (*Helicoverpaarmigera*), a polyphagous and highly mobile insect, is a pest of economic importance on many agricultural and horticultural crops. It has attained the status of major pest on a number of crops, including cotton, tobacco, corn, sorghum, sunflower, soybean, Lucerne and pepper (Torres-Villa et al. 1996). It has been recorded as a damaging pest on 180 cultivated and wiled plant species in at least 45 families (Venette et al. 2003a). Tomato fruit worm feeds on flowers, pods and fruits of pepper. Larvae move from one fruit to the next, destroying only small portions of each fruit. Damaged fruits may drop, ripen prematurely, or become infected with the pest. The entrance hole near the pedicel develops a dark scar. Monitor closely, looking for the larvae on plants; older larvae can be found by cutting into fruits. Young larvae are light yellow and spotted. Mature larvae are brown to gray in color with lengthwise stripes along the body. Adults are active at night. Maximum egg-laying coincides prior to or during host flower production (King 1994). Eggs hatch in 2 or 3 days and the larval stage lasts 14 – 21 days. Larvae move to green fruit soon after hatching, where they bore deeply into the fruit. Tomato fruitworm pupates in the soil; the adult emerges in 7 to 14 days.

In western Ethiopia fruit worm infestation on hot pepper was higher. It affects yield quantity as well as dry pod quality of the crop. In addition, hot pepper pod infestation by this insect was not studied well in the country generally and in Western Ethiopia particularly. Therefore, management of this pest is crucial to increase pepper yield by quantity and quality.

Objective of this study were to evaluate resistance/tolerance of different hot pepper varieties under production at Bako area and to screen different insecticides registered for tomato fruitworm managements.

Materials and Methods

Study Area

The experiment was conducted at Bako Agricultural Research Center in 2017 and 2018 under main cropping seasons.

Experimental Materials and Procedures

Three of the released hot pepper varieties (Marakofana, Bako local and Oda haro) were used to evaluate their resistance /tolerance to the pest. In addition, different insecticides registered (Deltametrin, Chlorpyrifos and Dimethoat) for the control of the pest was evaluated / screened.

Experimental Design

Treatments was arranged in a randomized complete block design (RCBD) with factorial combination of three varieties, three registered insecticide for tomato fruit worm and untreated plots for each variety. It was replicated three times. Plot size of each treatment was 3 m x 3 m.

Seedlings were transplanted at spacing of 30 cm apart from each other in a row and 70 cm between rows. Other agronomic practices were applied as recommended in the study area.

Data Collected

Flowering data, physiological maturity, stand count at harvest were collected. Six plants were pre-tagged from three middle harvestable rows. Data for number of pods per plant, number of infected pods, and number of non-infected pod per plant were collected from pre-tagged plants.Marketable and unmarketable pod dry weight were recorded after the pods were dry.

Data analysis

All collected data were subjected to ANOVA using SAS 9.3 software. Yield losses in different treatments were calculated as percent yield loss by employing the formula developed by Robert and James (1991):

$$\text{Relative percent yield loss} = \frac{100 \times (\text{YCP} - \text{YDP})}{\text{YCP}}$$

Where, YCP: Yield in controlled plot; YDP: Yield in diseased plots of the treatment.

Results and Discussions

Analysis of variance of the two years data in pod infestation by fruit worm indicated that significantly different by years (Table 1). Therefore, analysis was carried out separately for each year.

Table 1: mean square and probability level of pod infestation for two years (2017 and 2018)

Source	DF	Mean Square	P value
Variety	2	5.872	0.098
Chemicals	3	7.660	0.032
Rep	2	1.982	0.446
Year	1	39.796	**0.000**
Variety*chemicals	6	2.785	0.347
Variety*Year	2	8.579	0.036
chemical*Year	3	2.191	0.445

Total pod number per plant was significantly varied by variety in 2017 (Table 2). Total pod per plant was highest on Oda Haro (20 pods/plant) followed by Bako local (17 pods/plant). This may be due to the genetic makeup of the variety. However, total pods per plant were not differed by insecticide applied for management of fruit worm (Table 3). Number of infected pods per plant was significantly influenced by insecticide applied. Significantly, lower (2.72) infected pods were recorded from plots treated with Deltametrin. However, higher (4.79) infestation of pod number per plant were observed on dimethoat treated plots which was at par other management actions applied. Percent of pod infestation were significantly different (P<0.05) between varieties. In this cropping season, more than 32 % of the pods produced by MarakoFana variety was infested with fruit worm. However, lower (20.6%) of pod infestation was observed on Oda Haro variety. In addition, insecticide application significantly different in percent of pod infestation by fruit worm. Application of Deltametrin reduced (16.36%) percent pod infestation than the other treatments. However, no significance difference (P<0.05) were observed between other treatment options in percent pod infestation. Generally, percent of pod infestation was higher in 2017 cropping season. This may be due to application of insecticides were late after the insect infested the crop. Even though higher percent of infestation of fruit worm was recorded on MarakoFana variety, highest marketable dry pod weight (871.56 kg/ha) was recorded on this variety followed by Oda Haro (825.26 kg/ha).

Table 2: Effect of variety on yield and fruit worm insect infestation parameters in 2017/18 main cropping season

Treatment	Total podper plant	Infested pod /plant (no.)	% ofInfestation	Marketable pod (kg/ha)	Unmarketable pod wt.	Dried wt. of Infected pod	Total Yield
Marakofana	14.583 c	4.62 a (2.22)	32.364 a	871.56 a	186.59 a	88.17 a	1058.15 a
Bako local	17.000 b	3.76 a (2.01)	21.648 b	671.43 b	101.32 a	38.49 b	772.75 b
Oda haro	20.000 a	4.12 a (2.11)	20.865 b	825.26 a	79.17 a	44.71 b	904.43 b
Mean	17.194	4.16 (2.11)	25.35	789.418	122.359	57.12	911.777
Cv	10.994	18.27	41.03	19.772	34.650	44.5264	17.863
P	0.0001	Ns	0.019	0.0123	0.2826	0.0001	0.001

Table 3: Effect of insecticides on yield and fruit worm insect infestation parameters in 2017/18 main cropping season

Treatment	Total pod per plant	No. of infested pod per plant	% of infestation	Marketable pod (kg/ha)	unmarketable pod wt.	Dried wt. of Infected pod	Total Yield
Chlorpyrifos	17.889 a	4.58 a (2.22)	26.93 a	869.14 a	139.33 a	64.9 a	1008.47 a
Deltametrin	17.222 a	2.72 b (1.75)	16.01 b	818.17 a	99.82 a	35.63 b	917.99 a
Dimethoat	17.444 a	4.79 a (2.27)	28.49 a	749.38 a	124.69 a	63.49 a	874.07 a
Control	16.222 a	4.57 a (2.21)	28.39 a	720.99 a	124.69 a	64.48 a	846.58 a
mean	16.8055	4.164 (2.113)	24.959	789.417	122.359	57.125	911.777
Lsd	2.286	1.66	10.01	ns	ns	24.867	ns

In 2018 cropping season, number of pods per plant was significantly varied between the varieties and insecticide applications for management of fruit worm. Variety Oda Haro showed significantly higher (37.25 pods per plant) pod number per plant followed by Bako Local (26.62 pods per plant) (Table 4). Similar to the previous year, percent of pod infection was significantly varied between varieties, which was higher (12.62% of the total pod per plant) for MarakoFana variety. The result also showed that marketable dry pod yield was significantly different between the varieties. Oda Haro and MarakoFana varieties showed higher Dry marketable yield. Similar to these result different hot pepper varieties (accessions) showed different resistance for fruit worm (Abate and Gashawbeza 1997).

Insecticide application also significantly varied in number of pod infestation and percent of pod infestation by fruit worm. Application of Deltametrin showed lower (1.9 infested pod/plant) number of pod infestation and it is at par with Chlorpyrifos applied plots. The highest (14.34 %) percent pod infestation per plant was observed on untreated control plot. Application of insecticides for management of fruit worm were at par with each other in percent pod infestation (Table 4). Lower percent of pod infestation were observed on Chlorpyrifos and Deltametrin treated plots. Even though not significant marketable yield was higher on Chlorpyrifos and Deltametrin treated plots.

Table 4: Effect of hot pepper fruit worm management options yield and fruit worm insect infestation parameters in 2018/19 main cropping season

Treatment	Total pod /plant	Infested pod number	% of infestation	Infected pod weight	Marketable yield/ha (kg)	Total yield (kg/ha)	Unmarketable yield
Variety							
Marakofana	18.18 c	2.29 b	12.62 a	17.49 ab	1105.8 a	1218.5 a	112.74a
Bako local	26.62 b	2.11 b	8.46 b	13.142 b	847.0 b	928.9 b	81.90b
Oda haro	37.25 a	3.58 a	9.54 b	21.117 a	1324.2 a	1417.2 a	92.98 ab
Mean	27.35	2.658	10.206	17.250	1092.35	1188.22	95.87
Lsd	4.016	0.713	2.959	7.90	252.35	268.03	26.422
Cv	17.35	31.685	34.245	54.11	26.97	26.40	32.55
P	<.0001	0.0005	0.022	ns	0.002	0.004	
Chemicals							
Chlorpyrifos	25.36 b	2.100 b	8.149 b	10.856 b	1148.6 a	1231.5 a	82.91 b
Deltametrin	25.47 b	1.911 b	8.623 b	8.689 b	1105.4 a	1286.0 a	80.65 b
Dimethoat	31.04 a	2.933 a	9.708 b	23.200 a	1083.8 a	1189.9 a	106.10 ab
Control	27.53 ab	3.689 a	14.344 a	26.256 a	1031.6 a	1045.4 a	113.89 a
Mean	27.35	2.658	10.206	17.250	1092.35	1188.2	95.87
Lsd	4.64	0.823	3.417	9.125	291.39	309.49	30.509
Cv	17.35	31.685	34.245	54.11	26.97	26.40	32.55
P	ns	0.0006	0.004	0.001	ns	ns	

Means in the column accompanied by the same letter (s) are not significantly difference at (P< 0.05%)

Yield Loss and Cost Benefit

Relative yield loss was calculated from two years data and higher relative yield loss of 62.092 % was calculated from an untreated plot compared to Deltametrin treated plot (Table 5). However, lower relative yield loss was observed on plots sprayed with Chlorpyrifos and Deltametrin. In Pakistan yield loss due to Fruit worm reported about 20% (Usman, et al. 2012) and 25% Umeh et al. (2002) on tomato. Abate and Adhanom (1982) reported that yield loss on hot pepper due to fruit worm was as high as 27% in Ethiopia. Partial budget analysis was also calculated for insecticide management options from the mean of two years yield. The highest (ETB 47973.50 ha^{-1}) marginal benefit was obtained from chlorpyrifos treated plot followed by Deltametrin (ETB

47659.25 ha^{-1}) treated plot. However, Marginal Rate of Return (MRR) was higher (28.13%) on plots sprayed with Deltametrin (Table 5).

Table 5: Yield loss and Cost benefit analysis of hot pepper production as influenced by fruit worm management in 2017-2018 main cropping season.

Treatments	Mean Marketable yield	Relative Yield loss	Gross Return(ETB ha^{-1})	Marginal Cost (ETB ha^{-1})	Marginal benefit (ETB ha^{-1})	MRR (%)
Control	360.495	62.092	18024.75	0.00	18024.75	-
Dimethoat	890.490	6.361	44524.50	890.00	43634.50	24.72
Deltametrin	950.985	0.000	47549.25	890.00	46659.25	28.12
Chlorpyrifos	987.270	-3.816	49363.50	1390.00	47973.50	18.95

Conclusions and Recommendations

The result of this study demonstrated that different varieties responded differently for tomato fruit worm infestation on hot pepper both years. Compared to other two varieties MarakoFana showed higher percent of pod infestation with fruit worm. Insecticide application also significantly reduced percent of pod infestation. Chlorpyrifos and Deltametrin application showed lower number of pod infestation and percent of pod infestation. Marginal benefit obtained from Chlorpyrifos treated plot was higher, followed by Deltametrin treated plot. However, switching from untreated control to use of Deltametrin for fruit worm management showed highest MRR calculated. Therefore, it was recommended that production of Oda haro and Bako local were pertinent where fruit worm infestation was high like Bako area and. It was recommended that producer has economic potential to apply insecticide would be spray Deltametrin to produce MarakoFana which has highmarket price variety.

References

Abate T, and GashawbezaAyalew. 1997. Sources of resistance in tomato against fruit worms. Pest Management Journal of Ethiopia 1(1 and 2):1-8

Bosland, P. W., Votava, E.J., 2003. Peppers: Vegetable and Spice Capsicums. CAB International, England, p.333.

CSA (Central Statistical Agency). 2016. *Area and production of major crops*. Volume I, Addis Ababa, Ethiopia

Huffnagel, H.P. 1961. Agriculture in Ethiopia. Food andAgriculture Organization (FAO), Rome, 24, Kaiser, W.J. and R. Hannan, 1987. Seed-treatment fungicides for control of seed borne Ascochyta lentils on lentil. PlantDisease. 71: 58-62.

King, A.B.S., 1994. *Heliothis*/*Helicoverpa*(Lepidoptera: Noctuidae). In: Matthews, G.M., Tunstall, J.P. (Eds.), Insect Pests of Cotton. CABI, UK, pp. 39–106

Mohammed M, Wilson LA, Pi LA, Gomes P (1992). Postharvest losses and quality changes in hot peppers (*Capsicum frutescens*L.) in the roadside marketing system in Trinidad. *Trop. Agric*. 69: 333-340.

Ochoa-Alejo, N. and Ramirez-Malagon, R. 2001. Invited Review: In vitro chilli pepper biotechnology. *In Vitro Cellular and Developmental Biology-Plant* 37:701-729.

Robert, G.D. and James, H.T. 1991. A Biomerical approach. *Principles of statistics 2nd ed*. New York.USA
Tusiime, G., Tukamuhabwa, P., Nkalubo, S., Awori, E. and Tumwekwase, S. 2010. Development of a hot pepper root rot and wilt disease management strategy through genetic resistance, chemical application and proper choice of rotational crops. *Second RUFORUM Biennial Meeting* 20-24 September 2010, Entebbe, Uganda.
Venette, R.C., Davis, E.E., Da Costa, M., Heisler, H. and Larson, M. 2003. Mini Risk Assessment: false codling moth, *Thaumatotibia*(=*Cryptophlebia*) *leucotreta*(Meyrick) [Lepidoptera: Tortricidae]. University of Minnesota, Department of Entomology, CAPS PRA. 1-30. [Available: http://www.aphis.usda.gov/ppq/ep/pest detection / pra /tleucotretapra.pdf] accessed: 01/05/2009

Integrated Management of Major Faba bean (*Vicia faba* L.) diseases: Chocolate spot (*Botrytis fabae*), Ascochyta blight (*Ascochytafabae*) and Rust (*Uromycesviciae- fabae*)) on the Highlands of Guji, Southern Oromia

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Abstract

Faba bean is one of the most economically important pulse crops cultivated in Ethiopia. However, its average yield at the national level remains lower than an attainable potential yield. This is partly due to low soil fertility, inappropriate agronomic packages and diseases and pest problems. Hence, this experiment was conducted to investigate integrated disease management methods against major faba bean diseases in Guji Zone, Southern Oromia. The experiment was conducted in SongoBericha station of Bore Agricultural Research Center during the 2017 and 2018 main cropping seasons. The factors studied were two fungicides (Fungozeb 80% WP at 3 kg/ha and Natura 250 EW at 500 ml/ha), two frequencies and four planting dates at 7 days interval.The experiment was laid out in a factorial arrangement of Randomized Complete Block Design with three replications. Data on phonological, growth yield and yield related parameters were collected and analyzed using SAS software. The result showed that the highest plant height (140 cm) and 139.2 cm was recorded for spraying fungicide once and Natura alone, respectively. The interaction of fungicide spray frequency, fungicide type and planting date had significant effect on almost all parameters except plant height. The highest number of total pods per plant (21.27) was recorded at planting date two by application of fungicide Natura twice whereas the highest number of seeds per pod (6.17) was recorded for fungicide fungozeb spray *once at mid-planting of faba bean. The highest grain yield (4674 kg ha -1) was recorded due to spraying of Fungicide Natura twice. The highest chocolate spot severity (48.4 %) was recorded from faba bean sown late July; the highest severity Ascochyta blight (46.22%) was recorded from early planting with spraying of fungicide once and the highest severity (19.26%) was recorded from faba bean sown on 17th July. Thus, it can be concluded that integration of moderately resistant variety with sowing date can provide better control of the diseases compared to fungicidal treatments alone.***

Key words: Fungozeb, Natura, Sowing date, Walki.

Introduction

Faba bean (*Vicia faba* L.) is one of the earliest domesticated food legumes in Ethiopia and is now cultivated on large areas in the highlands parts, between 1800-3000 masl where it requires chilling temperature and annual rain fall of 700-1000 mm (Gemechu*et al*., 2003).

On the highlands of Guji, faba bean is fist in terms of acreage and volume of production among other pulse crops. It is a multi-purpose crop that plays an important role in the socio-economic life of farming communities. It serves as source of food because it contain about 24% protein, 2% fat, 50% carbohydrate and offers an average of 700 calories per serving (Etemadi*et al*., 2015) and also used as cash crops. In addition it makes a significant contribution to soil fertility restoration as a rotational crop as it fixes atmospheric nitrogen (Samuel *et al*., 2008).

In spite of its importance, the productivity of faba bean in this area is nearly less than 1 tha^{-1} now days, despite the availability of high yielding varieties (> 4 tha^{-1}) (MOA, 2010). Some biotic and abiotic factors are the main reason of the low productivity of faba bean (Agegnehu*et al*., 2006). Among biotic factors, chocolate spot (Botrytis fabae), Ascochyta blight (*Ascochytafabae*), rust (*Uromycesviciae-fabae*), downy mildew (*Peornosporaviciae*) and foot rots (*Fusarium spp*.) diseases quite important (Torres *et al*., 2006). Chocolate spot is considered to be the most important and destructivefaba bean disease in Ethiopia causing yield loss of up to 61% on susceptible cultivars (Dereje and Beniwal, 1987).Similarly, on the highlands of Guji, it is the most widespread and destructive disease (BOARC Pulse, 2016).

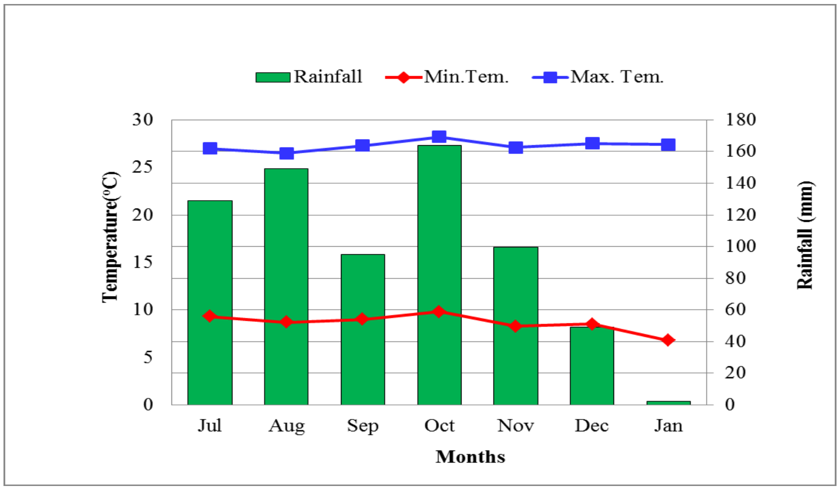
A number of management options have been developed in other countries to minimize the effects of chocolate spot on faba bean yield. These include use of resistant/tolerant varieties; use of cultural practices such as crop rotation, crop residue management, adjusting planting dates, and fungicide application (Hawthorne, 2004). In Ethiopia, growing moderately resistant varieties,application of chlorothalonil or mancozeb and late planting have been recommended (Sahile, 2008). Similarly, Ermias and Addisu (2013) also reported that integrated use of sowing date with fungicides also provides better control of this disease on the Bale highlands. However, the dynamic nature of disease, environmental prevalence especially acidity (i.e. low level of phosphorus and potassium) and humidity aggravate the disease from location to location. In addition to this, the efficacy of fungicide depends on multitude interaction including the environmental conditions. Therefore, this study was conducted to evaluate integrated effect of fungicides with plating date for the management of chocolate spot in Guji Zone. Hence, the objective of the study was to evaluate and recommend an economical integrated disease management method for fababean producing areas of Guji zone and similar agro-ecologies.

Materials and Methods

Description of the Study Area

The experiment was carried out during the 2017 main cropping season at Bore Agricultural Research Center, Guji Zone of Southern Oromia. Bore Agricultural Research Center 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 - Adola. Geographically, the experimental site is situated at the latitude of 06o23‟55‟‟‟‟ N – 06^{o}24‟15‟‟‟‟ N and longitude of 38^{o}34‟45‟‟‟‟ E – 38^{o}35‟5‟‟‟‟E at an altitude of 2728 meters above sea level. The research site represents highlands of Guji Zone, receiving high rainfall and characterized by a bimodal rainfall. The first rainy season is from April to October and the second season starts in late November and ends at the beginning of March. The major soil types are *Nitosols* (red basaltic soils) and *Orthic Aerosols* (Yazachew and Kasahun, 2011; Wakene *et al*., 2014). The soil is clay loam in texture and strongly acidic with pH value of around 5.13. According to climate data from National Meteorological Agency, Hawassa Branch Directorate (2004-2015), Bore had an annual mean rainfall of 1015.6 mm. The mean annual maximum and minimum temperatures during the aforementioned period were 22.7 and 10.36 o C, respectively. The hottest period of the year extends from December to March whereas the coldest season extends from May to January. According to meteorological information recorded in the last one decade, the maximum rainfall was recorded in the months of August (170.14 mm) and September (196.48 mm) in Bore. During the crop growing season, the total amount of rainfall received was 1538.8 mm out of which 163.7 mm was received in

October followed by 149.3 mm in August. Also the annual maximum and minimum air temperatures of the growing season were 22.39 and 11.66 o C, respectively.



Experimental Materials, Treatments and Experimental Design

Faba bean variety, Walki which is moderately resistant to chocolate spot and having yield potential of 24-52 qt/ha on research station and 20-42 qt/ha on farmers' field was used for the experiment. The variety was registered in 2008 for areas with altitude range of 1900-2800 m.a.s.l.

Treatments consisted of two fungicides (Fungozeb 80% WP at 3 kg/ha and Natura 250 EW at 500 ml/ha) with two frequencies and four planting dates at 7 days interval. Unsprayed treatment was included as control. The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times in factorial combination. The plot size was 3.0 m × 2.40 m. The spacing between plots and blocks was 1.0 m and 1.5 m, respectively. The inter- and intra-row spacing was 40 cm and 10 cm, respectively. The outermost row on both sides of each plot and three plants on both sides of each row were considered as border plants, and used for data collection to avoid border effects. Thus, the harvestable plot size was 2.4 m × 1.6 m having four rows each with 24 plants (96 plants). Blended (NPS) fertilizer was applied at the rate of 150 kg ha^{-1} and mixed thoroughly with soil to avoid direct contact with the seeds. Fungicide was tank mixed and applied at recommended ratewhen diseases appeared and then at two weeks interval. Finally, all the other agronomic practices were followed as per the recommendation for the crop.

Data Collection and Measurements

Phenological parameters

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

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

Growth parameters

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

Number of primary branches per plant: The average number of primary branches emerged directly from the main shoot was counted from ten randomly taken plants at physiological maturity and the average number of primary branches was reported as number of primary branches per plant.

Yield and yield components

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

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

Hundred seed weight (g): was determined by taking weight of 100 randomly sampled seeds from the total harvest from each net plot area and the weight was adjusted to 10% moisture level.

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

Statistical Data Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD and the General Linear Model (GLM) of Gen Stat 15th edition (GenStat, 2012) and the interpretations were made following the procedure described by Gomez and Gomez (1984). Least Significance Difference (LSD) test at 5% probability level was used for mean comparison when the ANOVA showed significant differences.

Results and Discussion

Phenological and Growth Parameters of Faba bean

Days to flowering

The interaction of fungicide frequency, fungicide type and planting date had significant (P<.01) effect on days to 50% flowering. Significantly, highest number of days to reach flowering (63.67 days) was recorded from early sowing with no fungicide application which was statistically at par with once or twice fungicide application.The shortest time to flowering (50.67 days) was recorded due to onetime spraying of fungicide Natura combined withthe second planting date (Table 1). Early sowing was led to early flowering as compared to the other planting dates across all once or twice fungicide spray.

Table1 Means of days to flowering of faba bean as affected by the interaction of fungicide frequency and fungicide application rates at Songo Bericha during 2017 and 2018 main cropping season.

Fungicide Frequency	Fungicide Type	Planting date			
		July 17	July 24	July 31	August 7
Control	Control	63.67a	$52.33^{f\text{-}i}$	$53.64^{f\text{-}i}$	55.67^{def}
Frequency one	Fungozeb	61.33^{abc}	51.67^{ghi}	57.67^{cde}	55^{efg}
	Natura	62.33^{ab}	50.67^{i}	56def	55.67^{def}
Frequency two	Fungozeb	60.33^{abc}	51^{hi}	57.67^{cde}	$54.67^{e\text{-}h}$
	Natura	59.33^{bcd}	51.67^{ghi}	56^{def}	$54^{e\text{-}i}$
CV(%)=4.2					
LSD(0.05)=3.91					

Number of primary branch per plant

The interaction of fungicide frequency, fungicide type and planting date had no significant effect on primary branch, but the interaction of fungicide frequency and type as well as fungicide types and planting date had significant (P <0.01) effect on the number of primary branches. Two timesapplication of fungicide Natura resulted in the highest number of primary branches per plant (0.88) while the lowest number of primary branches (0.392) was recorded from treatment that received no fungicide application (Table 2, 3).

Table 2: Means of number of primary branch per plant of faba bean as affected by the interaction of fungicide frequency and application rates at SongoBericha during 2017 and 2018 main cropping season.

Treatments	**Fungicide Type**		
Fungicide Frequency	**Control**	**fungozeb**	**Natura**
Control	0.392^{b}		
Frequency one		0.625^{b}	0.78^{a}
Frequency two		0.675^{ab}	0.88^{a}
CV(%)=57			

LSD (0.05)= 0.31

Table 3: Means of number of primary branch per plant of faba bean as affected by the interaction ofplanting date and fungicide type at Songo Bericha during 2017 and 2018 main cropping season.

Fungicide type	Planting date			
	July 17	July 24	July 31	August 7
Control	0.43bcd	0.4[cd]	0.33[d]	0.4[cd]
Natura	0.88ab	0.98[a]	0.65[abcd]	0.81[abc]
Fungozeb	0.61abcd	0.92[ab]	0.41[d]	0.67[abcd]
CV(%)=50 LSD(0.05)=0.55				

Plant height

The analysis of variance showed significant (P < 0.05) differences in plant height due to the main effects of fungicide type and its frequency. However, there was no interaction effect of fungicide frequency, fungicide type and planting date and main effect of planting date on plant height (Table 4). The highest plant height (140 cm) was attained by one time application of fungicide and it was statistically at par with twice application of fungicide, while the lowest plant height (129.9cm) was recorded from the control. In this experiment, fungicide type also exhibited significant (P<0.05) difference on plant height. Application of Natura resulted in the highest plant height (139.2cm) while the lowest plant height (129.9cm) was recorded fromnil application of fungicide (Table 4). Plots treated with Natura, showed 7.03% increase in plant height over untreated plots. Consistent with this result, Khan *et al.* (2009) reported that maximum plant height was observed in field pea treated with fungicide Mancozeb

Table 4. Means of plant height (cm) of faba bean as affected by main effect of planting date, fungicide application frequency and fungicide application type at Songo Bericha during 2017 and 2018 main cropping season

Treatments	**Plant height**
July 17	137.9
July 24	137.4
July 31	136.9
August 1	133.4
CV(%)=8.1 LSD(0.05)= NS	
Fungicide Frequency (P<0.05)	

Control	129.9^{b}
Frequency one	140^{a}
Frequency Two	136.1^{ab}
CV(%)= 7.6 LSD(0.05)= 8.48	
Fungicide Type(P<0.05)	
Control	129.9^{b}
Natura	139.2^{a}
Fungozeb	136.9^{ab}
CV(%)=7.7 LSD(0.05)= 8.57	

Yield and Yield Components

Number of pods per plant

The analysis of variance showed significant (P < 0.05) differences among treatments in the number of pods per plant due to interaction effects of fungicide frequency, fungicide type and planting date. The highest number of total pods per plant (21.27) was recorded from the second planting date by twice application of fungicide Natura which was statisticallyat par with the number of pods obtained by application of both fungicides at first to fourth planting date except at spraying of both natura and fungozed only at once in late sowing (planting date three and four) whereas the lowest number of total pods (12.9) was obtained from the control (Table 5).

Table 5: Means of number of pods per plant of faba bean as affected by the interaction of of planting date, fungicide application frequency and fungicide application rates at Songo Bericha during 2017 and 2018 main cropping season.

Fungicide frequency	Fungicide Type	Planting date			
		July 17	July 24	July 31	August 7
Control	Control	16.8^{a-e}	16^{cde}	12.9^{e}	16.07^{b-e}
Frequency one	Fungozeb	19.9^{abc}	17.5^{a-e}	14e	15.93^{cde}
	Natura	21.17^{ab}	19.13^{a-d}	14.63^{de}	14.63^{de}
Frequency two	Fungozeb	15.93^{cde}	17.73^{a-e}	14.4^{de}	15.87^{cde}
	Natura	21.23^{a}	21.27^{a}	15.8^{cde}	16^{cde}
CV (%)=18.4 LSD (0.05)=5.11					

Hundred seed weight: The analysis of variance revealed that interactions of fungicide frequency, fungicide type and planting date had highly significant (P<0.01) effect on hundred seed weight (Table 6). Spraying of fungicide Natura twice on late sown (August 7) faba bean scored significantly the highest hundred seed weight (74.3 g) while the lowest hundred seed weight (64.3 g) was recorded fromspraying fungicide fungozeb twice on early plantedfaba bean. In conformity with this result, Dagne *et al*., (2017) reported that the highest (59.57g) 100- seed weight was obtained when faba bean variety Mosisa was sprayed with Mancozeb every seven days while the lowest 100- seed weight (42.1g) was obtained from the local varieties in unsprayed plots.

Table 6: Means of hundred seed weight (g) of faba bean as affected by the interaction of fungicide frequency and fungicide Type at Songo Bericha during 2017 and 2018 main cropping season

Fungicide Frequency	**Fungicide Type**	**Planting date**				**mean**
		July 17	July 24	July 31	August 7	
Unsprayed		68.5 $^{b-f}$	67.8 $^{c-f}$	67.2 ^{def}	68.3 $^{c-f}$	67.95
Frequency one	Fungozeb	65.6^{ef}	70.9^{a-d}	67.4 $^{c-f}$	68.9 $^{b-f}$	68.20
	Natura	67.7^{c-f}	69.0 $^{b-f}$	68.3 $^{c-f}$	69 b-f	68.50
Frequency two	Fungozeb	64.3 ^{f}	68.5 $^{c-f}$	71.7 $^{a-d}$	73.5^{ab}	69.50
	Natura	68.1 $^{c-f}$	70.5^{a-e}	72.2^{abc}	74.3^{a}	71.23
Mean		66.84	69.34	69.36	70.76	
CV (%)	4.92					
LSD (0.05)	4.30					

Grain yield: The grain yield was significantly ($P<0.05$) affected by interactions of fungicide spry frequency, fungicide type and plating date (Table 7). The result generally showed an increase in grain yieldas fungicide frequency increased. The highest grain yield (6094 kg ha $^{-1}$) was recorded due to spraying of fungicide Natura twice forJuly 24 plantingwhereas the lowest (3334 kg ha $^{-1}$) grain yield was obtained from late planted control. Similar result was reported by Dagne *et al*., (2017) where the highest(5933 kg ha^{-1}) grain yield was obtained from faba bean variety Mosisa sprayed with Mancozeb every seven days and the lowest (2021 kg ha^{-1}) yield was

Fungicide Frequency	**Fungicide Type**	**Planting date**				**mean**
		July 17	July 24	July 31	August 7	
Unsprayed		3975^{cde}	4549^{bcde}	3703de	3334^{e}	3890.3
Frequency one	Fungozeb	5334^{ab}	4474^{bcde}	3561de	3994^{cde}	4341
	Natura	5404^{ab}	5010^{abc}	4604^{bcd}	4009^{cde}	4757
Frequency two	Fungozeb	5003^{abc}	4763^{bcd}	4285^{cde}	3623de	4419
	Natura	5163^{abc}	6094^{a}	4311^{bcde}	4396^{bcde}	4991
Mean		4976	4976	4093	3871	
CV (%)	16.9					
LSD (0.05)	1249.02					

obtained from unsprayed plots. Teshome and Tagegn (2013) also found that the maximum grain yield was obtained from first sowing date treated with 4 times spray of fungicide. Generally, Grain yield losses were reduced by fungicide spraying intervals as compared to the unsprayed plot of the respective treatments. Hawthorne (2004) indicated that the application of Mancozeb as a protective fungicide helps to reduce yield loss due to chocolate spot as it prevents pod abortion and plant damage.

Table 7: Means of grain yield (kg ha^{-1}) of faba bean as affected by the interaction of fungicide frequency and fungicide Type at Songo Bericha during 2017 and 2018 main cropping season

Effect of Fungicides Application and Planting Date on Severity of Faba bean Diseases

Severity of chocolate spot of faba bean: The interaction of fungicide spray frequency, fungicide type and planting date had significant (P<0.05) effect on chocolate spot (Table 8). Chocolate leaf spot was aggressive during pre-flowering and post-flowering butless aggressive during flowering and grain filling growth stages. Severity of chocolate spot was very high for early sownfaba bean and the highest severity (42.8 %) was recorded from early planting with onetime spraying of fungicide. The lowest severity (29.88%) was recorded from two times application of fungicide Natura for late sowing of faba bean which reduced the disease by 9.6 % as compared to untreated plot. In line with this result, Dagne *et al.*, (2017) also reported that the highest mean final disease severity index (51.45%) was recorded on the unsprayed plots and the lowest mean final disease severity (11.11%) was observed on the weekly sprayed plots (Table 8).

Table 8: Interaction effect of fungicide spray frequency, fungicide type and planting date on severity chocolate spot of faba bean at Songo Bericha 2017 and 2018 main cropping season

Fungicide spray Frequency	**Fungicide Type**	**Planting Date**				**Mean**
		July 17	July 24	July 31	August 7	
Unsprayed		41.4^{ab}	38.8^{abc}	37^{abcd}	31.1^{de}	37.08
Frequency one	Fungozeb	39.5^{abc}	42.8^{a}	37.5^{abcd}	35.19^{abcd}	37.43
	Natura	41.2^{ab}	33.4^{cde}	39.4^{abc}	33.4^{cde}	36.85
Frequency two	Fungozeb	36.5 $^{a-e}$	39.9^{abc}	36.4 a-e	37.7^{abcd}	37.63
	Natura	35.8 $^{a-e}$	33.9^{cde}	34^{cde}	29.88 ^{e}	34.74
Mean		38.88	37.76	36.86	37.7	
CV (%)	11.7					
LSD(0.05)	7.12					

Ascochyta blight Severity of faba bean

In the beginning, the disease was noticeable because of the irregular dark spots that form on the pods; when these spots mature they become dark brown and damp and picnidia appeared (these symptoms are observed during grain drying before threshing. Thus, the interaction of fungicide frequency, fungicide type and planting date had significant ($P<0.05$) effect on control of ascochyta blight onfaba bean (Table 9). Earlyplanted of faba bean was highly infected by ascochyta blight where the highest severity (42.8%) was recorded from faba bean sown on 24th July with onetime spraying of fungicide fungozeb while the lowest severity (31.2%) was recorded from late plantedfaba bean at early August.

Table 9: Interaction effect of fungicide spray frequency, fungicide type and planting date on severity Ascochyta blightof faba bean at Songo Bericha 2017 and 2018 main cropping season

Fungicide spray Frequency	Fungicide Type	Planting Date				Mean
		July 17	July 24	July 31	August 7	
Unsprayed		41.4^{ab}	38.8^{abcd}	37^{a-e}	32.1^{de}	37.33
Frequency one	Fungozeb	39.5^{abc}	42.8^{a}	37.5 $^{a-e}$	31.2^{e}	37.75
	Natura	41.2^{ab}	33.4^{cde}	39.4^{abc}	33.4^{cde}	36.85
Frequency two	Fungozeb	36.$^{5a-e}$	39.9^{abc}	36.4 $^{a-e}$	37.7^{a-e}	37.65
	Natura	35.8^{b-e}	33.9^{cde}	34 ^{cde}	31.9^{e}	33.90
Mean		38.88	37.76	36.86	33.36	
CV (%)	11.3					
LSD (0.05)	6.86					

Rust severity of faba bean at Songo Bericha on station: The interaction of fungicide frequency, fungicide type and planting date had significant ($P<0.01$) effect on control of faba bean rust (Table 10). Thus, unsprayed faba bean was severelyinfected by rust where the highest severity (27.20%) was recorded from faba bean sown on 17th July for the control while the lowest rust severity (16.5%) was recorded from one or two times Natura application with planting of faba bean in July. Khan *et al* (2009) reported that application of fungicides up to three times showed significant differences among fungicides and field pea (*Pisum sativum*) varieties.

Table 10: Interaction effect of fungicide spray frequency, fungicide type and planting date on severity rust of faba bean at Songo Bericha 2018 and 2019 main cropping season

Fungicide spray Frequency	Fungicide Type	Planting Date				Mean
		July 17	July 24	July 31	August 7	
Unsprayed		27.2^{a}	25.9^{ab}	23.5^{bcde}	22.2 $^{c-f}$	24.70
Frequency one	Fungozeb	22.$^{2\ c-f}$	24.7^{abcd}	25.9^{ab}	22.2 $^{c-f}$	23.75
	Natura	22.2 $^{c-f}$	**16.5^{g}**	22.2 $^{c-f}$	21.2 ^{def}	20.53
Frequency two	Fungozeb	22.2^{c-f}	22.2 $^{c-f}$	22.2 $^{c-f}$	24.7^{abcd}	22.83
	Natura	19.0^{fg}	20.6^{ef}	19^{fg}	24.9^{abc}	20.88
Mean		22.56	21.98	22.56	23.04	

CV (%)	9.90
LSD (0.05)	3.69

Conclusions and Recommendation

Integrated Management of major faba bean (*Vicia faba* L.) diseases was investigated on Nitisols and Orthic Aerosols soils of Guji Zone, Southern Ethiopia. It was conducted during the main 2017 cropping season with the objective of investigating integrated disease management methods against major faba bean diseases at Guji Zone, Southern Ethiopia. The result showed that fungicidal treatment in combination with sowing faba bean in different day intervals have resulted in significant variation on phonological, growth yield and yield related parameters except plant height. Utilizing fungicide Natura with different frequencies under field conditions compared with fungicide Fungozed revealed that Natura resulted in increasedfaba bean yield. However, integration of moderately resistant variety with sowing date rather than fungicide treatment, which is offer less environmental safety, is proved to be better management option of the disease. Thus, it can be recommended thatintegration of moderately resistant variety with early sowing is a better management option. Further investigation is needed in vitro and in vivo to compare effectiveness of biological and chemical methods to control disease on faba bean.

References

Dereje Gorfu and Beniwal, S.P.S. 1987. Preliminary survey of faba bean disease in the major production areas of Ethiopia. In: *Results of Research Done on Faba bean in Ethiopia*, ICARDA/IAR/IFAD-Nile valley project during the cropping season. IAR, Addis Ababa, Ethiopia. pp. 78-84.

Ermias Teshome and Addisu Tagegn. 2013. Integrated management of Chocolate spot (*Botrytis fabae* Sard.) of Faba bean (*Vicia faba* L.) at highlands of Bale, south eastern Ethiopia.*Research Journal of Agricultural and Environmental Management*, 2(1): 11-14.

Etemadi, F., Hashemi, M., Mangan, F. and Weis, S. 2015. Fava beans Growers guide in new England PP 2-24.

GemechuKeneni, MussaJarso, TezeraWolabu. 2003. Faba bean (*Viciafaba* L.) genetics and Breeding Research in Ethiopia: A Review. In: Ali Kemal, Kenneni Gemechu, Ahmed Seid, Malhatra Rajendra, Beniwal Surendra, Makkouk Khaled, Halila MH, eds. Food and Forage legumes of Ethiopia: Progress and prospects. Proceedings of the workshop on Food and Forage Legume, 22-26 September 2003. Addis Ababa, Ethiopia.

Hawthorne, W. 2004. Faba bean disease management strategy for southern region. http://www.sardi.sa.gov.au/pdfserve/fieldcrops/publications/advicefactsheets/brochure.pd

MoA (Ministry of Agriculture). 2010. Animal and plant health regulation directorate. Crop variety register. Issue No. 14. Addis Ababa, Ethiopia. pp. 71-73.

Sahile, S., Chemeda Fininsa, Sakhuja, P.K. and Seid Ahmed. 2008. Evaluation of Pathogenic Isolates in Ethiopia for the control of Chocolate Spot in Faba bean. *African Crop Science Journal*, 17(4): 187 - 197

Tekalign Afeta. 2016. Quantification and Assessment of Severity and Incidence of Major Economically Important Faba bean and Field pea Disease in Highlands of Guji Zone, southern Oromia (unpublished data)

Torres, A.M., Roman, B., Avila, C.M., Satovic, Z., Dubiales, D., Sillero, J.C. and Moreno, M.T. 2006. Faba bean breeding for resistance against biotic stresses:Towards application of marker technology. *Euphytica*, 147: 67–80 DOI: 10.1007/s10681-006-4057-6

Integrated Management of Barley Shoot fly on theHighlands of GujiZone,Southern Oromia

ABSTRACT

*This study was initiated to assess the effect of Integrated Management of Barley Shoot flyon yield and yield componenst of Barley (**Hordeum vulgare** L.). Afield experiment was conducted during the 2017-18 main cropping season at Bore Agricultural Research Center to evaluate the effect of integrated barley shoot fly management on yield and yield components of barely and to determine an economically feasible optionshoot fly management for barley production. The treatments consisted of five levels of insecticides (Apron star, Dynamic, Procid plus, Joint and Torpido and four levels of planting dates. The experiment was laid out in Randomized Complete Block Design (RCBD) in a factorial arrangement with three replications. Analysis of variance revealed that interaction of the two factors (chemicals and planting dates) significantly affect most parameters except thousand kernels weight, number of tillers per plant and number of productive tillers per plant. Generally, all parameters recorded over all treated plots were significantly higher than untreated/control plots. Thus using insecticides and adjusting planting date can help to improve yield andyield components byreducing the degree of barley shoot fly infestation. The highest grain yield (4403 kg h^{-1}) and lower shoot flyinfestation wereachieved from combined application of Torpido + first planting date. The partial budget analysis, however, revealed that combined applications of Torpido insecticide and planting in the last week of Julygave the best economic benefit 26941.78 Birr ha^{-1}. Therefore, based on this study it can be concluded that the use of Torpido insecticide and planting in the late Julycan be recommended for production of barley in the study area and other areas with similar agro-ecological conditions.*

Key words: Insecticides, interaction effect, main effect, shoot fly, sowing date

Introduction

In Ethiopia, cereal crops are majorly produced for several purposes where they are greatly contributing towards sustaining food security. Farmers in different parts of the country are growing different types of cereal crops based on their agro-ecological suitability to address their family food demand. Particularly, farmers in high land parts of the country are producing barley for home consumption and income generation. As a result, it's commonly called as a poor man's crop that is able to give yield in marginal environments that is unsuitable to other crops at higher elevation (Zerihun*et al*., 2007). It ranks 5^{th} in terms of area (993,918.89 ha) and production (19,533,847.83) next to wheat and followed by finger millet (CSA, 2016).

The crop grows well at altitudes ranging between 1500–3500 maslbut is predominantly grown at altitudes ranging between 2000–3000 masl (MoA, 1998). The highlands ofGuji Zone is also found within most suited agro-ecological adaptation for barley crop production. Farmers in the area are usually producing barley as major crop for home consumption as well as for cash generation. It ranks second next to maize both in area (17,969.07 ha) and production (315,115.09). However, the production and productivity of the crop remains lower (17.54qt/ha) in relation to the national average (19.65qt/ha) and regional average (22.52qt/ha) productivity (CSA, 2016). This may be due to several production constraints like in insect pests, diseases low level of soil fertility, lack of improved varieties and others.

Barley shoot fly is one of the major biotic constraints to barley production onGuji highlands. A survey of *Barley shoot fly* incidence and damage level conducted in 2014 and 2015 indicated that there is high infestation which can cause high yield loss in susceptible varieties.However there is no known management practices used by farmers so far. Therefore, there is a need to evaluate and recommend different management options such integrated management which can be economically and environmentally most viable and sustainable.The objective of the study was to evaluate integrated approaches in barley shoot fly management and recommend the best option.

Materials And Methods

Description of the study area

The experiment was conducted at two locations of Bore district which represents highland agro-ecology of Guji Zone.Bore district is located at 385 km from Finfinnee to the South. The climatic conditions of the district comprises an annual rain fall of 1250mm, mean temperature of 17.5-28 Degree Celsius. Bore district was selected for this experiment as it represents the hotspot areas for barley shoot fly infestation.

Experimental design and treatments

For this experiment five insecticides namely Joint, Torpido, Dynamic, Proced Plus and Apronstarand four planting datesat seven days interval were used.The experiment was laid out in RCBD with three replications. Each experimental plot has 2.5 m long and 1.2 m wide, with six rows 20 cm apart, giving a gross plot area of 3 m^2. Spacing for adjacent blocks was 1.5 m and 1 m between plots. Sowing was done by hand drilling and covered lightly with soil. Seed and fertilizer were applied as per the recommendation ratesfor barley production.All other agronomic practices were also applied as recommended for barley production.

Data collection

Data were collected from a net plot of four rows and selected plants. Collected data includedays to heading (DTH), days to 90% maturity (DTM), grain filling period (GFP), plant height (PH), spike length (SL), total number of tillers/plant, total number of fertile tillers/plant, 1000-kernel weight (TKW), grain yield/ha (Gy kg/ha) and shoot fly infestation.

Data analysis: The recorded data were subjected to Analysis of Variance (ANOVA) as suggested by Gomez and Gomez (1984) using GenStat 18thVersion. Mean separation was carried out using Least Significant Difference (LSD) at 5 percent levels of significance.

Results and Discussion

Days to heading

The Analysis of Variance revealed that the main effect of planting date was highly significant (P < 0.01) on days to heading of barley while the two-factor interactions of Chemical × planting datessignificantly (P<0.05) influenced days to 50% heading. However, the main effect of insecticide did not significantly affect days to 50% heading of the crop. The highest prolonged duration to reach 50% heading was observed in response to the combination of planting date one and two across all pesticides. However, the minimum duration to 50% heading was observed in the application of Apronsarat fourth planting date (Table 1).

Table 47. Interaction effect of chemical and planting date on days to heading of barley

Insecticides	Days to heading				Days to maturity			
	Planting dates				Planting dates			
	P1	P2	P3	P4	P1	P2	P3	P4
Control	83^{a}	83.33^{a}	79.33^{bc}	75^{e}	146^{a}	139.7^{c}	134.3^{d}	127.3^{e}
Apronstar	83^{a}	83^{a}	79.67^{b}	73.33^{f}	144^{b}	139.7^{c}	133^{d}	127.3^{e}
Dynamic	83^{a}	83^{a}	78.33^{d}	75^{e}	144^{b}	139^{c}	133^{d}	127.3^{e}

Proced	83 a	83 a	79 bcd	74.67 e	144 b	139.3 c	133.3 d	126.3 e
Joint	83 a	83 a	79 bcd	74.67 e	144 b	139.7 c	133.7 d	126 e
Torpido	83 a	83 a	78.67 cd	75 e	144 b	139.3 c	133 d	127.3 e
LSD(0.05)	0.91				1.55			
CV (%)	0.7				0.7			

Means with the same letter(s) in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, NS= non - significant, LSD = Least Significant Difference at 5% level

Days to physiological maturity: The main effect of planting dateand interaction of the factors highly significantly ($P < 0.01$) influenced days to physiological maturity of barley. But the main effect ofinsecticidesdid not significantly affect days to physiological maturity.

The longest physiological maturity (168.7 days) was recorded forthe first planting date with control/untreated whereas the shortest days to physiological maturity (126 days) was recorded from combination of Joint and the fourth planting date. The increase in days to maturity of barleyfor the controltreatment might be due to rejuvenation of the crop though the level of infestation wasthe highest.

Plant height: The two factor interaction and main effect of insecticides significantly ($P < 0.05$) influenced plant height. On the other hand, the main effect of planting date had no significant effect on this same parameter.The result indicated that height of barley plants increased as infestation was decreased (Table 2). The highest plant height (115.8cm) was recorded for insecticide Joint coupled with the second planting date while the shortest plant height (101.9cm) was recordedfor the controlcombined with third planting date of the two factors.

Spike length: The Analysis of Variance revealed significant ($P < 0.05$) interaction of the two factorsand main effect of planting date on the spike length whereas the main effect of chemical did not have significant effect on this parameter. Thus, the longest spikes (9.00 cm) were obtained fortreatment combination of insecticide Joint and the first planting date whereas the shortest spikes were produced for the combination of the Procedplus and first planting date(Table 2). The highest spike length of the treated plotsin relation to the untreated control might have resulted from improved root growth and increased uptake of nutrients and better growth favouredbyreduced shoot fly infestation.

Table 48. Main effect of chemicals and planting date on plant height and spike length of Barley

Insecticides	Plant height (cm)				Spike length (cm)			
	Planting dates				Planting dates			
	P1	P2	P3	P4	P1	P2	P3	P4
Control	103.6 cd	102.5 d	101.9 d	102.7 d	7.778 c-f	8.944 ab	8.944 ab	8.611 abc

Aprstar	113.7^{ab}	115.1^{a}	110.6^{a-d}	102.6^{d}	7.5 0^{def}	8.500^{abc}	7.889^{c-f}	7.944^{c-f}
Dynamics	111.0^{a-d}	105.1^{bcd}	111.2^{a-d}	113.8^{ab}	7.833^{c-f}	8.222^{a-d}	8.00^{b-e}	8.278^{a-d}
Proced	110.2^{a-d}	109.4^{a-d}	113.1^{ab}	114.6^{a}	7 .00^{f}	8.944^{ab}	8.611^{abc}	8.5 00^{abc}
Joint	112.8^{abc}	115.8^{a}	109.7^{a-d}	107.8^{a-d}	9.00^{a}	8.667^{abc}	8.167^{a-d}	8.111^{a-d}
Torpido	107.6^{a-d}	114.2^{ab}	109.1^{a-d}	115.1^{a}	7.111^{ef}	8.611^{abc}	7.889^{c-f}	8.444^{a-d}
LSD(0.05)	9.33				0.98			
CV (%)	5.2				7.3			

Yield and Yield Components

Number of tillers per plant

The main effect of chemical and planting date did not significantly ($P<0.05$) influence the number of tillers of barley. Similarly the two-factor interaction (chemical × planting date) also did not significantly affect this parameter. This finding agrees with that of Wakene*et el* (2014).

Table 49. Interaction effect of chemical and planting date on number of tillers and number of productive tiller per plant of barley

Insecticides	Number of tiller/plant				Number of fertile tiller/plant			
	Planting dates				Planting dates			
	P1	P2	P3	P4	P1	P2	P3	
Control	3.222	3.667	3.722	3.611	2.833	3.167	3.278	
Apr	3.667	3.056	3.556	3.389	3.222	2.833	3.056	
Dyn	3.50	3.444	3.389	3.278	3.111	3.00	3.00	
Pro	3.722	3.50	3.389	3.722	3.167	3.111	3.056	
Join	3.389	3.389	3.50	3.389	2.889	2.944	3.056	
Torp	3.778	3.278	3.444	3.722	3.222	2.722	3.056	
LSD(0.05)	NS				NS			
CV (%)	9.9				11.2			

Means with the same letter(s) in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, LSD= Least Significant Difference at 5% level

Number of productive tillers

The main effect of insecticide and planting date did not significantly ($P<0.05$) influence the number of productive tillers of barley. Similarly the two-factor interaction (insecticide × planting date) also did not significantly affect this parameter.

Thousand kernels weight

The main effect of insecticide and planting date did not significantly ($P< 0.05$) influence thousand kernels weight of barley. Similarly the two-factor interactions did not significantly affect thousand kernels weight.The highest thousand kernels weight (60.42 g) was recorded forcombined application of Torpidowiththe first planting date whereas the minimum thousand kernel weight (32.11 g) was observed for application of Torpidocombined with fourth planting dateeven though there were not statistically significant differences.

Table 50. Interaction effect of chemicals and planting date on number of kernels per spike of barley

	Grain yield (kg/ha)				TKW (g)			
Chem.	Planting date				Planting date			
	P1	P2	P3	P4	P1	P2	P3	P4
Control	2296 de	2724 b-e	2185 e	2352 de	36.69	37.47	40.41	48.71
Apr	3961 ab	2719 b-e	3543 a-d	2667 b-e	42.11	36.38	36.82	37.7
Dyn	3331 a-e	2728 b-e	2886 b-e	3277 a-e	60.42	39.17	40.54	46.07
Pro	3894 ab	2468 cde	3967 ab	3962 ab	44.42	36.27	35.73	38.98
Join	3853 ab	3108 a-e	2880 b-e	2721 b-e	36.22	42	36.32	50.64
Torp	4403 a	3727 abc	3231 a-e	2877 b-e	48.53	36.17	36.19	32.11
LSD(0.05)	1327.15				NS			
CV (%)	25.6				17.8			

Means with the same letter in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, LSD=Least Significant Difference at 5% level

Grain yield

The main effects of insecticide and planting date and their interactions significantly (P< 0.05) affected grain yield of barley.Late sowing significantly decreased grain yields. Thus, the highest grain yield (4403 kg ha^{-1}) was obtained from combined application of Torpidoand first planting date and it was statistically at par with Procedeplus at first planting date and Joint applied for the first planting date whereas the lowest grain yield (2185 kg ha^{-1}) was recorded from the combinations of control of third planting date (Table 4). The highest grain yield at the Torpido and first planting date might have resulted from better growth favouredbydecreased shoot fly infestation which enhanced yield components and yield.In general, grain yield obtained from the treated plots exceeded the grain yield from the untreated/control plots by about 33.13%.

Barley shoot fly Infestation

The main effects of insecticide and their interactions significantly (P< 0.0) affected the barley shoot fly infestation. The highest infestation (62.84) was obtained from combination of control and third planting date whereas the lowest barley shoot fly infestation recorded from application of Torpido at first planting date (Table 5).This indicated that grain yield is correlated with infestation level.

Partial Budget Analysis

Analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 5 below. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation by farmers. The studies 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. As indicated in table below, the partial budget analysis showed that the highest net benefit (Birr 26941.78 ha^{-1}) was recorded at the combination of Torpido and first planting date and lowest was from control treatment. To use the marginal rate of return (MRR%) as basis of recommendation, the minimum acceptable rate of return should be between 50 to 100% (CIMMYT, 1988). In this study application of Torpido at first planting date gave the maximum economic benefit (26941.78 ha^{-1}). Therefore, on economic grounds, application of Torpido at 250ml/100kg seed as seed dressing and sowing at late Julywould be best and recommended for production of barley in the study area and other areas with similar agro-ecological conditions.

Table 51. Partial budget and marginal rate of return analysis for management of barley shoot fly through chemical and planting date

Treatments		**AGY by 10% (kg ha^{-1})**	**GB (Birr ha^{-1})**	**TVC (Birr ha^{-1})**	**NR (Birr ha^{-1})**
Insecticides	planting date				
Control	P2	2451.82	17162.76	0	17162.76
Control	P3	1966.87	13768.08	0	13768.08
Control	P4	2116.47	14815.32	0	14815.32
Control	P1	2066.61	14466.24	0	14466.24
Dynamic	P2	2455.61	17189.28	475	16714.28
Dynamic	P1	2997.69	20983.86	475	20508.86
Dynamic	P3	2597.48	18182.34	475	17707.34
Dynamic	P4	2949.21	20644.44	475	20169.44
Apron Star	P2	2447.40	17131.80	550	16581.80
Apron Star	P1	3565.01	24955.08	550	24405.08
Apron Star	P3	3188.26	22317.84	550	21767.84
Apron Star	P4	2400.05	16800.36	550	16250.36
Procideplus	P1	3504.43	24531.00	690	23841.00
Procideplus	P4	3565.73	24960.12	690	24270.12
Procideplus	P3	3570.14	24990.96	690	24300.96
Procideplus	P2	2221.41	15549.84	690	14859.84
Joint	P2	2796.98	19578.88	800	18778.88
Joint	P4	2448.54	17139.78	800	16339.78
Joint	P3	2592.44	18147.06	800	17347.06
Joint	P1	3467.49	24272.40	800	23472.40
Torpido	P1	3963.11	27741.78	800	26941.78
Torpido	P4	2589.70	18127.92	800	17327.92

Torpido	P3	2908.05	20356.32	800	19556.32
Torpido	P2	3353.99	23477.94	800	22677.94

AGY:adjusted grain yield, GB:groth benefitTVC:total variable cost, NR: net return

Conclusion

Analysis of the results revealed that interaction of the two factors (insecticides and planting dates) significantly affected almost all parameters except thousand kernels weight, number of tiller per plant and number of productive tiller per plant. Generally, all parameters recorded over all treated plots were significantly higher than untreated/control plot. Thus using of insecticide and adjusting planting date improved yield and yield components anddecreaseed barley shoot fly infestation. The highest grain yield (4403 kg h^{-1}) was obtained from combined application of Torpidoand first planting date whereas the lowest barley shoot fly infestation recorded from combined application of Torpidoand first planting date. The partial budget analysis revealed that combined applications of Torpido insecticide and planting in the last week of Julygave the best economic benefit 26941.78 Birr ha^{-1}. Therefore, based this study it can be concluded that combined application of this chemical and planting date can be recommended for farmers for production of barley in the study area and other areas with similar agro-ecological conditions.

References

CIMMYT (Centro Internacional de Mejoramiento de Maiz y Trigo/International Maize and Wheat Improvement Center). 1988. From Agronomic data to Farmer Recommendations: An Economic work Book. Mexico, D.F.: CIMMYT.

CSA (Ethiopian Central Statistical Agency). 2016. Agricultural sample survey Report on area and production for major crops 1: 1-118

MoA (Ministry of Agriculture), 1998. National Livestock Development Project (NLDP) Working Paper 1-4. AddisAbaba, Ethiopia.

Shegaw Derbew,2017. Adaptations of Exotic Barley Genotypes to Low moistureEnvironments in Southern Ethiopia.Greener Journal of Agricultural Science. *DOI: http://doi.org/10.15580/GJAS.2017.6.071617088)* Vol. 7 (6):126-131

Zerihun J., 2007. Variability and Association of yield and yield-related traits in some barley (*Hordeum Vulgare* L.) landraces and Crosses. An M.Sc. Thesis presented to the school of Graduate Studies of Haramaya University.