Oromia Agricultural Research Institute, Workshop Proceedings for Completed Research Activities of Adaptation and Generation of Agricultural Technologies

Correct citation: Dagnachew Lule, Chemeda Daba, Temesgen Jembere, Teshome Bogale, Kamil Ahimed, Girma Mengistu, Ayalew Deme, Kefyalew Asefa, Tesfaye Letta, Tadele Tadesse, Kissi Wakweya, Tilahun Geleto, Tesfaye Alemu, Dereje Woltedji & Kedir Wako (eds.), 2018. Oromia Agricultural research institute workshop proceeding on Adaptation and Generation of Agricultural Technologies, 25-27 June 2018, Adama**,** Ethiopia.

Designer: Natnael Yisak

Tell: +251-114707102/+251-114707118 Fax: +251-114707127/4707126 P.O. Box: 81265, *Email:* ***info@iqqo.org***, *website:* ***http://www.iqqo.org***, Addis Ababa, Ethiopia.

Donor partners

ACKNOWLEDGEMENTS

The authors would like to thank the World Bank and all other donor partners of Agricultural Growth Program-II (AGP-II) for financial support. All research activities presented in this proceeding were funded by AGP-II. Oromia Agricultural Research Institute, the respective research centers and the staff members are cordially acknowledged for hosting and executing the research activities. All authors of the references cited in each manuscript is duly acknowledged.

TABLE OF CONTENTS

CROP RESEARCH

Stability and adaptability study of advanced bread wheat genotypes in the highlands of Bale zone

Behailu Mulugeta*[1], Mulatu Abera[1], Tilahun Bayisa[1], Tesfaye Leta[2] and Tamene Mideksa[1]
[1] Sinana Agricultural Research Center, P.O.Box: 208, Bale Robe, Ethiopia
[2]OromiaAgricultural Research Institute, P.O.Box: 81265, Addis Ababa, Ethiopia
*Corresponding author: behailu.mulugeta30@gmail.com

Abstract
Thirty-five bread wheat genotypes were tested at three locations in 2016 and 2017 under rainfed condition to select high yielding, disease resistant and suitable for optimum environments. The experiment was laid out using alpha lattice design with three replications. There was considerable variation among genotypes and environments for grain yield. The highest mean grain yield was recorded for genotypes ETBW 8003 (4692.1kg ha^{-1}) and ETBW 6114 (4174.7 kg ha^{-1}), respectively. Additive main effect and multiplicative interaction (AMMI) analysis also showed that Interaction Principal Component (IPCA)-1 and IPCA 2 captured 54.30 % and 17.90 % of the genotype by environment interaction sum of squares, respectively. AMMI stability value revealed that ETBW 7698, ETBW 7698, ETBW 7559, ETBW 7412, ETBW 8005, ETBW 8006, ETBW 6114 and ETBW 8003 showed stable performance, but genotypes ETBW 8003 and ETBW 6114 were the most stable and thus recommended for verification at on station and on farmer's field for possible release.

Introduction
Wheat (*Triticum spp.*) is one of an important cereal crop grown around the world for more than 10,000 years and believed to be originated in South Western Asia. It is one of the major cereal crops in the highlands of Ethiopia, adapted in the range of 1500 to 2800 meter above sea level (Harlan, 1971). Bread wheat (*Triticum eastivum* L.) has originated from natural hybrids of three diploid wild progenitors native to the Middle East (*Triticum urartu* with A genome, *Aegilops speltoides* with B genome, and *Triticum dicoccum* with AB genome (Ozkan *et al.*, 2001).

Different biometrical and statistical analysis models have been used by many scientists to determine stability and adaptability of crop varieties around the globe (Piepho, 1996; Becker *et al.*, 1988; Lin *et al.*, 1986). Among these, Additive Main Effect and Multiplicative Interaction (AMMI) is a popular model in determining the stability and adaptability of genotypes over several environments and years. It was first used in social science (Crossa, 1990), and later adapted to the agricultural science (Piepho, 1996), and found an appropriate model in predicting yields of genotypes in specific environments (Annicchiarico, 1997). AMMI combines the analysis for the genotype and environment main effect with several graphically represented interactions of principal component analysis (IPCAs) (Crossa, 1990) and helps to summarize the pattern and relationship of genotypes, environment and their interaction (Gauch and Zobel, 1996). AMMI analysis was also used to determine stability of the genotypes across locations using the PCA (principal component axis) scores and ASV

(AMMI stability value). Genotypes having least ASV were considered as widely adapted. Similarly, IPCA2 score near zero revealed more stable, while large values indicated more responsive to environments and thus less stable genotypes.

In Ethiopia, currently wheat ranks fourth in terms of area coverage (about 1.7million hectares) and volume of production (about 4.5 million tons), contributing 16.6% and 18% of total area and production of cereal crops, respectively (CSA, 2016). Even though the nutritional and economic contribution of wheat in Ethiopia is rewarding, the productivity is far below the potential because of several biophysical and socio-economic constraints including traditional production and inadequate technological interventions. Development of crop varieties resistant to major biotic and a biotic stress, improving nutritional quality, improving adaptation to changing environments and different agro ecologies are among the best strategies of confronting those production constraints. The aim of the present study was, therefore, to determine the stability and yield performance of advanced bread wheat genotypes evaluated across multiple environments using AMMI, ASV, GGE and Eco-valance stability models and recommend for possible release in the test environments and similar agro ecologies.

Materials and methods

Plant materials and Experimental Design

The experiment was conducted at three potential wheat producing districts (Sinana, Agarfa and Goba) of Bale zone for two years (2016 and 2017). A total of 35 bread wheat genotypes including three commercial varieties (Dambal, Mada Walabu and local check Holandi) were evaluated during the *bona* (August to December) cropping season (Table 1). Field experiment was laid out using Alpha lattice design with three replications. The plot size was $3m^2$ (6 rows of 2.5m long) with a row to row spacing of 20 cm. Fertilizer was applied at the rate of 41/46 kg ha^{-1} N/P_2O_5. All agronomic and crop management practices were applied uniformly to all genotypes as per the recommendation for bread wheat.

Statistical analysis

Before computing the combined analysis, error variance homogeneity test was verified using Hartley`s test (F-max test) (Gomez and Gomez, 1984). In the combined analysis of variance, locations were considered as random variable and genotypes were considered as fixed variable. Data analysis was performed by using R statistical software version 3.4.5 (R software, 2018) and Genotype by Environment Analysis with R (GEA-R version 4.0) (Pacheco *et al*., 2016). Eco-valance (Wrickes, 1965) and Additive main effects and multiplicative interaction AMMI (Zobel *et al*., 1988) models were used to compute stability. In the AMMI model, the magnitude obtained in the first principal component (IPCA1) of each genotype was used as indicator of stability. The lower the absolute value of IPCA-1, the stable the genotype.

The AMMI model was used based on the formula suggested by Crossa *et al*. (1990).

$$Y_{ij} = \mu + G_i + E_j + (\Sigma K_n U_{ni} S_{nj}) + Q_{ij} + e_{ij}$$

Where: (i = 1, 2,…35: j = 1, …6); Y_{ij} = the performance of the i genotype in the j environment; μ= grand mean; G = additive effect of the i genotype (genotype mean minus the grand mean); K = Eigen value of the PCA axis n; E = additive effect of the j^{th} environment (environment mean deviation); U and S = Score of genotype i and environment j for the PCA axis n; Q = Residual for the first n multiplicative components and; e = error.

AMMI stability Value

The AMMI stability value (ASV) was calculated for each genotype according to the relative contribution of IPCA1 to IPCA2 to the interaction sum of square as described by Purchase *et al.* (1997) as follow:

$$ASV = \sqrt{\left[\frac{IPCA1\ sum\ of\ square}{IPCA2\ sum\ of\ square}(IPCA1\ Score)\right]^2 + (IPCA1\ scpre)^2}$$

ASV= AMMI stability value, IPCA1 = interaction principal component analysis 1, IPCA2 = interaction principal component analysis 2, SSIPCA1 = sum of square of the interaction principal component one and SSIPCA2 = sum of square of the interaction principal component two

Results and discussion

Combined Analysis of Variance (ANOVA)

The highest combined mean grain yield was obtained from genotype ETBW8003 (4692.1kg ha^{-1}) and ETBW6114 (4174.7kg ha^{-1}) (Table 1). But, the lower mean performance was recorded for ETBW7638 (1361.1kg ha^{-1}). The result of pooled analysis of variance showed highly significant difference ($p<0.01$) for days to heading and maturity, plant height, grain yield, and thousand kernel weight (TKW) (Table 1). ETBW8003 and ETBW6114 also revealed the highest TKW, test weight and moderately resistance to Yellow rust, Stem rust, Leaf rust and Septoria (Table 1).

Additive main effect and multiplicative interaction (AMMI)

The AMMI analysis of variance revealed that 32.96 % of the total sum square (TSS) was attributable to environmental effects. Genotype and GEI contributed 50.20 % and 16.85% of the TSS, respectively. Therefore, large TSS of genotype indicated that genotypes are diverse, similarly the environment also variable. This finding is in agreement with Taye *et al.* (2000); Kaya *et al.* (2002) and Alberta *et al*. (2004).

Variance analysis using AMMI model detected significant effects of genotype, location and genotype by location interaction (Table 2). The change in relative rankings of genotypes over various locations was revealed by G x E interaction. The genotype effect was responsible for the greatest part of the variation, followed by locations and genotype by location interaction effects. Taye *et al* (2000); Kaya *et al*. (2002) and Albert *et al*. (2004) also reported supportive to the present finding. Plotting based on both genotypes and environment on the same graph, the association between the environment and genotypes were clearly observed (Fig 1). AMMI

analysis showed that IPCA 1 and IPCA 2 captured 54.30 % and 17.90 % of the genotype by environment interaction sum of squares.

AMMI stability Value and Yield Stability Index

The analysis based on AMMI stability value indicated that ETBW 7698, ETBW 7559, ETBW 7412, ETBW 8005, ETBW 8006, ETBW 6114, and ETBW 8003 were among genotypes with lower ASV values and revealed that these genotypes are relatively more stable than other genotypes used in the study, whereas ETBW 7595 and ETBW 8012 were found as the least stable genotypes (Table 3). Purchase (1997) noted that AMMI stability value (ASV) can quantify and rank genotypes according to their yield stability. Genotypes ETBW 7595, ETBW 7402, ETBW 7715, ETBW 6657, ETBW 8005, ETBW 7998, ETBW 6114, and ETBW 8003 also revealed the least Yield stability index (YSI) indicating that these genotypes are stable genotypes.

Results from the present AMMI analysis of variance of the 35 bread wheat genotypes also revealed that only mean square of the first interaction principal component axis (IPCA1) was found to be highly significant ($P<0.01$). But, the second and third IPCAs captured in non-significant portion of the variability and AMMI with two, three or four IPCA axes is the best predictive model (Crossa *et al.,* 1991)**.** IPCA score of genotypes were reported by Guach and Zobel, 1996 and Purchase (1997) by indication stability of genotypes across test environments. Therefore, predictive evaluation using F-test at $p<0.01$ revealed one principal components axes were significant (Table 2).

Stability analysis using Eberhart and Russell and Eco-valance model

Genotypes having high grain yield, about a unit regression coefficient over the environment's ($bi = 1.00$), a lower deviation from regression (s^2di) and lower eco-valance value are referred as stable. Accordingly, genotypes ETBW 7698, ETBW 7559, ETBW 7412, ETBW 8005, ETBW 8006, ETBW 6114, and ETBW 8003 were among the stable genotypes (Table 3).

Table 1. Combined Mean performance of agronomic traits and disease reactions of 35 bread wheat genotypes tested at Sinana, Agarfa and Goba during 2016 and 2017 main growing season

		Yield, Agronomic and Disease Data										
SN	Genotype	DTH	DTM	PLH	STP	BW	GY	TKW	HLW	YR	SR	LR
1	ETBW 7402	67	136	97.9	79.7	2.7	4020.3	46.1	84.6	20s	25s	0.0
2	ETBW 7408	66	135	86.0	74.2	1.7	1830.0	34.7	74.0	40s	10ms	0.0
3	ETBW 7409	66	134	93.9	79.7	1.9	3153.6	40.4	77.7	40s	10ms	0.0
4	ETBW 7412	64	135	90.9	75.5	1.8	2884.6	40.9	78.3	40s	10s	0.0
5	ETBW 7435	67	135	96.3	79.2	2.4	3696.6	48.1	79.9	25s	15s	0.0
6	ETBW 7524	62	133	84.8	76.4	1.8	3274.5	40.6	78.7	50s	20s	0.0
7	ETBW 7527	65	134	90.9	81.7	2.4	3895.5	43.0	80.5	20ms	30s	0.0
8	ETBW 7528	65	132	83.6	79.3	2.1	3457.3	42.4	79.7	40s	trms	0.0
9	ETBW 7559	63	135	91.1	78.3	2.0	2413.1	33.0	74.9	50s	10s	0.0
10	ETBW 7569	64	136	86.2	78.1	2.2	3321.5	41.6	81.5	30s	5s	0.0
11	ETBW 7595	65	136	93.3	80.3	2.1	3907.6	48.3	82.8	20ms	10s	0.0
12	ETBW 7621	63	135	90.0	76.1	2.1	3525.6	43.9	81.3	10ms	20s	0.0
13	ETBW 7638	64	135	88.6	72.8	1.7	1361.1	31.5	74.4	50s	20s	0.0
14	ETBW 7661	63	136	87.6	79.7	2.0	3889.7	44.7	83.3	20s	30s	0.0
15	ETBW 7698	64	135	83.8	76.1	1.7	2851.2	42.6	81.0	25s	5s	0.0
16	ETBW 7715	63	134	90.7	78.1	2.0	4230.2	45.1	81.8	20ms	20s	0.0
17	ETBW 7718	65	135	86.6	76.9	2.0	3746.6	43.9	81.9	5ms	40s	0.0
18	ETBW 7729	63	134	91.6	76.9	2.0	3372.0	39.0	77.4	30s	10ms	0.0
19	ETBW 7797	67	136	91.1	77.8	2.4	3709.3	42.7	84.3	10mr	20s	0.0
20	ETBW 6657	64	135	91.1	81.9	2.2	3923.7	46.2	81.9	15ms	25s	0.0
21	**ETBW 6114**	**67**	**138**	**88.7**	**85.6**	**3.0**	**4474.7**	**38.8**	**82.5**	**15ms**	**15s**	**0.0**
22	ETBW 6940	70	137	92.7	81.7	2.5	3944.3	40.6	82.7	40s	5ms	0.0
23	ETBW 7866	64	134	88.3	76.7	2.0	3285.4	39.6	79.7	40s	10s	0.0
24	ETBW 6873	67	135	92.8	81.4	2.3	3738.7	43.4	81.0	15ms	20s	0.0
25	ETBW 7188	69	139	99.7	79.2	2.5	3689.0	43.0	81.3	25s	40s	0.0
26	ETBW 7978	67	137	95.6	85.8	2.7	3783.5	49.7	83.7	10s	10s	0.0
27	ETBW 7998	67	136	99.5	81.9	2.6	3676.6	42.7	84.6	15s	20s	0.0
28	**ETBW 8003**	**68**	**138**	**101.8**	**80.3**	**2.8**	**5011.1**	**49.2**	**84.3**	**15ms**	**10s**	**0.0**
29	ETBW 8005	65	136	99.5	81.1	2.6	4139.1	46.6	83.7	15ms	15ms	0.0
30	ETBW 8006	66	137	86.3	75.3	2.1	3753.9	41.4	83.9	15ms	20s	0.0
31	ETBW 8012	66	135	90.3	78.6	2.2	3941.5	45.8	81.6	15s	40s	0.0
32	ETBW 8051	66	136	85.2	78.1	2.1	3105.0	47.8	82.7	30s	5s	0.0
33	Dambel	68	137	99.6	80.3	2.4	3824.7	41.2	81.7	30s	5ms	0.0
34	M.Walabu	67	137	98.9	78.9	2.3	2351.6	35.8	77.2	40s	10ms	0.0
35	Holandi	65	135	116.7	79.2	2.2	2132.9	36.4	77.5	40s	40s	0.0
Mean		**65**	**136**	**92.3**	**78.9**	**2.2**	**3448.5**	**42.3**	**80.8**			
CV (%)		**2.2**	**1.9**	**5.1**	**9.1**	**20.72**	**20.3**	**9.23**				
SE		**1.5**	**2.6**	**4.7**	**7.2**	**0.45**	**717.8**	**3.9**				
LSD at 5%		**0.9**	**1.7**	**3.2**	**4.7**	**0.3**	**470.1**	**2.6**				

Key: DTH: days for heading, DTM: days to maturity, PLH: plant height (cm), TKW: thousand kernel weight (gm), HLW: test weight (kg/hl), GY: grain yield (kg/ha), SR: stem rust (%), YR: yellow rust (%), Lr: leaf rust, S: Susceptible, MS: moderately susceptible, SMS: Susceptible to moderately susceptible, Mr: Moderately resistance, CV (%): Coefficient of variations, LSD: Least significant differences

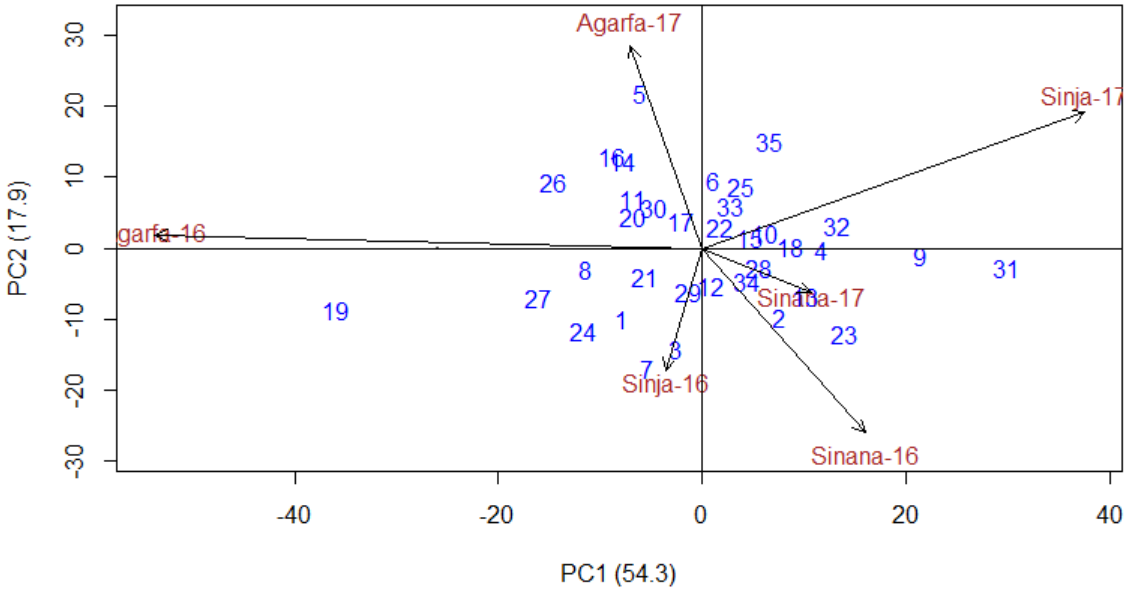
Table 2. AMMI analysis of variance for grain yield tested at six locations (Sinana, Agarfa and Goba) during 2016 and 2017.

Variables	Df	MS	Explained %
Environment	5	48648521**	33
Rep (Environment)	12	1382096**	0
Genotype	34	10892350**	50.18
Genotype x Environment	170	731419**	16.85
Residuals	408	484774	
AMMI PC1	38	1775739**	54.30
AMMI PC2	36	616950.8^{ns}	17.90
AMMI PC3	34	571228.7^{ns}	14.54
AMMI PC4	32	282671.2^{ns}	8.06
AMMI PC5	30	206190.2^{ns}	4.90

**p<0.01, Ns= non-significant, DF=degrees of freedom, MS=mean square.

Which won where /what GGE biplots

Polygon view of a biplot was the best way to visualize the interaction patterns between genotypes and environments and to effectively interpret a biplot (Yan and Kang, 2003). In this study, the 'which won where' feature of biplot identified wining genotypes; ETBW 8003, for instance was the winning/corner genotype at Sinana, Agarfa, and Sinja (Fig 2). The vertex genotypes were the most responsive genotypes, as they have the longest distance from the origin in their direction as suggested by Yan and Tinker (2006). Ranking of the tested genotypes also showed that ETBW 8003 (4692.1kg ha^{-1}) and ETBW 6114 (4174.7kg ha^{-1}) are the ideal candidate genotypes to all test locations (Fig 3).



NB. 1= ETBW 7402,2= ETBW 7408,3= ETBW 7409,4= ETBW 7412,5= ETBW 7435,6= ETBW 7524, 7= ETBW 7527,8= ETBW 7528,9= ETBW 7559,10= ETBW 7569,11= ETBW 7595,12= ETBW 7621, 13= ETBW 7638,14= ETBW 7661,15= ETBW 7698,16= ETBW 7715,17= ETBW 7718,18= ETBW 7729,19= ETBW 7797, 20= ETBW 6657, 21= ETBW 6114, 22= ETBW 6940, 23= ETBW 7866, 24=ETBW 6873,25= ETBW 7188, 26= ETBW 7978, 27= ETBW 7998, 28= ETBW 8003, 29= ETBW 8005, 30= ETBW 8006, 31= ETBW 8012, 32= ETBW 8051, 33=Dambel, 34= m.walabu, 35= holandi

Figure1. AMMI of the first two IPCA's of 35 advanced bread wheat genotypes

Table 3. Mean performance of grain yield and stability of the tested genotypes across locations.

S/N	Genotype	GY mean	IPCA1	IPCA2	IPCA3	ASV	rASV	YSI	rYSI	bi	s^2di	ω_i
1	ETBW 7402	4143.40	-0.27	-0.04	0.16	16.87	19	25	6	0.88	0.04	821573.5
2	ETBW 7408	1860.30	0.26	-0.11	0.14	16.49	18	52	34	0.77	-0.04	618971.9
3	ETBW 7409	3215.06	-0.04	-0.39	0.13	14.91	16	43	27	1.26	-0.02	714168.7
4	ETBW 7412	2909.56	0.37	-0.15	-0.25	20.6	26	56	30	1.00	0.14	1203286.4
5	ETBW 7435	3905.11	-0.09	0.48	-0.30	24.37	29	44	15	1.14	0.22	1565635.2
6	ETBW 7524	3499.36	0.08	0.07	-0.36	9.85	8	31	23	1.22	0.06	859526.8
7	ETBW 7527	3940.64	-0.22	-0.39	0.14	19.28	23	36	13	1.10	0.07	968186.3
8	ETBW 7528	3616.78	-0.39	-0.11	0.11	19.93	24	45	21	0.89	0.04	912759.4
9	ETBW 7559	2336.92	0.61	-0.25	-0.19	37.57	33	64	31	1.04	0.51	2681515.2
10	ETBW 7569	3289.50	0.15	-0.08	0.02	10.99	12	37	25	0.78	-0.51	569802.6
11	ETBW 7595	4063.70	-0.22	0.07	-0.29	13.7	15	22	7	1.27	-0.09	466341.2
12	ETBW 7621	3521.00	0.08	-0.17	-0.09	5.53	3	25	22	1.10	0.02	739941.1
13	ETBW 7638	1356.50	0.29	-0.02	0.37	18.95	22	57	35	0.56	-0.02	1022947.1
14	ETBW 7661	4018.20	-0.15	0.38	0.07	18.41	20	28	8	0.72	0.06	1086055.3
15	ETBW 7698	2986.30	0.19	0.02	-0.10	8.48	6	35	29	1.02	-0.08	328166.0
16	ETBW 7715	4269.10	-0.18	0.36	-0.10	20.22	25	28	3	1.31	0.13	1363665.4
17	ETBW 7718	3808.80	0.01	0.03	0.04	5.21	2	20	18	1.28	-0.18	277135.5
18	ETBW 7729	3351.30	0.25	0.03	0.16	15.03	17	41	24	0.96	-0.04	479991.9
19	ETBW 7797	3977.40	-1.00	-0.29	-0.02	63.26	35	45	10	1.41	0.40	6639403.4
20	ETBW 6657	4204.30	-0.20	-0.06	-0.61	12.69	14	19	5	1.46	0.02	1227045.9
21	**ETBW 6114**	**4474.70**	**-0.17**	**-0.08**	**0.14**	**10.53**	**11**	**13**	**2**	**0.91**	**-0.07**	**407503.2**
22	ETBW 6940	3919.80	0.04	0.23	0.20	4.33	1	15	14	0.86	-0.08	358417.2
23	ETBW 7866	3285.20	0.40	-0.35	-0.03	27.3	31	57	26	1.12	0.22	1557938.5
24	ETBW 6873	3839.00	-0.31	-0.23	0.20	23.4	27	44	17	1.24	0.09	1158947.7
25	ETBW 7188	3628.30	0.11	0.64	0.49	11.01	13	33	20	0.49	0.20	2031409.0
26	ETBW 7978	3979.14	-0.37	0.25	-0.02	26.95	30	39	9	1.20	0.14	1311284.8
27	ETBW 7998	3973.92	-0.42	-0.22	-0.17	28.8	32	43	11	1.27	0.23	1714389.1
28	**ETBW 8003**	**5011.78**	**0.09**	**-0.04**	**0.21**	**10.24**	**10**	**11**	**1**	**0.79**	**-0.12**	**344816.3**
29	ETBW 8005	4240.31	-0.03	-0.08	-0.03	6.51	4	8	4	1.20	-0.12	243668.3
30	ETBW 8006	3948.58	-0.18	0.14	-0.06	10.09	9	21	12	0.92	-0.05	475744.8
31	ETBW 8012	3776.25	0.67	-0.16	-0.05	52.24	34	53	19	0.63	0.83	4278605.7
32	ETBW 8051	3100.03	0.36	0.07	-0.19	23.46	28	56	28	0.98	0.07	922078.1
33	Dambel	3851.69	0.04	0.20	0.28	7.64	5	21	16	0.76	-0.04	624995.5
34	Mada Walabu	2290.00	0.08	-0.14	0.32	8.95	7	39	32	0.63	-0.01	573124.5
35	Holandi	2150.14	0.15	0.39	-0.33	18.87	21	54	33	1.03	0.06	898045.3

Key: ASV =AMMI stability value, rASV=Rank of ASV, YSI=Yield stability Index, rYSI= rank of YSI, IPCA= Interaction Principal Coordinate Axis, ω_i = Wrickes Ecovalance, bi= Regression coefficient, S^2di =deviation from regression

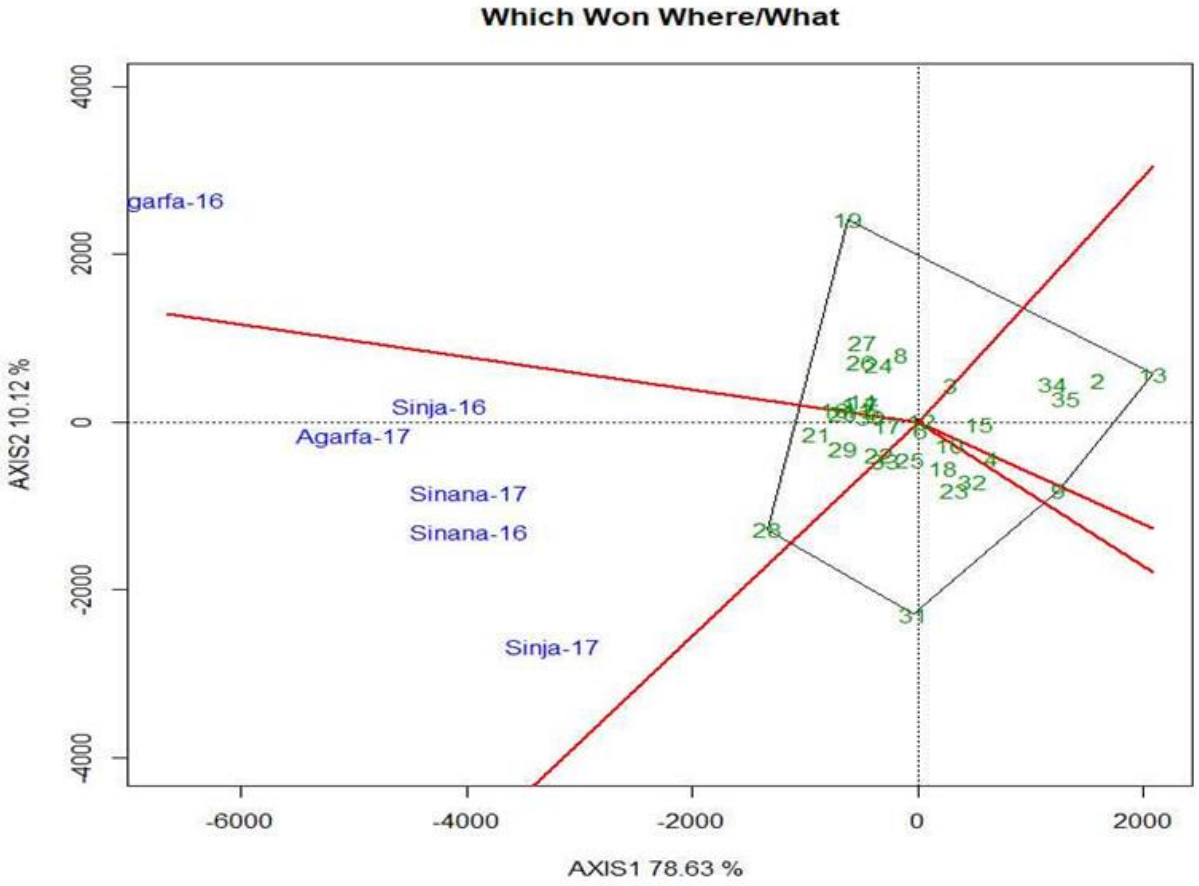


Figure 2: The polygon view of GGE biplot of 35 Bread wheat genotypes over the environment

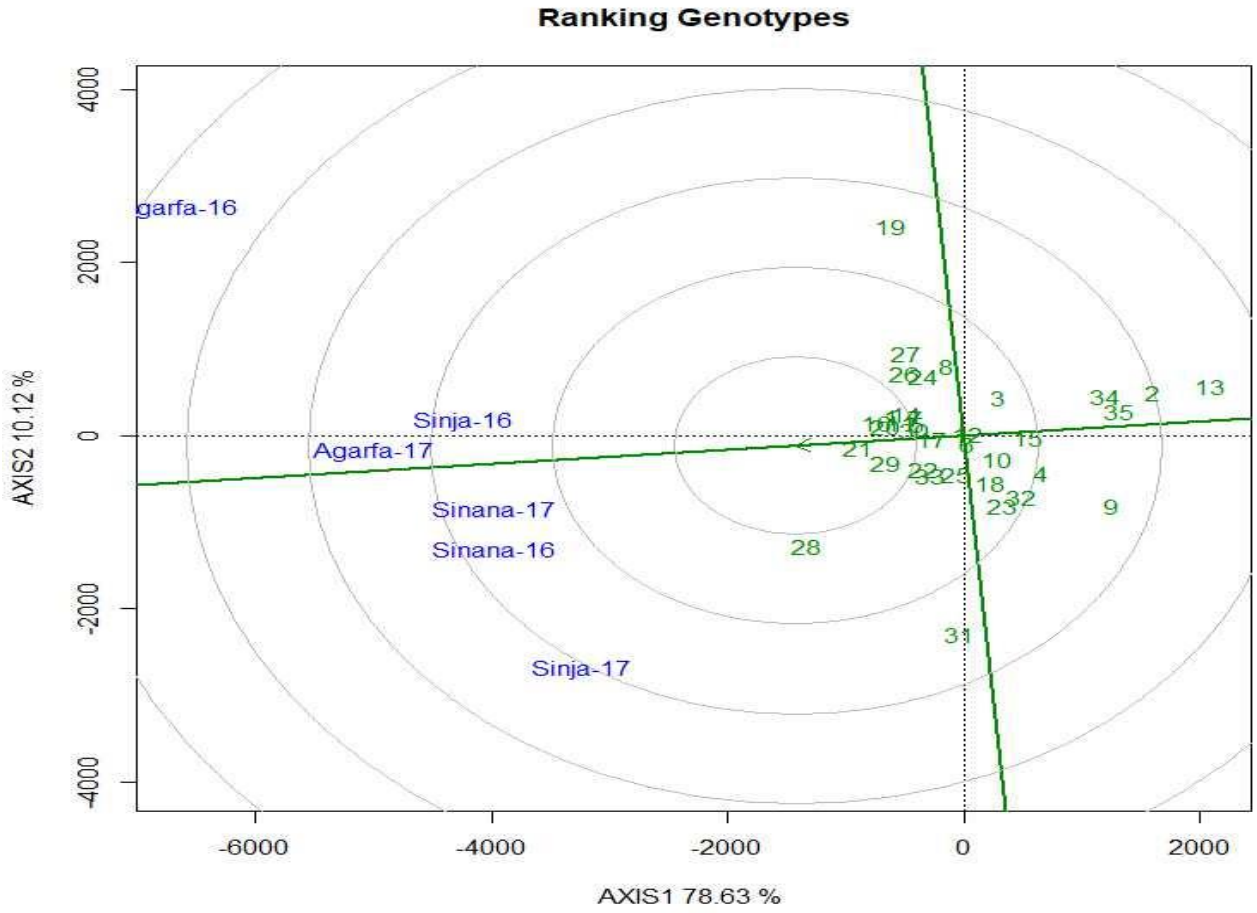


Figure 3: Ranking ideal genotypes for ideal environment

Conclusion

The highest mean grain yield performance was recorded for genotype ETBW 8003(4692.1kgha^{-1}) followed by ETBW 6114 (4174.7kgha^{-1}). AMMI analysis revealed that only mean square of the first interaction principal component axis (IPCA1) was found highly significant (P<0.01). Genotype ETBW 8003 and ETBW 6114 were found stable and high yielder across all locations. These genotypes also have good test weight, TKW, better disease resistance and white seed color. Therefore, these genotypes are recommended for verification and possible release for wider production.

Reference

Alberta, M.J.A. (2004). Comparison of statistical methods to describe genotype by environment interaction and yield stability in multi-location of maize trails. M.Sc. Thesis in University of the Free State.

Annicchiarico, P. (1997). Joint regression vs AMMI analysis of genotypes by environment interactions for cereals in Italy.*Euphytica*, **94**:53-62.

Becker, H.C., and Leon, J. (1988). Stability analysis in plant breeding. *Plant breeding*, **101**:1-23.

Central Statistical Agency (CSA) (2016). Report on area and production of major crops (private peasant holdings, meher season). Statistical bulletin 532, *CSA*, Addis Ababa, Ethiopia.

Cross J (1990). Statistical analysis of multi-location trails. *Adv.Agro.***45**:56-86.

Gauch, H.G., and Zobel R.W. (1996). AMMI analysis of yield trails. In: Kang, M.S. and Zobel, H.G. Jr (Eds), genotype by environment interaction, CRC Press, Boca Raton. Pp: 85-120.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research, 2nd edit. John Wiley and Sons, New York.

Harlan, J.R. (1971). Agricultural Origins: Centers and Non-Centers. *Science*, **174**:468-474.

Kaya,Y.C., Palta and Taner, S.(2002). Additive main effect and Multiplicative interaction analysis of yield performance in bread wheat genotypes a cross environments. *Turk.J. Agric.***26**:275-279.

Lin, C.S., and Binns, M.R., and Lefkovitch, L.P. (1986). Stability analysis: Where do we stand? *Crop Sci.***26**:894-900.

Ozkan H, Levy AA, and Feldman, M. (2001).Allopolyploidy-induced rapid genome evolution in the wheat (*Aegilops-Triticum*) group. *Plant Cell*, **13**: 1735-1747.

Pacheco, A., Vargas, M., Alvarado, G. , Rodríguez, F., López, M. , Crossa, J.andBurgueño, J.(2016). GEA-R (Genotype x Environment Analysis with R for Windows).

Piepho HP (1996). Analysis of genotypes environment interaction and phenotypic stability. In: Kang, M.S. and Zobel, H.G. Jr (Eds), genotype by environment interaction, CRC Press, Boca Raton. Pp: 151-174.

Purchase, J.L. (1997). Parametric analysis to describe GXE interaction and stability in winter wheat. PhD thesis, Department of Agronomy, Faculty of Agriculture, University of the Orange Free State, Bloemfonten, South Africa.

R software (2018).R Foundation for Statistical Computing Platform.

Taye, G., Getachew,T. and Geletu,B.(2000). AMMI adjustment for grain yield and classification of genotypes and environments in field pea (*Pisumsativum L.*). *J.Genet.Breed*, **54**:183-191.

Wricke, G. (1965). On a method of understanding Ecological diversity in field research.*Z pflanzeuzuccht*, **47**: 92-96.

Yan, W. and Kang, M. S. (2003). GGE biplot analysis: A graphical tool for breeders, geneticists, and agronomists. CRC Press, Boca Raton, FL. pp 213.

Yan W, Tinker NA, 2006. Biplot analysis of multi-environment trial data: principles and application. *Canadian J. Plant Sci*. 86:623-645.

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

Registration of "Sinja" Bread Wheat (*Triticum eastivum* L.) Variety

Behailu Mulugeta*[1], Tilahun Bayisa[1], Tesfaye Leta[2], Mulatu Abera[1] and Tamene Mideksa[1]
[1] Sinana Agricultural research Center, Bale Robe, Ethiopia
[2] Oromia Agricultural research Institute, Addis Ababa, Ethiopia
*Corresponding author Email: behailu.mulugeta30@gmail.com

Abstract
Improved crop variety plays an important role in enhancing production and productivity of crops and thereby contributing to the change in livelihood of farmers. The name *Sinja* was given to bread wheat variety developed through crossing of the adapted released varieties such as Dure and Mada Walabu. *Sinja* (Dure/Madda Walabu 14-1-2 2005B SnCr) and the others 31 pipeline genotypes were evaluated against standard check Mada Walabu and local check Holandi from 2013/14 to 2015/16 at Sinana, Goba, Robe area, Selka and Agarfa in the Southeastern Ethiopian. *Sinja* variety showed stable yield performance across all environments than the other tested genotypes. Therefore, *Sinja* was released in 2018 for its high grain yield potential and resistant to the major bread wheat diseases.
Key words: Bread wheat (*Triticum eastivum*), Sinja**,** Food security, Stability

Introduction
Wheat is one of the biggest three globally grown cereal crops (Maize, Rice and Wheat). About 600 million metric ton of wheat is produced each year and accounts 30% of global cereal crops production (www.csiro.au). Being stable food, it provides around 20% of human daily energy and also provides a significant healthy benefit for human kind (www.csiro.au). Development of improved bread wheat variety is one of the most important mechanisms for the increment of production and productivity thereby improving the livelihood of the farmers in our country. Even though many bread wheat varieties have been released for production in Ethiopia over the past decades, most of them were pushed out of production within few years after release mainly due to the newly evolving and existing virulent race of rusts. Besides, the recurrent climate change is also becoming a challenge and hence there is a need to develop a climate resilient crop variety. Therefore, pyramiding a minor gene and creating genetic variability by hybridizing locally adapted varieties and/or new introduction of exotic materials is highly important to prolong the duration that a given released crop variety can stay in production.

Varietal Origin and Evaluation
The variety '*Sinja'* was developed through hybridization of locally adapted varieties of Dure and Mada walabu (Dure/Madda Walabu 14-1-2 2005B SnCr). Sinja and the other pipeline varieties were evaluated against the standard check Mada Walabu and local check Holandi at Sinana, Goba, Robe area, Selka and Agarfa from 2014/15 to 2015/16 with the objective of developing stable, high yielding and disease resistant/tolerant variety to farmers and other bread wheat producers residing in the highlands of Bale and similar agro-ecologies.

Agronomic and morphological characteristics of 'Sinja' variety

Days to heading and maturity for this variety ranges from 63 to 65 and 136 to 156, respectively. Sinja has a plant height ranging from 87cm to 98cm which make it resistant to lodging, thousand kernel weight from 31 to 35 and test weight from 78 to 84. Sinja showed better land coverage and seed size as compared to standard and local checks. It is early maturing and adapted to rainfed highland irrigated lowland areas. Summary of agronomic and morphological characteristics is shown in Table 1 and Appendix 1.

Yield performance

At early breeding stages, Sinja variety was evaluated at Sinana on-station from 2008 to 2014 for seed yield and other yield related parameters and showed better yield performance while comparing with standard and local checks used in the evaluation. In mult-environment yield trial at Sinana, Goba, Robe area, Selka and Agarfa from 2014/15 to 2015/2016, Sinja gave mean yield performance ranging from 2623 to 3985qt/ha. On farmers field trails from 2014/15 to 2015/16, seed yield obtained ranged from 2326 to 4001 qt ha^{-1}.

Stability Performance

Yield stability is an important parameter that plant breeder should give a due attention in breeding program for development of better adapting variety in multi-location. Yield stability was evaluated in multi- environment trails for two years with 35 bread wheat genotypes to evaluate the yield and stability of the genotypes based on the methods postulated by Wrickes, (1965), Eberhart and Russell (1966), and Zobel *et al*. (1988). As compared to standard and local checks, Sinja showed about unit value of regression coefficient, smaller value of ecovalance and AMMI stability value, indicating the stability of the variety performing over environments.

Disease Reaction

Currently the majority of the released bread wheat varieties are pushed out of production due to rust disease pressure evolving from time to time and therefore, disease (mainly rusts) is important parameters that should be given great attention in variety development program. *Sinja* variety is moderately resistance to Yellow rust (*Puccinia striiformis* f. sp. *tritici*), stem rust (*Puccinia graminis* f. sp. *tritici*) and leaf rust (*Puccinia triticina*) (Table 1).

Quality analysis

Quality parameters such as dry gluten percent, protein percent, Zeleny index and moisture were measured to see the nutritional quality of this variety under laboratory test. Accordingly, Sinja variety showed dry gluten and protein percent of 26.9 and 12.08, respectively. It has moisture and Zeleny index of 11.48 and 59.08, respectively.

Table 1. Summary of mean performance of agronomic traits and disease reactions of 35 bread wheat genotypes over locations and years

SN.	Genotypes	DH	DM	PLH	ST	BMW	Gy	TKW	HLW	SR	YR	LR	Sep.
1	Wabe / Galema 6-4-4 2005B SnCr	71.1	144.3	96.1	84.7	2.4	3126.7	33.7	80.9	5s	15s	10ms	83
2	Galema / Madda walabu8-3-1 2005B SnCr	67.3	142.7	93.9	85.1	2.1	2609.5	28.9	74.1	90s	60s	10ms	84
3	Galema / Madda walabu 8-3-1 2005B Sn Cr	66.9	142.7	92.8	84.4	2.0	2428.1	27.7	72.7	80s	70s	5s	84
4	Galema / Madda walabu8-3-3 2005B SnCr	67.3	143.2	93.5	87.3	2.2	2824.0	28.5	70.6	90s	70s	10ms	84
5	Galema / Madda walabu 8-3-4 2005B SnCr	68.3	143.2	90.8	82.3	2.1	2576.6	29.3	72.3	90s	80s	10s	83
6	Galema / Madda walabu8-4-4 2005B SnCr	65.3	142.9	93.9	83.0	2.1	3521.5	35.7	80.1	40ms	40ms	10ms	84
7	Wabe / Mitike 9-1-12005B SnCr	66.8	143.6	101.6	87.0	2.2	3333.6	38.7	65.5	40s	40s	10ms	84
8	Mitike / Sofumer 11-5-1 2005B SnCr	66.6	144.1	114.5	83.8	2.0	2695.5	32.6	77.8	40s	40s	10s	81
9	Mitike / Sofumer 11-5-2 2005B SnCr	66.9	144.8	118.2	86.9	2.4	3023.4	33.7	78.6	40s	40s	10ms	81
10	Wabe / Sofumer 12-4-1 2005B SnCr	65.2	143.4	100.1	88.1	2.3	3168.4	33.1	79.5	15s	10s	5s	83
11	Wabe / Sofumer 12-4-2 2005B SnCr	65.7	144.2	97.1	86.9	2.2	2912.7	31.9	77.5	15s	20s	5ms	83
12	Wabe / Sofumer 12-4-3 2005B SnCr	66.5	144.0	95.8	86.6	2.2	3005.6	32.3	78.1	20s	20s	5ms	83
13	Wabe / Sofumer 12-7-1 2005B SnCr	70.3	144.6	104.4	82.4	2.1	3057.4	33.7	80.9	30s	30s	5ms	83
14	**Dure / Madda walabu 14-1-2** 2005B SnCr	**64.7**	**143.8**	**93.6**	**82.3**	**2.1**	**3913.2**	**35.5**	80.8	**5s**	**5s**	**5ms**	**83**
15	Wabe / Madda walabu 16-2-1 2005B SnCr	69.5	147.4	105.0	84.3	2.4	3004.3	37.6	78.7	5s	5s	5ms	82
16	**Wabe / Madda walabu 16-2-3** 2005B SnCr	**70.0**	**147.3**	**104.3**	**81.5**	**2.6**	**3372.1**	**38.6**	77.9	**5s**	**5s**	**trms**	**83**
17	Mitike / Abola 19-7-1 2005B SnCr	68.9	144.6	91.5	86.3	2.4	3220.1	47.7	75.8	40s	50s	10s	82
18	Sofumer / Madda walabu26-1-1 2005B SnCr	64.9	143.7	112.3	84.8	2.4	3342.3	39.7	81.6	5s	5s	10ms	82
19	Sofumer / Dure 27-6-1 2005B SnCr	67.3	145.3	109.9	86.3	2.5	3059.4	35.9	77.7	40s	40s	10s	81
20	Sofumer / Dure 27-6-2 2005B SnCr	65.3	145.8	117.1	86.3	2.6	2588.7	29.8	70.8	70s	60s	10s	81
21	Sofumer / Dure 27-8-3 2005B SnCr	63.8	143.9	106.7	86.7	2.2	2418.0	26.5	72.7	90s	60s	15s	83
22	Sofumer / Dure 27-8-4 2005B SnCr	64.1	144.0	104.3	84.9	2.1	2102.3	22.8	73.3	90s	60s	15s	83
23	Dashen / Madda walabu 31-4-4 2005B SnCr	73.4	142.7	93.7	81.3	2.3	2741.9	30.6	77.5	15s	25s	5ms	82
24	Dashen / Madda walabu 31-5-1 2005B SnCr	70.7	145.1	97.6	86.2	2.6	3766.9	41.2	79.9	15s	10s	10ms	81
25	Dashen / Madda walabu 31-5-2 2005B SnCr	69.0	143.8	92.1	83.3	2.2	3548.7	36.0	78.9	15s	25s	10s	82
26	Dashen / Madda walabu 31-6-3 2005B SnCr	70.8	144.7	89.9	80.6	2.2	3112.3	33.0	78.0	20s	25s	15ms	81
27	Dashen / Madda walabu 31-6-4 2005B SnCr	71.2	144.8	86.3	82.5	2.2	3202.5	33.2	77.9	30s	30s	10ms	81
28	Dashen / Sofumer 32-2-1 2005B SnCr	68.5	142.9	90.1	83.5	2.1	3227.5	34.5	78.9	10s	15s	15ms	83
29	Dashen / Sofumer 32-2-2 2005B SnCr	68.7	143.6	89.7	84.2	2.2	3529.0	35.7	79.7	10s	20s	10ms	82
30	Dashen / Sofumer 32-2-3 2005B SnCr	68.4	143.6	89.4	82.4	2.1	3495.1	34.5	78.7	10s	20s	10ms	83
31	ETBW 6161	68.7	147.6	94.1	84.4	2.8	3442.7	37.5	79.6	30s	30s	5ms	82
32	ETBW 6175	67.7	144.6	101.2	85.5	2.6	3392.9	30.8	77.7	40s	40s	10ms	83
33	ETBW 6142	67.3	145.6	88.2	81.4	2.2	2868.2	33.6	77.3	10s	30s	5ms	82
34	St.check (Mada Walabu)	70.7	144.6	99.4	84.5	2.4	3313.6	38.0	77.7	30s	15s	10ms	84
35	Local Check	67.2	142.0	114.6	82.3	2.1	2069.5	29.9	74.1	80s	80s	10ms	84
Mean		67.9	144.2	99.0	84.4	2.3	3041.8	33.8					
CV (%)		4.77	5.75	8.98	11.81	22.58	26.92	30.61					
LSD (5%)		2.32	ns	6.37	ns	0.41	587.51	7.42					

*DH: days for heading, DM: days to maturity, PLH: plant height (cm), St: stand percentage, BMW: biomass weight (kg), TKW: thousand kernel weight (gm), Gy: grain yield (kg/ha), HLW: hectoliter weight (kg/hl) Sr: stem rust (%), Yr: yellow rust (%), Lr: leaf rust (%), S: Susceptible, MS: moderately susceptible, SMS: Susceptible to moderately susceptible, Mr: Moderately resistant, Tr: Trace, Trms: Trace with moderately susceptible , Trmr: Trace with moderately resistant, R: Resistant, CV(%): Coefficient of variations,

Conclusions

A stabile and high yielding variety is a vehicle for increasing production and productivity thereby improving the livelihoods of farmers. *Sinja* is stable and adaptable across multi-environments in southeastern Ethiopia. It has good agronomic traits, high gluten content and high protein percentage. Sinja is a moderately resistance variety to the common rust disease. It is the first variety released from locally adaptable cross at Sinana Agricultural research Center. Therefore, smallholder farmers and other bread wheat producers inhabiting around Bale highland and areas with similar agro-ecology can grow *Sinja* variety with its full agronomic and other management recommendations.

Reference

Wricke G (1965). On a method of understanding Ecological diversity in field research. *Z pflanzeuzuccht,* **47**: 92-96.

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

http://www.csiro.au

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

Appendix 1. Agronomic and Morphological characteristics of Sinja variety

1	Variety Name	Sinja (Dure / Madda walabu 14-1-2 2005B SnCr)
2	Adaptation area	Highlands of Bale and West Arsi
	Altitude(m.a.s.l)	2200-2600
	Rain fall(mm)	>750
3	Fertilizer (Kg/ha)	
	P_2O_5	100
	N	50
4	Planting Date	Mid June to Early September in Bale highlands and similar agro-ecology
5	Seed Rate(Kg/ha)	150
6	Days to heading	63 to 65
7	Days to maturity	136 to 156
8	Plant height(cm)	87 to 98
9	Seed color	White
10	Thousand Kernel weight	31 to 35
11	Quality data	
	Dry Gluten (%)	26.9
	Protein (%)	12.08
	Moisture (%)	11.48
	Test weight (Kg/hl)	78 to 84
12	Crop pest reaction	Moderately Resistant
13	Yield (Qt/ ha)	
	On farm	23-40
	On station	26-39
14	Year of Release	2018

Yield advantage of 18.1 % and 89.4 % over standard check Madda walabu and local check Holandi, respectively

Registration of *'Adoshe'* Food Barley (*Hordeium vulgare* L.) Variety

Hiwot Sebsibe*, Kasahun Tadesse, Endeshaw Tadesse and Girma Fana
Sinana Agricultural Research Center, P. O. Box 208, Bale-Robe, Ethiopia
*Corresponding author email: hiwotsebsibe@yahoo.com

Abstract

Adoshe is a common name for barley (*Hordeium vulgare* L.) variety with pedigree designation of QUINA/MJA//SCARRLETT. The variety has been developed and released by Sinana agricultural research center for commercial production in the highlands of Bale. It has been verified at Sinana, Goba, Robe, Dodola and Dinsho areas during 2017 main cropping season. *Adoshe* showed high mean grain yield, tolerant to major barley disease and relatively stable across locations and years than the standard checks *Harbu* and *Biftu, and local check Aruso. Adoshe* was tolerant to barley shoot fly than *Harbu* and *Biftu* and exhibit compensatory growth after shoot fly damage.

Keywords: *Adoshe*; *Barley* (*Hordeium vulgare* L); *Yield Performance; Resistance*

Introduction

Adoshe (QUINA/MJA//SCARRLETT) is food barley variety released in 2018 under Oromia Agricultural Research Institute by Sinana Agricultural Research Center. It was originally introduced from ICARDA barley improvement research program and developed through pure line selection methods. It has been verified at Sinana, Goba, Robe, Dodola and Dinsho areas during 2017 main cropping season. The variety was evaluated by National Variety Release committee and officially released for wider production in the highlands of Bale and areas with similar agro-ecologies.

Varietal Characteristics

Adoshe is six-rowed variety, erect growth habit with average days to heading and maturity date of 74 and 121 days, respectively (Appendix 1). The variety has medium plant height (81cm) and this character is preferred by the local community for its tolerance to lodging problem. On the other hand, seed color is white and has average thousand-kernel weight of 33.2 g. It is also characterized by better tolerance to main biological insect pest (shoot fly) than the standard check (*Harbu* and *Biftu)*; and showed rapid compensatory growth after damage by the insect.

Yield Performance

Adoshe (QUINA/MJA//SCARRLETT) was tested together with 18 barley genotypes including checks in regional variety trial at 5 environments in major barley producing areas in Bale highlands during 2014- 2015 consecutive years. It was evaluated along with *Harbu* and *Biftu* as standard check and *Aruso* as the local variety at Sinana, Robe, Goba, Dinsho and Dodola. The combined mean grain yield of this variety was better than all genotypes evaluated. Beside, *Adoshe* showed 19% and 41.5% yield advantage over the standard check (*Biftu)* and local check (*Aruso*), respectively. On research field *Adoshe* gave yield ranging from 3.2 to 4.1 ton ha^{-1}, whereas 3.5 to 4.2 tons ha^{-1} on farmers' field.

Stability performance

Stability analysis for grain yield of 18 food barley genotypes including checks were conducted using multi year and multi location data. According to joint regression model, a variety with high mean yield, regression coefficient (bi) of unity and with deviation from regression (S2di) =0 is stable (Eberhart and Russell, 1966). In this regard, *Adoshe* is stable variety with high mean grain yield, regression coefficient (bi) of 1.07 which is nearly unity and deviation from regression of 0.02 which is equivalent to zero. Therefore, it has shown stable yield performance across locations of evaluation as well as higher mean grain yield over check varieties (*Harbu, Biftu* and *Aruso*).

Disease Reaction

Data recording was done for all genotypes including this variety for major barley diseases such as net blotch (*Pyrenophora teres* Drechs.), scald (*Rhynchosporium secalis* Oud.), stem rust *(Puccinia graminis* f. sp. *Tritici)* and barley leaf rust (*Puccinia hordei* Otth) at across all environments. Data was taken at 51-69% plant growth stages (Zadoks *et al*., 1974) across locations. Both net blotch and scald were scored using 00-99 double digit scale (Saari and Prescot,1975) where the first digit indicates the spread of disease in a plot (% incidence) and the second digit indicate the percentage of leaf area infected (% severity). Whereas, barley leaf rust and stem rust data were collected based on Stubs *et al*. (1986) methodology. The net blotch response of the candidate variety (*Adoshe*) was comparable with checks variety (Table 1); however, it appears that *Adoshe* was less resistant to these diseases. But the variety *Adoshe* less susceptible for stem rust *(Puccinia graminis* f. sp. *Tritici)* and barley leaf rust (*Puccinia hordei* Otth) than checks.

Adaptation

Adoshe variety is recommended for production in the highlands of Bale with annual rainfall of about 750 -1600mm and areas with similar agro-ecologies. On black soils, 100 kg DAP (diammonium phosphate) fertilizer is recommended to give good yield and with 125 kg seed rate. In addition, the variety can be planted early March for *Ganna* season and early August for *Bona* season.

Conclusion

Adoshe is a stable variety in grain yield performance, has good agronomic traits and tolerant to shoot fly infestation. It is resistance for major barley attacking disease in the area. *Adoshe* was released for major barley growing regions of Bale highlands and similar agroecology. The variety will be helpful for local farmers mainly due to its yield performance, productive tillers and relatively disease free than other varieties grown in the area.

Table 1. Summary of pooled mean yield and other data across location and years

Variety	DH	DM	PH	ST	YLD	TKW	HLW	NB	SR	LR	SC	BSF	
												Inf.	D.pla
Adoshe	74	121	81	78	3.2	34.4	67.4	78	5ms	5ms	0	0.5	0.13
Harbu	64	114	103	81	2.5	37.7	63.5	81	10ms	20s	1	0.7	0.27
Biftu	65	115	102	84	2.7	37.8	64.0	78	10ms	20s	2	0.4	0.32
Aruso	63	114	100	80	2.3	40.5	65.4	84	10ms	15ms	2	0.3	0.28

Key: **DH=days to heading, DM= days to maturity, PH= plant height, YLD= grain yield t ha-1, TKW= thousands kernel weight, HLW=hectoliter weight, NB= Net blotch, SR= stem rust, LR=leaf rust, SC= scald, BSF=barley shoot fly, Inf= infestation and D.pla=dead plant*

Table 2. Combined mean grain yield and other agronomic traits of food barley regional variety trial over years (2014-2015) and over locations (Sinana, Robe Goba, Dinsho and Dodola).

Genotypes	DH	DM	PH	ST	YD	TKW	HLW
IBLSGP09/10#3	69.0	119.8	94.0	79.0	2.9	35.2	65.4
APL/6/P.STO/3/BIRAN/UNA80//LIGNEE640/4/BLLUS/5/PENTUNIA I	74.8	122.0	109.0	82.0	2.6	43.0	64.6
TRADITION//PENCO/CHEVRON-BAR	76.6	122.0	81.0	75.0	2.3	37.0	65.0
P.STO/3/BIRAN/UNA80//LIGNEE640/4/BLLUS/5/PENTUNIA1/6/ZARZA	68.9	121.1	84.0	79.0	2.7	33.6	64.2
P.STO/3/BIRAN/UNA82//LIGNEE640/4/BLLUS/5/PENTUNIA1/6/ZARZA	71.4	121.8	82.0	77.0	2.6	33.8	65.8
SCARRLETT/QUILMES PAMPA	69.5	119.8	87.0	80.0	2.8	34.7	65.6
QUINA/MJA// SCARRLETT	74.2	121.6	81.0	78.0	3.2	34.4	67.4
BRS 180/M97.77/6/ P.STO/3/BIRAN/UNA80//LIGNEE640/4/BLLUS/5/ PENTUNIA1/6/ZARZA1/6/DURUMMOND	67.3	117.0	78.0	75.0	2.4	28.3	60.2
ELMIRA/4/EGEPT4/TERAN78//P.STO/3/QUINA 1	69.2	120.3	94.0	81.0	2.9	34.0	66.3
KAB43/CABUYA	72.5	122.6	89.0	76.0	3.2	36.8	66.6
OLMO/CABUYA//CHAMICO/3/ PENTUNIA1	72.7	123.7	86.0	73.0	2.7	37.0	64.8
ZHEDAR#1STANDARD-BAR/FOSTER/3/M84/4/PENCO/CHEVRON-BAR	73.6	121.3	88.0	71.0	2.3	38.4	63.6
ESMERALD/3/SLLO/ROBUST//QUINA/4/M104	72.9	122.4	83.0	74.0	2.5	40.7	64.8
BSI	65.7	116.9	94.0	79.0	3.0	38.3	64.5
QUINA/MJA// SCARRLETT/ P.STO/3/QUINA 1	67.2	117.9	88.0	75.0	2.9	35.0	66.0
Harbu	64.8	114.6	103.0	81.0	2.5	37.7	63.5
Biftu	65.6	115.6	102.0	84.0	2.7	37.5	64.0
Aruso	63.4	114.4	100.0	80.0	2.3	40.5	65.4
Means	69.9	119.7	90.0	77.8	2.7	36.4	
LSD	2.8	1.9	7.3	10.1	23.8	6.1	
CV	3.2	3.6	10.5	12.6	10.1	3.6	

Key: **DH=days to heading, DM= days to maturity, PH= plant height, YLD= grain yield t ha-1, TKW= thousands kernel weight, HLW=hectoliter weight*

Appendix I. Agronomic and morphological characteristics of *Adoshe* (QUINA/MJA//SCARRLETT)

Agronomic characters	
Altitude (m.a.s.l)	2300 -2600
Rain fall (mm)	750 -1600
Fertilizer rate (DAP in kg/ha)	100
Seed rate(kg/ha)	125
Planting date	Mid-June to early August
Days to heading	74
Days to maturity	125
Plant height(cm)	82
Growth habit	Erect
1000 seed weight(g)	33.6
Seed color	White
Row type	6 row
Hectoliter weight (Kg/L)	67.4
Crop pest reaction	Moderately Resistance
Grain yield(t/ha)Research field	3.2 -4.1
Grain yield (t/ha) Farmer's field	3.5 -4.2
Year of released	2018

Reference

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

Zadoks, J.C., Chang, T.T. and Konzak, C.F. 1974. A decimal code for the growth stages of cereals. *Weed Research* 14:415-421.

Registration of *'Moeta'* Malt Barley (*Hordeum vulgare* L.) Variety

Hiwot Sebsibe*, Endeshaw Tadesse, Kasahun Tadesse, and Girma Fana
Sinana Agricultural Research Center P O Box 208, Bale-Robe, Ethiopia
*Corresponding author email: hiwotsebsibe@yahoo.com

Abstract
Moeta (LEGACY/4/TOCTE//GOB/HUMAI10/3/ATAH92/ALELI/5/ARUPO/K8755 //MORA) is six- row malting barley variety developed at Sinana Agricultural Research Center (SARC). *Moeta* was tested in a multi location variety trial from 2014- 2015 cropping session along with twenty three genotypes. It was released in 2018 for its better grain yield, good agronomic performance and good malting quality. *Moeta* is moderately resistant to major barley disease common in the area. Therefore, the variety is recommended for the highlands of major barley growing areas of the country.
Keywords: Moeta, Yield Performance, Grain quality, Resistance

Introduction
Moeta (LEGACY/4/TOCTE//GOB/HUMAI10/3/ATAH92/ALELI/5/ARUPO/K8755//MORA), a six rowed malt barley variety developed by the Sinana Agricultural Research Center (SARC). It was originally introduced from ICARDA barley improvement research program. The material has been evaluated together with other genotypes in different breeding nurseries advanced variety trial stage since 2012 in multilocations of Bale highland. The variety was evaluated by National Variety Release committee and officially released for wider production in the highlands of Bale and areas with similar agro-ecologies.

Varietal characters
Moeta is six row malt barley variety. The special merits of *Moeta* are the row type, one of the most important criteria for selection. The grain yield of this variety was better than all genotype that are evaluated in the same environment. This variety has medium plant height, early maturity, lodging resistance and has good protein content for malt production. On average, the variety needs 69 days for heading and 122 days to reach physiological maturity (Table 3). It has white seed color. The average thousand kernels is 37.3g and test weight is 65 kg/hl (Appendix 1).

Grain Yield Potential and Stability
Twenty three malt barley genotypes along with two standard checks were evaluated at Sinana, Robe, Goba, Dinsho and Dodola during 2014-2015 cropping seasons. Combined analysis of variance depicted that the genotype *Moeta* (LEGACY/4/TOCTE//GOB/ HUMAI10/3/ ATAH92/ALELI/5/ARUPO/K8755//MORA) gave grain yield of 3.4 tons ha^{-1} on the research field whereas it gives 3.5 to 5.1 tons ha^{-1} on farmers' field. It was selected and verified in 2017. This variety has grain yield advantages of 21.8% and 30% over the standard checks, *Behati* and *Bekoji* variety, respectively. According to joint regression model, a variety with high mean yield, regression coefficient (bi) of unity and with deviation from regression (S2di) =0 is stable (Eberhart and Russell, 1966). In this regard, *Moeta* is stable variety with high

mean grain yield, regression coefficient (bi) of 1.26 which is nearly unity and deviation from regression of 0.04 which is near to zero. Therefore, it has shown stable yield performance across locations of evaluation as well as higher mean grain yield over checks.

Disease and Shoot fly Resistance

Moeta was evaluated for resistance to major barley diseases such as net blotch (*Pyrenophora teres* Drechs.), scald (*Rhynchosporium secalis* Oud.), stem rust *(Puccinia graminis* f. sp. *Tritici)* and barley leaf rust (*Puccinia hordei* Otth) across all environments in fields under natural infection. Its level of resistance was better than the standard checks for leaf rust, stem rust and net blotch and comparable for scald and shoot fly.

Malt Quality Evaluation

Moeta, *Behati* and *Bekoji* were evaluated for important malt quality. The malting profile for *Moeta* is better than checks for kernel weight, plump kernels, hectoliter weight and grain protein content. The variety is characterized by having low percent of protein content which were in the accepted range. Desirable protein content range for 2-rowed barley is 9.0-11.0% and for 6-rowed barley is 9.0-11.5% (Anonymous, 2012). *Moeta* has shown relatively high percentage of malt extract to *Behati* and *Bekoji* (Table 2). The grain and malt quality analysis result of the variety was in agreement to the quality standred set by malt factory.

Adaptation

Moeta is released for the highlands of Bale and similar agro-ecologies. It performs very well in area having an altitude of 2300 to 2600 m a.s.l and annual rainfall of 750-1600 mm. This variety give better grain yield if it is produced with recommended fertilizer rate of 150 kg/ha DAP only and seed rate of 100 kg/ha in clay-loam soil. For best performance of the variety, it is better if planting is done from mid-June to early August in *Meher* (*Bonaa*) and to the end of March during *Belg* (*Gannaa*) season.

Conclusion

Moeta is superior variety compared to the standard checks in grain yield performance in the multi-location trials across the testing environments with good malting quality attribute and yield stability. It has better agronomic performance with moderate tolerance to leaf diseases. Hence, cultivation of the new variety is recommended in major barley growing areas of the country having similar climatic conditions with the testing sites.

Table 1. Summary of pooled mean grain yield, other agronomic and qualitative data

Variety	DH	DM	PH	ST	YLD	HLW	NB	SR	LR	SC	BSF	
											Inf.	D.pla
Moeta	69	122	89	74	3.0	65.0	82	5ms	5ms	0	0.2	0.2
Behati	71	123	87	67	2.5	67.5	88	10ms	10ms	1	0.4	0.2
Bekoji	73	124	92	73	2.6	68.6	86	15ms	20s	2	0.4	0.2

**DH=days to heading, DM= days to maturity, PH= plant height, YLD= grain yield t ha-1, TKW= thousands kernel weight, HLW=hectoliter weight, NB= Net blotch, SR= stem rust, LR=leaf rust, SC= scald, BSF=barley shoot fly, Inf= infestation and D.pla=dead plant*

Table 2. Summary of laboratory analysis for major malt quality of *Moeta* and the checks

Variety	Thousand kernel weight(gm)	Protein Content (%)	Extract difference (%)	Friability (%)	*B*-Glucan Content (mg/L)
Moeta	37.3	10.2	81.8	73.3	250.5
Behati	46.6	10.9	79.5	55.8	670.7
Bekoji	42.8	10.6	80.6	66.6	547.5

Table 3. Combined mean grain yield and other agronomic traits of malt barley regional variety trial over years (2014-2015) and over
locations (Sinana, Robe, Goba, Dinsho and Dodola).

Genotypes	DH	DM	PH	ST	YD	TKW	HLW
IBLSGP09/10#14	68	121	86	73.6	2.7	50.6	66.9
IBCB-SPRING09/10#62	74	124	84	62.0	2.0	43.3	66.4
IBCB-SPRING09/10#63	70	121	83	71.4	2.7	44.3	65.4
IBCB-SPRING09/10#64	69	121	82	69.2	2.5	49.7	65.7
BSI 49	69	121	83	71.5	2.3	47.5	66.4
BSI54	72	125	90	78.1	2.7	40.4	64.5
IBON-H135	71	122	85	76.5	3.1	46.6	66.3
IBON-H166	70	122	87	75.0	2.9	39.8	64.9
IBON-H168	71	124	86	68.7	3.1	35.4	64.6
DRUMMOND/M111/6/P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PENTUNIA	69	121	92	72.4	2.6	45.9	65.6
ESTAZUEL JACRANDA COLON//CANCEL	70	120	86	70.0	2.6	46.7	65.7
LEGACY/4/TOCTE//GOB/HUMAI 10/3/ATAH92/ALELI/5/ARUPO/K8755//MORA	69	122	89	74.6	3.0	37.3	65.0
CANELA/DEFRA	69	122	85	68.9	2.8	35.2	62.6
MSE/CONLON	74	125	77	68.7	2.6	51.3	67.7
PFC9216/BICHY 2000	68	120	86	66.3	2.6	50.3	66.1
API/MOLINA 94	77	123	79	66.6	2.4	40.7	64.1
TR#17	78	124	78	64.9	2.2	41.6	65.3
TR#18	71	127	89	65.2	2.5	48.3	66.5
TR#19	69	124	85	73.5	2.9	43.4	67.2
Bekoji	73	124	92	72.7	2.6	42.8	68.9
Behati	71	123	87	66.7	2.5	46.6	67.5
Holker	73	125	99	71.6	2.5	43.1	68.8
Beka	76	127	106	80.4	2.4	39.0	68.1
Means	71.2	122.9	86.8	70.7	2.6	43.9	66.08
CV %	3.8	2.9	8.1	11.8	25.3	7.7	
LSD	4.4	5.7	11.2	13.0	1.1	5.4	

Key: **DH=days to heading, DM= days to maturity, PH= plant height, YLD= grain yield t ha-1, TKW= thousands kernel weight, HLW=hectoliter weight*

Appendix I. Agronomic and morphological characteristics of *Moeta* (LEGACY/4/TOCTE// GOB/ HUMAI10/3/ATAH92/ALELI/5/ARUPO/K8755//MORA)

Agronomic characters	
Altitude (m.a.s.l)	2300 -2600
Rain fall (mm)	750 -1600
Fertilizer rate (DAP in kg/ha)	150
Seed rate(kg/ha)	100
Planting date	Mid-June to early August
Days to heading	69
Days to maturity	122
Plant height(cm)	89
Growth habit	Erect
1000 seed weight(g)	37.3
Seed color	White
Row type	6 row
Hectoliter weight (Kg/L)	65
Crop pest reaction	Moderately Resistance
Grain yield(t/ha)Research field	3.4
Grain yield (t/ha) Farmer's field	3.5 -5.1
Year of released	2018
Breeder/maintainer:	SARC/OARI

Reference

Anonymous. (2012). Progress report of All India coordinated wheat and barley improvement project 2011-12. Vol. VI. Barley Network. Directorate of Wheat Research, Karnal, India.

Bayeh Mulatu and Berhane Lakew. 2011. Barley research and development in Ethiopia – an overview. *1n:* 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.

Eberhart, S.A. and Russell, W.A. 1966. Stability parameters for comparing varieties. *Crop Science* 6:36-4

Registration of "Dursi" Newly Released Tef (*Eragrostis Tef* (Zucc.) Trotter) Variety

[1*]Girma Chemeda, [1]Chemeda Birhanu, [1]Kebede Desalegn, [1]Gudeta Bedada and [2]Dagnachew Lule
[1]*Bako Agricultural Research Center, Cereal Crop Research, P.O.Box: 03, Bako, Ethiopia*
[2]*Oromia Agricultural Research Institute (OARI), Addis Ababa, Ethiopia*
[1]**Corresponding author: girmachemeda@yahoo.com*

Abstract
Dursi (Acc. 236952) is improved tef variety developed at Bako Agricultural Research Center (BARC). *Dursi* was tested at Shambu, Gedo and Arjo sub sites of Bako Agricultural Research Center during 2016 and 2017 main cropping season along with 10 other pipeline varieties. Dursi was selected for its best and stable performance, verified at on-station and on farmers' field, evaluated by the national variety release technical committee and released. This variety has about 26% yield advantage over the standard check and stable performance in the acidic soils of western Oromia. Therefore, the variety is recommended for wider production in the highlands of Western Oromia and similar agro-ecologies.

Key words: *Eragrostis Tef,* Genotype and Genotype by environment interaction (GGE), Stability

Introduction
Eragrostis tef (Zucc.) Trotter, is a self pollinated warm season annual grass with the advantage of C4 photosynthetic pathway (Seyfu, 1997). Tef is among the major Ethiopian cereal crops grown on about 3 million hectares annually (CSA, 2015), and serving as staple food grain for over 70 million people. Tef has an attractive nutritional profile, being high in dietary fiber, iron, calcium and carbohydrate (Hager *et al*., 2012). Besides, it has high level of phosphorus, copper, aluminum, barium, thiamine and excellent composition of amino acids essential for humans (Abebe *et al*., 2007). The straw (*chid*) is an important source of feed for livestock. Generally, the area devoted to tef cultivation is high because both the grain and straw fetch high domestic market prices. Tef is also a resilient crop adapted to diverse agro-ecologies with reasonable tolerance to both low (especially terminal drought) and high (water logging) moisture stresses. Tef, therefore, is useful as a low-risk crop to farmers due to its high potential of adaptation to climate change and fluctuating environmental conditions (Balsamo *et al.*, 2005). Nevertheless, tef was considered as "orphan" crop: the one receiving no international attention regarding research on breeding, agronomic practices or other technologies applicable to smallholder farmers (Seyfu, 1997).

Because of its gluten-free proteins and slow release carbohydrate constituents, tef is recently being advocated and promoted as health crop at the global level (Spaenij-Dekking *et al*., 2005). Inadequate research investment to the improvement of the crop is one among the major tef productivity constraints. Therefore the objective of this activity was to evaluat and release high yielding, lodging and diseases tolerant tef variety for tef growing areas of western parts of the country.

Variety origin and evaluation

Dursi was formerly introduced from Ethiopian Biodiversity Institute (EBI). Eleven selected genotypes were evaluated at Regional Variety Trial (RVT) stage against standard (Kena) and local check for two consecutive years (2016 and 2017) at Shambu, Gedo and Arjo research sub sites. Dursi was selected for its best and stable yield performance, verified at on-station and on farmers' field and officialy released in 2018.

Morphological and Agronomic characteristics

"*Dursi*" has medium plant height, good tillering capacity, tolerant to lodging and major tef diseases. Detail description of the variety is presented in Table 1 and Table 2. During the multi-location trial, combined analysis of variance across the three locations revealed highly significant ($p<0.01$) difference among genotypes for plant height, panicle length, shoot biomass, lodging % and grain yield qt ha^{-1} (Table 1).

Table 1. Mean grain yield (qt/ha) per location across years

Accession	Shambu		Gedo		Arjo		Mean	% yield
	2015/16	2016/17	2015/16	2016/17	2015/16	2016/17		advantage
Acc.236952	25.07	21.2	22.56	23.3	21.34	23.63	22.85	26
Acc.55253	21.87	23.02	21.95	21.81	20.12	21.81	21.76	19.29
DZ-01-1001	19.16	20.61	17.03	18.58	16.75	18.87	18.5	
DZ-01-1004B	19.31	20.42	16.53	16.77	16.72	16.52	17.71	
DZ-01-102	21.80	20.3	19	20.1	20.74	19.69	20.27	11.13
DZ-01-385	20.44	18.82	18.71	21.02	14.77	20.81	19.1	
DZ-01-739	19.22	19.97	19.43	18.48	17.55	18.41	18.84	
DZ-01-778	20.65	19.02	20.02	18	18.53	18.83	19.18	
DZ-01-821	20.18	18.94	19.38	18.51	18.31	19.14	19.08	
Kena	20.09	20.43	18.3	16.37	17.83	16.44	18.24	
Local	16.91	17.98	17.48	18.06	17.06	17.77	17.54	
Mean	20.25	20.43	19.18	19.27	18.16	19.27		
CV	8.9	6.3	6.6	6.1	11.3	4.3		
F-Value	<0.005	<0.002	<0.001	<0.001	<0.028	<0.001		

Table 2: Mean Agronomic traits across years and locations

Genotype	GYTha-1	LD%	LR	NFT	PH	PL	SBMT/ha
Local check	1.75	60.56	1.00	16.34	40.19	24.67	66.21
DZ-01-1004B	1.77	56.67	3.42	17.97	43.03	29.53	79.79
Acc.236952	2.29	6.89	1.50	18.88	45.24	34.13	87.71
DZ-01-821	1.91	10.00	2.76	18.33	51.41	32.87	67.36
Acc.55253	2.18	13.61	1.60	20.91	49.02	33.07	89.56
Kena	1.82	79.44	2.00	18.38	45.58	29.67	82.54
DZ-01-739	1.88	6.89	1.41	21.24	56.07	27.47	87.75
DZ-01-1001	1.85	18.89	3.39	18.32	50.99	32.07	62.71
DZ-01-102	2.03	60.00	1.61	17.89	47.00	33.53	79.82
DZ-01-385	1.91	7.67	3.56	20.43	50.54	26.80	86.17
DZ-01-778	1.92	43.33	3.11	20.56	51.91	30.20	84.64
Mean	1.94	32.85	2.31	19.02	48.27	30.36	79.80
CV%	6.70	34.00	26.40	14.10	10.30	8.30	18.90
LSD	0.09	8.66	0.75	1.77	3.28	3.49	9.97
F-Value	**	**	**	**	**	**	**

Key: $GYTha^{-1}$=Grain yield per hectare, LD%=Lodging %, LR=leaf rust, NFT=Number effective tiller, PH=plant height, PL=Panicle Length, SBMT/ha=Shoot Biomass ton per hectare

Grain Yield Performance

The average grain yield combined over locations and over years for *Dursi* variety is (22.85qt ha^{-1}) which is higher than Kena (standard check) (18,24 qt ha^{-1}.) and the local check (17.54 qt ha^{-1}). The variety yielded 20-24 qt ha^{-1} on research station and 18-22 qt ha^{-1} on farmers' field.

Table 1. Agronomic & morphological characteristics of Dursi variety

Agronomic characters and descriptions of *Dursi*	
Variety name	*DURSI* (Acc. 236952)
Adaptation area	Shambu, Gedo, Arjo, and similar agro ecologies
▪ Altitude (masl)	1850-2500
▪ Rainfall (mm)	1800-2000
Seeding rate (kg/ha)	10 and 15 (row spacing and broad cast, respectively)
Spacing (cm):	20cm Between rows
Planting date:	Early July to mid July
Fertilizer rate (kg/ha):	▪ 100 DAP all at planting ▪ 50 UREA (half at planting & half after 25 days)
Days to heading:	70
Days to maturity:	132
1000 seed weight (g):	0.3
Plant height (cm):	115
Seed color:	cream White
Panicle color:	yellowish at maturity
Crop pest reaction*	
Grain yield (qt/ha):	▪ On farmers field: 18-22qt/ha. ▪ On-station: 20-24 qt/ha.
Year of release:	2018
Breeder/ maintainer:	BARC/OARI

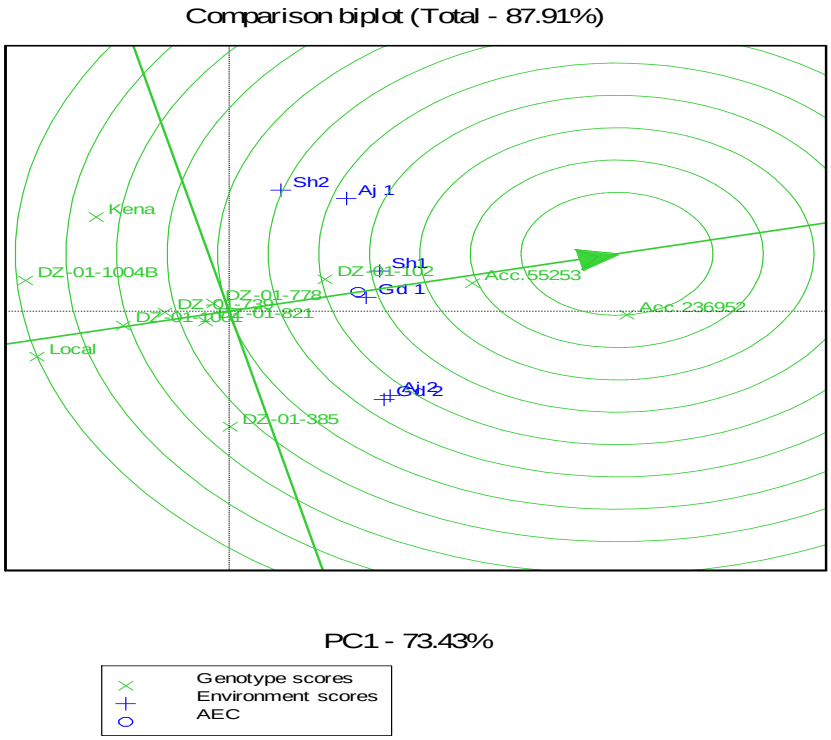
*=Tolerant to major Tef diseases (Head smudge and Rust)

Stability performance

The GGE biplot analysis revealed that the released variety *Dursi* or Acc. 236952 fall relatively close to the concentric circle near to average environment axis, suggesting their potential for wider adaptability with better grain yield performance (Fig 1).

Adaptation

Dursi is released for the high lands of Western Oromia and similar agro-ecology receiving sufficient amount rain fall (1800mm-200mm) and altitude ranges of 1850-2500 m.a.s.l. The variety performs best with its full agronomic recommendations presented in Table 1.



Key: SH1 and SH2=Shambu year one and two, Gd1 and GD2= Gedo year one and two, Aj1 and Aj2=Arjo year one and two

Fig 1: GGE biplot analysis showing stability of genotypes and test environments

Conclusion

Dursi is stable in its grain yield and has good agronomic traits that make it suitable for production in its recommended domain of Western high highlands of Oromia when its agronomic recommendations maintained.

References

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

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

Central Statistical Agency (CSA) 2015. The federal Democratic Republic of Ethiopia. Central Statistical Agency Agricultural Sample Survey 2014/15: Report on Area and Production of Major Crops (Private peasant Holdings, Maher Season), Vol III. Addis Ababa.

Seyfu Ketema. 1997. Tef. *Eragrostis tef* (Zucc.) Trotter. Promoting the conservation anduse of underutilized and neglected crops. 12. Institute of Plant Genetics and CroPlant Research, Gatersleben/International Plant Genetic Resources Institute, Rome, Italy

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

Genotype by environment interaction and stability analysis of Bread wheat (*Triticum aestivum* L.) genotypes in mid and highlands of Bale, South-eastern Ethiopia

Behailu Mulugeta[1]*, Tilahun Bayisa[1], Mulatu Abera[1], Tesfaye Letta[2] and Tamene Mideksa[1]
[1]Sinana Agricultural research Center, P.O. Box 208, Bale Robe, Ethiopia,
[2]Oromia Agricultural research Institute, P.O. Box 81265, Addis Ababa, Ethiopia,
*Corresponding author: behailu.mulugeta30@gmail.com

Abstract
Thirty-five bread wheat genotypes including three standard checks were tested at three locations in 2016 and 2017 under rainfed condition to select high yielding, stable and disease resistant bread wheat genotypes suitable for optimum environments. The experiment was laid out using alpha lattice design with three replications. There was highly significant ($p<0.01$) variation among genotypes and environments for grain yield. The highest combined mean grain yield was recorded for genotype ETBW 8362 (4607.31 kg ha^{-1}). Stability was estimated using Additive main effect and multiplicative interaction (AMMI). AMMI analysis also showed that IPCA1 and IPCA2 captured 46.60 % and 24.1 % of the genotype by environment interaction sum of squares. Genotypes ETBW 8362 and ETBW 8310 were stable and high yielder across all locations and recommended to be verified for possible release.

Introduction
Wheat is one of the major cereal crops widely produced in the highlands and mid-altitudes areas of south east, central and North West parts of Ethiopia. Ethiopia is the largest wheat producer in the Sub-Saharan Africa (FAOSTAT, 2016). Among the types of wheat, bread wheat (*Triticum aestivum* L.) and durum wheat (*T. turgidum* L. var. durum) are popularly produced by small scale farmers. Arsi and Bale highlands are the major wheat producing regions of Ethiopia and are thought to be the wheat belts of East Africa (SARC, 2018). The area under wheat production is estimated to be about 1.7 million hectares, which makes the country the largest wheat producer in Sub-Saharan Africa (CSA, 2016).

Information regarding phenotypic stability is found an important tool for the selection of crop varieties and breeding programs (Singh, 1990). Genotype by Environment Interaction (GEI) mostly complicates breeding, testing and selection of superior genotypes in the variety development program (Singh and Chaudhary, 1977).). Therefore, it is important for breeders to identify specific genotypes adapted or stable to different environment(s), thereby achieving quick genetic gain through selection of genotypes for high adaptability and stability under varying environmental conditions prior to their release as cultivars. In the absence of genotype by environment interaction, only the mean grain yields across environments are sufficient indicator of genotypic performance (Yan and Kang, 2003).

The phenotypic performance of genotypes under different agro-ecology is not necessarily similar. The concept of stability was coined in several ways by many scientists and a variety of statistical procedures (univariate and multivariate) are in fact available to determine stability of genotypes over varied environment (Scarpim, *et al.*, 2000; Sneller, *et al*., 1997;

and Cross, 1990). AMMI analysis was used to determine stability of the genotypes across locations using the PCA (principal component axis) scores and ASV (AMMI stability value). It is a hybrid that involves both additive and multiplicative components of two way data structure and considered to efficiently diagnose GEI in graphical methods. In AMMI model, additive portion is separated from interaction by supporting it with Analysis of variance (ANOVA). From this, the principal component Analysis (PCA) provides a multiplicative interaction applied to analyze interaction from additive ANOVA model. Then, the biplot of PCA scores are plotted against each other to give visual inspection and interpretation of GEI components. The AMMI model also combines the analysis of variance for genotypes and environments main effect with PCA of the GEI (Kaya, *et al.*, 2002).

In the AMMI model, the combination of analysis of variance and principal component analysis along with prediction assessment is an important approach to understand genotype by environment interaction and helps to obtain better estimate of grain yield of genotypes with its stability and adaptability over various environment (Kaya, *et al.*, 2002). Therefore, the objectives of the present study were to estimate genotype by environment interaction and to determine the stabile and high yielder bread wheat genotypes suitable for optimum environments of Bale zone and similar agro-ecologies of south eastern Ethiopia.

Materials and Methods

Plant materials and experimental design

The experiment was conducted at three potential wheat producing locations (Sinana, Gololcha and Ginir) of Bale. A total of 35 bread wheat genotypes including three released commercial varieties (Dambal, Sanate and Mada Walabu) were evaluated for two consecutive years (2016/17-2017/18) during the *bona* (August to December) cropping season (Table 1). The field experiment was conducted using Alpha lattice design with three replications. The plot size was 3 m^2 (6 rows of 2.5 m long) with a row to row spacing of 20 cm. Fertilizer was applied at the rate of 41/46 kg ha^{-1} N/P_2O_5. All agronomic and crop management practices were applied uniformly to all genotypes as per the recommendation for wheat.

Statistical analysis

Hartley`s test (F-max test) was used to assess the homogeneity of error variance prior to computing the combine analysis over environment (Gomez and Gomez, 1984). For this analysis, locations and genotypes were considered as random and fixed variable, respectively. Data analysis and genotype by environment interaction analysis was done using R statistical software (Pacheco *et al*., 2016; R software, 2018).

The combined analysis of quantitative trait was conducted by using the following linear Additive model:

$$\mathbf{P_{ijs}=\mu + L_s+(\tau xl)_{is} + \pi_{j(s)} + \tau_i+\xi_{ijs}}$$

P_{ijs} = phenotypic value of i^{th} genotype under j^{th} replication at s^{th} location, μ=grand mean; τi=the effect of i^{th} genotype; $\pi j_{(s)}$ =the effect of replication j within locations; $_{Ls=}$the effect of location; $(\tau xl)_{is}$=the interaction effects between genotype and location; and ξ_{ijs} =Pooled error

Stability analysis were done using the methods of: Eco-valance (Wrickes, 1965), Eberhart and Russell (1966), and Additive main effects and multiplicative interaction AMMI (Zobel *et al*., 1988) The AMMI model was done based the formula suggested by Cross (1990).

$$\mathbf{Y_{ij} = \mu + G_i + E_j + (\Sigma K_n U_{ni} S_{nj}) + Q_{ij} + e_{ij}}$$

Where (i = 1, 2,…35: j = 1, …6); Y_{ij} = The performance of the i genotype in the j environment; μ = The grand mean; G = Additive effect of the i genotype (genotype mean minus the grand mean); K = Eigen value of the PCA axis n; E = Additive effect of the j^{th} environment (environment mean deviation); U and S = Scorer of genotype i and environment j for the PCA axis n; Q = Residual for the first n multiplicative components and; e = error.

Eberhart and Russell and AMMI stability analysis

The slope of regression value (b_i) was computed according to Eberhart and Russell (1966). Wricke's eco-valance ($\omega^2 i$) was calculated as suggested by Wrickes (1965).

AMMI is the best model to estimate stability of genotypes grown multi environment trial due to its degree of visualizing GEI in graphic structure and separate the additive portion from interaction by the analysis of variance. The AMMI stability value (ASV) was calculated for each genotype according to the relative contribution of IPCA1 to IPCA2 to the interaction sum of square as described by Purchase (1997) as follow:

$$ASV = \sqrt{\left[\frac{IPCA1\ sum\ of\ square}{IPCA2\ sum\ of\ square}(IPCA1\ Score)\right]^2 + (IPCA1\ scpre)^2}$$

ASV = AMMI stability value, IPCA1 = interaction principal component analysis 1, IPCA2 = interaction principal component analysis 2, SSIPCA1 = sum of square of the interaction principal component one and SSIPCA2 = sum of square of the interaction principal component two

Results and Discussion

Analysis of variance

The result of pooled analysis of variance revealed highly significant difference (*p<0.01)* for days to heading and maturity, plant height, grain yield, and thousand kernel weight (TKW) over combined locations (Table 1). The highest pooled mean performance of grain yield was recorded for the genotype ETBW 8362 (4607.31 kg ha^{-1}), whereas the lowest mean was obtained from Genotype ETBW 8163 (2951.97 kg ha^{-1}) (Table 1). Genotype ETBW 8362 also revealed the highest TKW, test weight and also found moderately resistance to yellow rust, stem rust, leaf rust and septoria (Table 1). The results for combined analysis of variance showed that differences among genotypes, locations and genotype by location interactions were statistically different at probability level of p<0.01 for traits such as days to heading, days to maturity, plant height, stand percent, thousand kernel weight and grain yield

Additive main effect and Multiplicative interaction (AMMI)

The AMMI analysis of variance for grain yield revealed that 35.76 % of the total sum square (TSS) was attributable to environmental effects. Genotype and GEI contributed 40.20 % and 23.95% of the total sum of squares, respectively. Therefore, large TSS of genotype indicated

that genotypes are diverse, and the environment also found variable. This finding agrees with Taye *et al.* (2000), Kaya, *et al.* (2002) and Alberta (2004).

Table 1. Combined Mean performance of agronomic traits and disease reactions of 35 bread wheat genotypes tested at Sinana, Gololcha and Ginir during 2016 and 2017 main growing season

		Yield, Agronomic and Disease Data									
SN	Genotype	DTH	DTM	PLH	STP	BW	GY	TKW	HLW	YR	SR
1	ETBW 8252	62	128	79.61	76.94	1.96	2892.25	41.17	79.33	5ms	trms
2	ETBW 8253	62	126	87.50	76.11	2.09	3140.47	36.41	79.47	30s	5s
3	ETBW 8265	66	126	82.83	72.78	1.68	2489.61	37.35	82.40	40s	trms
4	ETBW 8280	60	128	88.28	78.61	2.17	3806.44	40.71	80.27	10s	15s
5	ETBW 8283	60	128	86.33	73.33	1.63	2243.25	32.15	78.67	60s	5s
6	ETBW 8287	63	125	87.94	77.22	2.14	4042.64	45.46	83.07	5ms	5ms
7	ETBW 8292	67	127	76.17	71.67	1.22	1453.89	25.55	78.67	60s	0
8	ETBW 8310	58	126	86.22	77.78	2.02	4470.11	37.43	84.13	30s	trms
9	ETBW 8336	62	128	81.33	73.61	1.94	3385.14	39.74	81.33	30s	trms
10	ETBW 8348	63	129	80.67	74.72	1.96	3057.58	39.37	82.13	10s	0
11	ETBW 8359	63	127	82.56	78.33	1.92	3643.31	37.26	83.20	10s	trms
12	ETBW 8362	57	127	85.06	76.11	1.89	4607.31	36.78	84.27	15ms	trms
13	ETBW 8064	63	128	79.00	78.89	2.17	3079.50	33.07	83.07	10ms	0
14	ETBW 8065	64	129	80.11	79.72	2.21	3108.64	34.77	81.60	10ms	trms
15	ETBW 8066	63	126	83.06	78.89	2.03	3552.69	35.19	84.00	10s	trms
16	ETBW 8070	61	127	82.94	78.06	2.12	3621.36	36.66	83.47	15s	trms
17	ETBW 8145	63	127	85.11	77.50	2.13	3698.61	37.71	83.47	5ms	0
18	ETBW 8290	61	125	86.61	78.33	2.11	3885.78	38.12	81.60	40s	trms
19	ETBW 8163	62	126	78.22	73.89	1.74	2951.97	32.70	82.53	30s	15s
20	ETBW 8342	63	125	85.11	79.17	1.93	2698.36	33.40	79.47	40s	5ms
21	ETBW 8309	61	129	84.94	73.06	1.83	3171.58	41.19	82.27	40s	5ms
22	ETBW 8206	61	128	80.22	74.17	2.04	3453.06	39.09	83.20	50s	5ms
23	ETBW 8264	60	127	84.83	75.28	1.68	2435.42	31.73	79.07	50s	0
24	ETBW 8304	63	125	87.94	75.83	2.06	3506.92	44.88	82.93	40s	trms
25	ETBW 8332	63	129	83.67	73.61	1.92	3071.67	41.44	82.67	30s	0
26	ETBW 8338	59	128	84.56	76.94	2.07	4088.25	38.74	83.73	40s	20s
27	ETBW 8411	58	127	89.39	79.72	2.01	3924.06	35.34	82.93	20s	trms
28	ETBW 8441	61	127	79.17	74.17	1.98	3809.72	35.79	84.60	5ms	trms
29	ETBW 8442	63	128	79.22	79.72	2.16	3671.81	32.61	82.53	15ms	trms
30	ETBW 8445	60	127	76.28	76.67	1.89	3972.75	38.17	83.73	30s	0
31	ETBW 8451	64	126	80.00	76.67	2.10	3262.08	29.27	81.33	40s	0
32	ETBW 8452	59	128	85.06	78.61	2.12	3309.72	36.68	83.87	80s	0
33	Mada Walabu	61	127	90.67	79.17	2.18	**3025.92**	36.07	79.73	40s	30s
34	Dambal	61	127	88.83	76.11	1.93	**3627.19**	38.81	83.20	30s	5ms
35	Sanate	62	127	96.56	83.33	2.31	**4141.68**	37.73	79.47	10ms	5s
	Mean	62	127	83.89	76.71	1.98	3380.02	36.82	82.04		
	CV (%)	2.89	1.33	5.78	8.47	20.7	21.50	21.50			
	SE	1.8	1.7	4.85	6.50	0.41	725.40	3.83			
	LSD at 5%	1.2	1.2	3.2	4.25	0.27	475.20	2.60			

Key: DTH: days to heading, DTM: days to maturity, PLH: plant height (cm), STP: Stand percent, BW: Biomass weight(Kg/plot), (TKW: thousand kernel weight (gm), HLW: test weight (kg/hl), GY: grain yield (kg ha^{-1}), SR: stem rust (%), YR: yellow rust (%), LR: leaf rust (%), S: Susceptible, MS: moderately susceptible, SMS: Susceptible to moderately susceptible, Mr: Moderately resistance, CV (%): Coefficient of variations, LSD: Least significant differences

AMMI analysis of variance for grain yield (kg ha^{-1}) revealed highly significant ($p < 0.01$) differences for genotype, location and genotype by location interaction (Table 2). The presence of the genotype by location interaction was indicated by changes in relative rankings

of genotypes over various locations. The genotype effect was responsible for the greatest part of the variation, followed by locations and genotype by location interaction effects. Taye *et al.* (2000), Kaya *et al*. (2002) and Alberta (2004) also reported similar results with this report. Both genotypes and environment were plotted on the same graph and showed clear association between the environment and genotypes (Figure 1). AMMI analysis also showed that IPCA1 and IPCA2 captured 46.60 % and 24.1 % of the genotype by environment interaction sum of squares and this two PCA's accurately predict the AMMI model (Table 2 and Figure 1). Yan and Rajcan (2002) reported that the best accurate model of AMMI can be predicted by using the first two PCA's.

Table 2. AMMI analysis of variance for grain yield tested at six locations (Two year)

Variables	Df	MS	F-value	Pr(>F)	% explained
Environment	5	45048255**	78.0556		35.76
Rep (Environment)	12	577130^{NS}	1.3542	0.1854	
Genotype	34	7460827**	17.5063		40.2
Genotype: Environment	170	887484**	2.0824		23.95
AMMI PCA1	38	1850800**	4.34		46.60
AMMI PCA2	36	1011523**	2.37		24.10
Residuals	408	426179^{NS}			

**p<0.01, NS= non-significant, Df =degrees of freedom, MS=mean square.

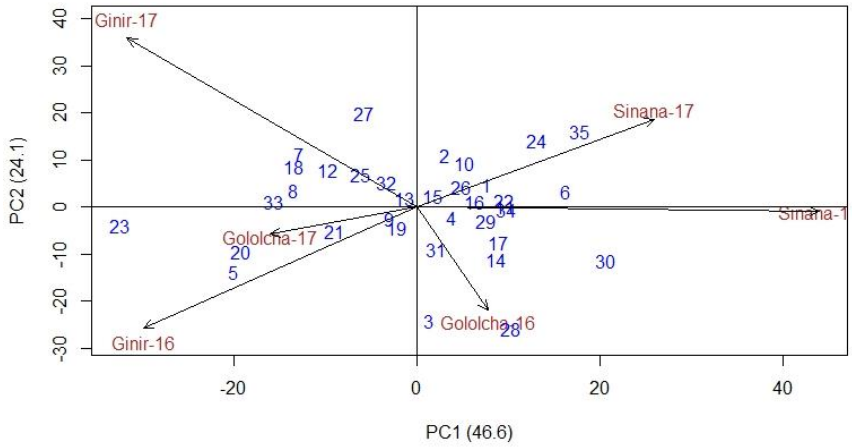


Figure 1. AMMI of the first two IPCA's (Numbers 1 -35 represent genotypes mentioned in Table 1)

Linear regression and Eco-valance

Genotypes having high mean grain yield, a unit regression coefficient over the environment's (*bi* = 1.00), lower value of deviation from regression (S^2di) (Eberhart and Russel, 1996) and lower eco-valance (Wricke, 1965) is considered to be stable. Accordingly, genotypes ETBW 8411, ETBW 8342, ETBW 8441, ETBW 8348, ETBW 8310, ETBW 8070, ETBW 8362 and ETBW 8066 were found among the stable genotypes based on regression coefficient (b_i) (Table 3). Genotypes ETBW 8064, ETBW 8163, ETBW 8336, ETBW 8070, ETBW 8359, and ETBW 8066 are with lower deviation from regression coefficient (b_i) and Eco-valance. Based on AMMI analysis of IPCA1 and IPCA2, genotype ETBW 8310 and ETBW 8362 were selected at Gololcha and Ginir, and genotype ETBW 8287 and ETBW 8362 were selected at Sinana.

AMMI stability Value and Yield Stability Index

Purchase (1997) reported that calculating the AMMI stability value (ASV) is a balanced measure of stability. Therefore, the genotypes with lower ASV are considered more stable and genotypes with higher ASV are unstable. The analysis based on AMMI stability value indicated that ETBW 8280, ETBW 8336, ETBW 8064, ETBW 8066, ETBW 8070, ETBW 8163, ETBW 8452, and ETBW 8338 were among genotypes with lower ASV and revealed that these genotypes are relatively more stable than other genotypes used in the study, whereas ETBW 8264 and ETBW 8263 scored higher ASV and thus least stable genotypes (Table 3). Purchase (1997) noted that AMMI stability value (ASV) can quantify and rank genotypes according to their yield stability. Genotypes ETBW 8362, ETBW 8310, ETBW 8338, ETBW 8287, ETBW 8411, ETBW 8445, ETBW 8290, and ETBW 8441 also revealed the least yield stability index (YSI) indicating that these genotypes are stable genotypes.

Results from the present AMMI analysis of variance also revealed that only mean square of the first and second interaction principal component axis (IPCA1 and IPCA2) were found to be highly significant ($P<0.01$). Yan and Rajcan (2002) reported that the best accurate model of AMMI can be predicted by using the first two PCA's which is in agreement with the present study. But, the third and fourth IPCA's captured in non-significant portion of the variability. Some scholars reported that AMMI with three or four IPCA axes is the best predictive model (Crossa, *et al.,* 1991)**.** IPCA score of genotypes were reported by Guach and Zobel (1996) and Purchase (1997) by indication stability of genotypes across test environments. Therefore, predictive evaluation using F-test at $p<0.01$ revealed two principal components axes were significant (Table 2).

Stability analysis based on GGE biplot

GGE biplot was the best way to visualize the interaction patterns between genotypes and environments and to effectively interpret a biplot (Yan and Kang, 2003). In this study, the 'which won where' feature of the biplot identified winning genotypes; ETBW 8362 (represented by genotype # 12) for instance, was the winning/corner genotype at Sinana, Gololcha and Ginir (Fig 2). The vertex genotypes were the most responsive genotypes, as they have the longest distance from the origin in their direction as suggested by Yan and Tinker (2005). In contrast, result also showed some genotypes which fall in sectors where genotypes poorly adapted and genotype ETBW 8292 (genotype # 7) poorly performed and adapted in the environments used

Table 3. Mean performance of grain yield, AMMI stability value (ASV), Rank of ASV (rASV), Yield stability Index (YSI), rank of YSI (rYSI) and IPCA's of 35 bread wheat genotypes grown at multilocations and years

S/N	Genotype	YLD	IPCA1	IPCA2	ASV	rASV	YSI	rYSI	b_i	S_2d_i	ω_i
1	ETBW 8252	2892.25	0.24	0.13	11.63	12	42	30	0.86	0.10	973874.00
2	ETBW 8253	3140.47	0.09	0.33	11.72	13	36	23	0.64	0.13	1307005.27
3	ETBW 8265	2489.61	0.02	-0.79	24.2	29	61	32	0.79	0.40	2242687.68
4	ETBW 8280	3806.44	0.14	-0.11	5.74	5	15	10	0.63	0.20	1660390.99
5	ETBW 8283	2243.25	-0.66	-0.37	31	34	68	34	0.56	0.48	2810657.04
6	ETBW 8287	4042.64	0.45	0.16	22.9	27	32	5	1.25	0.30	1891349.93
7	ETBW 8292	1453.89	-0.38	0.36	21.21	24	59	35	0.64	0.18	1558204.30
8	ETBW 8310	4470.11	-0.40	0.14	19.06	22	24	2	1.06	0.16	1198086.19
9	ETBW 8336	3385.14	-0.09	-0.09	4.91	3	22	19	0.86	-0.12	144535.88
10	ETBW 8348	3057.58	0.18	0.30	11.87	14	41	27	1.02	-0.66	582050.83
11	ETBW 8359	3643.31	0.26	0.05	13.44	16	29	13	1.78	-0.09	1500636.51
12	ETBW 8362	4607.31	-0.29	0.24	15.74	20	21	1	1.30	0.32	2454744.27
13	ETBW 8064	3079.50	0.02	0.06	2.74	1	26	25	0.88	-0.12	106990.90
14	ETBW 8065	3108.64	0.30	-0.36	16.52	21	45	24	0.91	0.10	958733.40
15	ETBW 8066	3552.69	0.05	0.07	3.26	2	18	16	1.20	-0.13	111400.16
16	ETBW 8070	3621.36	0.19	0.02	8.9	8	23	15	1.12	-0.08	309575.79
17	ETBW 8145	3698.61	0.24	-0.24	14.47	19	30	11	0.89	0.01	736945.32
18	ETBW 8290	3885.78	-0.42	0.28	20.68	23	31	8	0.76	0.17	1338703.72
19	ETBW 8163	2951.97	-0.04	-0.15	5.4	4	33	29	0.91	-0.10	131699.08
20	ETBW 8342	2698.36	-0.57	-0.29	28.4	30	61	31	1.04	0.50	2639006.06
21	ETBW 8309	3171.58	-0.22	-0.12	13.5	17	39	22	0.91	-0.01	549901.58
22	ETBW 8206	3453.06	0.31	0.03	13.4	15	33	18	1.29	-0.01	745156.29
23	ETBW 8264	2435.42	-1.00	-0.08	45.4	35	68	33	0.18	0.90	5518191.04
24	ETBW 8304	3506.92	0.43	0.47	23.1	28	45	17	1.46	0.50	2913340.34
25	ETBW 8332	3071.67	-0.14	0.24	11.1	11	37	26	0.66	0.01	886077.82
26	ETBW 8338	4088.25	0.11	0.19	7.9	7	11	4	1.30	-0.07	482860.12
27	ETBW 8411	3924.06	-0.17	0.63	21.6	25	32	7	0.99	0.23	1685412.43
28	ETBW 8441	3809.72	0.27	-0.75	29.4	31	40	9	1.15	0.64	3177408.86
29	ETBW 8442	3671.81	0.19	-0.08	10.9	10	22	12	1.37	-0.02	817712.86
30	ETBW 8445	3972.75	0.60	-0.36	30.9	33	39	6	1.29	0.50	2633767.74
31	ETBW 8451	3262.08	0.05	-0.35	9.5	9	30	21	0.62	-0.06	736154.37
32	ETBW 8452	3309.72	-0.14	0.11	7	6	26	20	0.86	-0.06	396519.45
33	Mada Walabu	3025.92	-0.50	0.00	21.9	26	54	28	0.83	0.18	1344674.72
34	Dambal	3627.19	0.31	-0.04	13.5	18	32	14	1.31	-0.02	696633.50
35	Sanate	4141.68	0.58	0.39	29.5	32	35	3	1.48	0.48	3049662.35

Key: ω_i = Wrickes Ecovalance, bi= Regression coefficient, S^2di =deviation from regression

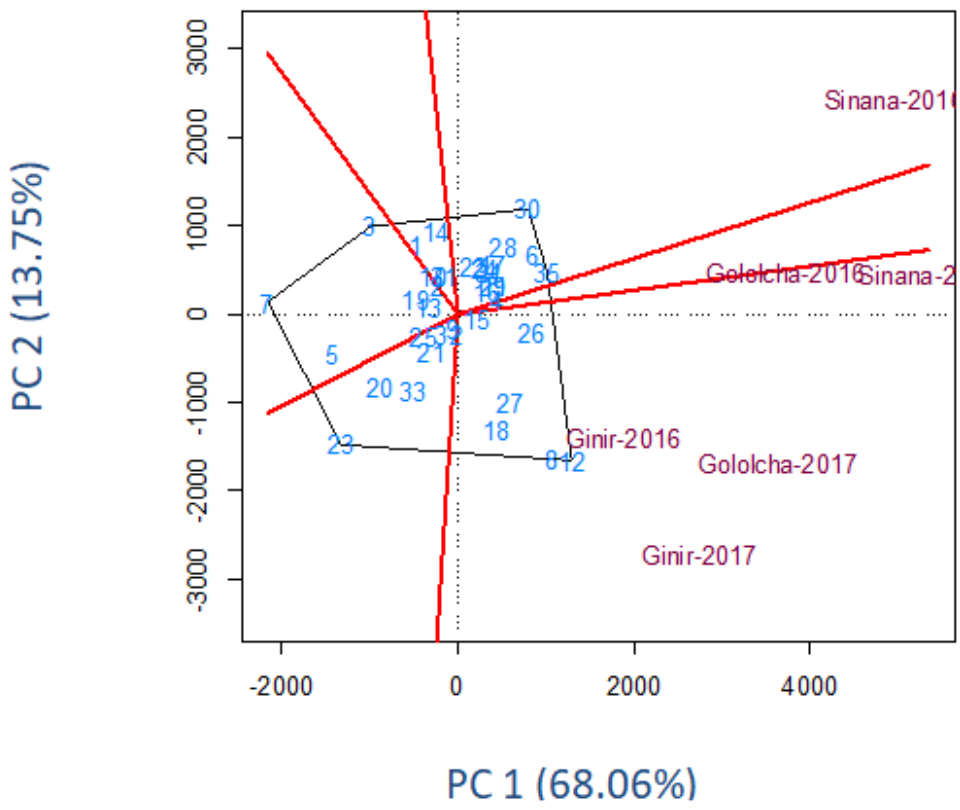


Figure 2. The polygon of GGE biplots of 35 Bread wheat genotypes over the environment

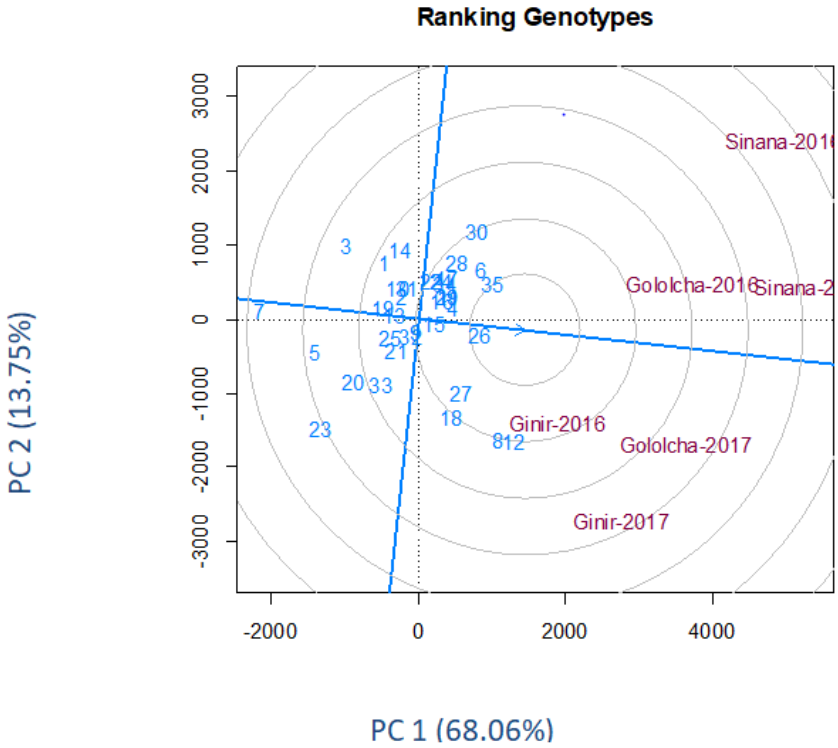


Figure 3: Ranking ideal genotypes for ideal environment

Using ranking genotypes, genotypes that are ideal for all environments also visualized using imaginary line. An ideal genotype should have the highest mean performance and be stable. Therefore, genotype ETBW 8362 (4607.31 kg ha^{-1}) and ETBW 8310 (4470.11 kg ha^{-1}) were found ideal to all locations (Fig. 3).

Conclusion and recommendation

The AMMI analysis for the additive main effect and multiplicative interaction effect revealed significant variance for genotype, location and genotype by location interaction. In multi-environment trial, considering both the stability and mean grain yield is vital. Genotype ETBW8310 and ETBW8362 were found stable and high yielder across all locations. Genotypes with a low PCA score show low G x E interactions and this indicated the stability of genotypes. GGE biplot identified ETBE 8362 as winning corner genotypes. The two genotypes (ETBW 8310 and ETBW 8362) have good test weight and TKW, better disease resistance and white seed color. So, ETBW 8310 and ETBW 8362 genotypes are recommended for verification and release for farmers.

Reference

Alberta, M.J.A. 2004. Comparison of statistical methods to describe genotype by environment interaction and yield stability in multi-location of maize trails. M.Sc. Thesis in University of the Free State.

Central Statistical Agency (CSA). 2016. Report on area and production of major crops (private peasant holdings, meher season). *Statistical bulletin 532, CSA,* Addis Ababa, Ethiopia.

Cross J. (1990). Statistical analysis of multi-location trails. *Adv. Agro.***45**:56-86.

Crossa, J., Fox, P.N., Pfeiffer, W.H. Rajaram, S. and Gauch, H.G.1991. AMMI adjustment for statistical analysis of an international wheat yield trial. *Theor. App. Gen.,* **81**: 27-37.

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

FAOSTAT .2016. Agricultural production statistics. (*http://www.fao.org/faostat.)*

Gauch, H.G., and Zobel R.W.1996. AMMI analysis of yield trails. In: Kang, M.S. and Zobel, H.G. Jr (Eds), genotype by environment interaction, CRC Press, Boca Raton. Pp: 85-120.

Gomez, K.A. and Gomez, A.A. 1984. *Statistical Procedures for Agricultural Research*, 2nd edit. John Wiley and Sons, New York.

Kaya,Y.C., Palta and Taner, S. 2002. Additive main effect and Multiplicative interaction analysis of yield performance in bread wheat genotypes a cross environments. *Turk.J. Agric*. **26**:275-279.

Pacheco, A., Vargas, M., Alvarado, G. , Rodríguez, F., López, M. , Crossa, J.and Burgueño, J. 2016. GEA-R (Genotype x Environment Analysis with R for Windows).

Purchase, J.L. 1997. Parametric analysis to describe GXE interaction and stability in winter wheat. PhD thesis, Department of Agronomy, Faculty of Agriculture, University of the Orange Free State, Bloemfonten, South Africa.

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

SARC (Sinana Agricultural Research Center) 2008. *Annual Report on Cereal Crop Research*. Cereal Crop Research Division, Sinana Agricultural Research center, OARI, Sinana, Ethiopia.

Scarpim, C.A., Olivera, V.R., Braceini, A.L., Cruz, C.D., Andrade, C.A., and Vidial, M.C.G. 2000. Yield stability in maize(Zea mays L.) and correlation among parameters of the Eberhart and Russel, Lin and bianns and Huelan models. *Genet.Mol.Biol*.,**23(2)**:387-393.

Singh, R.K. and Chaudhary 1977. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani publishers, New Delhi-Ludhiana India.

Sneller, C.II., Norquest, L.K., and Dombek, D. 1997. Repeatability of yield stability statistics in soybean.*Crop Sci*. **3**: 383-390.

Taye, G., Getachew, T. and Geletu, B. 2000. AMMI adjustment for grain yield and classification of genotypes and environments in field pea (*Pisumsativum L*.).*J.Genet.Breed*, **54**:183-191.

Wricke G. 1965. On a method of understanding Ecological diversity in field research.*Z pflanzeuzuccht*,**47**: 92-96.

Yan, W. and Kang, M. S. 2003. GGE biplot analysis: A graphical tool for breeders, geneticists, and agronomists. CRC Press, Boca Raton, FL. pp213.

Yan, W. and Rajcan, I. R. 2002. Biplot analysis of test sites and trait relations of soybean in Ontario.*Can. J. Plant Sci*. **42**: 11-20.

Yan, W. and Tinker, N. A. 2005. An integrated biplot system for displaying, interpreting, and exploring genotype 9 environment interaction.*Crop Sci*. **45**: 1004-1016.

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

Additive Main Effect and Multiplicative Interaction (AMMI) and Stability Analysis for Grain Yield of Faba Bean Varieties in the Highlands of Oromia Region, Ethiopia

Tekalign Afeta[1 2*], Bulti Tesso [2] and Dagnachew Lule [3]
[1]Bore Agricultural Research Center, Bore, Ethiopia
[2]School of Plant Sciences, Haramaya University, Haramaya, Ethiopia
[3]Oromia Agricultural Research Institute, Addis Ababa, Ethiopia
Corresponding Author: tekafeta2009@gmail.com

Abstract
Thirteen released faba bean varieties were evaluated across five faba bean growing environments of Oromia highlands during 2017/18 cropping season to determine the stability for grain yield and estimates the magnitude of genotype x environment interaction. The experiment was laid out in randomized complete block designs with three replications. Genotypes, environments and genotype by environment interaction showed highly significance differences ($P \leq 0.01$) for grain yield. The three varieties; Walki, Tumsa and Gebelcho were well performed with combined mean grain yield of 3.35 t ha^{-1}, 3.10 t ha^{-1} and 3.08 t ha^{-1}, respectively. Stability analysis parameters such as regression coefficient (bi), deviation from regression (S^2di), variance (Wi) ecovalence, AMMI stability value and Genotype Selection Index (GSI) revealed that Gebelcho and Shallo varieties were the most stable, but Holeta-2 and Mosisa were the most unstable varieties. AMMI1 biplot showed Gebelcho and Shallo had higher mean grain yield than the grand mean and placed near to the origin (horizontal line). Among the environments, Bore and Uraga were the most favorable environments. Variety Dosha and Tumsa were specifically adapted to Bore and Alleyo environments, respectively. Walki was the best variety for Gedo and Anna Sorra; Alloshe and Mosisa perform better in Uraga.
Keywords: Adaptability; AMMI; Faba bean; Grain yield stability; Variety

Introduction
Faba bean (*Vicia faba* L.) is one of the earliest domesticated food legumes in the world (Singh *et al*., 2013). It is believed that faba bean was introduced to Ethiopia soon after its domestication around 5000 B.C. (Asfaw *et al*., 1994) and the country is now considered as one of the secondary centers of genetic diversity (Bond, 1976; Hailu *et al*., 1991). Accordingly, it grown in mid altitudes and highland regions of Ethiopia between 1800-3000 meters above sea level (ICARDA, 2006; Musa and Gemechu, 2006); where it required chilling temperature with the annual rain fall of 700-1000 mm (Musa and Gemechu, 2006).

Faba bean is one of the major pulses grown in the highlands of Ethiopia (Musa and Gemechu, 2006). Ethiopia is the second largest faba bean producing country in the world next to People's Republic of China and the first in Africa followed by Egypt and Morocco (Saxena, 1991; Haciseferogullari *et al*., 2003; Musa and Gemechu, 2006). Pulses grown in 2016/17 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 was drawn from the same crops. From this

area, faba bean took up 3.40% (about 427,696.80 ha) of the grain crop area. Among pulses, faba bean accounted for 3.02% (about 8,780,108.79 quintals) (CSA, 2017). The productivity of the crop under smallholder farmers is not more than 1.89 tons ha^{-1} (CSA, 2015), despite the availability of high yielding varieties (> 2.0 tons ha^{-1}) (MOA, 2011).

Ethiopia is a country of great environmental variation (EMA, 1988). Where environmental differences are great, it may be expected that the interaction of genotypes with environment will also be great. As a result, one cultivar may have the highest yield in one environment, while a second cultivar may excel in others. This necessitated the study of genotype by environment interaction to know the magnitude of the interactions in the selection of genotypes across several environments besides calculating the average performance of the genotypes under evaluation. G x E interaction of faba bean have been formerly studied by several researchers (Gemechu and Musa, 2002; Musa and Gemechu, 2004; Gemechu *et al*., 2006; Abdelmula and Abuanja, 2007; Karadavut *et al*., 2010; Fekadu *et al.*, 2012; Tamene *et al*., 2015). The aim of this study was to determine the magnitude and nature of G x E interaction for grain yield of faba bean varieties and to identify stable high yielding variety(s) under wide production for the tested environments and similar agro-ecologies of Oromia highlands, Ethiopia.

Materials and Method

Description of the Study Sites

Field experiment was conducted during the 2017/18 main cropping seasons from July to January at five selected highland agro-ecologies of Oromia region. The locations were Gedo, Bore, Alleyo, Anna Sorra and Uraga (Table 1).

Table 1. Altitude, rainfall, soil type, latitude and longitude of the studied locations

Location	Code	Altitude (m.a.s.l)	Rainfall (mm)	Soil type	Global Position	
					Latitude	Longitude
Gedo	E1	2240	1186.4	NA	9^0 02' N	37^0 25' E
Bore	E2	2736	1550	Nitosols	6^0 24' N	38^0 35' E
Alleyo	E3	2692	NA	Nitosols	6^0 19' N	38^0 39' E
Anna Sorra	E4	2451	NA	Nitosols	6^0 10' N	38^0 42' E
Uraga	E5	2385	1204	Slightly Nitosols	6^0 05' N	38^0 35' E

Sources: Yazachew and Kassahun, 2011; Wakene *et al*., 2014; NA: Not Available.

Plant Materials, Experimental Design and Management

Thirteen (13) faba bean varieties released from federal and regional research centers were obtained from Holeta Agricultural Research Center (HARC) and Sinana Agricultural Research Center (SARC). Randomized Completely Block Design (RCBD) with three replications was used. Each variety was sown in 4 rows; 4m length with 40cm inter-row spacing and 10cm between plants and fertilizer rate 19/38/7 $N/P_2O_5/S$ Kg ha^{-1} was applied at planting time.

Table 2. Description of the thirteen faba bean varieties used in the experiment

Variety	Code	Pedigree	Source	Seed size	Year of release	Adaptation area (m.a.s.l)	Breeder/ Maintainer
Shallo	G1	EH011-22-1	Introduction	Small	2000	2300 - 2800	SARC
Mosisa	G2	EH99047-1	Introduction	Medium	2013	2300 - 2800	SARC
Alloshe	G3	EH03043-1	Introduction	Large	2017	2300 - 2800	SARC
Walki	G4	Bulga-70 x ILB4615	Hybridization	Medium	2008	1800 - 2800	HARC
Gebelcho	G5	Tesfa x ILB4726	Hybridization	Large	2006	1800 - 3000	HARC
Tumsa	G6	Tesfa x ILB 4726	Hybridization	Large	2010	2050 - 2800	HARC
Obsie	G7	CS20DK x ILB 4427	Hybridization	Large	2007	1800 - 3000	HARC
Dosha	G8	Coll 155/00-3	Collection	Medium	2009	1900 - 2800	HARC
Bulga70	G9	Coll 111/77	Collection	Small	1995	2300 - 3000	HARC
Hachalu	G10	EH960091-1	Introduction	Large	2010	1900 - 2800	HARC
Holeta-2	G11	BP1802-1-2	Introduction	Small	2001	1800 - 3000	HARC
Gora	G12	EH91026-8-2 x BPL44-1	Hybridization	Large	2012	1900 - 2800	HARC
Didia	G13	-	Hybridization	Large	2014	1800 - 2800	HARC

Sources: Holeta Agricultural Research Center (HARC) and Sinana Agricultural Research Center (SARC)

Statistical Analysis

The analysis of variance (ANOVA) for each location was done. Variance homogeneity was tested and combined analysis of variance was performed using the linear mixed model (PROC ANOVA) procedure to partition the total variation into components due to genotype (G), environment (E) and G x E interaction effects. Genotype was treated as a fixed effect and environment as a random effect. Comparison of varietal means was done using Duncan's Multiple Range Test (DMRT) at the 5% probability level. The method of Eberhart and Russell (1966) was used to calculate the regression coefficient (bi) and deviation from regression (S^2di). It was calculated by regressing mean grain yield of individual genotypes/environments on environmental/genotypic index. Ecovalence (Wi) suggested by Wricke (1962) measure was also computed to further describe stability.

$$W_i = \sum[\, X_{ij} - \bar{X}i - \bar{X}j + \bar{X}\,]^2$$

where, X_{ij} = the mean performance of genotype i in the j^{th} environment, X_i and X_j = the marginal means of genotype i and environment j respectively, and X. = the overall mean. Thus, genotypes with a low W_i value are stable

AMMI combines analysis of variance and principal component analysis into one model with additive and multiplicative parameters. The AMMI model is:

$$Y_{ij} = \mu + G_i + E_j + \sum_{n=0}^{N} \lambda_k \alpha_{ik} \gamma_{jk} + \theta_{ij} + \varepsilon_{ij}$$

where, Y_{ij} = the yield of the i^{th} genotype in the j^{th} environment, μ = the grand mean, G_i and E_j = the genotype and environment deviations from the grand mean respectively, λ_k = the eigenvalue for IPCA axis k, α_{ik} and γ_{jk} = the genotype and environment principal component scores for axis k, the summation handles N number of principal components retained in the model, θ_{ij} = the AMMI residual and ε_{ij} = the error (Zobel *et al*., 1988).

The main important feature of AMMI analysis is its graphical (biplot) representation which can displays main effect means on the abscissa and scores for the first axis (IPCA1 values) as ordinate of both genotypes and environments simultaneously (Crossa, 1990; Gauch and Zobel *et al*., 1988). A large genotypic IPCA1 value reflects more specific adaptation to environments with IPCA1 values of the same sign. On the contrary, genotypes with IPCA1 values close to zero show wider adaptation to the tested environments.

The AMMI stability value (ASVi) (Purchase, 1997) based on the AMMI model`s IPCA1 and IPCA2 scores for each genotype was also computed. ASVi is in effect the distance from the coordinate point to the origin in a two dimensional scatter gram of IPCA1 scores against IPCA2 scores. AMMI stability value was calculated in the excel spread sheet using the formula developed by Purchase *et al.* (1997).

$$ASV = \sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1\ Score)\right]^2 + (IPCA2Score)^2}$$

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

Genotype selection index was also calculated by the formula suggested by Farshadfar *et al.* (2003). Here it is calculated by taking the rank of mean grain yield of genotypes (RY_i) across environments and rank of AMMI Stability Value ($RASV_i$) a selection index GSI was calculated for each genotype which incorporate both mean grain yield and stability index in a single criteria (GSI_i) as:

$$GSI_i = RASV_i + RY_i$$

where, RASV is the rank value of genotypes for AMMI stability value and RY is the rank value of genotypes for grain yield. A genotype with the least GSI is considered as the most stable (Farshadfar, 2008).

Result and Discussion

Analysis of Variance and Mean Performances

According to the results of combined ANOVA for grain yield; the environments, genotypes, G x E interaction, error and replication within locations contributed 53.12%, 13.50%, 18.31%, 13.46% and 1.61%, respectively (Table 3) of the total sum of squares. The environmental main effect accounted higher from the total variation in grain yield. This indicated the test environments were highly variable and large differences among the test environments on the yield performance of faba bean varieties. The previous report on faba bean in Ethiopia also indicated that the environmental effect accounted for the largest part of the total variation (Mulusew *et al.*, 2008; Tamene *et al*., 2015). On the other hand, genotype and G x E interaction effects accounted lower from the total variation in grain yield. This study clearly showed that the environments were distinct, and the genotypes responded differently to the different environments in terms of grain yield. The G x E interaction effects was also observed to be cross-over type for grain yield. Previous reports also showed that tremendous levels of G x E interaction effects exist in faba bean in the different environments in Ethiopia (Gemechu and Musa, 2002; Musa and Gemechu, 2004; Gemechu *et al*., 2006; Tamene *et al*., 2015).

Table 3. Combined analysis of variance for grain yield (tonnes ha^{-1}) of 13 faba bean varieties across five locations during 2017/18 main cropping season

Sources	Degrees of freedom(DF)	Sum of squares(SS)	Mean squares(MS)	SS%
Total	194	245.66		
Environments	4	130.50	32.62**	53.12
Block (Environments)	10	3.96	0.396	1.61
Genotype	12	33.16	2.76**	13.50
Genotype x Environment	48	44.97	0.94**	18.31
Pooled Error	120	33.07	0.28	13.46
Mean = 2.70				
CV (%) = 19.46				
R^2 = 86.54				

Key: ** = highly significant at the level of 1% probability, ns = non-significant; CV = coefficient of variability, R^2 = R-squared.

The mean performance of thirteen faba bean varieties for grain yield across each environment and combined over environments are presented in Table 4. The highest mean grain yield of 5.46 tons ha^{-1} was recorded from Dosha at Bore and the least was 0.30 tons ha^{-1} recorded from Mosisa variety at Anna Sorra. The significant interaction suggests that grain yield of varieties varied across the testing environments from 3.35 tons ha^{-1} to 1.90 tons ha^{-1}, which recorded by varieties Walki and Holeta-2, respectively. On average, the highest (3.82 tons ha^{-1}) and the lowest (1.62 tons ha^{-1}) environment mean grain yield were observed at Bore and Anna Sorra, respectively (Table 4).

Stability Analysis for Grain Yield

Analysis based on Eberhart & Russell's Regression Model

The highly significance of mean square for G x E interaction ($P \leq 0.01$) was observed for grain yield (Table 3). This allowed the partitioning of G x E interaction effects in environment linear, G x E (linear) interaction effects (sum squares due to regression, bi) and unexplained deviation from linear regression (pooled deviation mean squares, S^2di). Besides, the analysis of variance for linear regression revealed highly significant differences ($P \leq 0.01$) between varieties (Table 5). The G x E (linear) interaction was highly significant, indicating that the stability parameter "bi" estimated by linear response to change in environment was not the same for the varieties (Table 5). Pooled deviation mean square was also highly significant, indicating that the differences in linear response among varieties across environments did not account for the interactions. Therefore, the fluctuation in performance of varieties grown in various environments was not fully predictable (partially unpredictable). Similar result was obtained in bean genotypes tested (Firew, 2003; Setegn and Habtu, 2003) in different part of Ethiopia and (Ferreira *et al*., 2006) in Brazil.

Table 4. The mean grain yield (tons ha^{-1}) of 13 faba bean varieties at individual environment during 2017/18 main cropping season

Entry	Variety	Test Environments					
		Gedo	Bore	Alleyo	Ana Sorra	Uraga	GM
1	Shallo	2.64	4.34^{b}	2.00^{b-e}	1.66^{c-f}	3.72^{a-c}	2.87^{b-e}
2	Mosisa	2.41	3.12^{c-e}	2.14^{b-d}	0.30^{g}	3.98^{ab}	2.39^{f}
3	Alloshe	2.26	3.68^{b-e}	2.71^{ab}	1.82^{b-e}	**4.29^{a}**	2.95^{b-e}
4	Walki	**2.94**	4.45^{ab}	2.59^{a-d}	**2.92^{a}**	3.86^{a-c}	3.35^{a}
5	Gebelcho	2.54	4.36^{b}	2.65^{a-c}	2.08^{a-d}	3.75^{a-c}	3.08^{a-c}
6	Tumsa	2.41	4.68^{ab}	**3.39^{a}**	1.26^{d-f}	3.75^{a-c}	3.10^{ab}
7	Obsie	2.46	4.19^{bc}	2.50^{b-d}	1.13^{e-g}	2.36^{e}	2.53^{ef}
8	Dosha	1.82	**5.46^{a}**	2.61^{a-d}	1.32^{d-f}	3.77^{a-c}	3.00^{a-d}
9	Bulga70	1.71	2.99^{de}	1.25^{e}	0.92^{fg}	2.98^{de}	1.97^{g}
10	Hachalu	2.19	3.72^{b-e}	2.08^{b-e}	2.62^{ab}	2.72^{de}	2.67^{c-f}
11	Holeta-2	1.64	1.83^{f}	1.80^{de}	0.79^{fg}	3.38^{b-d}	1.90^{g}
12	Gora	2.23	2.90^{ef}	2.53^{b-d}	2.22^{a-c}	3.18^{cd}	2.61^{d-f}
13	Didia	2.04	3.99^{b-d}	1.85^{c-e}	2.07^{a-d}	3.35^{b-d}	2.66^{c-f}
EM		2.25	3.82	2.32	1.62	3.47	2.70
CV(%)		31.870	16.765	21.207	31.680	12.499	19.456

NB: GM = genotypic means, EM = environmental means, EMS = error mean square, CV = coefficient of variation. Values with the same letters in a column are not significantly different.

Table 5. Analyses of variance for varieties mean yield and environmental mean yield

Sources	Degrees of freedom	Sum of squares	Mean squares
Varieties	12	11.159	0.929**
Env.+ (G x E)	52	58.632	1.127**
Env. in linear	1	43.643	43.643**
G x E (linear)	12	5.084	0.424**
Pooled deviation	39	9.906	0.254**
Residual	130	13.483	0.104

Key: ** = significant at the level of 5% and 1% probability, respectively

According to Eberhart and Russell's (1966) a stable genotype should have regression coefficients (bi=1) closer to one and deviation from regression nearly equal to zero ($S^2di \sim 0$). But, stability alone is not sufficient and thus should be accompanied by high grain yield. Based on these parameters, varieties Gebelcho and Alloshe had relatively high grain yield performance; regression coefficient closer to unity could be considered as stable and adaptable to wider environments. Gebelcho and Shallo had deviation from regression ($S^2di=0$) closer to zero and high grain yield performance selected as most stable varieties (Table 6). Similar results were reported by Tamene *et al*. (2015) and Tadele *et al*. (2017). However, varieties Dosha and Tumsa had coefficient of regression greater than unity, i.e. below average stability, and deviation from regression (S^2di) different from zero with high mean grain yield. This indicated that these varieties were best fit for specific adaptation in the favorable environments. Conversely, variety Bulga70 had regression coefficient closer to unity (1.025) and deviation from regression very close to zero (0.07), but it is the lowest in mean grain yield indicating its stability to unfavorable environments (Table 6). These results are in lines with

Firew (2003) in common bean; Adane (2008) in linseed; Yasin and Hussen (2013) in field pea.

Wricke's (Wi) Ecovalence Analysis

Wricke's ecovalence was determined for each of the 13 faba bean varieties evaluated at five environments (Table 6). The most stable varieties according to the ecovalence method of Wricke's (1962) were Gebelcho, Shallo and Bulga70 while Dosha, Mosisa and Holeta-2 were unstable.

Table 6. Mean yield, regression coefficients (bi), deviation from regression (S^2di) and Wricke's (Wi) ecovalence values for thirteen faba bean varieties tested in five environments

Variety	Code	Means (tha^{-1})	Rank	bi	Rank	S^2di	Rank	Wi	Rank
Shallo	G1	2.87	6	1.207	6	0.10	4	0.432	3
Mosisa	G2	2.39	11	1.302	8	0.60	13	2.107	12
Alloshe	G3	2.95	5	1.033	4	0.19	7	0.563	5
Walki	G4	3.35	1	0.767	7	0.15	5	0.617	6
Gebelcho	G5	3.08	3	1.027	2	0.02	1	0.049	1
Tumsa	G6	3.10	2	1.328	10	0.32	10	1.317	8
Obsie	G7	2.53	10	0.979	1	0.52	11	1.551	9
Dosha	G8	3.00	4	1.743	13	0.28	9	2.694	13
Bulga70	G9	1.97	12	1.026	5	0.07	3	0.215	2
Hachalu	G10	2.67	7	0.512	11	0.27	8	1.618	10
Holeta-2	G11	1.90	13	0.692	9	0.59	12	2.052	11
Gora	G12	2.61	9	0.414	12	0.05	2	1.289	7
Didia	G13	2.66	8	0.969	3	0.16	6	0.487	4

Additive main effects and multiplicative interaction (AMMI)

The ANOVA for grain yield using the AMMI method accounted about 13.50% of the total sum of squares (SS) attributable to the genotypes (G), 53.12% to the environments (E) and importantly 18.31% to G x E interaction effects (Table 7). A large total variation due to E indicated the overwhelming influence that environments have on the yield performance of faba bean varieties. Similar results were reported from the G x E studies on soybean (Asrat *et al.*, 2009), on field pea (Tamene *et al.*, 2013), on cowpea (Nunes *et al.*, 2014). Likewise, Yan and Kang (2003) also reported environment as the predominant source of variation. In the current study, the largest variation in yield explained by environments indicated the presence of different environments that can be grouped into mega-environments. Moreover, this study revealed that the magnitude of the G x E interaction sum of squares was 1.36 times larger than that for genotypes indicating the differential responses of varieties across environments. This result is consistent with that of a previous study of faba bean (Mulusew *et al*., 2008) and durum wheat (Shitaye, 2015) in Ethiopia.

The multiplicative component of AMMI further revealed that the highly significant ($P \leq 0.01$) G x E interaction were decomposed into PCA; the first IPCA explained 43.37% and the second IPCA explained 37.08%, and the first two IPCA totally 80.45% of the G x E interaction variation. Haynes *et al*. (1998); Yan and Kang (2003) reported that if the

percentage of the first two principal components would explain more than 50% of the total variation, the biplot would be a good alternative to study the genotype by environment interaction. Only first and second interaction principal components (IPCA) were highly significant (Table 7). Zobel *et al*. (1988) stated AMMI with two interaction principal component axes was the best predictive model for cross validation of the yield variation explained by the G x E interaction, which is in line with the previous findings reported by Bahrami *et al*. (2009); Asrat *et al.* (2009); Mohammad *et al*. (2011); Hintsa and Fetien (2013); Tamene *et al*. (2013); Mulusew *et al*. (2014); Shitaye (2015).

In this study, the proportion of the first interaction principal component axis sum of squares (IPCA1 = 43.37%) to the interaction sum of squares was greater than that of the second interaction principal component axis (IPCA2 = 37.08%) (Table 7). This indicated that the existence of differential yield responses among the faba bean varieties across the testing environments due to the presence of significant G x E interaction effect. Therefore, in order to identify a faba bean cultivars with specific or relatively broader adaptation, studies on the magnitude and patterns of G x E interaction effect is of paramount importance in highlands of Oromia region. This finding is in agreement with that reported for bread wheat (Hintsa and Fetien, 2013; Shitaye, 2015), field pea (Tamene *et al*., 2013) and faba bean (Tamene, 2015). The third and fourth interaction principal component axis captured mostly noise (residual) and therefore did not help to predict validation observations. Thus, the interaction of the thirteen varieties of faba bean with five environments was best predicted by first two interaction principal components and environments that easily visualized with the aid of a biplot. This result confirms that the previous findings of (Asrat *et al.*, 2009; Mohammad *et al*., 2011; Tamene *et al*., 2013; Mulusew *et al*., 2014; Shitaye, 2015).

Table 7. AMMI analysis of variance for grain yield of 13 faba bean varieties evaluated at five environments

Sources	DF	SS	MS	Total variation explained (%)	GxE (%) explained	GxE (%) cumulative
Total	194	245.66				
Environments	4	130.50	32.62**	53.12		
Rep.(Environment)	10	3.96	0.396	1.61		
Genotypes	12	33.16	2.76**	13.50		
G x E Interactions	48	44.96	0.94**	18.31		
IPCA1	15	19.50	1.30**		43.37	43.37
IPCA2	13	16.67	1.28**		37.08	80.45
IPCA3	11	5.50	0.50^{ns}		12.23	92.68
IPCA4	9	3.29	0.37^{ns}		7.32	100.00
Pooled Error	120	33.07	0.28			

Key: ** = significant at the level of $P \leq 0.01$ probability; ns = non significant.

AMMI 1 bi-plot for grain yield

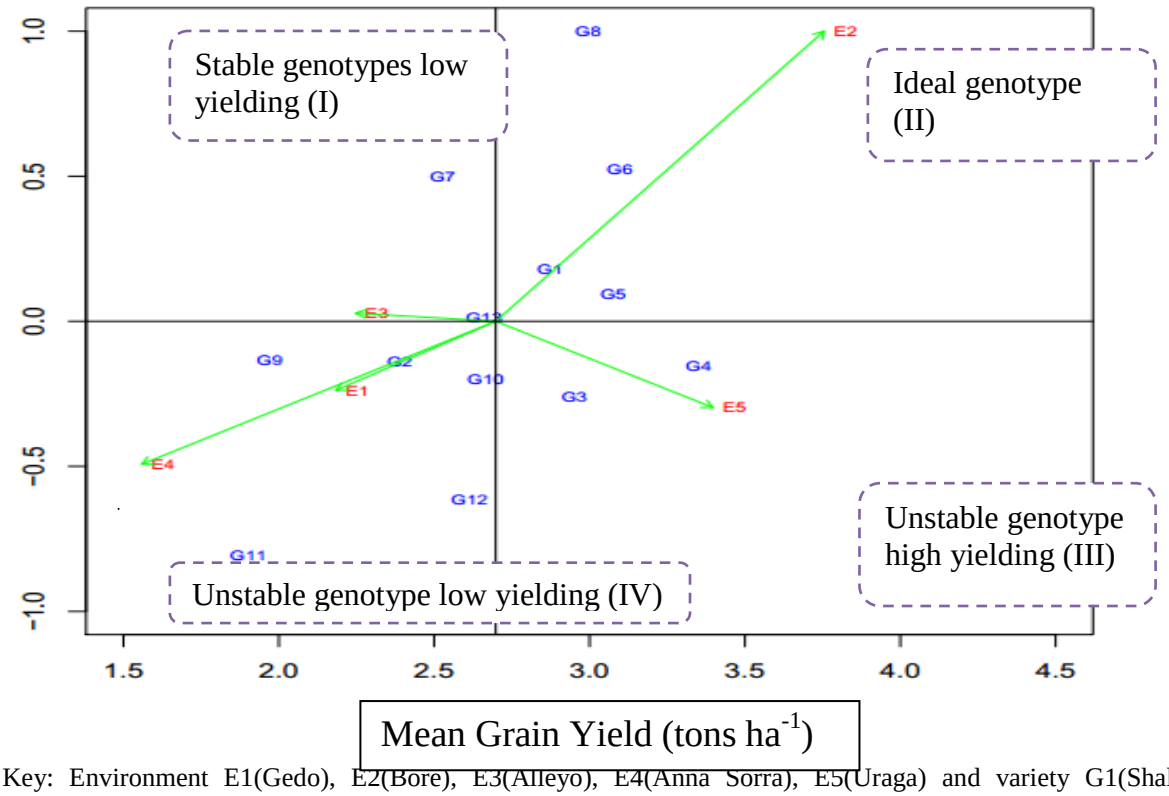
The six varieties; G4 (Walki), G6 (Tumsa), G5 (Gebelcho), G8 (Dosha), G3 (Alloshe) and G1 (Shallo) were relatively had higher grain yield than the other varieties and located to the right side of the grand mean (Figure 1). The two varieties; G11 (Holeta-2) and G9 (Bulga70) were

the lowest varieties and located to the left of the perpendicular line, in which they were far apart from the origin. Holeta-2 was interactive variety with unstable performance across testing environments. The two varieties; Gebelcho and Shallo were stable nearly place to the origin (horizontal line). Among the test environments, it is clear that there is variability observed ranging from the lower yielding environment in quadrant I and IV to the high yielding environment in quadrant II and III. Generally, E4 (Anna Sorra) was categorized under the least low yielding unfavorable faba bean environment as compared to the two low yielding environments (Gedo and Alleyo), while E2 (Bore) and E5 (Uraga) were high yielding favorable environments for the tested materials (Fig 1).

AMMI 2 bi-plot for grain yield

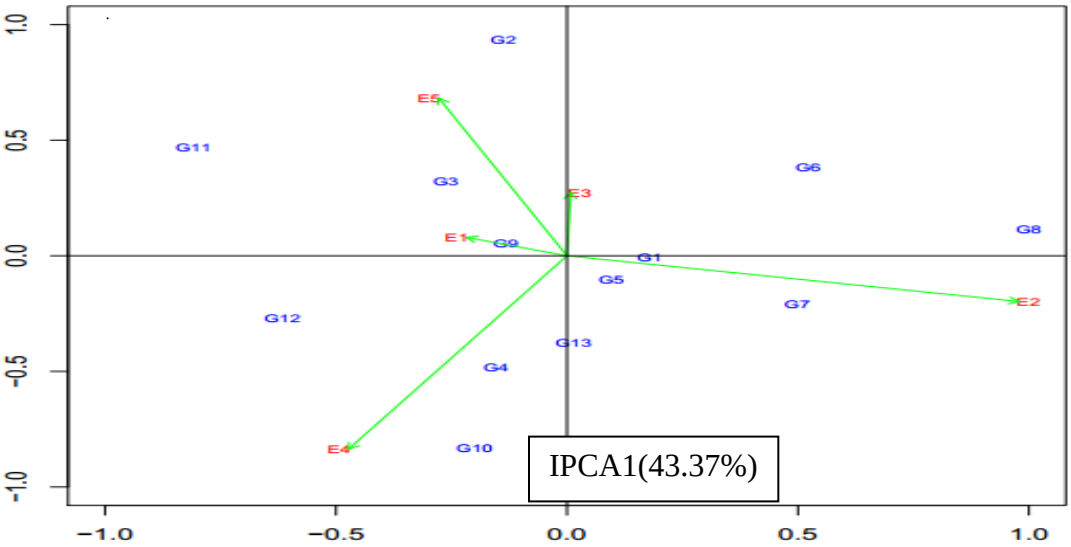
In case of the AMMI2 biplot from below graph, genotypes which occur close to each other have similar yielding performance across all testing environments, while those genotypes which far apart may differ in mean yield or show a different pattern of response over the environments. Accordingly, varieties G5 (Gebelcho) and G1 (Shallo) which occur close to each other in the AMMI2 biplot (Figure 2) had similar performance to all environments. Genotypes that are close to environment indicate their better adaptation to that particular environment. Here, Dosha and Mosisa were showed specifically adapted to favorable environments, as they are close to environments E2 (Bore) and E5 (Uraga), respectively (Figure 2). Besides to the above in the AMMI1 biplot, genotypes which occur nearer to the origin are less sensitive to environmental changes where as those genotypes which occur distant from the origin are sensitive to environmental change and have large interaction. Hence, varieties Gebelcho, Shallo and Bulga70 were close to the origin and have good responses among the changed environmental conditions, which indicating their minimum contribution to the total G x E interaction variance and are considered as stable varieties. Whereas, varieties G2 (Mosisa), G10 (Hachalu) and G11 (Holeta-2) were distant from the origin and have considerable contribution to the G x E interaction variance and unstable.

However, with respect to the testing environments, E2 (Bore) and E4 (Anna Sorra) were scattered far from the origin indicating that these environments contribute higher amount of variation to the total G x E interaction. Particularly, Bore was the most discriminating environment. On the contrary, E1 (Gedo) and E3 (Alleyo) were located close to the origin indicating lower contribution to the G x E interaction variance and least discriminating environments.



Key: Environment E1(Gedo), E2(Bore), E3(Alleyo), E4(Anna Sorra), E5(Uraga) and variety G1(Shallo), G2(Mosisa), G3(Alloshe), G4(Walki), G5(Gebelcho), G6(Tumsa), G7(Obsie), G8(Dosha), G9(Bulga70, G10(Hachalu), G11(Haleta-2), G12(Gora) and G13(Didia).

Figure 1. AMMI1 biplot of IPCA1 against mean yield of 13 faba bean varieties tested at five environments



Key: Environment E1(Gedo), E2(Bore), E3(Alleyo), E4(Anna Sorra), E5(Uraga) and variety G1(Shallo), G2(Mosisa), G3(Alloshe), G4(Walki), G5(Gebelcho), G6(Tumsa), G7(Obsie), G8(Dosha), G9(Bulga70, G10(Hachalu), G11(Haleta-2), G12(Gora) and G13(Didia).

Fig 2. AMMI2 biplot interaction of IPCA1 and IPCA2 Scores of 13 faba bean varieties across five environments

The IPCA scores of genotypes in the AMMI analysis indicate the stability or adaptation over environments (Gauch and Zobel, 1996; Purchase, 1997; Alberts, 2004). The greater the IPCA1 scores, negative or positive, (as it is a relative value), the genotype is specifically adapted to certain environments with IPCA1 scores of the same sign. However, the genotype with high mean performance and with large value of IPCA1 score are consider as having specific adaptability to the environments. By considering the IPCA1 scores alone, varieties Dosha and Tumsa were unstable genotypes which specifically adapted to higher yielding environments with average grain yield above the grand mean yield. Although this result indicated inconsistent yield performance across locations, it demonstrated site specific adaptability for those varieties (Dagnachew *et al.,* 2014). Whereas varieties Gora, Obsie and Holeta-2 were also unstable but adapted to lower yielding environments with average grain yield below the grand mean (Table 9). Genotypic stability is crucial in addition to grain yield (Naroui *et al*., 2013). Conversely, variety Didia with below grand mean yield, also showed IPCA1 very close to zero (0.03), indicating consistence in yield performance across locations.

According to the AMMI model, the genotypes which are characterized by means greater than grand mean and the IPCA1 score nearly zero are considered as generally adaptable to wider environment. Since variety Gebelcho had high mean grain yield along with the IPCA1 score closer to zero, it was less influenced by the environmental fluctuations and could be considered as stable variety, which had general adaptation over all the testing environments (Table 9). AMMI analysis was also conducted and the stability of genotypes was predicted on the basis of mean performance and the magnitude of IPCA1 scores in soybean (Zobel *et al.,* 1988), maize and wheat (Crossa *et al.,* 1990) and chickpea (Mahnaz *et al*., 2013).

Similar signs of IPCA1 score for both the genotype and the environment indicate positive interaction and thus higher yield of the genotype at that particular environment. Accordingly, Dosha and Tumsa among the varieties, and Bore and Alleyo from the environments had similar negative sign of IPCA1 score. Hence, these varieties could be specifically adapted to both locations respectively. Similarly, Walki and Alloshe were suited to commercial production in Gedo and Uraga, respectively (Tables 8 and 9).

Table 8. Mean yield response and estimates of first two IPCA scores in respect of five environments

Environment	Code	EN. Mean (t ha^{-1})	IPCA1Score	IPCA2 Score
Anna Sorra	E4	1.624	0.66826	-1.13273
Alleyo	E3	2.317	-0.03790	0.36916
Bore	E2	3.825	-1.35496	-0.26885
Gedo	E1	2.254	0.32231	0.10820
Uraga	E5	3.467	0.40229	0.92422
Grand mean		2.70		

Key: EN mean = environmental mean and IPCA = interaction principal component axis

AMMI Stability Value (ASV)

In ASV method, the genotype with least ASV score is the most stable. However, stability needs to be considered in combination with yield (Farshadfar, 2008). Thus, varieties Walki and Tumsa had higher grain yield but with high ASV were identified as best varieties to

validate for yield performance and specific adaptability. In this study, AMMI stability value distinguished varieties Gebelcho and Shallo as the best stable varieties within good yield performances (Table 9). Odewale *et al*., 2013 reported that two out of the five coconut genotypes grown across nine environments in southern Nigeria showed smaller ASV and thus better stability. Farshadfar (2008) noted three out of the 20 bread wheat genotypes evaluated gave smaller ASV and higher grain yield than the grand mean and thus better relative stability.

Genotype Selection Index (GSI)

Simultaneous consideration of grain yield and ASV in single nonparametric index is needed. Nevertheless, stable genotypes would not inevitably provide the best yield performance and hence identifying genotypes with high grain yield coupled with consistent stability across growing environments has paramount importance. In this regard, genotype selection index was utilized to further identify stable genotypes with better yield performance. Therefore, based on the GSI, Gebelcho, Walki and Shallo were considered as the best three most stable varieties with high grain yield. Whereas, varieties Holeta-2, Gora and Mosisa were unstable (Table 9). This result was consistent with Biru *et al*. (2017) on Chickpea.

Table 9. AMMI stability value, Genotype selection index, yield rank and principal component axis

Variety	Means (t ha^{-1})	Rank	IPCA1 scores	IPCA2 scores	ASV	Rank	GSI	Rank
Alloshe	2.95	5	0.25127	0.30987	0.427	5	10	4
Bulga70	1.97	12	0.12693	0.05171	0.157	2	14	6
Didia	2.66	8	-0.01332	-0.35947	0.360	4	12	5
Dosha	3.00	4	0.96047	0.10822	1.129	13	17	7
Gebelcho	3.08	3	0.09247	-0.09924	0.147	1	4	1
Gora	2.61	9	0.59202	-0.25854	0.739	9	18	8
Hachalu	2.67	7	0.19264	-0.80020	0.831	10	17	7
Holeta-2	1.90	13	0.77634	0.45046	1.014	12	25	10
Mosisa	2.39	11	0.13175	0.89917	0.912	11	22	9
Obsie	2.53	10	-0.47841	-0.20029	0.594	7	17	7
Shallo	2.87	6	0.17213	-0.00531	0.201	3	9	3
Tumsa	3.10	2	-0.50132	0.36695	0.692	8	10	4
Walki	3.35	1	0.14717	-0.46333	0.494	6	7	2

Key: ASV = AMMI stability value, GSI = genotype selection index, IPCA= interaction principal component axis.

The Overall Ranking of Tested Varieties based on Stability Parameters

Based on the result observed from the different stability measurements, Gebelcho and Shallo were the most stable varieties (Table 10). Likewise, Walki and Gebelcho were the highest yielding varieties with mean grain yield of 3.35 tons ha^{-1} and 3.08 tons ha^{-1}, respectively. Varieties, Mosisa and Holeta-2 were unstable and ranked 11^{th} and 13^{th} for grain yield, respectively (Table 10).

Table 10. Ranking of 13 faba bean varieties for mean grain yield based on the some of stability parameters

Variety	Yield		AMMI model				Regression model				Conventional model		Overall Rank
	Mean (tha^{-1})	R	ASV	R	GSI	R	bi	R	S^2di	R	Wi	R	
Shallo	2.87	6	0.201	3	9	3	1.207	6	0.10	4	0.432	3	2
Mosisa	2.39	11	0.912	11	22	9	1.302	8	0.60	13	2.107	12	10
Alloshe	2.95	5	0.427	5	10	4	1.033	4	0.19	7	0.563	5	4
Walki	3.35	1	0.494	6	7	2	0.766	7	0.15	5	0.617	6	3
Gebelcho	3.08	3	0.147	1	4	1	1.027	2	0.02	1	0.049	1	1
Tumsa	3.10	2	0.692	8	10	4	1.328	10	0.32	10	1.317	8	5
Obsie	2.53	10	0.594	7	17	7	0.979	1	0.52	11	1.551	9	6
Dosha	3.00	4	1.129	13	17	7	1.743	13	0.28	9	2.694	13	9
Bulga70	1.97	12	0.157	2	14	6	1.026	5	0.07	3	0.215	2	4
Hachalu	2.67	7	0.831	10	17	7	0.512	11	0.27	8	1.618	10	8
Holeta-2	1.90	13	1.014	12	25	10	0.692	9	0.59	12	2.052	11	11
Gora	2.61	9	0.739	9	18	8	0.414	12	0.05	2	1.289	7	7
Didia	2.66	8	0.360	4	12	5	0.969	3	0.16	6	0.487	4	4
GM	2.70												

Key: GM = grand mean, ASV = AMMI stability value, GSI = genotype selection index, bi = coefficient of regression, S^2di = deviation from regression, Wi = Wrick's (1962) ecovalence, R = rank and OR = overall rank.

Conclusion and Recommendation

Genotype by environment interaction and stability measuring trials helps to identify genotypes with both high performance and high stability; and test environment evaluation to identify test environments that are both informative (discriminating) and representative. Based on the specific and wider adaptability the varieties were selected. Generally, from this experiment Gebelcho and Shallo were most stable better yielding performance, above the grand mean and recommended for wider production in the tested environments and similar agro-ecologies. Varieties, Dosha and Tumsa were selected as they had high specific adaptation to environments of Bore and Alleyo, respectively. Walki was the best variety for Gedo and Anna Sorra, Alloshe and Mosisa for Uraga. Test environments (locations) that are both discriminating and representative like Bore is good test environment for selecting generally adaptable varieties. Discriminating but non-representative test environment like Anna Sorra is useful for selecting specifically adaptable varieties because the target environments were divided into two mega-environments. The identified varieties have been promoted to the demonstration trials as per their adaptability.

References

Abdelmula, A.A. and Abuanja, I.K. 2007. Genotypic responses, yield stability, and association between Variability, correlation and path coefficient analysis of yield and some yield components in faba bean (*Vicia faba* L.) populations. *Journal of Damascus University for Agricultural Sciences*, 27(1): 83-95.

Adane Choferie. 2008. Genotype by Environment Interaction and Stability Analysis of Linseed (*Linum usitatissimum* L.). In Central and Southeastern Ethiopia. M.Sc. Thesis Presented to the School of Graduate Studies of, Awassa College of Agriculture, Hawassa University.p.39.

Alberts, M.J.A. 2004. A Comparison of Statistical Methods to Describe Genotype x Environment interaction and yield stability in multi-location maize trials. MSc. Thesis. Department of Plant Sciences. The University of the Free State, Bloemfontein.

Asfaw Telaye, Tesfaye G, Desta Beyene. 1994. Genetics and breeding of faba bean. *In*: Asfaw T, Bejiga G, Saxena MC, Solh MB (edition) Cool-season food legumes of Ethiopia. Proceeding of the first national cool-season food legumes review conference, December 1993, Addis Ababa, Ethiopia. ICARDA/IAR. ICARDA, Syria, p 440.

Asrat Asfaw, Fistum Alemayehu, Fekadu Gurmu and Mulugeta Atnaf. 2009. AMMI and SREG GGE biplot analysis for matching varieties onto soybean production environments in Ethiopia. *Scientific Research and Essay*, 4(11): 1322-1330.

Bahrami, S., M. R. Bihamta and M. Solouki. 2009. Adaptation and Stability Analysis of Hulless Barley (*Hordeum vulgare* L.) Genotypes in Temperate Regions of Iran. *Trakia Journal of Sciences*, 7(2): 8-17.

Biru Alemu, Kassahun Tesfaye, Teklehaimanot Haileselassie and Dagnachew Lule. 2017. Genotype by environment interactions and grain yield stability of released and advanced Desi type chickpea (*Cicer arietinum* L.) genotypes in western Ethiopia.

Bond DA. 1976. Field beans (*Vicia faba* L.). *In*: Simmonds NW (ed) Evolution of crop plants. Longman, London.

Crossa, J. 1990. Statistical analysis of multi location trials. *Advanced Agro*nomy, 44: 55-86

Crossa, J., H.G. Gauch, and R.W. Zobel. 1990. Additive main effects and multiplicative interaction analysis of two international maize cultivar trials. *Crop Science*, 6: 36-40.

CSA (Central Statistical Agency). 2015. Agricultural Sample survey 2014/2015. Report on Area and Production of crops (private peasant holdings, Meher season), Volume I. Statistical Bulletin, 578. Addis Ababa, Ethiopia.

CSA (Central Statistical Authority). 2017. Federal Democratic Republic of Ethiopia, Agricultural Sample Survey for the 2016/17 Crop Season. Volume I. Report on Area and Production of Major Crops. Statistical Bulletin 584, Addis Ababa, Ethiopia, 11-41.

Dagnachew Lule, Masresha Fetene, Santie de Villiers and Kassahun Tesfaye. 2014. Additive Main Effects and Multiplicative Interactions (AMMI) and genotype by environment interaction (GGE) biplot analyses aid selection of high yielding and adapted finger millet varieties. *Journal of Applied Biosci*ence, 76:6291– 6303.

Eberhart SA, Russell WA. 1966. Stability parameters for comparing varieties. *Crop Science*, 6: 36–40.

Ethiopian Mapping Authority (EMA) 1988. National Atlas of Ethiopia. Addis Ababa, Ethiopia.

Farshadfar E, Sutka J. 2003. Locating QTLs controlling adaptation in wheat using AMMI model. *Cereal Research Community*, 31:249-254.

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 Science*, 11: 1791-1796.

Fekadu Gurmu, Ersulo Lire, Asrat Asfaw, Fitsum Alemayehu, Yeyis Rezene, Daniel Ambachew. 2012. GGE-Biplot Analysis of Grain Yield of Faba Bean Genotypes in Southern Ethiopia. *Electronic Journal of Plant Breeding*, 3(3): 898-907.

Ferreira D.F., Demetrio C.G.B., Manly B.F.J., Machado A.A., and Vencovsky R. 2006. Statistical model in agriculture: Biometrical methods for evaluating phenotypic stability in plant breeding. *Cerne lavras*, 12(4): 373-388.

Firew Mekbib. 2003. Yield stability in Common bean (*Phaseolus vulgaris* L.) genotypes. *Euphytica*, 130: 147-153.

Gauch H.G. and Zoble R.W. 1988. Predictive and post dictive success of stastistical analysis of yield trial. *Theoretical and Applied Genetics*, 76: 1-10.

Gauch HG, 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.

Gauch, H.G. 1992. Statistical analysis of regional yield trials: AMMI analysis of factorial designs. Elsevier Health Sciences, the Netherlands.

Gemechu Keneni and Musa Jarso. 2002. Comparison of three secondary traits as determinants of grain yield in faba bean on waterlogged vertisols. *Journal of Genetics and Breeding*, 56: 317-326.

Gemechu Keneni, Musa Jarso and Welabu T. 2006. Faba bean (*Vicia faba* L.) genetics and breeding research in Ethiopia: A Review. *In*: Ali K, Gemechu Keneni, Ahmed S, Malhotra R, Beniwal S, Makkouk K, Halila MH (eds) Food and forage legumes of Ethiopia: Progress and prospects. Proceedings of a workshop on food and forage legumes. September 2003, Addis Ababa, Ethiopia. ICARDA, Aleppo, Syria, p 351.

Haciseferogullari, H., I. Gezer, Y. Bahtiyarca, and H.O. Menges. 2003. Determination of some chemical and physical properties of Sakız faba bean (*Vicia faba* L. Var. major). *Journal of Food Engineering*, 66:475-479.

Hailu Mekbib, Abebe Demissie, Abebe Tullu. 1991. Pulse crops of Ethiopia: Genetic resource and their utilization. *In*: Engels JMM, Hawkes JG, Melaku W (eds) Plant genetic resources of Ethiopia. pp 328-343.

Haynes K G, Lambert D H, Christ B J, Weingartner D P, Douches D S, Backlund J E, Fry Wand Stevenson W. 1998. Phenotypic stability of resistance to late blight in potato clones evaluated at eight sites in the United States American, *Journal Potato Research*, 75: 211-21.

Hintsa, G. Hagos and Fetien Abay, 2013. AMMI and GGE biplot analysis of bread wheat genotypes in the Northern part of Ethiopia. *Journal of Plant Breeding and Genetics*, 01: 12-18.

ICARDA (International Center for Agricultural Research in the Dry Areas). 2006. Screening techniques for disease resistance in faba bean . Aleppo, Syria.

Karadavut, U., Palta, C., Kavuramci, Z. and Bolek, Y. 2010. Some grain yield parameters of multi-environmental trials in faba bean (*Vicia faba* L.) genotypes. *International Journal of Agriculture and Biology,* 12 (2): 217-220.

Mahnaz Rashidi, Ezatollah Farshadfar, Mohammad Mahdi Jowkar. 2013. AMMI analysis of phenotypic stability in chickpea genotypes over stress and non-stress environments. *International Journal of Agriculture and Crop Sciences*, 5(3): 253-260.

MOA (Ministry of Agriculture). 2011. Animal and Plant Health Regulation Directorate. *Crop variety register*. Issue No.14. Addis Ababa, Ethiopia. pp. 71-73.

Mulusew Fikere, D.J. Bing, Tadele Tadesse and Amsalu Ayana, 2014. Comparison of biometrical methods to describe yield stability in field pea (*Pisum sativum* L.) under south eastern Ethiopian conditions. *African Journal of Agricultural Sciences*, 9(33): 2574-2583.

Mulusew Fikere, Tadele Tadesse and Tesfaye Letta. 2008. Genotype-Environment Interactions and Stability Parameters for Grain Yield of Faba Bean (*Vicia faba L*.) Genotypes Grown in South Eastern Ethiopia. *International Journal of Sustainable Crop Production,* 3(6):80-87.

Musa Jarso and Gemechu Keneni. 2004. Classification of some waterlogged variety testing environments on Ethiopian vertisols on the basis of grain yield response of faba bean genotypes. *Ethiopian Journal of Natural Resource,* 6(1):25-40.

Musa Jarso and Gemechu Keneni. 2006. *Vicia faba* L. *In*: Brink M, and Belay G (eds). Plant resources of tropical Africa 1: Cereals and Pulses. PROTA Foundation, Netherlands/Backhuys Publishers, Leiden, Netherlands/CTA, Wageningen, Netherlands.

Naroui Rad MR, Abdul Kadir M, Rafii Hawa MY, Jaafar Naghavi MR, Farzaneh Ahmadi. 2013. Genotype × 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 Sciences,* 7(7):956-961.

Nunes, H.F., Francisco, R.F., Filho, Valdenir, Q.R., Regina andL. F., Gomes. 2014. Grain yield adaptability and stability of blackeyed cowpea genotypes under rainfed agriculture in Brazil. *African Journal of Agricultural Research*, 9(2): 255-261.

Odewale JO, Ataga CD, Agho C, Odiowaya G, Okoye MN, Okolo EC. 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 Agriculturaland Environmental Management*, 2(1): 001-010.

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

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

Setegn Gebeyehu and Habtu Assefa. 2003. Genotype X Environment Interaction and Stability Analysis of Seed Yield in Navy Bean Genotypes. *African Crop Science Journal*, 11(1): 1-7.

Shitaye Homma. 2015. AMMI, Stability and GGE Biplot Analysis of Durum Wheat Grain Yield for Genotypes Tested under Some Optimum and High Moisture Areas of Ethiopia. *Academic Journal of Entomology*, 8(3): 132-139.

Singh KA, Bharati RC, Manibhushan NC, Pedpati A. 2013. An Assessment of faba bean (*Vicia faba* L.) current status and future prospect. *African Journal of Agricultural Research* 8(50): 6634-6641.

Tadele Tadesse, Behailu Mulugeta, Gashaw Sefera and Amanuel Tekalign. 2017. Genotypes by Environment Interaction of Faba Bean (*Vicia faba* L.) Grain Yield in the Highland of Bale Zone, Southeastern Ethiopia. *Plant*, 5(1): 16-17.

Tamene Temesgen, Gemechu Keneni, Tadese Sefera and Mussa Jarso. 2015. Yield stability and relationships among stability parameters in faba bean (*Vicia faba* L.) genotypes. *The Crop Journal*, 3: 260 - 261.

Tamene Temesgen, Gemechu Keneni, Tadesse Sefera, Musa Jarso and Yeneneh Bekele. 2013. G x E interaction and performance stability for grain yield in field pea *(Pisum sativum* L.) genotypes. *International Journal of Plant Breeding*, 7(2): 116-123.

Wricke G.1962. On a method of understanding the biological diversity in field Research. *Z. Pfl.-Zücht* 47: 92-146.

Yan, W., and Kang M.S. 2003. GGE Biplot Analysis: A Graphical Tool for Breeders, Geneticists, and Agronomists. CRC Press, Boca Raton, FL.

Yasin Goa and Hussen Mohammed. 2013. Genotype x environment interaction and yield stability in Field pea (*Pisum Sativum* L.) tested over different locations in Southern Ethiopia. *Journal of Biology Agriculture and Healthcare*, 3(19):91-100.

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

Adaptability and Performance evaluation of Recently Released Tomato Varieties at West and Kellem Wollega Zones under Supplementary Irrigation

Kibiru Kena*, Zewdu Tegenu, Ashenafi Debela, Admasu Raga and Biru Alemu
Haro Sabu Agricultural Research Center, Haro Sabu, Ethiopia
Corresponding author: kibiruk12@gmail.com

Abstract

Tomato (Lycopersicon esculentum Mill.) is one of the most important edible and nutritious vegetable crops in the world. A total of 11 improved varieties introduced from Melkasa Agricultural Research Center (MARC) and one local check were evaluated to identify adaptable, high yielding and disease tolerant variety. The experiment was conducted at Meti and Kombolcha sites in Kellem Wollega zone, and Inango in West Wollega zone, Western Ethiopia. It was conducted during the 2016/2017 and 2017/2018 under supplemental irrigation. The combined analysis of variance (ANOVA) for fruit yield and other agronomic traits of 12 tomato varieties grown at five locations in 2016/2017 and 2017/2018 revealed significant varietal difference for all considered traits except for unmarketable yield and number of branches per plant. Melka shola, Melka salsa, Fetene and Miya varieties were found superior in terms of economic yield (marketable yield) and other parameters and thus they are recommended for further demonstration and popularization for wider production in test locations and similar agro-ecologies in Western Oromia under supplemental irrigation.

Keywords: Irrigation, Tomato, Yield stability

Background and justification

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important edible and nutritious vegetable crops in the world. It ranks next to potato and sweet potato with respect to world vegetable production. It is widely cultivated in tropical, subtropical and temperate climates and thus ranks third in terms of world vegetable production (FAO, 2006). Now days, its importance is increasing in Ethiopia. It is widely accepted and commonly used in a variety of dishes as raw, cooked or processed products more than any other vegetables (Lemma, 2002). It is one of an important cash-generating crop to small scale farmers and provides employment in the production and processing industries. It is also an important source of vitamin A and C as well as minerals. Such diverse uses made tomato an important vegetable in irrigated areas of agriculture in the country. It is a seasonal climbing plant of the family S*olanaceae*. It is grown as an annual and produced for its fruits. It is one of the most popular & important vegetables for fresh consumption as well as for processing. The plant requires a warm & dry climate. The optimum mean daily temperature for growth of tomato lies between 21^{o}C and 26^{o}C. Temperature above 32^{o}C during fruit development inhibits the formation of red color (MOA, 2012). The leading tomato producing countries are China, the United State of America, India, Egypt, Turkey, Iran, Mexico, Brazil and Indonesia (FAO, 2006). A total of 9,524.42 hectares of land was under tomato in the country and yielding about 591,563.36 quintals of tomato production in Ethiopia (CSA, 2016) with the production of 62.11quintals per hectare.

Tomato is an essential ingredient in the diet of the people and often used in almost every household. It is used in preparing soups, sauces, stews, salads and other dishes, and used in large quantities as compared to other vegetables (Ellis, 1998). The fruit is fairly nutritious and contains high amount of vitamins A and C (AVRDC, 2004). Such diverse uses make tomato an important vegetable in irrigated agriculture in Ethiopia and the production is rapidly increasing in many parts of the country. In Ethiopia tomato is one of the most important and widely grown vegetable crops, both during the rainy and dry seasons for its fruit by smallholder farmers, commercial state and private farms (Gemechis *et al*., 2012; Emana *et al*., 2014). Seed yield and quality of tomato is mainly dependent on the variety selected for seed production (George, 1999). A number of improved varieties and other agronomic packages have been recommended to the users to overcome the low productivity and quality of tomato in the country. According to MoA (2013), however, due to lack of sound seed multiplication and distribution system, the varieties had not reached farmers. Thus Tomato production has been restricted to certain regions of the country for several reasons, including the shortage of varieties and the lack of recommended package regarding production.

The shortage of varieties and recommended information packages, poor irrigation systems, lack of information on soil fertility, diseases and insect pests, high postharvest loss, lack of awareness of existing improved technology and poor marketing system are the major constraints in Ethiopian tomato production (Lemma, 2002). In Ethiopia, several tomato varieties had been released nationally and recommended by Melkassa Agricultural Research Center for commercial production and small scale farming systems. Varieties such as 'Melkashola' and Marglobe' are widely produced while 'Melka salsa' and 'Heinz 1350' have limited distribution and production. On the other hand, 'Fetane', 'Bishola', 'Eshete' and 'Matedel' are being tested (Lemma, 2002). In Western part of Ethiopia, particularly in West and Kellem Wollega zones farmers produce locally known tomato variety on their gardens which is very small in size and low fruit yield. To this end, the two zones unable to meet the domestic demand of tomato due to lack of improved variety. Therefore, the objective of this study was to evaluate performance of tomato varieties under supplemental irrigation and recommend the best performed variety in the studied areas.

Materials and Methods

Experimental Sites, Designs and Experimental Materials

A field experiment was conducted at Meti and Kombolcha sub sites of Haro Sabu ARC during the 2016/2017 and 2017/2018 under supplemental irrigation. A total of 11 varieties viz., Chali, Cochoro, Fetane, Melka Shola, Melka Salsa, Bishola, Metadel, Eshete, Miya, Galilama and Arp Tomato D2 collected from Melkasa Agricultural Research Center (MARC) were evaluated against one local check. Among these varieties six of them (Chali, Bishola, Melka Shola, Melka Salsa, Fetane, and ARP Tomato D2) are determinate in growing habit while the other five varieties are indeterminate (Miya, Eshete, Metadel, Galilama, Cochoro). The experiment was laid out in a randomized complete block design with three replications and with plot size of 4 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 100 cm between rows and 30 cm between plants were used.

Data collection and Statistical analysis

Data were collected in plot and plant basis. Some of the data taken were days to 50% flowering, days to 90% maturity, number of fruits per plant, number of cluster per plant, plant height, number of branches per plant, fruits weight, marketable yield, unmarketable yield and total yield. The collected data were subjected to analysis using GenStat software.

Results and Discussion

The combined analysis of variance (ANOVA) for fruit yield and other agronomic traits of 12 tomato varieties grown at five locations in 2016/2017 and 2017/2018 revealed significant varietal difference for all considered traits except for unmarketable yield and number of branches per plant (Table 1). The current result disagrees with the findings of Desalegn *et al*. (2016) whom found that non-significant variation for days to 50% flowering, days to maturity and fruit numbers per plant. The location effect was highly significant ($P < 0.05$) for a number of traits considered. The mean marketable yield of the tested tomato varieties indicated statistically significant varietal difference across test environments and seasons (Table 1).

Table 1. Combined analysis of variance (ANOVA) for fruit yield and other agronomic traits of tomato varieties grown at western oromia.

SV	DF	Mean squares					
		DFL	DIPR	DM	NBPP	PH	NCPP
Rep	2	397.94	2.39	327.56	16.178	39.93	34.35
Trt	11	41.61*	0.47*	52.9*	1.845	669.59**	39.14**
Loc	1	245.44**	1.39*	0.01	159.9**	1517.4**	389.2**
Yr	1	3422.2**	0.63	31358.5**	427.9**	5242.4**	25.21*
Trt*Loc	11	15.08	0.19	35.86	3.608	26.37	8.16
Trt*yr	11	26.01	0.37	58.45*	1.177	143.9**	6.265
Loc*Yr	1	1586.6**	1.39*	458.67**	136.60**	406.8**	171.7**
Trt*Loc*Yr	11	15.66	0.19	24.73	1.766	14.32	3.684
Error	94	16.31	0.19	20.75	3.049	32.42	5.705
CV (%)		8.9	31.2	4.7	24.5	11.5	24.2

Table 1. Continued …...

SV	DF	Mean squares					
		NFPC	NFPP	FW	MYKg	UMYKg	TYQ/ha
Rep	2	0.31	69.4	730.2	18.083	3.9	11143
Trt	11	1.84*	833.05**	8267.4**	19.82**	1.3	7290
Loc	1	12.9**	8812.5**	1206.8	4.044	1.3	7507
Yr	1	4.25*	26.27	1542.7	5986.9**	29.3**	366174**
Trt*Loc	11	1.31	218.79*	1331.4	12.808*	2.8	14014**
Trt*yr	11	1.40	92.77	445.9	22.672**	2.3	5834
Loc*Yr	1	0.05	819.40	267.7	56.267**	6.1	24493
Trt*Loc*Yr	11	0.87	161.22	832.7	7.192	1.2	4498
Error	94	0.84	77.54	606.6	4.055	1.5	4313
CV (%)		31.2	30.1	26.7	14.6	109.8	20.9

In terms of flowering, Eshete and a local cultivar were the earliest whereas Bishola was considered as late variety (Table 2). Furthermore, similar trends were observed for maturity among tested varieties. Besides, most of varieties that flowers early were characterized by short plant height than varieties flowering late. This result was in agreement with the findings of Benti *et al.* (2017) who stated that Eshete was characterized as taller variety. Biggest fruit weight was recorded from varieties Bishola and ARP Tomato D2. Melka shola, Melka salsa, and local cultivar provided the highest fruit clusters per plant while Eshete and Bishola were

the lowest. Low fruits per cluster were obtained from Eshete and Fetene while maximum number of fruits per cluster obtained from Melka salsa (Table 2).

The maximum marketable yield per hectare was obtained from Melka shola, Melka salsa, Fetene and Miya, respectively, while the minimum was obtained from Metadal (Table 2) This result was in agreement with findings of Benti *et al.*, (2017) who stated that minimum yield was obtained from Metadal variety in their study. Variety Miya gave significantly higher total fruit yield (340.33 Qha^{-1}) (Table 2) accompanied with higher marketable fruit yield. (Desalegn*et al*., 2016) also reported similar finding as variety Miya out yielded the rest varieties in their study. On the other hand, the current result disagrees with the findings of Desalegn *et al*., (2016) who reported that Fetene was the lowest yielder. The yield gap observed in this variety might be attributed to the differences in ecological condition it was raised.

Conclusion and Recommendation

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 shola, Melka salsa, Fetene and Miya varieties were found superior in terms of economic yield (marketable yield) and other parameters, and thus they are recommended for popularization and wider production in test locations and similar agro-ecologies in Western Oromia under supplemental irrigation.

Table 2.Combined mean of yield and yield components of tomato varieties over location and year

Variety	DF	DIPR	DM	NBPP	PH	NCPP	NFPC	NFPP	FW	MYKg/pl	UMYKg/pl	TYQ/ha
Arp.Tomato D2	45.42bcd	1.425abcd	96.25cd	7.229	46.29 ef	8.812cd	2.645bcde	21.83 c	120.78a	241.68abcd	22.557ab	309.91abc
Bishola	48.92a	1.417abcd	101.92a	6.729	58.95 a	7.625d	2.614bcde	19.12 c	120.76a	213.35de	24.363ab	284.36c
Chali	45.58bcd	1.767a	97.83bc	7.188	49.52 de	10.104bc	3.352ab	34.31 b	84.95cd	224.93cde	17.245ab	281.73c
Cochoro	44.25bcd	1.333cd	98.33abc	6.854	49.07 de	9.479cd	2.553cde	25.1 c	94.43bc	253.54abc	23.286ab	327.2abc
Eshete	43.67cd	1.4bcd	97.67bc	6.354	64.9 a	7.979d	2.364e	18.98 c	118.49a	239.5bcde	31.37a	323.09abc
Fetene	47.17ab	1.167d	99.5abc	7.708	43 fg	9.229cd	2.459de	21.94 c	**109.36ab**	278.44a	26.517ab	338.09ab
Galilama	46abc	1.396bcd	100.08ab	7.104	57.26 bc	10.333bc	3.279abc	33.54 b	90.57bc	252.86ac	18.049ab	312.66abc
Local	43.75cd	1.192d	96.17cd	7.646	39.16 g	13.312a	3.001abcde	39.27 ab	59.58e	244.07abc	13.347b	294.25abc
Melka Salsa	46.58abc	1.308cd	96.75bcd	7.375	44.16 f	12.312a	3.49a	43.92 a	53.5e	269.27ab	21.266ab	347.15a
Melka Shola	47.25ab	1.25d	97.75bc	7.479	52.69 cd	11.542ab	3.145abcd	35.42 b	64.38e	268.05ab	19.929ab	349.03a
Metadal	43.83cd	1.733ab	96.67bcd	7.083	46.04 ef	7.708d	2.963abcde	24.62 c	122.1a	201.66e	29.974a	281.67c
Miya	42.58d	1.65abc	93.83d	6.896	45.35 ef	10.042bc	3.322ab	32.56 b	66.31de	276.98ab	21.843ab	340.33a
LSD(0.50)	3.273	0.359	3.693	NS	4.615	1.936	0.741	7.138	19.96	1.632	NS	NS
CV(%)	8.9	31.2	4.7	24.5	11.5	24.2	31.2	30.1	26.7	14.6	109.8	20.9

Where DF, DIPR, DM,NBPP,PH,NCPP,NEPC,NFPP,FW, MYKg/pl, UMYKg/.plo, TYQ/ha, LSD(0.50) and CV(%) are 50% flowering days, disease insect pest resistance, days to maturity, number branches per plant, plant height Number of cluster/plant, Number of fruits/cluster Number of Fruit/Plant FW= weight of fruits in (gm) Marketable Yield, unmarketable yield, Total yield Q/ha, least significance difference and coefficient of variation respectively.

References

AVRDC. 2004. Medium-term plan: 2004-2006. High lights. AVRDC-The World Vegetable Center, Shanhua, Taiwan.

Benti Gebisa, Gezu Degefa, Alemayehu Biri, Fikadu Tadesse, 2017. Performance Evaluation of Tomato (Lycopersiconesculentum Mill.) Varieties Under Supplemental Irrigation at Erer Valley, Babile District, Ethiopia. *Journal of Plant Sciences*. Vol. 5, No. 1, 2017, pp. 1-5

CSA (Central Statistical Agency). 2016. Agricultural Sample Survey 2015/2016: Report on Area and Production of Major Crops (Private Peasant Holdings, Meher Season). Volume-I, Statistical Bulletin 584, Addis Ababa, Ethiopia.

Desalegn Regassa, Wakene Tigre and Addis Shiferaw. 2016. Tomato (*Lycopersicon esculentum*Mill.) varieties evaluation in Borana zone, Yabello district, southern Ethiopia. *Journal of Plant Breeding and CropScience. 8(10), 206-210*

Ellis. 1998. Postharvest problems of tomato production in Ghana -Field studies of some selected major growing areas in Ghana. *Journal of the Ghana science association* volume 1 number 1, July (1998) pp. 55-59. ISSN: 0855-3823.

Emana, B., A. Ayana, T. Balemi and M. Temesgen, 2014. Scoping study on vegetables seed systems and policy in Ethiopia. Final Report, Asian Vegetable Research and Development Center, Shanhua, Taiwan.

FAO. 2006. FAO Production Year Book. Basic Data Unit, Statistics Division, FAO, Rome, Italy, No. 55, pp 125-127

Gemechis, A.O., P.C. Struik and B. Emana, 2012. Tomato production in Ethiopia: Constraints and opportunities. http://www.tropentag.de/2012/abstracts/full/659.pdf.George, R.A.T., 1999. Vegetable Seed Production. CABI Publishing, New York, Pages: 327

George, R.A.T., 1999. Vegetable Seed Production. CABI Publishing, New York, Pages: 327.

Lemma D, 2002. Reaserch experience and production prospects . ethiopian agricultural research organization(EARO), addis ababa Ethiopia,pp 28

Appendices

Appendix 1. Effect of varieties on yield and yield components of tomato at Meti subsite year one

Vartiety	DF	DM	DIPR	NBPP	PH	NCPP	NFPC	NFPP	FW	MYKg/ha	UMYKg/pot	TYQ/ha
Fetene	40.33a	87.67abc	1.167ab	6b	32.2fg	5.667c	2.33	13.33de	138.06ab	19.26bcd	1.541bcd	346.7cd
Bishola	40.33a	89.33a	1.4a	6b	50.97ab	5.667c	2.00	11.33e	150.51a	16.75de	2.555b	321.7de
Melka Salsa	35bc	76bcd	0.333b	7ab	36.67ef	10.667a	2.67	28.33a	64.11cd	19.75bcd	0.656d	340.1d
Metadal	33.67c	75.67cd	1.667a	6.333b	34.83fg	5.667c	2.33	13.33de	151.04a	17.68cde	2.243bc	332de
Arp TomatoD2	35bc	78.33a-d	1.5a	6b	40.67de	5.333c	2.67	14de	132.78ab	21.48ab	2.487b	399.4abc
Cochoro	35bc	87abc	1ab	6.667ab	48.17bc	7bc	2.67	17.33b-e	101.39bc	24.04a	1.181cd	420.3ab
Melka Shola	38.67ab	79a-d	0.5b	9a	42.73cd	9.333ab	2.75	26ab	59.89cd	23.77a	1.465bcd	420.6a
Eshete	35bc	86abc	1ab	7ab	52.97ab	7.333bc	2.33	16.67cde	127.63ab	18.3bcde	3.834a	368.9abcd
Miya	34c	71.67d	1.5a	6b	35.23efg	7bc	3.00	21abcd	66.33cd	20.54bc	0.986d	358.8cd
Galilama	35.67bc	89ab	1.417a	7.667ab	55.1a	9ab	2.33	20.33a-e	73.33cd	19.32bcd	1.222cd	342.4d
Local	32.33c	75cd	0.833ab	7.667ab	30.4g	10ab	2.33	23.33abc	52.5d	16.03e	0.96d	283.2e
Chali	36abc	79.67abcd	1.567a	6.667ab	45.27cd	8abc	2.33	18bcde	78.01cd	20.93ab	1.061cd	366.5bcd
LSD(.05)	4.49	13.22	0.89	2.51	5.65	3.22	NS	9.11	43.69	3.19	1.22	53.88
CV(%')	7.40	9.60	45.40	22.70	3.90	25.20	24.50	28.90	5.70	9.50	42.70	8.90

Appendix 2. Effect of varieties on yield and yield components of tomato at Kombolcha sub site year one

Vartiety	DF	DM	DIPR	NBPP	PH	NCPP	NFPC	NFPP	FW	MYKg/pl	UMYKg/pl	TYQ/ha
Fetene	50.67a	86.33abc	1.167d	13.67a	35.47gh	14bc	2.42d	33.67bc	105.33abc	22.82abc	2.663a	424.7ab
Bishola	49ab	91a	1.6bcd	10ab	52.5ab	11.33bc	2.706bcd	30.33bc	101.83a-d	18.87de	1.467abc	338.9ef
Melka Salsa	47.67abc	83bc	1.233cd	11.33ab	44.13de	14.67b	3.708abc	54.33a	41.83f	25.12a	1.035bc	436a
Metadal	45.67a-d	86.67abc	1.6bcd	10.67ab	38.17fg	11.67bc	3.768ab	43.67ab	115.06ab	18.27e	1.076bc	322.4f
Arp.Tomato D2	45abcd	84.67bc	1.533bcd	11.67ab	43.67def	13.33bc	2.581d	31.33bc	120.17ab	21.85bc	2.374ab	403.8abc
Cochoro	45abcd	84.33bc	1.667bc	11.33ab	50.53bc	12bc	2.964a-d	35.33bc	99.61a-d	23.32ab	1.611abc	415.5ab
Melka Shola	45abcd	83bc	2.167a	9.67b	48.03bcd	13.67bc	2.663cd	37bc	68.93def	18.53de	1.187abc	328.7ef
Eshete	43.67bcd	82.33c	1.6bcd	9b	56.3a	9.67c	2.707bcd	24.67c	129.19a	21.05bcd	0.987bc	367.2cde
Miya	43.67bcd	82c	1.767ab	11ab	38.57efg	11bc	3.87a	42.67ab	70.29c-f	22.01bc	1.463abc	391.2bcd
Galilama	43cd	87.67ab	1.5bcd	10ab	58.1a	13.67bc	3.034a-d	42.33ab	95.17a-d	20.51cde	0.561c	351.2def
Local	42.67cd	83.33bc	1.267cd	12ab	32.4h	20a	2.671cd	53.67a	57.42ef	14.81f	1.127bc	265.7g
Chali	41d	82.67c	1.5bcd	10.33ab	44.9cd	11.33bc	3.41a-d	39abc	88.56b-e	21.66bc	2.045abc	395abc
LSD(.05)	5.92	4.68	0.45	3.97	5.75	4.84	1.07	15.88	35.80	2.75	1.49	41.20
CV(%')	6.10	3.30	17.00	21.50	7.50	21.90	20.70	24.00	23.20	7.80	60.00	6.60

Appendix 3.Effect of varieties on yield and yield components of tomato at Meti sub site year two data

Variety	DF	DM	DIPR	NBPP	PH	NCPP	NFPC	NFPP	FW	MYKg/ha	UMYKg/plot	TYQ/ha
Arp.Tomato D2	69.33a	117.7a	1.33ab	5.583a	44.17cd	7.833cd	2.833a	20.58abc	123.44ab	6.881ab	0.1867c	249.4abc
Bishola	68.67a	116.7ab	1.33ab	5.417a	65.25ab	6.917d	3.167a	18c	128.44ab	8.958ab	0.7807ab	309.5abc
Melka Shola	67.33a	116.7ab	1.167b	5.833a	53.58bc	10.917ab	2.833a	28.42abc	61.91d	9.728ab	0.1627c	368.4a
Melka Salsa	66.33a	115.7abc	1.833ab	5.5a	38.83d	10.83ab	2.75a	29.58abc	47.33d	6.03b	0.1317c	216.1c
Chali	66a	115.7abc	2a	5.417a	48.17cd	8.833a-d	2.333a	19.58bc	84.87bcd	7.576ab	0.2047c	240.6bc
Galilama	63.33a	114abc	1.33ab	5.75a	51.67bcd	9abcd	3.167a	30.58abc	114.98abc	8.096ab	0.3767bc	272.8abc
Eshete	59.67ab	114.3abc	1.5ab	5.083a	69.08a	8.5bcd	2.083a	20.42bc	133.85a	9.712ab	0.3593bc	342.8ab
Cochoro	58.67ab	111.7bc	1.33ab	4.5a	44.58cd	8.25bcd	2.167a	19.42bc	71.73cd	6.708ab	0.0727c	268.2abc
Metadal	58.67ab	112.3abc	1.83ab	5.417a	54.58abc	6.667d	2.917a	20.08bc	115.27abc	6.101ab	1.1693a	289abc
Fetene	58.33ab	112.7abc	1.167b	5.333a	49.17cd	7.417cd	2.5a	17.58c	114.56abc	9.114ab	0.528bc	278.6abc
Local	58.33ab	113abc	1.333ab	5a	40.5cd	10.167abc	3.417a	34.17a	44.5d	9.125ab	0.0207c	288.1abc
Miya	48.33b	111c	1.667ab	5.167a	50.08cd	11.5a	3.25a	32.08ab	43.43d	10.065a	0.4773bc	279.9abc
LSD(0.50)	12.01	5.431	0.8128	2.044	14.7	2.957	1.458	13.67	48.1	4.001	0.526	120.717
CV(%)	11.5	2.80	32.3	22.6	17.1	19.6	30.9	33.4	31.4	28.9	83.5	25.1

Appendix 4.Effect of varieties on yield and yield components of tomato at Kombolcha sub site year two

Variety	DF	DIPR	DM	NBPP	PH	NCPP	NFPC	NFPP	FW	Mykg/Plot	UMYKg/plot	TYQ/ha
Chali	51.33a	2a	113.3a	6.333a	59.75 b	12.25a	5.333a	60.67a	88.38abc	5.166cde	0.2337a	215.9b
Melka Shola	51a	1.167b	112.3ab	5.417a	66.42 ab	12.25a	4.333a-d	50.25ab	66.78bc	6.226bcde	0.1291a	209.7b
Galilama	50.67ab	1.333ab	109.7bc	5a	64.17 ab	9.67ab	4.58abc	40.92bcd	78.79abc	7.37abcd	0.1527a	225.8b
Local	50.33ab	1.333ab	113.3a	5.917a	53.33 b	13.08a	3.583a-d	45.92abc	83.9abc	9.727ab	0.1927a	282.4ab
Bishola	49.67abc	1.333ab	110.7abc	5.5a	67.08 ab	6.58b	2.583cd	16.83ef	102.26ab	3.621e	0.2667a	168.1b
Melka Salsa	49abc	1.833ab	112.3ab	5.667a	57 b	13.08a	4.833ab	63.42a	60.73c	9.857a	3.461a	393.1a
Fetene	48abcd	1.167b	111.3ab	5.833a	55.17 b	9.83ab	2.583cd	23.17def	79.5abc	7.916abcd	0.8057a	259ab
Miya	47.67abcd	1.667ab	110.7abc	5.417a	57.5 b	10.67ab	3.167abcd	34.5bcde	85.19abc	8.642abc	2.6407a	309.3ab
Cochoro	47bcd	1.333ab	110.3abc	4.917a	53 b	10.67ab	2.417cd	28.33cdef	106.73a	5.608cde	1.9853a	251ab
Metadal	46cd	1.833ab	112ab	5.917a	56.58 b	6.83b	2.833bcd	21.42ef	107.04a	3.472e	0.503a	165.4b
Eshete	45d	1.5ab	108c	4.333a	81.25 a	6.42b	2.333d	14.17f	83.28abc	4.65de	0.6027a	159.3b
Arp.Tomato D2	44.33d	1.333ab	104.3d	5.667a	56.67 b	8.75ab	2.5cd	21.42ef	104.97ab	6.815abcde	0.712a	278ab
LSD(0.50)	3.885	0.8128	3.097	2.03	9.43	4.586	2.203	19.01	38.28	3.6	3.605	166.449
CV(%)	4.7	32.3	1.7	21.8	9.2	27.1	38	32	25.9	32.3	218.7	40.04

Appendix 5.Effect of varieties on yield and yield components of tomato at Inango sub site year two data

Variety	DF	DIPR	DM	NBPP	PH	NCPP	NFPC	NFPP	FW	MYKg/Plot	UMYKg/ha	TYQ/ha
Local	51.67a	1.33ab	113a	4.167ab	51.75bc	17.83bc	4.583a	70.75a	55.97e	10.811a	1.193cd	351.8abc
Melka Shola	50.67a	1.17b	112ab	5.5a	55.58b	24.17a	2.333bc	60.83ab	70.32de	10.722a	2.125abc	417.8a
Metadal	49.67ab	1.83ab	113a	3.333ab	46.5bc	12.58cde	2.5bc	31.42cd	85.58cd	7.614ab	2.801a	299.5abc
Fetene	48.67abc	1.17b	111bc	3.75ab	46.58bc	12.67cde	2.75bc	30.42cd	131.12a	11.99a	1.692a-d	381.5ab
Chali	48abc	2a	104e	9.17e	37.17c	2.5b	2.167c	20d	71.71de	4.683b	1.141cd	190.7c
Miya	48abc	1.67ab	109.3c	4.417ab	45.83bc	16.33bcd	3bc	47.83bc	64.04de	9.671ab	0.691d	362.4abc
Cochoro	47.33abc	1.33ab	106d	3.083b	43.58bc	10.75de	2.583bc	25.92d	89bcd	7.776ab	1.495bcd	281abc
Eshete	47.33abc	1.5ab	111.7ab	4.083ab	70.92a	11.75de	3.417abc	34.58cd	108.75abc	8.393ab	2.54ab	377.2ab
Galilama	47.33abc	1.33ab	105de	3.083b	47.08bc	13.83b-e	2.917bc	36.67cd	86.8cd	9.748ab	2.171abc	371.1ab
Melka Salsa	45.33bc	1.83ab	111.7ab	3.917ab	41.67bc	19.25ab	3.667ab	67.42a	48.03e	9.246ab	0.768d	350.4abc
Arp.Tomato D2	44.67c	1.33ab	104.3de	8.92e	42bc	2.25b	2.417bc	21.08d	107.36abc	6.727ab	0.706d	219.1bc
Bishola	44.67c	1.33ab	104.7de	10.58e	55.67b	3b	2.333bc	24.92d	115.71ab	7.293ab	1.568bcd	283.6abc
LSD(0.50)	4.669	0.8128	1.779	2.285	14.85	5.641	1.409	17.47	27.904	5.667	1.109	174.868
CV(%)	5.8	32.3	1	37.6	18	23.8	28.8	26.2	19.1	38.4	41.6	31.9

Multi-location adaptability and grain yield stability analysis of sorghum varieties in Ethiopia

Gebeyehu Chala[1*], Bulti Tesso[2], Dagnachew Lule[3] and Kebede Dessalegn[4]
[1]Oromia Agricultural Research Institute, Mechara Agricultural Research Center
[2]Haromaya University, Alemaya, Ethiopia, [3]Oromia Agricultural Research Institute, Addis Ababa, Ethiopia, [4]Oromia Agricultural Research Institute, Bako Agricultural Research Center, Bako, Ethiopia
[*]Corresponding author: gebeyehuchal@gmail.com

Abstract
Identification of adaptable, stable and high yielding genotypes under varying environmental conditions prior to release as a cultivar is the first step for plant breeding and this has direct bearing on the adoption of the variety, its productivity and total production of the crop. A total of twenty-two sorghum varieties were evaluated at five locations (Bilo Boshe, Bako, Gute, Mechara and Miesso) in 2017 main cropping season using Randomized Complete Block Design in three replications with the objectives of determining the magnitude and nature of genotype by environment interaction for grain yield and yield related traits, and to identify stable high yielding sorghum varieties for wider and/or specific environments. The combined analysis of variance revealed that significant effect of locations and genotype by location interactions for grain yield. This showed that, genotypes were inconsistent for grain yield across the testing locations. Birmash gave the highest grain yield with average yield of 3.5 ton ha^{-1} with better performance across locations. Baji was the second high yielding variety with mean grain yield of 3.3 ton ha^{-1}. Eberhart and Russell regression model and AMMI stability value models revealed that, Emahoy was the most stable variety followed by Baji and Birmash. The first two IPCAs accounted for a total of 88.64% of the interaction sum square. In genotype x environment interaction analysis, the result indicates that, the observed yield variations among varieties were due to the GxE effects rather than main effect of genotypes and environments. Results of ASV parameter showed that, the six most stable and high yielding genotypes are Gambella-1107, Gobiye, Baji, ESH-1, IS9302 and Emahoy. Emahoy variety is the 3rd top high yielder and the most stable variety selected by the two stability parameters as well as high mean yield. Therefore, Emahoy is the promising and recommended variety from all tested varieties across the test locations.

Key words*:* AMMI model, ASV, Correlation, GxE Interaction, IPCAs, Sorghum, Stability

Introduction
Sorghum [*Sorghum bicolor* (L). Moench] belongs to the order Poales and the family Poaceae and the genus Sorghum (Wikipedia, 2011). It has 2n = 20 chromosomes and an estimated genome size of 750 Mb being twice the genome of rice and six times the genome of Arabidopsis (Passardi *et al*., 2004). Sorghum is a dryland cereal crop grown on approximately 44 million hectares of land (Prakash *et al*., 2010), in 99 countries (ICRISAT, 2009) with an annual production of 60 million tons (Iqbal *et al.*, 2010). Nowadays, it is widely cultivated in different parts of Ethiopia. (De Wet and Huckabay 1967; Doggett 1988; Smith and Frederiksen, 2000) stated that Ethiopia is the primary center of origin and hence, center of

diversity for sorghum. Sorghum is now widely found in the dry areas of Africa, Asia, Americas and Australia (Dickon *et al.,* 2006).

Although sorghum is cultivated both in tropical and temperate climates, it is best known for its adaptation to the drought- prone semi-arid tropical (SAT) regions of the world (Baummhardt, 2000). It is adapted to environments with 400-600 mm annual rainfall that are too dry for other cereals (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). With the frequent and cyclical occurrence of drought and erratic rainfall, it could be an insurance crop to the small-scale resource-poor farmers constituting most of the rural farming community in Ethiopia (Abdissa, 1997). Owing to its natural drought resistant qualities, sorghum is a promising crop to overcome the food and feed shortage, particularly in rain fed and arid areas (CSA, 2016).
It is also one of the most important cereal crops of the tropics grown extensively over wider areas with altitude ranging from 400 to 3000 meters above sea level (m.a.s.l) due to its ability to adapt to adverse environmental conditions. This has made sorghum a popular crop in world wide. It is the major source of energy and protein for millions of people living in arid and semi-arid region of the world. It occupied third position in terms of production in Africa after wheat and maize and fifth in the world after wheat, maize, rice and barley (FAO, 2017).

Sorghum is among cereal crops used for food for the poorest people who live in semiarid regions of the world (Jiang *et al*., 2013). Moreover, it is widely used as a source of nutrition, fodder, biofuel, fiber and confection (Abubakar and Bubuche, 2013). It is able to grow under severe stress conditions. Sorghum can be cultivated successfully on almost all soils and in the temperature range of 16–40^{0}C (Abubakar and Bubuche 2013). It is a staple food crop on which the livelihood of millions of Ethiopian depends.

Ethiopia is the third largest sorghum producer in Africa next to Nigeria and Sudan (FAO, 2012). In Ethiopia, a total of 4.34 million tons of sorghum is being produced per annum. The mean yield level in the country is estimated at 2.4 t ha^{-1}. The crop is the major food cereal after maize and tef in terms of number of growers, area coverage and grain production in the country (FAO, 2017). Oromia, Amhara and Tigray regions are the major three sorghum producers in the country (CSA, 2016). Out of the total sorghum area harvested in 2014 main cropping season, Oromia region accounts 39.92% (669,575.97 hectares), Amhara and Tigray regions contributed 33.31% (558,827.95 hectares) and 12.82% (215,111.82 hectares), respectively.

Genotype x environment interaction is the major concern for plant breeders for developing improved cultivars. GEI results from a change in the relative rank of genotype performance or a change in the magnitude of differences between genotype performances from one environment to another. In multi-environment trials, the phenotype of an individual in each test environment is a measure of an environment main effect, a genotype main effect, and the genotype by environment interaction (GEI) (Yan and Tinker, 2005). The GE interaction reduces the correlation between phenotype and genotype and and hence selection progress.

More than forty sorghum varieties were released in the country from different regional and national research centers during the last 40 years (MoA, 2015). However, most of the varieties were not evaluated for their specific and wider adaptability and thus exhibit fluctuating yields when grown in different environments or agro-climatic zones. To address this challenge, multi- environment yield trials are crucial 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 and generally falls into two classes: (1) the ability to perform at an acceptable level in a range of environments, referred to as general adaptability, and (2) the ability to perform well only in desirable environments, known as specific adaptability (Farshadfar and Sutka, 2008). Nevertheless, information on the effect of GEI on the yield performance of sorghum varieties under different environments in Ethiopia is limited. Therefore, the objectives of the current study were to determine the magnitude and nature of genotype by environments interaction for grain yield and also to determine the stability of sorghum varieties for grain yield and hence to identify and recommend stable high yielding variety (ies).

Materials and Methods

Description of the Study Area

The field experiment was conducted during 2017 main cropping season at five locations in Ethiopia where sorghum is widely grown. The locations were Bako, Gute, Biloboshe (Western Oromia), Mechara, and Mieso (Eastern Oromia). The detailed agro-ecological features of the locations are presented below in Table 1.

Table 1. Agro-ecological features of the experimental locations.

Locations	Altitude (m.a.s.l)	Ave. Rain fall (mm)	Soil Type	Geographic coordinates		Ave. Temp. (ºC)	
				Latitude	Longitude	Max.	Min.
Gute	1906	1633.5	Alfisoils	9º00'N	36º38'E	21.6	14.3
Biloboshe	1758	1568.6	Sandy Loam	9 º00'N	38 º10'E	21.4	14.2
Bako	1650	1425.3	Alfisoils	9º6' N	37º09'E	20.4	13.5
Mechara	1760	871	Sandy loam	8º36'N	40º18 'E	23.4	8.9
Mieso	1470	856.8	Vertisoil	16º06'N	37º 08'E	35.0	8.3

Source: Bako and Mechara Agricultural Research Centers

Plant Materials

The experimental plant materials comprised of 22 sorghum varieties including local check and varieties released from different research centers in Ethiopia working on sorghum.. A local check was included at each location. The detailed information about the experimental materials is presented in Table 2.

Table 2. Description of different sorghum varieties tested at five locations.

# No	Varieties	Pedigree	Year of Release	Adaptation area (m.a.s.l.)	Breeder/Maintainer
1	Baji	85 MW 5334	1996	1600-1900	MARC/EIAR
2	Birmash	NA	1989	1600-1900	MARC/EIAR
3	Geremew	87 BK -4122	2007	1600-1900	MARC/EIAR
4	Lalo	BRC-245	2006	>1600	BARC/OARI
5	Teshale	3443-2-0P	2002	1450-1850	SRARC/ARARI and MARC/EIAR
6	Melkam	WSV 387	2009	<1600	MARC/EIAR
7	Gobiye	P-9401	1999	<1850	MARC/EIAR
8	Abshir	P-9403	2000	<1850	MARC/EIAR
9	Dagim	IS10892XRS/R-20-8614-2 x IS	2011	1600-1900	SRARC
10	IS9302	NA	1981	1600-1900	MARC/EIAR
11	ESH-1	P-9501 A x ICSR14	2009	<1600	MARC/EIAR
12	Birhan	Key#8566	2002	<1850	SRARC/ARARI
13	Gambella-1107	NA	1981	1450-1850	MARC/EIAR
14	Emahoy	Pw01-092	2007	1600-1900	PARC/EIAR
15	Dekeba	ICSR 24004	2012	<1600	MARC/EIAR
16	Chemeda	Acc-BCC-5	2013	>1600	BARC/OARI
17	Local Check	-	-	-	Farmers
18	07MW6035	(89MW4122*85MW5552)*85MW5340	2016	1600-1900	MARC/EIAR
19	07MW6002	(89MW4122*85MW5552)*85MW5340	2016	1600-1900	MARC/EIAR
20	Assosa_1	Bambasi # 9	2015	1500-1850	AARC
21	Adukara	NA	2015	1500-1850	AARC
22	07MW6052	(89MW4122*85MW5552)*85MW5340	2016	1600-1900	MARC/EIAR

NB: EIAR=Ethiopian Institute of Agricultural Research, MARC=Melkasa Agricultural Research Center, BARC= Bako Agricultural Research Center, SRARC= Sirinka Agricultural Research Center, ARARI=Amhara Regional Agricultural Research Institute, OARI= Oromia Agricultural Research Institute, PARC= Pawe Agricultural Research Center, AARC= Assosa Agricultural Research Center, NA= Not Available

Experimental procedures

The trial was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental plot consists of two rows, each 5 m in length with 75 cm row to row spacing and 15 cm spacing between plants. Seeds were sown by hand drilling at the rate of 12 kg ha^{-1} as per the recommendation for row planting in sorghum. Thinning was done two weeks after emergence to adjust plant to plant spacing. NPS fertilizer was applied as per recommended rate. During planting, 100 kg ha^{-1} of NPS was applied in the seed furrow at planting. Urea was applied as top dressing in split application at the rate of 50 kg ha^{-1} at knee height stage. The field was kept free of weeds by hand weeding during the period of the experiment. All other recommended agronomic management practices such as land preparation and insect pest control were done.

Stability analysis

Eberhart and Russell's model

Yield stability was determined following the Eberhart and Russell (1966) model by regression of the mean grain yield of individual genotypes on environmental index and calculating the deviation from the regression.

$$Yij = \mu i + \beta iIj + \delta ij + \varepsilon ij$$

Where: Yij = the mean of the i^{th} genotype in the j^{th} environment,
μi = the grand mean,
βi = the regression coefficient of the i^{th} genotype on environmental index,
Ij = the environmental index obtained by the difference between the mean of each environment and the grand mean, δij = the regression deviation of the i^{th} cultivar in the j^{th} environment,

Additive Main effect and Multiplicative Interaction (AMMI) mode

In AMMI model the contribution of each genotype and each environment to the GEI is assessed using the biplot method where yield means are plotted against the scores of the IPCA1 (Zobel *et al.,* 1988*).* The AMMI model was calculated using the following formula:

$$Y_{ij} = \mu + \alpha_i + ß_j + \sum_{n=0}^{N} \lambda_n \gamma_{in} \delta_{jn} + \theta_{ij} + \varepsilon_{ij}$$

Where: Y_{ij} = the mean yield of genotype i in environment j, μ = the grand mean, α_i = the deviation of the genotype mean from the grand mean, β_j= the deviation of the environment mean from the grand mean, λ_n= the singular value for the IPCA n, N = the number of PCA axis retained in the model, γ_{in} = the PCA score of a genotype for PCA axis n, δ_{jn} = the environmental PCA score for PCA axis n, θ_{ij} = the AMMI residual and E_{ij}= the residuals.

AMMI's stability value (ASV)

The AMMI model does not make provision for a quantitative stability measure, such a measure is essential to quantify and rank genotypes according to their yield stability. This value was calculated according to Purchase (1997) as follow:

$$(ASV) = \sqrt{\left[\left(\frac{IPCA1SS}{IPCA2SS}\right)(IPCA1Score)\right]2 + (IPCA2Score)2}$$

In effect, the ASV is the distance from zero in a two dimensional scatter graph of IPCA1 (Interaction Principal Component Analysis axis 1) scores against IPCA 2 scores. Since the IPCA1 score contributes more to G x E sum of squares, 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 G x E sum of squares.

Results and Discussion

Mean grain yield and yield related traits at individual location

The mean grain yield value of varieties averaged over environments indicated that, Birmash, Baji and IS9302 followed by Emahoy gave higher grain yield (3.52, 3.34, 3.21 and 3.19 ton ha^{-1}, respectively) and the lowest for Abshir (1.52 ton ha^{-1}). All varieties showed inconsistent performances across all environments. Overall, the highest (5.44 ton ha^{-1}) grain yield was obtained from variety 07MW6002 at Gute.

Genotype x environment Interaction

The result of the combined ANOVA showed that, the total variation in yield was attributed to environmental (19.34%), genotypic (19.78%) and GEI (47.85%) effects (Table 6). This indicates that the largest proportion of the variation was due to the Genotypes x Environments Interaction. This is implies that GxE Interaction is the major factor that influence yield performance of sorghum genotypes in sorghum growing environments of Ethiopia. The sum of squares of GEI was 2.43 times higher than that of the genotypes. This result is not in agreement with that of Asfaw (2007, 2008), Hagos and Fetien (2011), Mahnaz *et al.* (2013), Sewagegne *et al.* (2013) who reported large environmental effects for sorghum genotypes.

Table 3. Mean grain yield (tons ha^{-1}) across different locations in 2017 cropping season

		Grain yield (ton ha^{-1}) of testing locations					
# No	Varieties	Bako	Biloboshe	Gute	Mechara	Miesso	MGY
1	Baji	3.123^{ab}	4.136^{ab}	4.311^{b}	3.863^{a-d}	1.287^{cd}	3.34
2	Birmash	2.674^{b-e}	4.229^{a}	4.795^{ab}	4.159^{a-c}	1.721^{a-d}	3.52
3	Geremew	2.808^{a-c}	3.294^{a-d}	4.655^{ab}	2.271^{f-k}	1.037 ^{d}	2.81
4	Lalo	2.909^{a-c}	4.051^{ab}	4.778^{ab}	2.110^{g-l}	1.680^{b-d}	3.17
5	Teshale	2.598^{b-e}	2.378^{de}	1.295^{ij}	4.331^{a-c}	2.500^{a}	2.62
6	Melkam	2.720^{a-d}	1.512^{e}	1.487^{g-j}	3.717^{b-e}	1.693^{a-d}	2.23
7	Gobiye	2.096^{d-f}	2.339^{de}	0.951^{ij}	2.280^{f-j}	1.476^{b-d}	1.78
8	Abshir	1.609^{f}	1.503^{e}	0.597^{j}	2.325^{f-i}	1.571^{b-d}	1.52
9	Dagim	1.675^{f}	4.034^{a-c}	4.419^{ab}	2.615^{d-h}	1.232^{cd}	2.79
10	IS9302	2.987^{a-c}	3.731^{a-c}	4.461^{ab}	3.490^{b-g}	1.368^{b-d}	3.21
11	ESH-1	2.801^{a-c}	1.538^{e}	1.735^{f-i}	2.333^{f-i}	1.832^{a-d}	2.05
12	Birhan	2.056 ^{ef}	1.477^{e}	0.682^{j}	2.429^{e-h}	1.650^{b-d}	1.61
13	Gambella-1107	2.452^{c-e}	2.994^{b-d}	2.634^{d-f}	4.121^{a-c}	1.747^{a-d}	2.97
14	Emahoy	2.970^{a-c}	2.884^{cd}	3.251^{cd}	4.871^{ab}	1.975^{a-c}	3.19
15	Dekeba	1.597 ^{f}	2.344^{de}	1.895^{f-i}	4.090^{a-c}	1.442^{b-d}	2.27
16	Chemeda	2.366^{c-e}	1.589^{e}	2.177^{e-h}	3.593^{b-f}	2.200^{ab}	2.38
17	Local check	2.635^{b-e}	1.357^{e}	4.445^{ab}	0.721^{m}	1.293^{cd}	2.12
18	07MW6035	2.750^{a-c}	3.425^{a-d}	3.099^{c-e}	0.941^{j-m}	1.241^{cd}	2.35
19	07MW6002	2.988^{a-c}	3.247^{a-c}	5.444^{a}	0.99^{i-m}	1.212^{cd}	2.82
20	Assosa_1	2.988^{a-c}	1.440^{e}	1.232^{h-j}	3.433^{c-g}	1.559^{b-d}	2.01
21	Adukara	2.379^{f}	1.468^{e}	2.823^{e-g}	5.120^{a}	1.559^{b-d}	2.76
22	07MW6052	2.834^{a-c}	3.693^{a-c}	3.929^{bc}	1.952^{h-m}	1.025^{d}	2.6
Mean		2.525	2.68	2.921	2. 98	1.559	2.553
CV%		13.2	31.5	18.9	24.4	27.5	
LSD (0.05)		0.551	1.382	0.91	1.199	0.708	

MGY = Mean grain yield, the same letters within the same columns are not significantly different

Stability Analysis

Eberhart and Russell Regression Model

According to Eberhart and Russell (1966) a stable genotype should have high yield, unit regression coefficient (b_i) and deviation from regression (Sd_i^2) nearly equal to zero. Based on these three parameters, varieties such as Gambella-1107 and Emahoy had regression coefficient closer to unity and deviation from regression very close to zero with mean grain yield greater than the average yield and hence could be considered as stable varieties Table 4.

Whereas, Baji and IS9302 were the second and third high yielder with regression coefficient of greater than one, deviation from regression (Sd_i^2) close to zero respectively, and thus best fit for specific adaptation in favorable environments. Varieties such as Chemeda, ESH-1 and Gobiye had regression coefficients less than one were specifically adapted to marginal environments.

Table 4. Mean yield, regression coefficients, coefficients of determination and deviation from regression

Varieties	Yield (ton ha^{-1})	Rank	b_i	Ranks	S^2d_i	Ranks	ri^2	MS-TXL	MS-REG
07MW6002	2.777	10	1.338	13	3.50	22	0.01	2.67	0.15
07MW6035	2.291	14	0.637	8	1.49	17	0.04	1.16	0.18
07MW6052	2.785	9	1.407	14	1.15	14	0.06	0.92	0.22
Abshir	1.521	22	-0.060	2	0.50	7	0.50	0.75	1.49
Adukara	2.664	11	3.830	22	2.69	20	0.17	2.16	1.11
Assosa_1	1.651	21	2.513	21	1.16	15	0.12	0.88	0.32
Baji	3.344	2	2.029	20	0.16	1	0.74	0.47	1.41
Birhan	1.659	20	-.064	1	0.58	9	0.46	0.81	1.50
Birmash	3.515	1	1.966	19	0.41	5	0.50	0.61	1.24
Chemeda	2.385	13	0.375	6	0.66	10	0.21	0.62	0.52
Dagim	2.795	7	1.675	16	1.35	16	0.13	1.17	0.61
Dekeba	2.273	15	1.107	10	0.97	11	0.01	0.73	0.02
Emahoy	3.190	4	1.425	15	0.55	8	0.13	0.47	0.24
ESH-1	2.048	18	0.077	3	0.34	3	0.52	0.54	1.13
Gambella-1107	2.789	8	1.173	11	0.38	4	0.03	0.29	0.04
Geremew	2.813	6	1.680	17	1.06	12	0.16	0.95	0.61
Gobiye	1.828	19	0.184	5	0.45	6	0.39	0.56	0.88
IS9302	3.208	3	1.843	18	0.24	2	0.57	0.41	0.95
Lalo	3.166	5	1.303	12	1.68	18	0.02	1.29	0.12
Local check	2.091	17	0.692	9	2.73	21	0.02	2.08	0.13
Melkam	2.226	16	0.577	7	1.11	13	0.07	0.89	0.24
Teshale	2.584	12	0.182	4	1.73	19	0.15	1.52	0.89

Key: MS-TXL = contribution of each variety to interaction MS, MS-REG = contribution of each variety to the regression component of the treatment by location interaction, MS-DEV (sd_i^2**)** =deviations from regression component of interaction, ri^2 = squared correlation between residuals from the main effects model and the site index, b_i = regression coefficient

Yield stability using AMMI Stability Values (ASV)

In additive main effect and multiplicative interaction stability value analysis (ASV) method, a genotype with least ASV score is the most stable across environments and the larger the ASV value, either negative or positive, the more specifically adapted a genotype is to certain environments (Purchase, 1997). ASV for each genotype along with their ranks is depicted in Table 5.

Table 5. The first four IPCA scores per varieties and ASV for the twenty two sorghum varieties sorted on mean grain yield **(**ton ha^{-1}) evaluated at five locations during 2017 main cropping season.

Varieties	Yield (ton ha^{-1})	Rank	IPCA1	IPCA2	IPCA3	IPCA4	ASV	Rank
07MW6002	2.777	10	-1.134	-0.269	0.309	-0.079	2.4791	22
07MW6035	2.291	14	-0.609	-0.491	-0.537	0.190	1.4122	15
07MW6052	2.785	9	-0.615	-0.142	-0.212	0.578	1.3440	13
Abshir	1.521	22	0.509	-0.401	-0.317	-0.270	1.1769	9
Adukara	2.664	11	0.781	0.297	0.680	0.266	1.7236	19
Assosa_1	1.651	21	0.543	0.275	0.066	0.154	1.2125	11
Baji	3.344	2	-0.287	-0.526	-0.108	0.378	0.8146	3
Birhan	1.659	20	0.526	-0.504	-0.224	-0.058	1.2483	12
Birmash	3.515	1	-0.304	0.681	-0.029	-0.186	0.9480	7
Chemeda	2.385	13	0.484	-0.194	0.339	-0.365	1.0690	8
Dagim	2.795	7	-0.604	0.544	-0.322	-0.545	1.4216	16
Dekeba	2.273	15	0.513	0.440	-0.102	-0.287	1.1983	10
Emahoy	3.190	4	0.380	0.393	0.264	0.079	0.9161	6
ESH-1	2.048	18	0.272	-0.648	0.126	0.097	0.8773	4
Gambella-1107	2.789	8	0.318	0.306	-0.118	-0.030	0.7552	1
Geremew	2.813	6	-0.678	0.130	0.192	0.121	1.4802	17
Gobiye	1.828	19	0.328	-0.370	-0.572	0.059	0.8046	2
IS9302	3.208	3	-0.362	0.392	0.074	0.179	0.8793	5
Lalo	3.166	5	-0.783	0.017	-0.328	-0.124	1.7020	18
Local check	2.091	17	-0.772	-0.639	0.858	-0.294	1.7960	20
Melkam	2.226	16	0.636	-0.197	0.234	0.241	1.3958	14
Teshale	2.584	12	0.858	-0.144	-0.275	-0.107	1.8694	21
Mean	**2.553**							

Key: IPCA=Integrated Principal Component Axis 1, 2, 3 and 4, ASV=AMMI Stability Value

Genotype x **Environment Interaction analysis of Variance by AMMI Model**

The combined AMMI ANOVA of the twenty two sorghum varieties over five locations for grain yield (ton ha^{-1}) is presented in Table 6. The ANOVA table indicated highly significant differences ($p<0.01$) for treatments (environments, genotypes and GEI). The total variation explained (%) was 86.44% for treatment and the remaining % for error. The greater contribution of the treatment over the error indicates the reliability of this multi-location experiment. The treatment variation was largely due to GEI variation (48.66%), genotype and accounted 20.08% and 17.71% 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 sorghum in Ethiopia is the interaction effect of Genotype and Environment. In the AMMI ANOVA, the GEI was further partitioned using PCA. The number of PCA axis to be retained is determined by testing the mean square of each axis with the estimate of residual using the F-statistics. The result of ANOVA showed that the first two IPCA are highly significant at $P<0.01$, this result suggests the inclusion of the first two interaction PCA axes in the model. Hence, the best fit AMMI model for this multi-location yield trial data was AMMI-2 (Table 6).

Table 6. AMMI analysis of variance for grain yield (ton/ha) of sorghum varieties tested at five locations during 2017 main cropping season.

		Sum of squares explained				
Source	DF	SS	%Total	%Contribution to the variation	% G x E	MS
Total	329	523				1.59
Treatments	109	452.1	86.44			4.148**
Genotypes	21	105	20.08			5.001**
Environments	4	92.6	17.71			23.14**
Block	10	6.61				0.661*
G x E	84	254.5	48.66			3.029**
IPCA 1	24	186.2			73.16	7.76**
IPCA 2	22	39.4			15.48	1.79**
Residuals	36	28.9			11.36	0.803
Error	206	64.3	12.29			0.312

DF = degree of freedom, SS =sum of squares, MS = mean of squares and, GxE= Genotype by Environment, %= percentage, * significant (P<0.05), ** = highly significant (P<0.01).

Summary and Conclusions

Multi-location trials are very important for selecting the best genotype for wide or specific environments before any recommendation of genotypes for commercial production. Multivariate analysis using AMMI model was used to give similar picture of response pattern, because the varieties' response is multivariate. In the AMMI analysis, the plot distribution of the varieties in the AMMI1 biplot explained more than 48.68% of the interaction. Based on the information generated from AMMI1 biplot, Biloboshe was the most favorable environment. Among the varieties, Emahoy had higher mean grain yield and had wide adaptation while Birmash with high mean yield had specific adaptation due to its instability in most stability parameters. In IPCA2 or AMMI2 biplot, Gute, Mechara and Biloboshe were the most discriminating environments, while Emahoy, Baji and Birmash were the most responsive varieties. Varieties and environments that fall in the same sectors interact positively; negatively if they fall in opposite sectors. Accordingly, varieties can be recommended for specific and wide adaptation. Baji was best at Bako. It was also the most widely adapted variety across the testing environment. Birmash was the best variety at Biloboshe, 07MW6002 performed best at Gute, Adukara performed best at Mechara and Teshale was the best at Miesso. However, from grain yield perspective and also as observed from the majority of stability parameters used, Emahoy variety is best for wider adaptability, followed by Baji and Birmash.

Reference

Abubakar, L. and Bubuche, T. S. 2013. Genotype x environment interaction on yield and its component of sorghum (*Sorghum bicolor* (L.) Moench) genotypes of some selected states in North-Western Nigeria. *International Journal of Current Agricultural Research*, 1(6): 27-29. http://www.wrpjournals.com/journals/V/IJCARAccessed on June 1, 2014.

Asfaw Adugna. 2007. Assessment of yield stability in sorghum. *African Crop Science Journal,* 15 (2): 83 – 92.

CSA (Central Statistical Agency). 2013. Agricultural Sample Survey and Area production of Crops. Statistical Bulletin 532, Volume I. Addis Ababa.pp14 - 63. Statistical Bulletin. V.505. Addis Ababa, Ethiopia.

CSA (Central Statistical Agency). 2016. Agricultural sample survey 2010/2011: report on area and production of crops (private peasant holdings, main season), vol. 1. Addis Ababa: Federal Democratic Republic of Ethiopia, Central Statistical Agency.

De Wet JMJ, Huckabay JP (1967) The origin of Sorghum bicolor. II. Distribution and domestication. Evolution 21 (4):787-802.

Doggett H (1988) Sorghum. Longman Scientific & Technical, London.

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

FAOSTAT. 2013. Database of agricultural production. Rome: Food and Agriculture Organization of the United Nations. Available at http://faostat.fao.org/default.aspx accessed November 2015.

FAOSTAT. 2017. Food and Agriculture Organization of the United Nations Data base of AgriculturalProduction.FAOStatisticalDatabases.Availableathttp://faostat.fao.org/site/339/default. aspx.

Firew Mekibib, 2003. Yield stability in common bean (*Phaseolus vulgaris* L.) genotypes. *Euphytica*, 130: 147-153.

Firew Mekbib, 2009. Farmers' breeding of sorghum in the centre of diversity, Ethiopia: I. Socio-ecotype differentiation, varietal mixture and selection efficiency. *Maydica*,54: 25-37.

Hagos Tadesse and Fetien Abay. 2011. Additive Main Effects and Multiplicative Interactions analysis of yield performance of sesame genotypes across environments in Northern Ethiopia. *Journal of the dry lands*, 4(1): 259-266.

ICRISAT (International Crops Research Institute for the Semi-Arid Tropics). 2009. online Available on the website http://www.icrisat.org/ Assessed on July 5, 2011.

Iqbal, A., Sadia, B., Khan, A.I., Awan, F.S., Kainthand, R.A. and Sadaqat, H.A. 2010. Biodiversity in the sorghum (*Sorghum bicolor* L. Moench) germplasm of Pakistan. *Genetics and Molecular Research*, 9 (2): 756-764.

Mahnaz, R., Ezatollah, F. and Mohammad, M. J. 2013. Additive Main Effect and Multiplicative Interaction Analysis of phenotypic stability in chickpea genotypes over stress and non-stress environments. *International Journal of Agriculture and Crop Sciences,* 5(36):253-260.

MOA (Ministry of Agriculture). 2015. Annual action plan report on cereals. Amhara National Regional State Bureau of Agriculture, Bahir Dar, Ethiopia.

Prakash, R., Ganesamurthy, K., Nirmalakumari, A. and Nagarajan, P. 2010. Heterosis for fodder yield in sorghum (*Sorghum bicolor* L. Moench). *Electronic Journal of Plant Breeding*, 1(3): 319-327.

Passardi, F., Longet, D., Penel, C. and Dunand, C. 2004. The class III peroxidase multigenic family in rice and its evolution in land plants. *Phytochemistry*, 65: 1879–1893.

Purchase, J.L. 1997. Parametric analysis to describe genotype by environment interaction and stability in winter wheat. PhD.thesis. Department of Agronomy, Faculty of Agriculture, University of the Orange Free State, Bloemfonten, South Africa.

Setegn Gebeyehu and Habtu Assefa, 2003. Genotype x Environment Interaction and Stability Analysis of Seed Yield in Navy Bean Genotypes. *African Crop Science Journal*, 11(1): 1-7

Sewagegne Tariku, Taddesse Lakew, Mulugeta Bitew and Mitiku Asfaw, 2013. Genotype by environment interaction and grain yield stability analysis of rice (*Oryza sativa* L.) genotypes evaluated in north western Ethiopia. *Net Journal of Agricultural Science*, 1(1): 10-16.

Smith CW, Frederiksen RA (2000) Sorghum: origin, history, technology, and production, vol 2. John Wiley & Sons, USA.

Wikipedia, 2011.Sorghum bicolor scientific classification.[Online] Available http://en.wikipedia.org/wiki/Sorghum_bicolor November, 2011.

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

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.

Yan, W. and Tinker, N.A. 2005. An integrated biplot analysis system for displaying, interpreting and exploring genotype by environment interactions. *Crop Science*, 45: 1004–16.

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

Association among quantitative traits in Ethiopian food barley (*Hordeum vulgare* L.*)* landraces

Geleta Negash[1*], Dagnachew Lule[2] and Zerihun Jaleta[3]
[1]Haro Sabu Agricultural Research Center, P.O.Box 10, Haro Sabu, Ethiopia, [2]Oromia Agricultural Research Institute, Addis Ababa, Ethiopia, [3]Faculty of Agriculture, Department of Plant Sciences, Wollega University, Nekemte, Ethiopia

*Corresponding author: geleta2017@gmail.com

Abstract
Barley is recognized as one of the oldest crop and is believed to have originated from the Fertile Crescent Region. It is one of the most important crop for human consumption, animal feed, homemade beverages and health. It is relatively early maturing cereal crop, with high-yield potential in marginal areas where other cereal crops are not adapted. One hundred barley genotypes were laid out in 10 x 10 simple lattice design with two replications and evaluated during 2017 main cropping season at Mata sub site of Haro Sabu Agricultural Research Center. Sixteen quantitative traits were evaluated to assess the inter- relationship among yield and yield-related traits and their effect on grain yield. Genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients for most of the characters studied. Grain yield exhibited positive and significant genotypic and phenotypic correlation with most of the desirable characters. Results of path analysis showed that, thousand seed weight and biological yield exerted positive direct effect on grain yield both at genotypic and phenotypic levels.. The first seven principal components with an eigen value greater than one explained a large portion of the total variations (79.3%). Generally, characters that showed positive direct effect as well as positive and significant correlation coefficient with grain yield were known to affect grain yield in the favorable direction and and hence, these traits should be considered during selection to improve grain yield.

Keywords: Barley,Correlation, *Hordeum vulgare*, , Indirect Effect, Principal Component

Introduction

Barley *(Hordeum vulgare* L.) is belongs to the genus *Hordeum* and in tribe Triticeae of the family Poaceae. The genus, *Hordeum*, has 32 species distributed over wide geographical areas and diverse ecological habitats. Barley is a diploid species with a chromosome number of 2n=2x=14 (Kling and Hayes, 2009). Barley is recognized as one of the oldest crops, and is believed to have originated in the Fertile Crescent region some 8,000 to 10,000 years ago (Harlan, 2008). It is a cool season food crop, the most dependable, early maturing cereal grain with relatively high-yield potential including in the marginal areas where other cereal crops are not adapted (Martin and Leonard, 2010; Harlan, 2008). Limited availability of improved varieties for different production systems, poor yield-potential of the available varieties, biotic and abiotic stress are among the major constraints challenging the production and productivities of the crop. Among the biotic constraits,, diseases such as scald, cover and loose smuts and leaf and stem rusts; insects such as barley shoot fly, Russian wheat aphid and weeds are the major constarits in barely production. Studies conducted at Holeta indicated that scald and net blotch may reduce barely grain yield by 21-67% and 25-34%, respectively

(Eshetu, 1986). Barley shoot fly reduce barely yield by more than 56% and aphids may also cause 4% to 79% loss or even total crop failure under different infestations (Adugna and Kemal, 1986). From abiotic stresses, poor soil-fertility, water logging, drought and soil acidity are the major constraits in barely production (Berhanu *et al.*, 2006; ICARDA, 2009).

The inter relationship of quantitative characters with yield; determine the efficiency of selection in breeding programmes. Phenotypic correlation reflects the observed relationship, while genotypic correlation underlines the true relationship among characters. Correlation coefficient is the measure of the degree for linear association between the two variables (Gomez and Gomez, 1984). A knowledge of correlations that exists between desirable characters can facilitate the interpretation of results obtained and provide the basis for planning more efficient program for the future (Martintello *et al.*, 2005). Genotypic correlation coefficient offers a measure of the genetic association between characteristics and may provide an important criterion of selection procedures (Can and Yoshida, 1999). In most studies, genotypic correlation coefficient values are greater for most of the characters than their corresponding phenotypic correlation coefficients.Assaduzzaman (2014) reported genotypic correlation coefficients that were higher than their corresponding phenotypic correlation coefficient for all traits studied on fourteen Lablab genotypes in Bangladesh. Path coefficient analysis is simply a standardized partial regression coefficient and measures the direct and indirect effects for one variable upon another and permits the separation of the correlation coefficient into components of direct and indirect effects (Dewey and Lu, 1959). Using path coefficient analysis, it is easy to determine which yield component/s is/are influences the yield substantially. Up on this information, selection can then be based on that criterion thus making possible great progress through selection. Path coefficient analysis has been used by plant breeders to assist in identifying traits that are useful as selection criteria to improve crop yield (Garcia *et al.*, 2003; Kashif, *et al.*, 2004). Therefore, the present study was initiated wih objevctives to assess the association among some yield and yield attributing traits as well as the direct and indirect effects on grain yield in barely breeding.

Materials and Methods

The experiment was conducted during 2017 main cropping season at Haro Sabu Agricultural Research Center (HSARC), Mata research sub-site, Western Oromia, Ethiopia. The area is located at 8°53 '33"N latitude and 34°80'11"E longitude. Mata research sub-site has an elevation of 1900 meters above sea level. Soil types of this sub site is constitutes of 90% loam, 6% sand and 4% clay soils. Mean annual rainfall was 1219.15 mm. The minimum and maximum annual temperatures were 16.21 and 27.77 °C, respectively. A total of 100 food barley landraces along with tow released varieties viz. HB 1307 and Abdane and one local check were evaluated in this study (Appedix 1).These Experimental materials were arranged in 10 x 10 simple lattice design with two replications. Seed was drilled on 20 cm row spacing, 1.65 m row length and 1 m spacing between blocks. Seed rate of 85kg ha^{-1} was used and a combination of UREA and DAP fertilizer was applied at the recommended rate of 50 and 100 kg ha^{-1}, respectively. DAP 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 half at tiller initiation or 40 days after germination). All other agronomic practices were performed as per the recommendation for the crop.

Data collected and analysis

Ten plants were selected randomly before heading from each row and tagged with thread and all the necessary plant based data were collected from these sampled plants. Plant-based data collected includes; peduncle length, grain weight per spike, plant height, spike length, spike weight per plant, number of spikelets per spike**,** productive and total tillers per plant, flag leaf length and awn length. Data collected on plot based includes; days to heading, days to physiological maturity, thousand seed weight, grain yield, biological yield and harvest index. Phenotypic and genotypic correlations as well as path coefficient analysis were carried out using SAS software version 9.2 (SAS, 2008).

Correlation analysis

Associations between all possible pairs of quantitative traits were evaluated for their significance using SAS software.. Phenotypic and genotypic correlations between yield and yield related traits were estimated using the method described by Miller *et al.* (1958) and Kashiani and Saleh (2010) from the corresponding variance and covariance components as follows:

Phenotypic correlation coefficient

$$rpxy = \frac{pcov\ x.y}{\sqrt{\delta^2 px * \delta^2 py}}$$

Genotypic correlation coefficient

$$rgxy = \frac{gcov\ x.y}{\sqrt{\delta^2 gx * \delta^2 gy}}$$

Where, rpxy = Phenotypic correlation coefficient between characters X and Y, r*gxy* = genotypic correlation coefficients between characters X and Y, pcov x.y and gcov x.y are phenotypic and genotypic covariance between variables x and y, respectively, σ^2p =Phenotypic Variance between characters X and Y, σ^2g =Genotypic Variance between characters X and Y.

The calculated phenotypic correlation value was tested for its significance using t-test:

$$t = \frac{r_p}{SE(r_p)}$$

Where, r_p = Phenotypic correlation; SE (^r_p) = Standard error of phenotypic correlation obtained using in the following procedure (Sharma, 1998).

$$SE\ (r_p) = \sqrt{\frac{(1 - r^2{}_p)}{(n-2)}}$$

Where, n is the number of genotypes tested, r_p is phenotypic correlation coefficient.

The coefficients of correlations at genotypic levels were tested for their significance using the formula described by Robertson (1959) as indicated below:

$$t = \frac{r_{gxy}}{SEr_{gxy}}$$

The calculated "t" value was compared with the tabulated "t" value at (n-2) degree of freedom at 5% and 1% level of significance. Where, n = number of genotypes

$$SEr_{gxy} = \sqrt{\frac{1 - r^2_{gxy}}{2Hx.Hy}}$$

Where, h^2_x = Heritability of trait x; h^2_y = Heritability of trait y

Path Coefficient Analysis

Path coefficient analysis was conducted as suggested by Wright (1921) and worked out by Dewey and Lu (1959) using the phenotypic as well as genotypic correlation coefficients to determine the direct and indirect effects of yield components on grain yield based on the following relationship.

$$rij = Pij + \Sigma rik * Pkj$$

Where, rij = mutual association between the independent character i (yield-related trait) and dependent character, j (grain yield) as measured by the genotypic correlation coefficients; Pij = components of direct effects of the independent character (i) on the dependent character (j) as measured by the path coefficients; and ∑rikpkj = summation of components of indirect effects of a given independent character (i) on a given dependent character (j) via all other independent characters (k). Whereas the contribution of the remaining unknown characters is measured as the residual factor (P_R), which is calculated as:

$$P_R = \sqrt{(1 - \sum pijrij)}$$

Where: i=any trait in the model, j=dependent variable (grain yield) and r=correlation coefficient between any trait i and the dependent variable j. Residual (R) is the square root of non-determination; the magnitude of P_R indicates how best the causal factors account for the variability of the dependent factor (Singh & Chaudhary, 1999).

Principal Component Analysis (PCA)

Principal component analysis for 16 standardized quantitative traits was computed by using SAS software to identify the most important traits contributing to the total variations observed among the genotypes. As suggested by Johnson and Wichern (1988), principal components with Eigen values greater than one were considered**.**

Results and Discussions

Phenotypic and Genotypic Correlation

The relationship, direct and indirect associations between yield and yield related agronomic characters were studied using phenotypic and genotypic correlation and path coefficient analysis. The estimated values of phenotypic and genotypic correlation coefficients between all pairs of characters are presented in Table 1. In present study, the correlation analyses revealed that, the genotypic correlation coefficients were higher than the phenotypic correlation coefficients for most traits demonstrating that, the observed relation- ships among the various traits were due to genetic causes. This indicated that the phenotypic expression of correlations is reduced under the influence of environment. This is in agreement with the findings of Ahadu (2008), Sabesan et al. (2009), Jayasudha and Sharma (2010), Assaduzzaman (2014) and Patel et al. (2014).

Correlation of grain yield with other traits

Yield components like spike number per m^2, grain per spike, plant height and 1000-seed weight have significant effect on grain yield (Fathi and Rezaie 2000). Phenotypically, grain

yield showed positive and significant ($p < 0.01$) correlation with spike length ($r_{p=}0.25$) and awn length ($r_{p=}0.25$). Similarly, Singh and Chaudhary (1999) reported grain yield per plant had positive and significant correlations with tiller number, spikelet and grain number per spike and 1000 -grain weight at both genotypic and phenotypic levels. Grain yield showed negative and significant phenotypic correlation with days to heading ($r_{p=}$ -0.36) and days to maturity ($r_{p=}$-0.38). This is in agreement with the finding of Bhutta et al. (2005) and Blanco et al. (2010) who reported negative and significant correlation between days to heading and grain yield in barley. Grain yield showed positive and significant phenotypic correlation with plant height ($r_{p=}0.32$), thousand seed weight ($r_{p=}0.54$), biological yield ($r_{p=}0.76$), harvest index ($r_{p=}0.30$) and grain weight per spike ($r_{p=}0.32$). Tall plant generally excelled in their capacity to support kernel growth by stem reserve mobilization indicating selection for tall plant tends to increase grain yield per plant. This finding in agreement with Blum *et al.* (1989), Acevedo *et al*. (1991) and Alam *et al.* (2007) who reported positive and significant correlation of grain yield with plant height in barley.

Days to heading showed negative and significant correlation with spike length, plant height and 1000-seed weight, but positive and significant correlation with days to maturity. As far as plant height is concerned, it has positive and significant correlation with spike length, awn length, productive tillers per plant, grain yield and grain weight per spike. Similarly, trait like 1000-seed weight and biological yield has showed positive and significant correlation with plant height. Spike length has showed positive and significant correlation with productive tillers per plant, grain yield, 1000-seed weight, biological yield and awn length. Awn length has also showed positive and highly significant correlation with grain yield, grain weight per spike, 1000-seed weight and biological yield (Table1).

Genotypically, grain yield showed positive and significant correlation with grain weight per spike ($r_{g=}0.36$), spike weight per plant ($r_{g=}0.38$), 1000-seed weight ($r_{g=}0.66$), biological yield ($r_{g=}0.83$) awn length ($r_{g=}0.34$) and plant height ($r_{g=}0.23$). Yet, days to heading ($r_{g=}$ -0.43) and days to maturity ($r_{g=}$ -0.42) had negatively significant correlation with grain yield (Table 1). This finding in agreement with Budak (2000), Balcha (2002), Bhutta *et al*. (2005), Yağdı and Sözen (2009) who reported negative and significant correlation of grain yield with days to heading and days to maturity. This might be due to the presence of common genetic elements that controlled the characters in the same and/or in different directions. The observed significant positive correlation could be either due to the strong coupling linkage between the genes or as the result of pleiotropic genes that controlled these characters in the same direction (Kearsey and Pooni,1996). The negative correlations of grain yield with days to heading and maturity indicated that, early varieties would improve grain yield. Normally, inverse relationship between earliness characters and grain yield is necessary especially if stresses such as terminal heat and drought are expected. That means even if long duration of the growing period would mean that there would be more accumulation of dry matter over the extended growing period, there should be certain compromise between earliness as a stress escape mechanism and the possible yield reduction in moisture stress areas. This is in agreement with the finding of Gautam and Sethi (2002), Mohammad et al. (2006), Mohammadi et al. (2012), Tsegaye et al. (2012) and Zafarnaderi et al. (2013) who reported negative relationship between days to flowering and grain yield per plant in advance wheat lines.

Plant height had showed positive significant association with peduncle length, spike length, awn length, grain weight per spike, spike weight per plant, and biological yield. Peduncle length had positive and significant correlation with productive tillers per pant, 1000-seed weight and biological yield. Spike length had showed positive and significant correlation with awn length, productive and total tillers per plant, number of spikeletes per spike,1000-seed weight and biological yield. The correlation of awn length with grain weight per spike, spike weight per plant,1000-seed weight and biological yield was positive and significant. Productive tillers per plant had showed positive and significant correlation with total tillers per plant, number of spikeletes per spike, 1000-seed weight, biological yield and harvest index (Table1).

Table1: phenotypic correlation coefficients (above diagonal) and genotypic correlation coefficients (below diagonal) of the 16 character in 100 barley accessions

Traits	DH	DM	PH	PDL	SL	AL	FLL
DH	1	0.74**	0.03	-0.19*	-0.05	-0.16*	0.23**
DM	0.81**	1	-0.01	-0.23**	0.02	-0.05	0.28**
PH	0.1	0.09	1	0.60**	0.41**	0.21**	0.32**
PDL	-0.22*	-0.25*	0.60**	1	0.21**	0.16**	0.15*
SL	0	0.1	0.27**	0.17	1	0.17*	0.37**
AL	-0.16	-0.08	0.32**	0.19	0.23*	1	0.11
FLL	0.38**	0.47**	0.23*	0.1	0.20*	0.07	1
PTPP	-0.42**	-0.38**	0.1	0.20*	0.28**	0.2	-0.12
TTPP	-0.19	-0.17	0.07	0.17	0.30**	0.15	-0.02
YLD	-0.43**	-0.42**	0.23*	0.35**	0.18	0.34**	0.01
GWPS	-0.02	0.02	0.39**	0.11	0.08	0.39**	0.22*
SWPP	-0.16	-0.15	0.37**	0.11	0.01	0.41**	0.17
NSTPS	-0.27**	-0.16	-0.02	0.14	0.37**	0.02	-0.11
TSW	-0.40**	-0.37**	0.18	0.36**	0.21*	0.27**	-0.02
BYLD	-0.17	-0.18	0.36**	0.30**	0.23*	0.27**	0.16
HI	-0.43**	-0.42**	-0.26**	0.05	-0.12	0.05	-0.30**

Table 1: continued

Traits	TTPP	YLDTH	GWPS	SWPP	NSTPS	TSW	BYLD	HI
DH	-0.15*	-0.36**	-0.01	-0.16*	-0.24**	-0.32**	-0.14	-0.36**
DM	-0.15*	-0.38**	-0.02	-0.18*	-0.15*	-0.35**	-0.18*	-0.30**
PH	0.22**	0.32**	0.32**	0.36**	0.02	0.27**	0.41**	-0.15*
PDL	0.13	0.31**	0.09	0.09	0.13	0.31**	0.30**	0.03
SL	0.40**	0.25**	0.11	0.12	0.32**	0.30**	0.27**	-0.06
AL	0.09	0.25**	0.30**	0.32**	0.01	0.19**	0.22**	0.04
FLL	0.16*	0.13	0.20**	0.21**	-0.07	0.14	0.17*	-0.11
PTPP	0.94**	0.39**	0.11	0.14*	0.31**	0.39**	0.32**	0.11
TTPP	1	0.31**	0.06	0.08	0.26**	0.33**	0.27**	0.06
YLD	0.25*	1	0.32**	0.36**	0.23**	0.54**	0.76**	0.30**
GWPS	-0.05	0.36**	1	0.82**	-0.09	0.32**	0.34**	-0.03
SWPP	-0.09	0.38**	0.88**	1	-0.16*	0.33**	0.38**	-0.05
NSTPS	0.28**	0.24*	-0.2	-0.28**	1	0.22**	0.15*	0.13
TSW	0.27**	0.66**	0.23*	0.20*	0.27**	1	0.51**	0.01
BYLD	0.20*	0.83**	0.40**	0.41**	0.15	0.55**	1	-0.37**
HI	0.1	0.15	-0.11	-0.11	0.15	0.11	-0.41**	1

Key: DH = days to heading, DM= days to maturity, PH=plant height, PDL= peduncle length, SL=spike length, AL =awn length, FLL=flag leaf length, PTPP =productive tillers per plant, TTPP=total tillers per plant, YLDTH= grain yield, GWPS =grain weight per spike, SWPP =spike weight per plant, NSTPS=number of spikeletes per spike, TSW =thousand seed weight

Path Coefficient Analysis

Actually, many of the traits are correlated either negatively or positively because of mutual associations. As more variables are considered in the correlation table, these indirect associations become more complicated and less obvious. Therefore, path coefficient analysis provides more effective means of separating direct and indirect factors, permitting a critical examination of the specific forces acting to produce a given correlation and measuring the relative importance of the causal factors. Several authors (Dewey and Lu, 1959; Getachew *et al*., 1993) have used path coefficient analysis to partition correlation coefficients into direct and indirect effects using grain yield as a dependent variable.

Genotypic path coefficient

Biological yield had positive and significant correlation coefficient and it showed the highest positive direct effect (0.68) on grain yield. Peduncle length, awn length, productive tillers per plant, grain weight per plant, 1000-seed weight, number of spikeletes per spike had positive and significant correlation and exerted positive direct effect on grain yield. The direct effects of the rest of the characters were negative (Table 2). Therefore, the positive correlation they had with grain yield was largely due to the direct effect. Similarly, Getachew *et al.* (2007) reported positive direct effect of the number of productive tillers per plant on grain yield in Ethiopian barley landraces. The direct effects of the rest of the characters were negative (Table 2). Therefore, the positive correlation they had with grain yield was largely due to the direct effect. This result in line with the finding of Pathak (2008) who reported negative direct effect of plant height on grain yield and with Mogghhadam et al. (2009) and Blanco *et al.* (2010) who reported positive direct effect of 1000-seed weight on grain yield.Days to heading, days to maturity and plant height had negative direct effect. The indirect effects of days to heading, days to maturity and plant height with other characters were mostly negatives and negligible. The negative correlation coefficient of days to heading and maturity with grain yield were due to the direct effect but the positive correlation of plant height with grain yield was due to indirect effect (Table 2).

The negative direct effect of days to maturity and plant height on grain yield indicated the possibility that grain yield could be improved by focusing on medium maturing genotypes with optimum plant height to develop varieties against lodging problems. This is in agreement with Wolie and Dessalegn (2011) who found that, plant height and days to maturity had negative direct effect on grain yield. Singh and Chaundhary (1985) suggested an indirect effect seemed to be the cause of correlation and hence, these indirect causal factors (traits) should be considered simultaneously for selection. Besides,awn length, grain weight per spike, productive tillers per plant and thousand seed weight exhibited positive direct effects on grain yield indicated that, increasing in those traits could possibly to increase grain yield. Therefore, the genotypic residual value (0.4326) indicated that, the characters under study accounted for 56.74% of the variability with grain yield components (Table2).

Phenotypic path coefficient

Biological yield and harvest index showed positive and significant correlation (r= 0.76) and (r= 0.30) with grain yield and they had also exerted the highest direct effect (0.99) and (0.67) on grain yield, respectively. The existence of negligible and positive indirect effect of

biological yield and harvest index with most of the other characters determines that, the correlation of these traits with grain yield were found to be due to the direct effect (Table 3). Days to maturity has negligible positive direct effect on grain yield. The correlation of days to maturity with grain yield was because of indirect effect. Plant height, spike length, awn length, productive tillers per plant and 1000- seed weight had positive and negligible direct effect on grain yield and the phenotypic correlation they had with grain yield were positive. The indirect effect of biological yield through days to heading, total tillers per plant, grain weight per spike and harvest index counter balanced the direct effect of biological yield on grain yield. The indirect effect of harvest index through biological yield (-0.37) counter balanced the direct effect of harvest index on grain yield (0.67). The residual value (0.1731) showed the characters under the study accounted 82.7% of the variability in grain yield (Table 3).

Table.2 Estimates of direct (bold diagonal) and indirect (off diagonal) effect of traits on grain yield on the basis of genotypic correlation

Traits	DH	DM	PH	PDL	AL	PTPP	TTPP	GWPS	SWPP	NSTPS	TSW	BYLD	**rg**
DH	**-0.07**	-0.06	-0.01	-0.02	-0.01	-0.05	0.02	-0.00	0.00	-0.01	-0.05	-0.11	**-0.43****
DM	-0.05	**-0.07**	-0.01	-0.02	-0.01	-0.05	0.02	0.00	0.00	-0.01	-0.05	-0.12	**-0.42****
PH	-0.01	-0.01	**-0.13**	0.04	0.03	0.01	-0.01	0.03	-0.00	-0.00	0.02	0.25	**0.23****
PDL	0.01	0.02	-0.08	**0.07**	0.02	0.03	-0.02	0.01	-0.00	0.01	0.05	0.21	**0.35****
AL	0.01	0.01	-0.04	0.01	**0.09**	0.03	-0.02	0.03	-0.01	0.00	0.04	0.19	**0.34****
PTPP	0.03	0.03	-0.01	0.02	0.02	**0.13**	-0.09	0.00	0.00	0.02	0.05	0.18	**0.37****
TTPP	0.01	0.01	-0.01	0.01	0.01	0.12	**-0.10**	-0.00	0.00	0.01	0.04	0.14	**0.25***
GWPS	0.00	-0.00	-0.05	0.01	0.03	0.00	0.01	**0.09**	-0.01	-0.01	0.03	0.27	**0.36****
SWPP	0.01	0.01	-0.05	0.01	0.04	0.00	0.01	0.08	**-0.01**	-0.01	0.03	0.28	**0.38****
NSTPS	0.02	0.01	0.00	0.01	0.00	0.04	-0.03	-0.02	0.00	**0.05**	0.04	0.10	**0.24****
TSW	0.03	0.03	-0.02	0.03	0.02	0.04	-0.03	0.02	-0.00	0.01	**0.13**	0.38	**0.66****
BYLD	0.01	0.01	-0.05	0.02	0.02	0.03	-0.02	0.04	-0.01	0.01	0.07	**0.68**	**0.83****

Key: DH = days to heading, DM= days to maturity, PH=plant height, PDL= peduncle length, AL =awn length, PTPP =productive tillers per plant, TTPP=total tillers per plant, GWPS =grain weight per spike, SWPP, =spike weight per plant, NSTPS=number of spikeletes per spike, TSW =thousand seed weight, BYLD=biological yield, rg =genotypic correlation

Table.3 Estimates of direct (bold diagonal) and indirect (off diagonal) effect of traits on grain yield on the basis of phenotypic correlation.

Traits	DH	DM	PH	PDL	SL	AL	PTPP	TTPP	GWPS	SWPP	NSTPS	TSW	BYLD	HI	r_p
DH	**0.02**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.14	-0.24	-0.36**
DM	0.02	**0.00**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.18	-0.20	-0.38**
PH	0.00	0.00	**0.01**	-0.01	0.01	0.00	0.00	-0.01	-0.01	0.01	0.00	0.00	0.41	-0.10	0.32**
PDL	0.00	0.00	0.00	**-0.01**	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.29	0.02	0.31**
SL	0.00	0.00	0.00	0.00	**0.01**	0.00	0.00	-0.01	0.00	0.00	0.00	0.01	0.27	-0.04	0.25**
AL	0.00	0.00	0.00	0.00	0.00	**0.02**	0.00	0.00	-0.01	0.01	0.00	0.00	0.23	0.03	0.25**
PTPP	-0.01	0.00	0.00	0.00	0.01	0.00	**0.01**	-0.03	0.00	0.00	0.00	0.01	0.32	0.07	0.39**
TTPP	0.00	0.00	0.00	0.00	0.01	0.00	0.01	**-0.03**	0.00	0.00	0.00	0.01	0.27	0.04	0.31**
GWPS	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	**-0.03**	0.01	0.00	0.01	0.34	-0.02	0.32**
SWPP	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	-0.03	**0.02**	0.00	0.00	0.38	-0.03	0.36**
NSTPS	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	0.00	**0.00**	0.00	0.15	0.09	0.23**
TSW	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	0.01	0.00	**0.02**	0.51	0.01	0.54**
BYLD	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	0.01	0.00	0.01	**0.99**	-0.25	0.76**
HI	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.37	**0.67**	0.30**

Principal Component Analysis

The first seven principal components with an eigenvalue greater than one explained a large portion (79.1%) of the total variations. As suggested by Johnson and Wichern (1988), Eigen values greater than one were considered. The first principal components account for 23.1% of

the total variation, while the corresponding values for the second to the seventh PCs were 17.7%, 11.9%, 7.5%, 6.8%, 6.5% and 5.6% respectively (Table 4). Characters like grain yield, 1000-seed weight, biomass yield, productive tillers per plant, peduncle length and days to heading were the major contributors for the variation in the first principal component (Table 4).

Characters contributed more variation in the second principal component were grain weight per spike, spike weight per plant, number of seeds per spike, flag leaf length and plant height. Similarly, days to maturity, spike length, flag leaf length and harvest index were among the major variation contributors in the third principal component. Days to grain filling period, peduncle length, productive and total tillers per plant were showed greater absolute values of eigenvectors either in the fourth and/or in the fifth principal components. However, days to grain filling period, and peduncle length were exhibited greater absolute values either in the sixth and/or in the seventh principal components (Table 4).

Table 4: Eigenvalue, proportion and cumulative variances and eigenvectors on the first seven principal components for agronomic traits in 100 food barley accessions

characters	PC1	PC2	PC3	PC4	PC5	PC6	PC7
DH	-0.277	-0.242	0.271	-0.135	0.212	0.227	-0.151
DM	-0.256	-0.237	0.389	0.193	0.015	-0.028	-0.036
DGFP	0.026	-0.001	0.203	0.538	-0.318	-0.414	0.185
PH	0.199	-0.266	0.204	-0.196	-0.082	0.217	0.479
PDL	0.257	-0.016	0.136	-0.304	-0.273	0.343	0.364
SL	0.166	-0.014	0.388	0.165	-0.149	0.149	-0.16
AL	0.231	-0.162	-0.025	0.248	-0.139	0.090	0.154
FLL	-0.016	-0.275	0.317	0.109	-0.126	0.080	-0.164
PTPP	0.316	0.189	0.081	0.257	0.437	0.159	0.087
TTPP	0.244	0.180	0.168	0.275	0.512	0.235	0.048
YLDTH	0.390	-0.054	-0.078	-0.124	0.046	-0.156	-0.247
GWPS	0.197	-0.407	-0.183	0.169	-0.023	0.001	-0.048
NSPS	-0.055	-0.378	-0.276	0.195	0.271	-0.028	0.112
SWPP	0.208	-0.390	-0.266	0.125	-0.043	-0.010	-0.033
NSTPS	0.165	0.261	0.242	0.095	-0.140	-0.055	-0.189
TSW	0.354	0.066	0.040	-0.158	-0.175	-0.108	-0.242
BYLDTH	0.340	-0.183	0.114	-0.247	0.146	-0.287	-0.249
HI	0.059	0.268	-0.315	0.247	-0.243	0.214	0.102
Eigenvalue	4.398	3.368	2.261	1.426	1.290	1.233	1.056
Proportion %	23.100	17.700	11.900	7.500	6.800	6.500	5.600
Cumulative %	23.100	40.900	52.800	60.300	67.100	73.600	79.100

Key: PC= Principle components, DH = days to heading(days), DM= days to maturity(days), DGFP = days to grain filling period, PH=plant height(cm), PDL= peduncle length(cm), SL= spike length(cm), AL =awn length(cm), FLL = flag leaf length, PTPP =productive tiller plant^{-1}, TTPP=total tiller plant^{-1}, YLDTH =yield tons ha^{-11}, GWPS =grain weight spike^{-} (gm)^{1}, NSPS = number of seeds per spike ,SWPP = spike weight plant^{-1}(gm), NSTPS=number of spikeletes spike^{-1}, TSW =thousand seed weight(gm), BYLD= biological yield ,HI=harvest index

Conclusions and recommendations

Generally, there is strong correlation among most of the studied desirable characters that can afford basic information for further breeding activities for barely improvement. Characters that showed positive direct effect as well as positive and significant correlation coefficient with grain yield were known to affect grain yield to the favorable direction and these traits need much attention during selection. To this end, the present study revealed 1000-seed weight, biological yield, harvest index, awn length, and number of productive tillers per plant are the major traits that needs special attention in barley breeding activities. Therefore, high yielding genotypes can be selected by focusing on awn length, 1000-seed weight, biological yield, grain weight per spike and plant height. Since, these traits were correlated positively and significantly among themselves and with grain yield both at phenotypic and genotypic levels, they are useful in selection in barely improvement program, however, further evaluation of these materials over-locations and seasons are indispensable.

References

Acevedo, E., Craufurd, P. Q., Austin, R. B., & Perez-Marco, P. 1991. Traits associated with high yield in barley in low-rainfall environments. *The Journal of Agricultural Science*, *116*(1), 23-36.

Adugna Haile and Kemal Ali. 1986. A review of research on the control of insect pests of 77 food barley in Ethiopia small cereals. In: Tsedeke Abate, (eds). Proceedings of Symposium on First Ethiopian Crop Protection. Addis Ababa, Ethiopia, 4-7 February 1985, Institute of Agricultural Research.

Alam, M.Z., Haider, S.A., & Pau, N.K. 2007. Yield and Yield Components of Barley (*Hordeum vulgare* L.) cultivars in Relation to Nitrogen Fertilizer. *Journal of Applied Sciences Research,* 3(10), 1022-1026

Assaduzzaman, M.J., Bhuiyan, H., Hossain, M.A., & Sharif-AL-Raffi. 2014. Correlation and path coefficient analysis of fourteen different genotypes of lablab bean (*Lablab purpureus* L). *Bangla dish J.Pl. Breed. Genet*., 27(1),37-44

Balcha Y. 2002. Assessment of Stability and Character Association in Bread Wheat (*Triticum aestivum* L.) Genotype. M.Sc. thesis. Alemaya University. Ethiopia.

Berhanu Bekele, Fekadu Alemayehu &Berhane Lakew. 2006. Food barley in Ethiopia. In: Grando, Stefania and Helena Gomez Macpherson (eds). (2005). Food Barley: Importance, uses and local knowledge.Proceedings of the international workshop on food barley improvement, 14-17. January, 2002 Hammamet, Tunisia.ICARDA.

Blanco, A., Rajaram, S. & Kronstad, W.E. 2010. Agronomic potential of some barley genotypes. *Crop Sci*. 41, 670-676

Blum, A., Golan, G., Mayer, J., Sinmena, B., Shpiler, L., & Burra, J. 1989. The drought response of landraces of wheat from the northern Negev Desert in Israel. *Euphytica*, *43*(1-2), 87-96.

Can, N.D., & Yoshida, T. 1999. Genotypic and phenotypic variances and covariance's in early maturing grain sorghum in a double cropping. *Plant Prod. Sci.*, 2(1), 67-70

Dewey, D. R., & Lu, K. 1959. A Correlation and Path-Coefficient Analysis of Components of Crested Wheatgrass Seed Production 1. *Agronomy journal*, *51*(9), 515-518

Eshetu Bekele. 1986. A review of research on diseases of barley, tef and wheat. In: Tsedeke Abate (eds). Proceedings of Symposium on First Ethiopian Crop Protection, Addis Ababa, Ethiopia. 4-7 February 1985, Institute of Agricultural Research.

Fathi, G. H., & Rezaei moghddam, K. 2000. Path analysis of grain yield and yield components for some barley cultivars in Ahvaz region. *Agricultural Sciences and Technology*, *14*(1).

Garcia LF, del Moral, Rharrabti, Y., Villagas, D., & Royo C. 2003. Evaluation of grain yield and its components in durum wheat under Mediterranean conditions. *An ontogenic approach. Agron. J.*, 95 (3),266-274.

Getachew B., Tesemma, T., Becker, H.C., & Merker, A. 1993. Variation and Interrelationships of agronomic traits in Ethiopian tetraploid wheat landraces. *Euphytica* 71(5), 181-188.

Getachew, B., Tesemma, T., Becker, H.C., & Merker. A. 2007. Variation and interrelationships of agronomic traits in Ethiopian Barley landraces *Euphytica* 71 (3),181-188.

Gomez K.A., & Gomez, A.A. 1984. Statistical procedure for agricultural research Second Edition International Rice Research Institute John Wiley and Sons Inc

Harlan, J.R. 2008. *Evolution of Crop Plants*. New York. N.W Simmonds (eds.), University of Illinois Urbana Iii USA, Longman.

ICARDA 2009. ICARDA and Ethiopia: Ties that bind, No. 16, ICARDA, Aleppo, Syria, pp: 1-16.

Johnson, R. A., & Wichern, D. W. 1988. Applied multivariate statistical analysis. Prentice-Hall. *Journal of Agricultural Science* 43, 376-379.

Kashiani, P., & Saleh, G. 2010. Estimation of genetic correlations on sweet corn inbred lines using SAS mixed model. *Am J Agric Biol Sci*, *5*(3), 309-314.

Kashif, M. U. H. A. M. M. A. D., & Khaliq, I. H. S. A. N. 2004. Heritability, correlation and path coefficient analysis for some metric traits in wheat. *International Journal of Agriculture and Biology*, *6*(1), 138-142.

Kearsey, M.J., & Pooni, H.S. 1996. *The Genetical Analysis of Quantitative Traits*. Chapman and Hall, London, Weinhein, New York

Kling, J.G., &Hayes, P.M. 2009. Barley Genetics and Breeding Wrigley, C., Corke, H., H. Walker (eds.), *Encyclopedia of Grain Science*

Lenka, D., & Misra, B. 1973. Path-coefficient analysis of yield in rice varieties. *Indian journal of agricultural sciences*, *43*(4), 376-379.

Martin, J.H., Warren, H. L., & David, L. 1976. *Principles of Field Crops Production* (3rd ED.). New York, USA. MacMillan publishing Co. Inc.

Martin, J.H., & Leonard, W.H. 2010. *Principles of Field Crops Production*.2nd ed. London, MacMillan Company.

Martintello, P., Delocu, G., Boggini, G., Odoardi, M., & Stanca. A.M. 2005. Breeding progress in grain yield and selected agronomic characters of winter barley (*Hordeum vulgare* L.) over the last quarter of a century. *Pla..Br*. 99,289–294.

Miller, P. A., Williams, J. C., Robinson, H. F., & Comstock, R. E. 1958. Estimates of Genotypic and Environmental Variances and Covariance in Upland Cotton and Their Implications in Selection 1. *Agronomy journal*, *50*(3), 126-131.

Mogghhadam M., Ehdai, B., & Waines, J.G. 2009. Genetic variation and interrelationships of agronomic characters in landraces of spring barley from south eastern Iran *Euphytica* 95(5),361-369.

Pathak, N.N. 2008. Correlation and path analysis in barley under high temperature and moisture stress conditions. *Agron. J.* 50 (3), 126-131

Robertson, A. 1959. The sampling variance of the genetic correlation coefficient. *Biometrics*, *15*(3), 469-485.

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

Sharma, J.R. 1998. *Statistical and biometrical techniques in plant breeding*. New Delhi, New Age International (P) limited, publishers.

Singh, R. K., & Chaudhary, B.D. 1985. *Biometrical methods in quantitative analysis*. New Delhi, Kalyani, Publishers.

Singh, R. K., & Chaudhary, B.D. 1999. *Biometrical methods in quantitative genetics analysis*. New Delhi, Kalyani publishers.

Van Ginkel, M., Calhoun, D.S. Gebeyehu, G. Miranda, A. Tian-you, R.Pargas Lara, R.M. Trethowan, K. Sayre, J. Crossa ,K., &Rajaram. S. 1998. Plant traits related to yield of wheat in early, late, or continuous drought conditions. *Euphytica* 100, 109-121

Wallace D.H., Beredoin, J.P., Beaver, J., Coyana, D.O., Halseth, D.E., & Masya, P.N. 2011. Improvement efficiency for higher crop yield. *Theor. Appl. Genet*. 8(6),87-140

Wolie, A., & Dessalegn, T. 2011. Correlation and path coefficient analyses of some yield related traits in finger millet (*Eleusine coracana* (L.) Gaertn.) germplasms in northwest Ethiopia. *African Journal of Agricultural Research*, 6 (8),5099-5105.

Wright, S. 1921. Correlations and causations *J. Agri. Res.*20 (7),557-587

Appendex

Appendix:1 list of checks and 97 barley accessions collected from different regions of Ethiopia

Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)	Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)
1	64197	Amara	12-24-00-N	37-05-00-E	2090	26	64344	Oromiya	07-33-00-N	36-36-00-E	1880
2	3239	Amara	12-23-00-N	37-17-00-E	1830	27	64345	SNNP	07-10-00-N	36-21-00-E	2140
3	3240	Amara	12-18-00-N	37-10-00-E	1830	28	202536	Amara	12-47-00-N	37-40-00-E	1750
4	4560	Oromiya	09-10-00-N	35-42-00-E	1900	29	202537	Amara	12-47-00-N	37-40-00-E	1750
5	3465	Oromiya	08-57-00-N	37-46-00-E	1800	30	202538	Amara	12-47-00-N	37-40-00-E	1750
6	3583	SNNP	07-00-00-N	37-53-00-E	2140	31	202539	Amara	13-03-00-N	37-47-00-E	1810
7	3612	Oromiya	07-14-00-N	36-55-00-E	1810	32	202540	Amara	13-03-00-N	37-47-00-E	1810
8	3617	Oromiya	07-55-00-N	37-24-00-E	1890	33	202541	Amara	12-23-00-N	37-17-00-E	1830
9	3632	Oromiya	09-32-00-N	35-28-00-E	1800	34	202542	Amara	12-18-00-N	37-10-00-E	1830
10	3638	Amara	11-49-00-N	37-37-00-E	1780	35	202660	Oromiya	07-41-00-N	36-58-00-E	1810
11	3763	Amara	12-31-00-N	37-10-00-E	1870	36	202661	Oromiya	07-41-00-N	36-58-00-E	1810
12	3940	Oromiya	08-54-00-N	40-46-00-E	1830	37	202670	Oromiya	07-55-00-N	37-24-00-E	1890
13	3941	Oromiya	08-54-00-N	40-46-00-E	1890	38	202676	Amara	11-49-00-N	37-37-00-E	1780
14	3943	Oromiya	09-05-00-N	40-50-00-E	1870	39	202820	Oromiya	09-09-00-N	41-07-00-E	1910
15	235286	Tigray	13-38-00-N	39-17-00-E	1780	40	202536	Amara	12-47-00-N	37-40-00-E	1750
16	4193	Oromiya	09-02-00-N	40-44-00-E	1870	41	12970	SNNP	37-36-00-N	06-09-00-E	2150
17	4194	Oromiya	09-03-00-N	40-44-00-E	1840	42	212972	Oromiya	37-44-00-N	05-01-00-E	1850
18	4195	Oromiya	09-26-00-N	41-02-00-E	1800	43	217010	Amara	12-38-00-N	37-06-00-E	2090
19	202561	Oromiya	07-32-00-N	40-42-00-E	2090	44	217173	Oromiya	07-33-00-N	36-36-00-E	1880
20	239513	Oromiya	07-04-77-N	40-31-71-E	2050	45	217175	Oromiya	07-33-00-N	36-36-00-E	1880
21	64022	SNNP	06-53-00-N	37-48-00-E	2140	46	217176	SNNP	07-10-00-N	36-21-00-E	2140
22	64053	SNNP	06-12-00-N	37-35-00-E	2150	47	219151	Oromiya	09-19-00-N	41-03-00-E	2020
23	64248	SNNP	07-02-00-N	37-54-00-E	1900	48	219152	Oromiya	09-11-00-N	41-03-00-E	2100
24	64260	Oromiya	07-29-00-N	39-15-00-E	1910	49	219148	Oromiya	08-49-00-N	40-28-00-E	1800
25	237021	Amara	08-50-00-N	39-20-00-E	1750	50	219307	Oromiya	05-39-00-N	38-13-00-E	1880
51	219311	Oromiya	04-52-00-N	38-05-00-E	1870	76	235274	Tigray	13-31-00-N	39-07-00-E	1620
52	219316	Oromiya	05-53-00-N	39-11-00-E	1820	77	235283	Tigray	13-38-00-N	39-15-00-E	1900
53	219317	Oromiya	05-44-00-N	39-20-00-E	1800	78	235284	Tigray	13-40-00-N	39-15-00-E	1840
54	220677	Amara	08-48-00-N	39-21-00-E	2000	79	233030	SNNP	05-58-00-N	37-17-00-E	2030
55	221312	SNNP	07-13-00-N	37-46-00-E	2130	80	235299	Tigray	13-23-00-N	39-21-00-E	1860
56	221313	SNNP	07-13-00-N	37-46-00-E	2130	81	235635	SNNP	05-17-00-N	37-39-00-E	2150
57	221324	SNNP	06-09-00-N	37-36-00-E	2150	82	235636	SNNP	05-17-00-N	37-39-00-E	2150
58	223192	Tigray	13-43-00-N	39-28-00-E	1930	83	235637	SNNP	05-17-00-N	37-39-00-E	2150
59	223194	Tigray	12-42-00-N	39-31-00-E	1940	84	235651	Oromiya	04-56-00-N	38-11-00-E	1780
60	225179	SNNP	06-57-00-N	37-51-00-E	2100	85	235652	Oromiya	04-56-00-N	38-11-00-E	1780
61	225992	Amara	12-22-00-N	37-17-00-E	1830	86	235654	Oromiya	05-28-00-N	38-15-00-E	1880
62	229997	Oromiya	06-64-00-N	39-01-00-E	1940	87	235746	Amara	12-24-00-N	37-07-00-E	1920
63	230614	Oromiya	07-01-00-N	40-29-00-E	1870	88	237021	Amara	08-50-00-N	39-20-00-E	1750
64	230620	Oromiya	07-05-00-N	40-36-00-E	1800	89	237022	Oromiya	08-50-00-N	39-00-00-E	1800
65	219307	Oromiya	05-39-00-N	38-13-00-E	1880	90	239514	Oromiya	07-09-00-N	40-40-88-E	2050
66	230622	Oromiya	07-05-00-N	40-36-00-E	1820	91	241675	Oromiya	07-17-36-N	38-22-98-E	1720
67	225176	SNNP	06-57-00-N	37-51-00-E	2100	92	242098	Amara	11-06-00-N	39-47-00-E	1760
68	230624	Oromiya	07-08-00-N	40-42-00-E	1800	93	242574	Tigray	13-52-10-N	39-35-24-E	1820
69	230628	Oromiya	07-11-00-N	40-44-00-E	1790	94	242581	Oromiya	07-00-00-N	40-27-40-E	1828
70	232372	Oromiya	09-22-00-N	41-47-00-E	2020	95	243182	Oromiya	07-00-00-N	40-27-40-E	1828
71	231223	Oromiya	08-35-00-N	39-53-00-E	1780	96	243184	Oromiya	06-59-44-N	40-28-04-E	1830
72	232373	Oromiya	09-22-00-N	41-47-00-E	2020	97	243614	Amara	10-39-00-N	36-38-00-E	1815
73	233028	SNNP	05-55-00-N	37-20-00-E	2050	98	HB1307	Oromiya			
74	234337	Tigray	14-05-00-N	38-57-00-E	1810	99	Abdane	Oromiya			
75	235264	Tigray	12-58-00-N	39-34-00-E	1850	100	Local	Oromiya	08-53-33-N	34-80-11-E	1700

Identification of Bread Wheat Genotypes for Slow Rusting Resistance to Yellow Rust in Southeastern Ethiopia

Tilahun Bayisa[1*], Habtamu Terefe[2] and Tesfaye Letta[3]
[1]Sinana Agricultural Research Center, Bale Robe P.O. Box 208, Bale Robe, Ethiopia
[2]Haramaya University, Dire Dewa, P.O.Box 138, Dire Dewa, Ethiopia
[3]Oromia Agricultural Research Institute, P.O.Box:81265, Addis Abeba, Ethiopia

Abstract
Rapid evolution and spreadof new virulent races of yellow rust results in frequent failure of resistance of newly released varieties in Ethiopia. Thus, it is inevitable to identify durable sources of resistance. Hence, this study was conducted to identify slow rusting resistance genotypes and to understand the association of slow rusting characters with yield. Thirty bread wheat genotypes were tested at Sinana and Agarfa, Southeastern Ethiopia, in alpha lattice design with three replications. Susceptible varieties viz. PBW 343, Morocco and Digalu were planted as spreader rows to enhance natural infection. ANOVA showed highly significant (P < 0.01) difference among genotypes for all disease parameters at Sinana and Agarfa. Genotype x environment interaction showed that, there were significant differences among the tested genotypes for disease parameters. Based on disease parameters such as CI, FRS, AUDPC and rAUDPC, genotypes ETBW 8064, ETBW 8451, Kingbird, ETBW 8342, ETBW 8065, ETBW 8348, ETBW 8206, ETBW 8292, ETBW 8359 and ETBW 8290 grouped under high slow rusting resistance; whereasETBW 8163, ETBW 8070 and Pavov-76 grouped as susceptible at both locations.Genotypic and phenotypic correlation indicated that CI, FRS, AUDPC, r-value and rAUDPC had negative and highly significant association with grain yield. Generally, genotypes had showed a wide variability regarding yellow rust resistance ranging from complete resistance to susceptible. Therefore, best genotypes with durable slow rusting resistance will be selected to transfer resistance genes to high yielding but susceptible cultivars by employing conventional breeding method with MAS.
Keywords: AUDPC; Coefficient of infection; Final rust severity; Slow rusting; Yellow rust.

Introduction
Wheat yellow rust is a foliar disease of major economic importance on wheat production and can causes major losses of wheat yield. Yellow rust is most common in cooler wheat growing regions (Wellings, 2011). Yield losses up to 100% have been recorded when the initial infection occurred very early in the season particularly on susceptible wheat varieties (Chen, 2005). Early attack in the season leads to the occurrence of underdeveloped wheat plants and grain losses are attributed to damaged tillers and shriveled grain.

In Ethiopia repeated rust epidemics have occurred in the last three decades. The first yellow rust epidemics occurred in 1977 on wheat variety 'Laketch' (Hulluka *et al*., 1991). In 1988, another yellow rust epidemic noted on wheat variety, 'Dashen' which carried *Yr9* gene (Zewde *et al.*, 1990). In 2010, a devastating yellow rust epidemic pccurred on widely grown 'Kubsa' and 'Galema', bread wheat varieties and the *Yr27*-virulent strain attributed to be a major cause of this epidemic (Worku, 2014; Walter *et al.*, 2016). Another new race was detected in Ethiopia in 2016, after being first detected in Afghanistan in 2012 and 2013 on

resistance gene *PstS11*. The race was prevalent as epidemics in country, where a series of varieties became severely affected by yellow rust (Hovmoller *et al.*, 2016; 2017).

Management of yellow rust including cultural practice, application of fungicides and breeding for host resistance are the major control/management options. The use of fungicides in Ethiopia is limited by the fact that most wheat farmers are small holders who are resource constrained and cannot afford chemicals (Bishaw *et al*., 2010). In addition, the chemical fungicides are environmentally unsafe (Bux *et al*., 2012; McCallum *et al.*, 2016). An effective deployment of resistance genes for the management of yellow rust in wheat requires knowledge about the resistance status and the diversity of resistance genes in cultivars under consideration. Moreover, knowledge on the prevailing pathogen races is crucial as pathogens evolve their virulence frequently, thereby compromising the durability of resistance (Jin *et al*., 2008; Jin *et al*., 2009).

Slow rusting wheat cultivar is the simple solution for disease management, thus replacing susceptible cultivars with slow rusting is important in resistance diversity (Taye *et al.*, 2015). For such rapid evolution and spread of new virulent races of yellow rust, and frequent failure of new varieties with major gene yellow rust resistance in bread wheat improvement programs require to identify durable sources of resistance (Hei *et al.*, 2015). Therefore, identification of slow rust resistance against wheat yellow rust requires constant characterization and identification sources of resistance for deployment of new resistant genotypes that resist the prevailing virulent races. Hence, this study was designed to evaluate and identify advanced bread wheat genotypes with slow yellow rusting character under field conditions in Southeastern Ethiopia and to understand the association of slow rusting character with grain yield.

Materials and Methods

The experiment was conducted at Sinana Agricultural Research Centre (SARC) and Agarfa district in the 2017 main cropping season. Sinana Agricultural Research Centre is located in Bale Zone of Oromia National Regional State, Southeastern Ethiopia. It is situated at a distance of about 463 km away from Addis Ababa in the Southeastern direction. Geographically, SARC is located at 07°07′N latitude and 40°10′ E longitude at 2400 meter above sea level (m.a.s.l). The area is characterized by bimodal rainfall pattern and received annual total rainfall ranging from 750 to 1400 mm. The main season locally called 'Bona' which extends from August to December receives 270 to 842 mm rainfall, while the short season 'Ganna' which extends from March to June receives 250 to 562 mm rainfall annually. Mean annual minimum and maximum temperatures of the area are 9.6 and 20.7^{o}C, respectively. The soil texture of the area is clay loam having black color with pH ranges between 6.3-6.8 (SARC, 2006). Agarfa is located at 07°26′ N latitude and 39°87′ E longitude with an elevation of 2510 m.a.s.l. Its total annual rainfall ranges from 1000 to 1451 mm. The mean annual minimum and maximum temperatures are 7.3 and 22.8°C, respectively. The experiment at both locations was conducted in 2017 during the main cropping season.

The experimental materials comprised of thirty bread wheat genotypes which includes two released varieties *viz.* Kingbird, Pavon-76 and 28 advanced bread wheat lines. These

advanced lines were composed of materials introduced from CIMMYT, ICARDA and advanced genotypes generated from local crosses made at SARC by bread wheat breeding program (Table 1). The experiment was laid out in alpha lattice design with three replications having plot size of six rows of 0.2 m spacing and 2.5 m length. Four central rows were harvested for grain yield computations. Seed rate of 150 kg ha^{-1} and fertilizer rates of 41/46 N/P_2O_5 were used. Mixture of universal susceptible bread wheat varieties *viz.* PBW 343, Morocco and Digalu variety, which are extremely susceptible to yellow rust were planted around the blocks as spreader rows.Spreader rows were exposed to open environment for natural infection. Weed was controlled by using hand weeding as well as by using herbicide called Pallas 45OD.

Data collected

Disease data

Yellow rust severity: It was scored at seven days interval by estimating the approximate percentage of leaf area affected using modified Cobb's 0-100% scale recommended by Peterson *et al.* (1948); where, 0% is considered immune while 100% completely susceptible.

Coefficient of infection (CI): This was calculated based on data of the average 10 plants for each experimental unit multiplying the percentage severity (0-100%) with constant values for host response. The host responses were scored as: immune = 0.0, R (resistant) =0.2, MR (moderately resistant) = 0.4, MS (moderately susceptible) = 0.8, and S (susceptible) = 1.0.
CI = Disease severity percentage x Constant values of host response

Area under disease progress curve (AUDPC): This was calculated using the formula suggested by Campbell and Madden (1990) as follow:

$$AUDPC = \sum_{i=1}^{n-1} [t_{i+1}-t_i]\ [0.5\ (X_{i+1}+X_i)]$$

Where, x_i = the average severity of i^{th} record, X_{i+1} = the average severity of $i+1^{th}$ record and t_{i+1} - t_i = Number of days between the i^{th} record and $i+1^{th}$ record, and n = number of observations.

Final rust severity (FRS): The last disease severity score in modified Cobb's scale percentage severity (0-100%) multiplied with a constant value for the host response.

The infection rate (r-value): This was estimated in terms of disease severities recorded in different times using the Logistic model (Van der plank, 1968). The infection rate (r-value) per unit time (t) for each line was calculated as the slope of the regression equation of ln [y/(100 – y)] versus t, where y is average severity scored against time in days.

Relative area under disease progress curve (rAUDPC): This was calculated using the following formula:

$$rAUDPC\ (\%) = \frac{\text{AUDPC value of a genotype}}{\text{AUDPC of local or the most susceptible genotype}} \times 100$$

Grain yield (kg/ha): Grain yield in gram/plot at 12.5% moisture content was recorded and converted into kg/ha.

Table 1. List of bread wheat genotypes along with their respective pedigrees, selection history and origin used at Sinana and Agarfa, Southeastern Ethiopia in 2017 cropping season.

S/N.	Genotype	Pedigree	Selection history	Origin [a]
1	ETBW 8252	SW895124*2/FASAN/3/ALTAR84/AESQ//2*OPATA/4/ARREHANE	CMSA05Y01220T-040M-040ZTP0Y-040ZTM-040SY-9ZTM-01Y-0B	CIMMYT
2	ETBW 8064	Line 1 Singh/ETBW4919	KU07-01-0KU-0KU-0KU-0BK1-4KU	KARC
3	ETBW 8065	Line 1 Singh/ETBW4919	KU07-01-0KU-0KU-0KU-0BK1-5KU	KARC
4	ETBW 8066	Line 1 Singh/ETBW4919	KU07-01-0KU-0KU-0KU-0BK2-1KU	KARC
5	ETBW 8070	Line 1 Singh/ETBW4919	KU07-01-0KU-0KU-0KU-0BK2-22KU	KARC
6	ETBW 8145	OPATA/RAYON//KAUZ/3/MILAN/DUCULA	-	ICARDA
7	ETBW 8163	SUDAN#3/SHUHA-6//FLAG-5	ICW07-0774-0AP-0AP-0AP-05KUL	ICARDA
8	ETBW 8290	KACHU/KINDE	CMSS07B00101S-099M-099NJ-099NJ-10WGY-0B	CIMMYT
9	ETBW 8310	ND643/2*WBLL1//ATTILA*2/PBW65/3/MUNAL	CMSS07B00807T-099TOPY-099M-099NJ-099NJ-1WGY-0B	CIMMYT
10	ETBW 8336	PFAU/MILAN//ETBW 4921	-	ICARDA
11	ETBW 8342	N-AZRAQ-3/ETBW 4921	-	ICARDA
12	ETBW 8348	CMH82A1294/2*KAUZ//MUNIA/CHTO/3/MILAN/4/AMIR-2	-	CIMMYT
13	ETBW 8253	SOKOLL*2/ROLF07	CMSA05Y01226T-040M-040ZTP0Y-040ZTM-040SY-17ZTM-03Y-0B	CIMMYT
14	ETBW 8265	FRANCOLIN #1/4/2*BABAX/LR42//BABAX*2/3/KURUKU	CMSS07Y00670T-099TOPM-099Y-099M-099Y-21M-0RGY	CIMMYT
15	ETBW 8280	SNLG/3/EMB16/CBRD//CBRD/4/KA/NAC//TRCH	CMSA08Y00061T-079(1A1RSR26)B-050 ZTY-026(1A1RSR26)ZTM-03Y-03B-0Y	CIMMYT
16	ETBW 8283	KA/NAC//TRCH/3/DANPHE #1	CMSA07M00445S-040M-0NJ-0NJ-9Y-0B	CIMMYT
17	ETBW 8287	CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/HAR311	CMSS06Y00706T-099TOPM-099Y-099ZTM-099NJ-099NJ-41WGY-0B	CIMMYT
18	ETBW 8292	KACHU/KIRITATI	CMSS07Y00127S-0B-099Y-099M-099Y-4M-0WGY	CIMMYT
19	ETBW 8359	ALMAZ-11/3/PASTOR/FLORKWA-1//PASTOR	-	ICARDA

S/N.	Genotype	Pedigree	Selection history	Origin [a]
20	ETBW 8362	JAWAHIR-2//MILAN/DUCULA	-	CIMMYT
21	ETBW 8309	SUP152*2/KIRITATI	CMSS07B00612T-099TOPY-099M-099Y-099M-1WGY-0B	CIMMYT
22	ETBW 8206	FARIS-17//PFAU/MILAN	F5-MR-TA 2011-12	ICARDA
23	ETBW 8304	FRNCLN/4/WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1	-	ICARDA
24	ETBW 8338	HUBARA-5/ETBW 4922	-	ICARDA
25	ETBW 8411	CHAM-4/MUBASHIIR-9	ICW06-00411-1AP-0AP -03 SD	CIMMYT
26	ETBW 8445	HAAMA-16/MILAN	ICW03-0097-2AP/0TS-0AP-0AP-4AP-0AP-0DZ/0AP	CIMMYT
27	ETBW 8441	TURACO/CHIL/6/SERI82/5/ALD'S/4/BB/GLL/CNO67/7C/3/KUZ/TI	-	ICARDA
28	ETBW 8451	FLAG-6/ICARDA-SRRL-6	-	ICARDA
29	Kingbird	THELIN # 2/TUKURU	-	KARC
30	Pavon 76	VCM/CNO/7C/3/KAL/BB	CM8399-D-4M-3Y-1M-1Y-1M-0Y-0ETA	KARC

[a] KARC = Kulumsa Agricultural Research Center; CIMMYT = International Maize and Wheat Improvement Center; and ICARDA = International Center for Agricultural Research in the Dry Areas

Data Analysis: all measured disease parameters including CI, FRS, AUDPC, r-value, and rAUDPC were subjected to analysis of variance (ANOVA) following standard procedures using Proc Lattice and Proc GLM of SAS version 9.2 statistical software to estimate the prevailing variation among tested genotypes. Mean separation was carried out using Duncan's Multiple Range Test (DMRT) at 5 percent levels of significance depending on the significance of the analysis of variance for each trait. The structure of ANOVA for alpha lattice design was presented as below (Table 2). Disease parameters were homogenized using logarismc transformation ("*log x + 5"*) to calculate coefficient of variation.

Table 2. Structureof ANOVA table for analysis of alpha lattice design

Source of variation	Degrees of freedom	Sum of Squares	Mean squares
Replication	r-1	SSr	MS_r
Blocks (within replications, ignoring the genotypes)	r(b-1)	SSb	MS_b
Genotype (adjusted for blocks)	g-1	SSg	MS_g
Error	rg-rb-g+1	SSe	MS_e
Total	rg-1	SST	-

Estimation of phenotypic and genotypic correlations

The simple correlation coefficients were partitioned to genotypic and phenotypic components. Phenotypic and genotypic correlation coefficients were estimated using the formulae of AL-Jibouri *et al*. (1958).

$$r_{P_{xy}} = \frac{Cov_{P_{xy}}}{\sqrt{\sigma^2_{P_x}\sigma^2_{P_y}}}$$

Where, $r_{P_{xy}}$ = Phenotypic correlation coefficient between trait x and y, $Cov_{P_{xy}}$ = Phenotypic covariance between trait x and y; σ_{P_x} = Phenotypic variance of trait x

σ_{P_y} = Phenotypic variance of trait y

$$r_{G_{xy}} = \frac{Cov_{G_{xy}}}{\sqrt{\sigma^2_{G_x}\sigma^2_{G_y}}}$$

Where, $r_{G_{xy}}$ = Genotypic correlation coefficient between traits x and y

$Cov_{G_{xy}}$ = Genotypic covariance between traits x and y; σ_{G_x} = genotypic variance of trait x

σ_{G_y} = Genotypic variance of trait y

The coefficient of correlations at genotypic level was tested for their significance using the formula described by Robertson (1959) indicated below:

$$t = \frac{r_{G_{xy}}}{SE_{G_{xy}}}$$

The calculated value was compared with the Tabulated value at g-2 degree of freedom at 5% level of significance, where, g = number of lines

$SE_{g_{xy}} = \sqrt{\frac{(1-r^2_{g_{xy}})^2}{2H_xH_y}}$ Where, H_x = Heritability of the trait x, H_y = Heritability of the trait y

Results and Discussions

Analysis of variance

Test of homogeneity of error variance showed that the error mean squares were homogeneous for CI-1, CI-3, FRS, infection rate (r-value), AUDPC and rAUDPC. Hence, combined data analysis was done for thesecharacters. Combined ANOVA across locations were carried out for all disease parameters (Table 3). There was a highly significant difference at *P < 0.01* for all traits among the test genotypes. This indicated the presence of sufficient genetic variability for level of resistance/susceptibility among the genotypes tested. Ali *et al*. (2009) and Safavi and Afshar (2017) also evaluated different bread wheat genotypes for yellow rust resistance based on slow rusting parameters and they reported significant differences in resistance levels among the tested genotypes.

The genotype x environment interaction showed highly significant (*P < 0.01*) differences among wheat genotypes for disease parameters such as FRS, r-value, AUDPC and rAUDPC. Significant (*P < 0.05*) genotypic x environment interaction was also found for CI-1 and CI-3 (Table 3). This implies that the test genotypes responded differently to varying environments for these traits. This suggested that the importance of assessment of genotypes under different environments in order to identify better performing genotypes that show better performance across locations.

Table 3. Combined analysis of disease parameters in bread wheat genotypes tested at Sinana and Agarfa, in 2017 cropping season

Characters	Source of Variation						Mean	CV
	Loc [1]	Rep (Loc) [4]	Block (Loc x Rep) [30]	Genotype [29]	Genotype x Loc [29]	Error [86]		
CI-1	3.6^{ns}	3.4^{ns}	5.8*	120.0**	6.6*	3.5	2.7	7.8 (69.7)
CI-3	131.1*	36.1^{ns}	44.1^{ns}	991.4**	55.9*	29.0	8.4	10.9 (64.5)
FRS	315.9**	10.68^{ns}	31.3^{ns}	1822.6**	122.9**	21.6	12.1	11.4 (38.5)
r-value	0.0003^{ns}	0.001^{ns}	0.001^{ns}	0.01**	0.0009**	0.001	0.05	0.4 (74.2)
AUDPC	7741.3^{ns}	5302.6^{ns}	8550.6*	302841.7**	13961.8**	4779.3	149.2	15.9 (46.4)
rAUDPC	9.8^{ns}	52.8^{ns}	98.5*	3335.4**	140.5**	54.6	15.7	11.7(47.1)

CI-1 and 3 = coefficient of infection at 1^{st} and 3^{rd}, FRS = final rust severity, r-value = rate of disease development, AUDPC = area under disease progress curve, rAUDPC = relative area under disease progress curve, Loc = location, Rep = replication, ** = highly significant at *P < 0.01*,* = significant at *P < 0.05*, ns = no significant difference, Numbers in square bracket indicates degree of freedom, CV = coefficient of variation with log transformed data,number in bracket under CV indicates coefficient of variation not transformed.

Mean Performance of Disease Parameters

Coefficient of infection

The mean performance for 6 disease characters of 30 bread wheat genotypes evaluated at Sinana and Agarfa are presented in Table 4. The result showed wide variation for all these parameters among the genotypes. CI-1 at Sinana and Agarfa ranged from 0 to 24.3% and 0-22.0%, respectively. The highest CI-1 at Sinana recorded for genotype ETBW 8163 (24.3%) followed by genotype ETBW 8070 (15.0%) and genotype Pavon-76 (7.7%) and at Agarfa the same genotypes ranked in the top three. Similarly, genotypes ETBW 8163, Pavon-76 and ETBW 8070 had high CI-3 at both Sinana and Agarfa.

Based on CI values, genotypes were grouped according to Ali *et al.* (2007) and Safavi and Afshari (2017) as high slow rusting (0-20% CI), moderate slow rusting (21-40% CI) and susceptible (41-60% CI). From all genotypes tested at Sinana, 21 genotypes were grouped in to high slow rusting resistance category (Table 4). Whereas, three genotypes, ETBW 8163, Pavon-76 and ETBW 8070 were identified to have no slow rusting resistance to yellow rust at this location. At Agarfa, 24 genotypes were grouped under high slow rusting resistance category. Whereas, genotypes ETBW 8163 and Pavon-76 showed susceptible reaction butremaining genotypes such as ETBW 8280 and ETBW 8411 showed zero CI value and hence grouped as immune class (Table 4).

Final rust severity (FRS)

At Sinana and Agarfa FRS showed highly significant variation among genotypes. At Sinana FRS mean score ranged from 0 to 71.3% with mean of 13.4% and at Agarfa, it ranged from 0-69.3% with mean of 10.8%. High mean disease pressure was recorded at both testing sites for genotype ETBW 8163, followed by Pavon-76 and ETBW 8070. Based on FRS values, the tested genotypes grouped into three categories: those with values of 1-30%, 31-50% and 51-70% of FRS as high slow rusting resistance, moderate slow rusting resistance and susceptible, respectively (Broers *et al*. 1996; Ali *et al*., 2009; Safavi and Afshari, 2012; Hei*et al.*, 2015). At Sinana, twenty one genotypes were grouped under high slow rust resistance and at Agarfa, twenty five genotypes were grouped under high slow rusting resistance whereas in this location, two genotypes (ETBW 8163 and Pavon-76) were grouped in the category of low level of slow rusting resistance (Table 4).

Area under disease progress curve and relative area under disease progress curve

At Sinana, the highest AUDPC was recorded for genotypes ETBW 8163 (1008.6%-days) followed by genotypes ETBW 8070 (888.3%-days) and Pavon-76 (616.5%-days) (Table 4). Similarly, at Agarfa, genotypes ETBW 8163, Pavon-76 and ETBW 8070 showed high AUDPC values of 896.5%-days, 891.1%-days and 460.0%-days, respectively (Table 4).Based on the rAUDPC values, cultivars categorized into two distinct groups (Ali *et al*., 2007; Hei*et al*., 2015; Safavi and Afshari, 2017). The first group included genotypes exhibiting rAUDPC values less 30% with the ratio of the most susceptible genotype (ETBW 8163), while genotypes showing rAUDPC values 30 to 70% were categorized in the second group. At Sinana, five genotypes were grouped in the second category and the rest twenty-five genotypes were classified under the first category. Similarly at Agarfa, seven genotypes were

grouped under the second category and twenty-three genotypes were grouped in the first category (Table 4).

Infection rate (r-value)

At Sinana, the highest r-value scored for genotype ETBW 8348 (0.16 units day^{-1}) followed by Pavon-76 (0.14 units day^{-1}) and ETBW 8309 (0.13 units day^{-1}). Similarly, at Agarfa, genotypes ETBW 8290, ETBW 8348 and ETBW 8362 showed the highest r-value of 0.12 units' day^{-1}. Similar to the finding of Ali *et al.* (2008), Safavi (2012), Safavi and Afshari (2012) and Safavi and Afshari (2017), the present study also demonstrated that infection rate seemed an unreliable estimation of slow rust resistance when compared to CI, AUDPC and FRS, because it could not identify different levels of slow rusting resistance among some of the genotypes, as compared with other parameters. The present study identified that genotypes with better level of slow rusting resistance (having CI = 0-20 and FRS = 1-30) had high infection rate.Based on CI, FRS, AUDPC and rAUDPC, genotypes ETBW 8064, ETBW 8451, Kingbird, ETBW 8342, ETBW 8065, ETBW 8348, ETBW 8206, ETBW 8292, ETBW 8359 and ETBW 8290 grouped under high slow rusting resistance.

Genotypic and Phenotypic Correlation Coefficients

Genotypic correlation coefficients of grain yield with yellow rust disease parameters

Results of genotypic correlation coefficients at Sinana are presented in Table 5. Grain yield had highly significant ($P < 0.01$) negative genotypic correlation coefficient with all yellow rust disease parameters with values ranging from infection rate (-0.680) to AUDPC (-0.930). This indicates that genotypes with high CI-1, CI-3, FRS, AUDPC and r-value would result in reduced grain yield. Hence, selection of genotypes against these parameters may have significant role in yield improvement and to combact recurrent yellow rust epidemics. Safavi (2015) and Safavi and Afshari (2017) also reported high negative correlation coefficient between CI, FRS, AUDPC and r-value with grain yield. At Agarfa, high negative genotypic correlation of coefficient was observed between grain yield and FRS (-0.74) followed by AUDPC (-0.73) and CI-3 (-0.73) (Table 6).

Table 4. Mean performance of bread wheat genotypes for disease parameters at Sinana and Agarfa, in 2017

Genotypes	Sinana						Agarfa					
	CI-1	CI-3	FRS	AUDPC	r-value	rAUDPC	CI-1	CI-3	FRS	AUDPC	r-value	rAUDPC
ETBW 8280	0.1^{g}	0.08^{e}	0.1^{h}	2.1^{h}	0.0001^{g-j}	0.21^{h}	0^{f}	0^{g}	0^{i}	0^{g}	0^{g-i}	0^{g}
ETBW 8310	0.003^{g}	0.03^{e}	0.03^{h}	0.7^{h}	0.03^{e-j}	0.07^{h}	0.1^{f}	0.03^{g}	0.1^{i}	1.0^{g}	0.01^{f-i}	0.1^{g}
ETBW 8064	4.3^{ef}	11.1^{de}	18.8^{d}	200.9^{e}	0.08^{b-f}	19.9^{e}	5.8^{cd}	14.5^{c-e}	21.8^{de}	310.2^{cd}	0.08^{a-e}	34.6^{cd}
ETBW 8252	0^{g}	0^{e}	0^{h}	0^{h}	0^{g-j}	0^{h}	0.1^{f}	0.1^{g}	0.1^{i}	0.7^{g}	0.001^{f-i}	0.1^{g}
ETBW 8163	24.3^{a}	54.9^{a}	71.3^{a}	1009^{a}	0.1^{a-e}	100^{a}	22^{a}	46.7^{a}	69.3^{a}	896.5^{a}	0.1^{a-c}	100^{a}
ETBW 8451	2.3^{fg}	9.9^{de}	10.6^{d-g}	166.6^{ef}	0.06^{c-h}	16.5^{ef}	1.7^{ef}	5.6^{e-g}	9.0^{f-h}	123.0^{e-g}	0.09^{a-d}	13.7^{e-g}
ETBW 8309	4.6^{ef}	32.7^{c}	43.7^{c}	452.9^{d}	0.14^{ab}	44.9^{d}	3.4^{d-f}	20.6^{bc}	27.5^{cd}	365.2^{bc}	0.13^{a}	40.7^{bc}
Kingbird	1.6^{fg}	7.4^{de}	13.9^{d}	136.6^{e-g}	0.1^{a-c}	13.5^{e-g}	3.3^{d-f}	17.8^{b-d}	29.7^{cd}	311.0^{cd}	0.12^{ab}	34.7^{cd}
ETBW 8362	9.6^{c}	32^{c}	62.7^{b}	560.5^{c}	0.14^{ab}	55.6^{c}	2.1^{ef}	16.2^{b-d}	22.3^{de}	280.2^{cd}	0.13^{a}	31.3^{cd}
ETBW 8336	0^{g}	0^{e}	0^{h}	0^{h}	0^{g-h}	0^{h}	0.2^{f}	0.2^{g}	0.2^{i}	4.1^{g}	-0.006^{g-i}	0.5^{g}
ETBW 8253	0.1^{g}	0.05^{e}	0.05^{h}	1.4^{h}	0.02^{f-j}	0.14^{h}	0.2^{f}	0.2^{g}	0.2^{i}	2.4^{g}	-0.01^{hi}	0.3^{g}
ETBW 8265	0.01^{g}	0.03^{e}	0.03^{h}	0.5^{h}	0.01^{f-j}	0.05^{h}	0.1^{f}	0.1^{g}	0.03^{i}	0.7^{g}	-0.02^{i}	0.1^{g}
ETBW 8287	0.1^{g}	0.05^{e}	0.05^{h}	1.7^{h}	-0.01^{h-j}	0.17^{h}	0.03^{f}	0.03^{g}	0.1^{i}	0.8^{g}	0.01^{f-i}	0.1^{g}
ETBW 8342	0.3^{g}	1.3^{e}	3.2^{f-h}	27.0^{gh}	0.07^{d-g}	2.7^{gh}	0.2^{f}	0.7^{g}	1.1^{ih}	16.4^{g}	0.05^{c-h}	1.8^{g}
ETBW 8445	0.07^{g}	0.03^{e}	0.03^{h}	0.5^{h}	-0.02^{h-j}	0.05^{h}	0.1^{f}	0.1^{g}	0.1^{i}	1.1^{g}	0.001^{f-i}	0.1^{g}
ETBW 8065	6.0^{de}	12.9^{d}	16.8^{de}	233.2^{e}	0.06^{c-i}	23.1^{e}	6. 7^{cd}	10.8^{d-f}	16.9^{ef}	231.4^{c-e}	0.06^{c-g}	25.8^{c-e}
ETBW 8348	0.4^{g}	1.8^{e}	9.99^{e-g}	63. 6^{f-h}	0.16^{a}	6.3^{f-h}	0.6^{ef}	3.4^{fg}	8.5^{g-i}	70.2^{fg}	0.13^{a}	7.8^{fg}
ETBW 8145	0.4^{g}	0.3^{e}	0.3^{h}	7.4^{h}	-0.02^{ij}	0.7^{h}	0.2^{f}	0.2^{g}	0.2^{i}	4^{g}	0.01^{f-i}	0.5^{g}
Pavon-76	7.7^{cd}	43.2^{b}	62.7^{b}	616.5^{c}	0.14^{ab}	61.1^{c}	14.7^{b}	46. 7^{a}	58^{b}	891.1^{a}	0.1^{a-c}	99.4^{a}
ETBW 8206	0.5^{g}	0.6^{e}	0.6^{h}	12.9^{h}	0.01^{h-j}	1.3^{h}	1.5^{ef}	1.9^{fg}	1.7^{hi}	36.1^{fg}	-0.01^{g-i}	4.0^{fg}
ETBW 8411	0^{g}	0^{e}	0^{h}	0^{h}	0^{h-j}	0^{h}	0^{f}	0^{g}	0^{i}	0^{g}	0^{g-i}	0^{g}
ETBW 8292	0.6^{g}	1.3^{e}	2.5^{gh}	29.2^{gh}	0.06^{c-i}	2. 9^{gh}	0.3^{f}	0.3^{g}	0.3^{i}	6.1^{g}	0.001^{f-i}	0.7^{g}
ETBW 8066	0.1^{g}	0.1^{e}	0.1^{h}	2.3^{h}	-0.004^{g-j}	0.2^{h}	0.3^{f}	0.1^{g}	0.2^{i}	4.0^{g}	-0.01^{hi}	0.4^{g}
ETBW 8359	4.5^{ef}	8.8^{de}	8.1^{e-h}	155.8^{ef}	0.02^{f-j}	15. 5^{ef}	4.2^{de}	9.7^{d-g}	11.7^{fg}	172.1^{d-f}	0.06^{b-f}	19.2^{d-f}
ETBW 8070	15^{b}	53^{a}	64.7^{ab}	888.3^{b}	0.12^{a-c}	88.1^{b}	8.2^{e}	24.0^{b}	34.7^{c}	460.0^{b}	0.09^{a-d}	51.3^{b}
ETBW 8283	0^{g}	0^{e}	0^{h}	0^{h}	0^{g-j}	0^{h}	0.1^{f}	0.03^{g}	0.1^{i}	0.6^{g}	0.001^{f-i}	0.1^{g}
ETBW 8290	1.4^{fg}	4.0^{de}	11.8^{d-f}	89.1^{f-h}	0.11^{a-d}	8.8^{f-h}	0.2^{f}	5.1^{fg}	9.3^{f-h}	81.5^{fg}	0.13^{a}	9.1^{fg}
ETBW 8441	0.2^{g}	0.3^{e}	0.3^{h}	4.3^{h}	0.04^{d-j}	0.4^{h}	0.01^{f}	0.03^{g}	0.1^{i}	0.8^{g}	0.02^{e-i}	0.1^{g}
ETBW 8304	0.2^{g}	0.2^{e}	0.3^{h}	4.3^{h}	0.01^{f-j}	0.4^{h}	0.1^{f}	0.1^{g}	0.2^{i}	3.0^{g}	0.04^{d-i}	0. 4^{g}
ETBW 8338	0.3^{g}	0.2^{e}	0.2^{h}	4.8^{h}	-0.02^{j}	0.5^{h}	0.2^{f}	0.2^{g}	0.2^{i}	3.7^{g}	0.01^{f-i}	0.4^{g}
Mean	2.8	9.2	13.4	155.7	0.047	15.4	2.5	7.5	10.8	142.6	0.044	15.9
CV	6.3	10.7	11.2	16.4	0.43	10.7	9.2	11.2	11.6	15.4	0.39	12.6

CI 1, 2, and 3 = Coefficient of infection at 1st, 2nd, 3rd, FRS = final rust severity, r-value = rate of disease development, AUDPC = area under disease progress curve and rAUDPC = relative area under disease progress curve, number in bracket shows log transformed CV value.

Phenotypic correlation coefficients of grain yield with yellow rust disease parameters

Result of phenotypic correlation analysis at Sinana showed that grain yield had negative and highly significant association with CI-1, CI-2, CI-3, FRS, AUDPC, r-value and rAUDPC. Similarly, at Agarfa grain yield showed negative and highly significant phenotypic correlation with all yellow rust disease parameters considered in this study. This implies that on the average, increase in susceptibility, indicated by higher CI-1, CI-2, CI-3, FRS, AUDPC, r-value or rAUDPC, would result in a decreasing in grain yield or vice versa, with other factors being constant. The results of the highly negative correlation coefficient of grain yield with these slow rusting disease parameters is in agreement with the results reported by Dereje and Chemeda (2009) and other researchers such as Ahimad *et al.* (2010) and Safavi (2015).

Table 5. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among yield and yellow rust disease parameters at Sinana, during 2017 cropping season

Variable	GY	Tkw	CI-1	CI-2	CI-3	FRS	AUDPC	r-value
GY	1	0.79**	-0.90**	-0.86**	-0.92**	-0.92**	-0.93**	-0.68**
Tkw	0.74**	1	-0.80**	-0.77**	-0.75**	-0.77**	-0.79**	-0.63**
CI-1	-0.84**	-0.72**	1	0.98**	0.92**	0.89**	0.96**	0.53**
CI-2	-0.82**	-0.71**	0.94**	1	0.90**	0.85**	0.94**	0.51**
CI-3	-0.86**	-0.68**	0.88**	0.88**	1	0.98**	0.99**	0.67**
FRS	-0.88**	-0.73**	0.85**	0.84**	0.95**	1	0.98**	0.74**
AUDPC	-0.89**	-0.73**	0.93**	0.93**	0.99**	0.97**	1	0.66**
r-value	-0.59**	-0.57**	0.42**	0.46**	0.59**	0.69**	0.60**	1

Table 6. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients among yield and yellow rust disease parameters at Agarfa, during 2017 cropping season

Variable	GY	Tkw	CI-1	CI-2	CI-3	FRS	AUDPC	r-value
GY	1	0.74**	-0.68**	-0.72**	-0.73**	-0.74**	-0.73**	-0.54**
Tkw	0.65**	1	-0.75**	-0.77**	-0.80**	-0.82**	-0.80**	-0.68**
CI-1	-0.62**	-0.66**	1	0.93**	0.94**	0.94**	0.95**	0.48**
CI-2	-0.66**	-0.67**	0.92**	1	0.99**	0.97**	0.99**	0.60**
CI-3	-0.66**	-0.66**	0.91**	0.96**	1	0.99**	0.99**	0.65**
FRS	-0.70**	-0.74**	0.91**	0.95**	0.97**	1	0.99**	0.68**
AUDPC	-0.68**	-0.69**	0.93**	0.98**	0.99**	0.99**	1	0.64**
r-value	-0.48**	-0.55**	0.35**	0.49**	0.55**	0.60**	0.54**	1

GY = grain yield, CI-1st, 2nd and 3rd = first, second and third coefficient of infection, FRS = final rust severity, AUDPC = areas under disease progress curve, r-value = infection rate, ** = highly significant association at $P < 0.01$ and * = significant association at $P < 0.05$.

Conclusions

The results indicated that, studied bread wheat genotypes showed wide variability in terms of slow rusting resistance, ranging from complete resistance to susceptible under high disease pressure at both locations. Based on slow rusting parameters such as CI, FRS, AUDPC and rAUDPC genotypes viz. ETBW 8064, ETBW 8451, Kingbird, ETBW 8342, ETBW 8065, ETBW 8348, ETBW 8206, ETBW 8292, ETBW 8359 and ETBW 8290 grouped under high slow rusting resistance. Hence, these genotypes scan be used in future breeding program to improve existing cultivars with durable slow rusting resistance to yellow rust and high grain yield through transferring the genes responsible for the resistance to high yielding cultivars *via* molecular marker technology.

Reference

Ahmad, S., Afzal, M., Noorka, I.R., Iqbal, Z., Akhtar, N., Iftkhar, Y. and Kamran, M. 2010. Prediction of yield losses in wheat (*Triticum aestivum*L.) caused by yellow rust in relation to epidemiological factors in Faisalabad. *Pakistan Journal of Botany*, 42:401–407.

Ali, S., Shah, S. J. A. and Ibrahim, M. 2007. Assessment of wheat breeding lines for slow yellow rusting (*Puccinia striiformis*). *Pakistan Journal Biology*,10: 3440-3444.

Ali, S., Shah, S. and Maqbool. K. 2008. Field based assessment of partial resistance to yellow rust in wheat germplasm. *Journal of Agriculture and Rural Development*, 6: 99-106.

Al-Jibouri, H.A., Miller P.A. and Robinson. H.P.1958. Genetic and environmental variances and co variances in upland cotton cross of inter specific origin. *Agronomy Journal*, 50: 633- 636.

BishawZawude, Struik, P.C. and Van-Gastel, A.J.G. 2010. Wheat seed system in Ethiopia: Farmers' varietal perception, seed sources, and seed management. *Journal of Newthland Seeds*, 11: 281-327.

Broers, L.H.M., Subias, X.C. and Atilano, R.M.L. 1996. Field assessment of quantitative resistance to yellow rust in ten spring bread wheat cultivars. *Euphytica*,90: 9-16.

Bux, H., Ashraf, M., Hussain, F., Rattu, A.U.R. and Fayyaz, M. 2012. Characterization of wheat germplasm for stripe rust (*Puccinia striiformis*f.sp. *tritici*) resistance. *Australian Journal of Crop Science*, 6(1):116-120.

Campbell, C.L. and Madden, L.V. 1990. Temporal analysis of epidemics I. Description and comparison of disease progress curves. *In*: Introduction to plant disease Epidemiology, ISBN 0471832367. 532pp.

Chen, X. M. 2005. Epidemiology and control of stripe rust (*Puccinia striiformis*f.sp. *tritici*) on wheat. *Canadian Journal of Plant Patho*logy, 27:314–337.

Dereje Hailu and ChemedaFininsa. 2009. Relationship between stripe rust (*Puccinia striiformis*) and common wheat (*Triticum aestivum*) yield loss in highlands of Bale, southeastern Ethiopia. *Arch of Phytopathol and PFL*, 42:508–523.

HeiNetsanet, ShimelisHusien, Laing M. and AdmassuBelayneh 2015. Assessment of Ethiopian wheat lines for slow rusting resistance to stem rust of wheat caused by *Puccinia graminis*f.sp. *tritici. Journal of Phytopathology*. 163:353-363.

Hovmoller, M.S., Walter. S., Bayles, R., Hubbard. A., Flath. K., Sommerfeldt, N., Leconte. M., RodriguezAlgaba. J., Hansen. J.G., Lassen, P., Justesen. A.F., Ali, S. and de VallavieillePope, C. 2016. Replacement of the European wheat yellow rust population by new races from the centre of diversity in the near-himalayan region. *Plant Pathology*, 65: 402-411.

Hovmoller, S.M., Rodriguuez-Algaba. J., Thach. T., Justesen, F.A. and Hansen G.J. 2017. Report for *Puccinia striiformis* race analyses and molecular genotyping 2016, Global rust reference center (GRRC), Aarhus University, Denmark.

Hulluka Mengistu, WoldeabGetaneh, Andnew, Y., Desta, R. and Badebo, A. 1991. Wheat pathology research in Ethiopia. *In:* Hailu Gebre-Mariam, DG Tanner and Mengistu Hulluka (eds.). 173-217. Wheat research in Ethiopia: A historical perspective. Addis Abeba: IAR/CIMMYT.

Jin, Y., Szabo, L. J., Pretorius, Z. A., Singh, R. P., Ward, R. and Fetch, T. J.r. 2008. Detection of virulence to resistance gene *Sr24* within race TTKS of *Puccinia graminis*f.sp. *tritici.Plant Disease*, 92:923-926.

Jin, Y., Szabo, L.J., Rouse, M.N., Fetch, T. Jr., Pretorius, Z. A., Wanyera, R. and Njau, P., 2009. Detection of virulence to resistance gene *Sr36* within the TTKS race lineage of *Pucciniagraminis*f. sp. *tritici*. *Plant Disease,* 93:367-370.

McCallum, B.D., Hiebert, C.W., Cloutier, S., Bakkeren, G., Rosa, S.B., Humphreys, D.G., Marias, G.F., McCartney, C.A., Panwar, V., Rampitsch, C., Saville, B.J. and Wang, X. 2016. A review of wheat leaf rust research and the development of resistant cultivars in Canada. *Canada Journal Plant Pathology*, 38:118.

Peterson, R.F., Campbell, A.B. and Hannah A.E. 1948. A diagrammatic scale for estimating rust intensity of leaves and stem of cereals. *Canadian Journal Research*, 26: 496-500.

Robertson, G.E. 1959. The sampling variance of the genetic correlation coefficient. Biometrics 15: 469-485.

Roelfs, A. P., Singh, R. P. and Saari, E. E. 1992. Rust diseases of wheat: Concepts and methods of disease management. CIMMYT, D.F., Mexico.

Safavi S.A. 2012 Evaluation of slow rusting parameters in thirty seven promising wheat lines to yellow rust. Safavi, S. A. and Afshari, F. 2012. Identification of resistance to *Puccinia striiformis*f.sp. *tritici* in some elite wheat lines. *Journal of Crop Protection*, 1: 293-302.

Safavi, S. A., 2015. Effect of yellow rust on yield of rust-specific and slow rusting resistance wheat genotypes. *Journal of crop protection*,4(3): 395-408.

Safavi, S. A. and Afshari, F. 2017. A seven-year assessment of resistance durability to yellow rust in some wheat cultivars in Ardabil province, Iran. *Journal crop protection*, 2017, 6(3): 409-421.

SARC (Sinana Agricultural Research Center). 2006. Annual report. pp.1-50.

Taye Tolassa, ChimdessaFininsa and GetanehWoldeab. 2015. Yield variability of bread wheat under wheat stem rust pressure at Bore field condition of Southern Oromia. *Journal of Agricultural Science and Food Technology*, 1(2): 11-15.

Van der plank, JE., 1968 Disease resistance in plants. Academic press. New York.

Walter, S., Ali, S., Kemen, E., Nazari, K., Bahri, B., Enjalbert, Hansen, JG., Brown JK, Sicheritz-Pontén T, Jones J, de Vallvieille-Pope C, Hovmoller MS, and Justesen AF. 2016. Molecular markers for tracking the origin and worldwide distribution of invasive strains of *Puccinia striiformis.* Ecological Evolution. 6: 2790–2804.

Wellings, C. R. 2011. Global status of stripe rust: a review of historical and current threats. *Euphytica*. 179:129–141.

WorkuDenbel. 2014. Epidemics of *pucciniastriiformis*f.sp. *tritici* in arsi and west arsi zones of Ethiopia in 2010 and identification of effective resistance genes. *Journal of Natural Science Research*. 4:33-39.

Zewde, L., Tanner, D. G., Elias, E., Gorfu, A., Tarekegne, A., Geleto, T., Yilma, Z. and Gebre, H. 1990. The relative importance of yield limiting factors on bread wheat in the Ethiopian highlands. *In:* Sixth Regional Wheat Workshop: For Eastern, Centeral and Southern Africa. D. G. Tanner, M. Van Ginkel, and W. Mwangi, eds. CIMMYT, Mexico, D.F.

Multi-environmental Evaluation of Faba bean (*Vicia faba* L.) genotypes in West and Kelem Wollega Zones of Western Oromia

Dereje Abera*, Biru Alemu and Tashome Gutu
Oromia Agricultural Research Inistitute (OARI), Haro Sabu Agricultural Research Center, P.O.Box 10, Kellem Wollega, Dambi Dollo, Ethiopia.
Corresponding Author: dereaber@gmail.com*

Abstract
A field experiment was conducted on fourteen faba bean genotypes at sub sites of Haro Sabu Agricultural Research Center (Mata, Badesso and Lalo Asabi) for three consecutive main cropping seasons (2014/15-2016/17) withobjective to evaluate and select high yielding and stable genotypes over test environments that are tolerant to major faba bean diseases. Randomized complete block design with three replications was used with net plot size of 1.6m x3m. Pooled ANOVA showed significant difference among evaluated genotypes for plant height, number of pods per plant, hundreds seed weight and grain yield. All observed agronomic traits except days to flowering and days to maturity were showed significant differences across the testing environments. On the other hand, genotype by environment interaction had significant effect on number of pods per plant and grain yield. Stability parameters were estimated by employing AMMI stability value (ASV) and Genotype Selection Index (GSI). The total variation of 45.55%, 6% and 22.51% were contributed by environment, genotypes and genotype by environment interaction for grain yield, respectively. G10 (16.74Qt/ha) and G12(16.32Qt/ha) were identified for their better yield performance with yield advantage of 5.42 and 2.77%, respectively over the best standard check (Shalo=15.88Qt/ha). Besides, G10 and G12 had better mean value of thousand seed weight viz. 76.78 gram (G10) and 73.90 gm (G12) over Shalo (62.87 gram). AMMI biplot, ASV, GSI and GGE Biplot further confirmed that G10 and G12 were the most stable and widely adapted genotypes. Therefore, the identified genotypes (G10 and G12) were suggested to be released as new varieties for West and Kelem Wollega Zones and areas with similar agro-ecologies.

Keywords: *Faba bean, Stability, Yield*

Introduction
Faba bean (*Vicia faba* L.) is an important pulse crop grown in highlands of Ethiopia, where the soil and weather are considered to be congenial for better growth and development of the crop. The crop shares the largest area under pulses production in Ethiopia (Gezahegn*et al.*, 2016). Faba bean is a crop of manifold merits in the economy of the farming communities in the highlands of Ethiopia and serves as income and source of food to farmers, earns foreign exchange to country, and plays a significant role in soil fertility restoration in crop rotation through fixation of atmospheric nitrogen.

The crop is mainly produced in Tigray, Gondar, Gojjam, Wollo, Wollega, Shoa and Gamo-Gofa regions of Ethiopia (Gezahegn *et al.*, 2016). Nevertheless, faba bean production in Ethiopia is constrained by water logging, low yielding indigenous cultivars (Desta *et al.*,

2015) and diseases (Abebe *et al*., 2015). Correspondingly, the yield potential of faba bean has not been exploited in West and Kelem Wollega Zones of Western Oromia which might be attributed due to low yielding local cultivar used by farmers and disease pressure prevailing in the areas. In order to uplift the production and productivity of the crop; screening of faba bean genotypes that withstands major production constraints in the areas is crucial. Therefore, the present study was conducted to identify stable, high yielding varieties that are tolerant to major faba bean diseases in the study areas of West and Kelem Wollega Zones and other areas having similar agro-ecologies

Materials and methods

Description of the study area:

A field experiment was conducted at sub-sites of Haro Sabu Agricultural Research Center (Badesso and Mata) for three (2015-2017) consecutive main cropping seasons and one extra site (Lalo Asabi). The study sites have an elevation of 2016 m.a.s.l for Mata and 2054 m.a.s.l for Badeso with unimodal rain fall distribution pattern. Besides, these sites had sandy loam type soil textural class with PH of 4.59 and 5.65 and exchangeable acidity of 0.07 and 0.14 dS/m for Mata and Badesso, respectively.

Testing genotypes

Fourteen (14) faba bean genotypes including local check and two standard checks (Shallo and Moti) were evaluated for their performance on grain yield and yield related agronomic traits (Table 1).

Table 1: Lists of genotypes used in the study.

Code	genotype	Hosting Center
G1	Ek02016-1-4	Holeta Agricultural Research Center
G2	EK02018-1	Holeta Agricultural Research Center
G3	Eh06005-1	Holeta Agricultural Research Center
G4	Ek 01019-7-1	Holeta Agricultural Research Center
G5	Local check	Local
G6	Eh00126-2	Holeta Agricultural Research Center
G7	EKLS01022-1	Holeta Agricultural Research Center
G8	Eh00009-3	Holeta Agricultural Research Center
G9	EKIsr01009-2-2	Holeta Agricultural Research Center
G10	Eh00016-2	Holeta Agricultural Research Center
G11	Moti	Standard Check
G12	Eh06079-7	Holeta Agricultural Research Center
G13	Eh000012-4	Holeta Agricultural Research Center
G14	Shalo	Standard Check

Key:G=genotype

Experimental design

Randomized Complete Block Design (RCBD) with three replications, having a net plot size of 1.6mx3m each consisting of four harvestable rows was used. Six rows with 40 cm between rows and 20cm between plants were used for this experiment. The seed rate of 135 kg/ha was used for the experiment. Inorganic fertilizer DAP was applied at the rate of 100 kg/ha at sowing time. All agronomic practices were done as uniformly as required.

Data collection

Agronomic data were collected on plot and plant basis. Some of the data taken were number of pods per plant, number of seeds per pod, plant height, days to 50% flowering, days to physiological maturity, thousand seed weight, grain yield and major faba bean disease (Chocolate leaf spot)

Results and discussions

Analysis of variance

Analysis of Variance (ANOVA) was done for grain yield and other seven yield related traits mentioned above. The collected data were analyzed using SAS statistical package (SAS, 2006 version 9.03). Homogeneity of variance was tested and combined analysis of grain yield and other yield contributing agronomic traits was done using general linear model (Proc GLM) procedure to estimate contribution of genotype, environment and their interaction towards total variation observed. Mean separation was done using Least Significant Difference (LSD) employing the procedure developed by Gomez and Gomez (1984), whereas GGE biplot and AMMI stability analysis was done using GenStat computer software (2012).

Pooled analysis of variance showed significant difference among evaluated genotypes for plant height, number of pods per plant, hundred seed weight and grain yield. On the other hand, environment had significant effect on all observed agronomic traits except days to flowering and days to maturity. The genotype by environment interaction also exerted significant effect on pod/plant and grain yield (Table 2). Besides, the pooled analysis of variance showed non-significant difference among evaluated genotypes for days to flowering and maturity.

Table 2: Combined Mean square of yield and yield related traits of Faba bean genotype

Source of Variation	**DF**	**Mean Square**						
		DF	DM	PH	PPP	SPP	HSW	GY
Geno	13	10.99	6.98	1054.6*	28.28**	0.14	523.58**	35.67**
Rep	2	39.47	27.12	136.30	6.90	0.13	38.28	49.23
Env	6	31.99	298.6**	10779**	70.00**	2.32**	1983.26**	262.18**
G*E	52	12.22	5.49	302.34	7.16*	0.33	79.60	22.69**
Error		14.13	4.85	390.64	3.80	0.29	117.61	10.02

Key: - DF= days to flowering, DM =days to maturity, PH =plant height, PPP= number of pods per plant, SPP =number of seeds per pod, HSW =hundred seed weight, GY =grain yield.

Mean performance of grain yield and yield related traits of genotypes

Plant height ranged from 142cm (G6) to 165.43cm (G9) with over all mean value of 156.35 cm. Genotypes G10, G11 and G14 had higher number of pods per plant than the remaining genotypes. Higher mean value of thousand seed weight was recorded for all faba bean genotypes over standard check Shallo which had mean value of 62.87gram (Table 3). The minimum (10.14 Qt/ha) and maximum (21.08 Qt/ha) mean value of grain yield was obtained at Mata 2015 (Env2) and Mata 2016 (Env4), respectively (Table 4). The pooled analysis detected the lowest (12.44 Qt/ha) and highest (16.74 Qt/ha) mean value of grain yield from G8 and G10, respectively with over all mean value of 14.72 Qt/ha. The highest mean value of grain yield exhibited by G10 followed by G12 and G13. Like wises, the yield advantage of 5.42 and 2.77% was obtained from G10 and G12, respectively over the best standard check Shallo which had mean value of 15.88 Qt/ha (Table 3).

Table 3: Combined mean performance of grain yield and yield related traits of genotypes

Code	genotype	DF	DM	PH	PPP	SPP	HSW	GY	YAD (%)	DR
G1	Ek02016-1-4	46.95ab	132.52b	148.36de	7.04g	3.09a	75.46ab	13.13ef	-17.32	2.67
G2	EK02018-1	47ab	132.86b	154.43b-e	7.07g	3.12a	75.36ab	14.26c-f	-10.2	2.46
G3	Eh06005-1	47.29ab	133.81ab	148.59de	8.11e-g	3.15a	74.07a-c	14.31c-f	-9.89	2.71
G4	Ek 01019-7-1	47.57ab	132.95b	157.13a-d	8.5c-f	3.12a	78.76ab	14.9a-e	-6.17	2.29
G5	Local check	47.48ab	133.33ab	161.23a-c	9.18b-e	3.14a	68.53c-e	13.71ef	-13.66	2.4
G6	Eh00126-2	47.05ab	132.57b	142.74e	8.32ef	3.08a	72.65b-d	13.5ef	-14.99	2.63
G7	EKLS01022-1	47.24ab	132.81b	159.75a-d	8.7c-e	3.18a	79.42a	14.73b-e	-7.24	2.50
G8	Eh00009-3	45.62b	133.29ab	157.28a-d	7.4fg	3.24a	79.65a	12.44f	-21.66	3.04
G9	EKIsr01009-2-2	47.38ab	133.05ab	165.43ab	8.47d-f	3.33a	76.42ab	14.06d-f	-11.46	2.42
G10	Eh00016-2	48.14a	133.86ab	158.44a-d	10.07ab	3.18a	76.78ab	16.74a	5.42	2.21
G11	Moti	47.05ab	133.62ab	151.2c-e	9.96ab	3.2a	66.53de	15.87a-d	-0.06	2.38
G12	Eh06079-7	45.76b	133.29ab	166.57a	9.6a-d	3.22a	73.91a-c	16.32ab	2.77	1.92
G13	Eh000012-4	47.19ab	133.86ab	159.03a-d	9.67a-c	3.33a	74.01a-c	16.18a-c	1.89	2.25
G14	Shalo	47.43ab	134.38a	158.66a-d	10.44a	3.21a	62.87e	15.88a-d	0.00	2.58
	Mean	47.08	133.3	156.35	8.75	3.18	73.89	14.72		2.46
	CV	7.99	1.65	12.64	22.27	17.03	14.63	21.5		26.08
	Lsd	2.29	1.34	12.03	1.19	0.33	6.58	1.93		0.52
	Location	32.5	298.16**	10779.00**	70.47**	2.16**	2003.35**	263.38**		
	Genotype	10.85	6.97	1054.65**	28.29**	0.14	524.27**	36.14**		
	GXE	12.15	5.5	302.34	7.14**	0.32	80.79	22.64**		

Key: Whereas, DF= days to flowering, DM= Days to maturity, DR= disease reaction for chocolate leaf spot was recorded on 1-9 scale; where 1= resistance and 9= highly susceptible, GY= grain yield in ton/ha,PH= Plant height, PPP= Pod/plant, SPP= Seed/pod, HSW=Hundred seed weight in gram, YAD (%) = Percent of yield advantage, CV= Coefficient of variation, Lsd= least significant difference, GXE= Interaction of genotype by environment

The mean grain yield of the tested genotypes at the testing sites showed significant variation. From the pooled data, two genotypes, EH00016-2 (16.74Qt/ha) and EH 06079-7 (16.32Qt/ha) gave relatively higher grain yield than the standard check, Shallo (15.88Qt/ha). Similar result was also noted on sesame in Northern Ethiopia (Tadesse and Abay, 2011).

Table 4: Grain yield (Qt/ha) performance of faba bean genotypes across seven environments

Code	genotype	Env1	Env2	Env3	Env4	Env5	Env6	Env7	Comb
G1	Ek02016-1-4	9.27a-c	7.12c	13.26b-d	18.51de	15.7b-d	8.29h	19.8a-c	13.13ef
G2	EK02018-1	14.26ab	9.74a-c	12.1cd	18.34de	14.35cd	11.62fg	19.37a-d	14.26c-f
G3	EH06005-1	14.66a	8.67bc	17.6a-d	19.09c-e	14.19cd	8.97gh	16.97a-e	14.31c-f
G4	Ek 01019-7-1	9.09a-c	10.33a-c	19.11a-c	22.61a-d	13.6de	16.07c-e	13.49e	14.9a-e
G5	Local check	6.38c	13.85a	15.63a-d	18de	13.8cd	13.3ef	15de	13.71ef
G6	Eh00126-2	8.45bc	11.98ab	12.51b-d	19.05c-e	13.23de	11.38f-h	17.91a-e	13.5ef
G7	EKLS01022-1	10.44a-c	9.61a-c	19.42ab	21.84b-d	10.93e	15.28c-e	15.62b-e	14.73b-e
G8	EH00009-3	11.9a-c	8.02bc	10.31d	14.95e	14.29cd	9.33gh	18.31a-d	12.44f
G9	EKIsr01009-2-2	8.76a-c	12.34ab	11.47d	20.45c-e	13.26de	13.94d-f	18.17a-d	14.06d-f
G10	EH00016-2	9.61a-c	12.01ab	20.92a	24.91a-c	17.8ab	16.6b-d	15.33c-e	16.74a
G11	Moti	12.75ab	8.94bc	11d	27.87a	13de	17.3a-c	20.22a	15.87a-d
G12	EH06079-7	11.74a-c	9.84a-c	14.26a-d	19.5c-e	19a	19.95a	19.95ab	16.32ab
G13	EH000012-4	12.68ab	6.93c	16.07a-d	26.67ab	15.19b-d	19.33ab	16.39a-e	16.18a-c
G14	Shalo	9.96a-c	12.53ab	16.64a-d	23.3a-d	16.54a-c	14.82c-e	17.32a-e	15.88a-d
	Mean	10.71	10.14	15.02	21.08	14.63	14.01	17.42	14.72
	CV	12.60	26.86	29.02	16.57	11.62	13.30	15.62	21.50
	Lsd	6.13	4.57	7.32	5.86	2.85	3.13	4.57	1.93

Additive Main Effect and Multiplicative Interaction Effect (AMMI) Analysis

Combined analysis of variance showed significant variation of genotypes, environments and genotypes by environment interaction for grain yield and this indicated that there is unstable response of genotypes and fluctuation of grain yield with environmental change which clearly illustrated the presence of genotype by environment interactions.

Table 5: Partitioning of explained Sum of Square (SS) and Mean of square

Source	Df	SS	Ex.SS%	MS
Total	293	7872	100	26.87**
Treatments	97	5830	74.06	60.11**
Genotypes	13	472	6.00	36.31**
Environments	6	3586	45.55	597.71**
Block	14	332	4.22	23.71**
Interactions	78	1772	22.51	22.72**
IPCA1	18	723	40.8	40.18**
IPCA2	16	467	26.4	29.18**
Residuals	44	582	32.8	13.23
Error	182	1710		9.39

Whereas, Df= degree of freedom, Expected percentage of sum of square, MS= Mean of Square, SS=Sum of square, Interaction principal component analysis

From the total variation obtained for grain yield, 6%, 45.55% and 22.51% were contributed by genotypes, environment and genotype by environment interaction, respectively (Table 5).

IPCA1 and IPCA2 explained 40.8% and 26.4% interaction sum squares and contributed a total of 67.2% of total variation. According to Kempton (1984), in AMMI model the first two interactions principal component axis were best predictive model that explains the interaction sum of squares. The finding of the current study is supported by Tamane *et al*. (2015) who reported highly significant ($p \leq 0.01$) difference of genotype, environment and their interaction for grain yield in faba bean genotypes evaluated in multi-location of Ethiopia.

AMMI stability value (ASV) and Genotype Selection Index (GSI)

In AMMI model, the genotype with least AMMI stability value (ASV) score was considered as the most stable. Accordingly, genotypes such as EKISR01009-2-2, Shalo and EH06079-7 were showed a higher stability (Table 6). As stability per se is not a desirable selection criterion, because the most stable genotypes would not necessarily give the best yield performance, hence, simultaneous consideration of grain yield and ASV in single non-parametric index is needed. Accordingly, EH06079-7 (16.32 Qt/ha) and EH00016-2 (16.74Qt/ha) were found to be higher yielder genotypes and relatively stable.

Table 6. AMMI stability value, genotype selection index, yield rank and principal component axis

Code	Genotype	Mean	PC1	PC2	ASV	ASV Rank	Yd. Rank	GSI
G1	Ek02016-1-4	13.13	1.24	0.28	1.94	8	13	21
G2	EK02018-1	14.26	1.421	-0.22	2.22	9	9	18
G3	EH06005-1	14.31	0.73	0.87	1.42	5	8	13
G4	Ek 01019-7-1	14.9	-1.55	0.52	2.46	13	6	19
G5	Local check	13.71	-0.41	1.35	1.49	6	11	17
G6	EH00126-2	13.50	0.55	0.39	0.93	4	12	16
G7	EKLS01022-1	14.73	-1.15	0.39	1.82	7	7	14
G8	EH00009-3	12.44	1.79	0.11	2.77	14	14	28
G9	EKIsr01009-2-2	14.06	0.31	-0.23	0.54	1	10	11
G10	EH00016-2	16.74	-1.46	0.76	2.39	11	1	12
G11	Moti	15.87	-0.15	-2.37	2.39	10	5	15
G12	EH06079-7	16.32	0.33	-0.62	0.79	3	2	5
G13	EH000012-4	16.18	-1.22	-1.56	2.45	12	3	15
G14	Shalo	15.88	-0.42	0.33	0.73	2	4	6

Whereas, ASV= AMMI stability value, G= genotype, GSI= genotype selection index, Yd= yield, PC= principal component

Genotypes and Genotypes by environment interaction (GGE) Bi-plot analysis

The sector with vertex cultivar G13 may be referred to as the G13 sector; and environment Mata (MT) and Badesso (BD) fell in this sector. As a rule, the vertex cultivar is the highest-yielding cultivar in all environments that share the sector with it. In the same manner, in G11 sector, two environments fell. No environments fell in the sectors with G8 as vertex cultivars and this indicates that this vertex cultivar were not the best in any of the test environments. Moreover, this indicates that these cultivars were the poorest in some or all of the

environments. A cultivar located at the origin would rank the same in all environments and is not at all responsive to the environments.

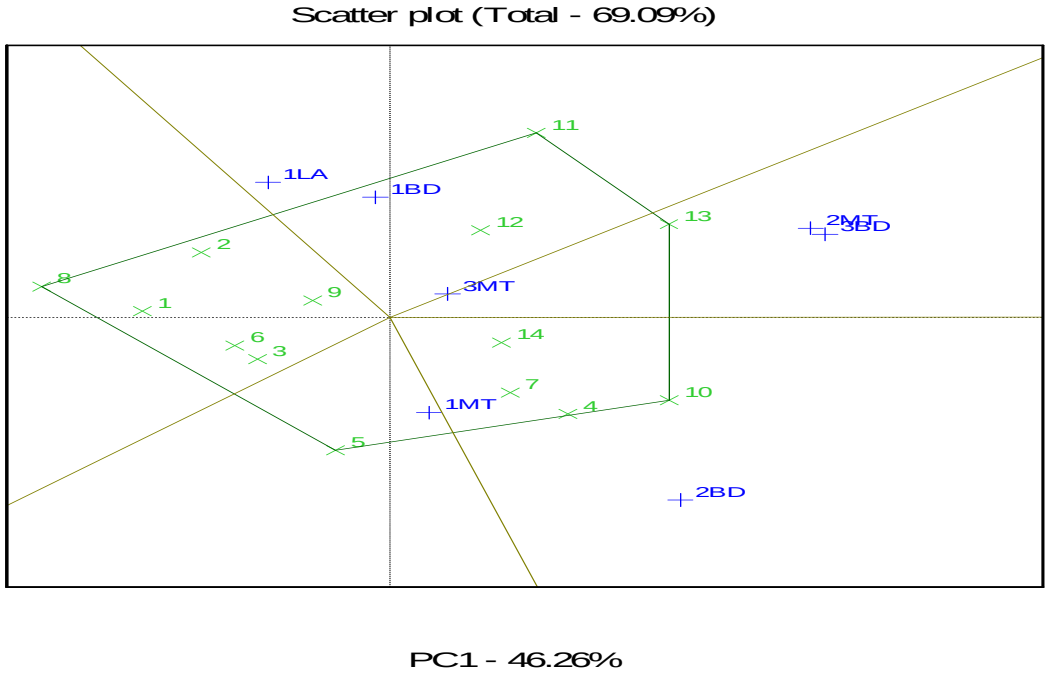


Figure 1. Scatter plot showing which- won-where pattern of the GGE bi-plot

In GGE biplot, the environments and genotypes obtained in the concentric (central circle) are considered as ideal environments and stable genotypes, respectively (Yan, 2002). Using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal variety. Therefore, ranking based on the genotypes-focused scaling, assumes that stability and mean yield are equally important (Farshadfar *et al.*, 2011). Genotype G13 followed by G10 and G12 were lied relatively near to the center of concentric circles and were ideal genotypes in terms of yield and stability (Figure 2). Similarly, Tamane *et al*. (2015) identified the best genotypes which had superior grain yield and yield stability.

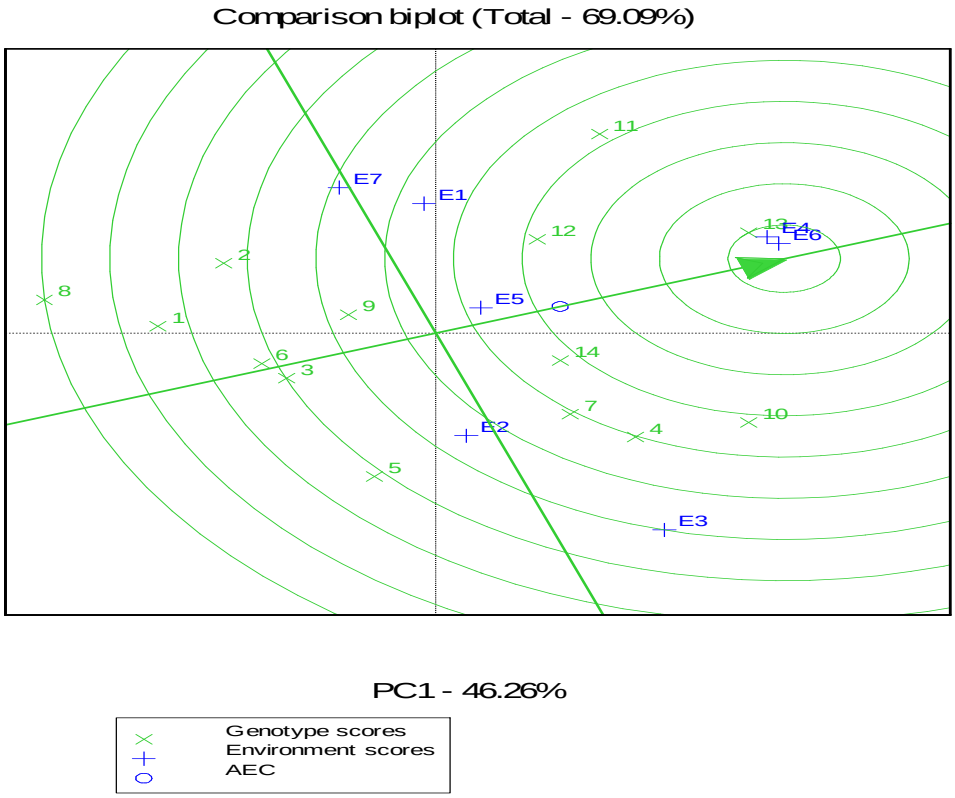


Figure 2. GGE bi-plot based on genotype-focused scaling for comparison of genotype for grain yield potential and stability.

Conclusions

Combined ANOVA showed significant variation among genotypes, environments and their interaction. AMMI biplot, ASV, GSI and GGE Biplot further confirmed that G10 and G12 were most stable and widely adapted, whereas G13 had stable coupled with relative better yield performance. Thus, G10 and G12 were selected as the candidate genotypes proposed for possible release as new variety of faba bean for West and Kellem Wollega zones of western Oromia and areas having similar agro-ecologies.

Reference

Abebe, E., Mekete, T., Seid, A., Meressa, B. H., Wondafrash, M., Addis, T., and Abate, B. A. (2015). Research on plant-parasitic and entomopathogenic nematodes in Ethiopia: a review of current state and future direction. *Nematology*, *17*(7), 741-759.

Desta, Y., Habtegebrial, K., and Weldu, Y. (2015). Inoculation, phosphorous and zinc fertilization effects on nodulation, yield and nutrient uptake of Faba bean (Vicia faba L.) grown on calcaric cambisol of semiarid Ethiopia. *Journal of Soil Science and Environmental Management*, *6*(1), 9-15.

Farshadfar, E., Zali, H., and Mohammadi, R. (2011). Evaluation of phenotypic stability in chickpea genotypes using GGE-Biplot. *Ann. Biol. Res*, *2*, 282-292.

Gezahegn, A. M., Tesfaye, K., Sharma, J. J., and Belel, M. D. (2016). Determination of optimum plant density for faba bean (Vicia faba L.) on vertisols at Haramaya, Eastern Ethiopia. *Cogent Food & Agriculture*, *2*(1), 1224485.

Gomez, K.A., and Gomez, A.A. (1984). Statistical procedure for agricultural research second Edition International Rice Research Inistitute John Wiley and Sons Inc.

Kempton, R.A. (1984). The use of biplots in interpreting variety by environment interactions. Journal of Agricultural Science 103:123-135.

SAS Institute Inc. (2006). Statistical analysis Software version 9.2, Cary, NC: SAS Institute.

Tadesse, H., and Abay, F. (2011). Additive main effects and multiplicative interactions analysis of yield performance of sesame genotypes across environments in North Ethiopia. *Journal of Drylands*, 4:259-266.

Tamene,T., Gemechu, K., and Hussein, M. (2015). Genetic progresses from over three decades of faba bean (Vicia faba L.) breeding in Ethiopia. Australia Journal of crop science, 9:41-48.

Yan, W., and Kang, M. S. (2002). *GGE biplot analysis: A graphical tool for breeders, geneticists, and agronomists*. CRC press.

Genotype by Environment Interaction and Stability Analysis of Food Barley Genotypes in Barely Growing Highlands of Ethiopia

Girma Fana, Endashaw Tadese, Hiwot Sebsibe and KassahunTadese
Oromia Agricultural Research Institute, Sinana Agricultural Research Center, P.O.Box 208, Bale-Robe, Ethiopia

Abstract

A trial was conducted in major barley growing highlands of Ethiopia for two years (2016-2018) with the objective of identifying high yielding and stable genotypes for variety verification and possible release. All agronomic and other management options except disease control were applied as per the recommendation of specific areas where the trial was conducted. The result showed statistically significant variation among the test environments and genotypes but the variation within the locations is very high. Out of the total variation, only 3% was attributed to the genotypic variance while the variance due to location was 83% with the remaining 14% contributed by the Genotype by Environment Interaction. The result showed that genotypes 6(PENCO/CHEVRON-BAR//FEG53.16/3/LEGACY//PENCON/CHEVRON-BAR) and 8 (P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU /5/PETUNIA1/6/M111/7/LEGACY/3/SVANHALS-BAR/MSEL//AZAF /GOB 24 DH) have mean yield higher than other genotypes and standard checks with the yield advantage of 5.7% and 7.3%, respectively compared to the best standard check, EH 1493. AMMI and GGE biplot were the two statistical models employed to evaluate the GEI in variety evaluation in the multi-environment yield trial. The two models were compared in the degree of precision to classify mega environments and discriminate genotypes with high yield performance and stability. Since the major source of variation is the Environment, GGE biplot method is the preferred model for mega-environment clustering and genotype discrimination in this study. AMMI classified the environments into two mega environments: the first cluster of environments that similarly discriminate genotypes are Kofele, Gasara, Dinsho, Agarfa, Gedo and Alemata, while the other cluster Shambu, Goba, Bekoji, Bore, Sinana, Adet and Adaba. GGE biplot identified four mega environments: the first included only Alemata while the second consisting of Adaba, Adet, Sinana and Bore. The third mega-environment contains only Goba and Bekoji while the fourth cluster includes Gedo, Dinsho, Kofele, Gasera and Agarfa. Shambu and Bore are the most discriminating environments for variety evaluation. Different stability parameters such as CV, Shukla's variance, ecovalence, R^2, Regression coefficient, Absolute rank difference, superiority measure and non-parametric ones were employed to determine the stability of genotypes. Genotype 8 has higher mean yield in all locations except at Alemata. Based on multiple criteria, genotypes 6 and 8 are more stable than others and hence selected for variety verification.

Key words: AMMI, discriminative, GGE biplot, multi-environment, stability

Introduction

Ethiopia is the second largest barley producer in Africa, next to Morocco, accounting for about 25 percent of the total barley production in the continent (FAO, 2014). Barley production and consumption has a longstanding tradition in Ethiopia where the country is considered as the center of diversity or secondary origin of the crop with more than 15,000 accessions conserved in the gene bank. In plant breeding programs, genotypes are evaluated in multi-environment trials (METs) by testing their performance across environments and selecting the best genotypes in specific environments. However, selection of superior genotypes in multi-environment trials usually results in genotype-by-environment interactions that often complicate the interpretation of results obtained and reduce efficiency in selecting the best genotypes (Annicchiarico and Perenzin, 1994). This interaction is due to the changes in genotype's relative performance across environments, as a result of differential responses of the genotypes to various abiotic and biotic factors (Dixon and Nukenine, 1997). Hence, a significant Genotype by Environment interaction (GEI) for a quantitative trait like grain yield can complicate the identification of superior genotypes for both improved crop development and new crop introduction. Statistical techniques have been proposed to facilitate the interpretation of GEI from MET's. The most commonly used statistical methods for analyzing GEI is the two-way cross classification analysis of variance (ANOVA). However, while this technique can adequately explain only the main effects and identify GEI as a source of variation, it fails to analyze the inherent effects of GEI. This is due to the additive nature of the ordinary ANOVA model does not allow it to analyze a non-additive interaction component and other statistical approaches are therefore required to identify the relationships of interaction.

The AMMI model has been suggested to be an efficient method because it captures a large portion of the Genotype by Environment (GE) sum of squares and uniquely separates main and interaction effects as required for most agricultural research purposes (Gauch, 2006). It has proved to be a powerful tool used by researchers to evaluate a number of genotypes established in a number of environments, identify stable and adaptable genotypes and determine the magnitude of GEI (Crossa, 1990). As a result, Gruneberg et al. (2005) reported that the AMMI model was highly efficient multivariate tool for the analysis of MET data. Likewise, the most well-known and appealing component of AMMI analysis is the graphical display of the results in a very informative biplot (AMMI1) which shows both main and interaction effects for both genotype and environment (Zobel et al. 1988). Yet, the AMMI1 biplot does not have the most important property of a true biplot, namely the inner-product property. In addition, the AMMI1 biplot does not display the discriminating ability and representativeness view of a biplot which is effective in evaluating test environments. This has been recognized by Yan et al., (2000) who adopted the proposal of Gabriel, (1971) by using the biplot technique to display the genotype main effect plus genotype-by-environment interaction (G+GE) of a METs data, and called it the GGE biplot.

GGE biplot is a graphical tool which displays, interprets and explores two important sources of variation, namely genotype main effect and GE interaction of MET data (Yan et al. 2000). GGE biplot analysis considers that only the G and GE effects are relevant and that they need to be considered simultaneously when evaluating genotypes. The GGE biplot has therefore

been used in crop variety trials to effectively identify the best-performing genotype across environments, identify the best genotypes for mega-environment delineation, whereby specific genotypes can be recommended to specific mega-environments and evaluate the yield and stability of genotypes (Yan and Kang, 2003; Yan and Tinker, 2006). The relative versatility of the GGE biplot, especially in mega-environment analysis and genotype selection, is worthy of being exploited for selection of genotypes for specific environments. More importantly, it would assist in guiding the direction of varietal development for stable ecology based selections.

The differences between the GGE biplot and AMMI methods are; firstly, AMMI stands for the additive main effect and multiplicative interaction (Gauch, 1992), and GGE stands for genotype main effect plus GE interaction (Ma, 2004). Secondly, the GGE biplot analysis is based on environment-centered principal component analysis (PCA), whereas AMMI analysis is established on double centered PCA (Kroonenberg, 1995). However, according to Yan and Tinker (2006), AMMI could be misleading if used for the purpose of "which-won-where" (i.e., identification of mega-environments as well as their wining genotypes). Also, Ding et al. (2007) asserted that the GGE biplot is superior to the AMMI, because it provides a lot more visual interpretations than the AMMI, by allowing the visualization of any crossover GE interaction which is usually essential to breeding programs. Several multi-environment trial studies have compared the AMMI and GGE biplot analyses to obtain an effective tool for analyzing GEI and have come out with differing results. Kandus et al. (2010) found the AMMI model was the best model to describe the GEI in maize. Stojaković et al. (2010) and Mitrovic et al. (2012) also found out that the models provided similar results. Moreover, (Rad et al., 2013) indicated that both models performed equally using data on bread wheat while Samonte et al (2005) found the AMMI and GGE biplot analyses complementing one another. Contrary to these findings, Yan et al. (2007) compared the GGE biplot and AMMI analyses and concluded that the GGE biplot was superior to the AMMI biplot in mega-environment analysis and genotype evaluation. The main objectives of this study were to study GEI and predict the yield stability of barley genotypes for varietal recommendation.

Materials and Methods

The trial was conducted with 25 genotypes including three standard checks as National Variety Trial for two years (2017 and 2018) at different barely growing locations in Ethiopia viz., Adet, Gassara, Agarfa, Alemata, Bekoji, Bore, Dinsho, Gedo, Goba, Kofele, Shambu, Adaba and Sinana. The design used was alpha lattice with three replications. The agronomic packages used were seeding rate of 125 kg/ha and fertilizer rate of 46-46 kg/ha N-P_2O_5. The trial was laid out with a plot size of 3 m^2 (1.2m x 2.5m). Plot area of 2 m^2 (4 central rows) were used as harvestable plots which were used to estimate the yield per hectare. Grass weeds were controlled by hand weeding and 2, 4-D was sprayed to control the major broadleaf weeds.

Analysis of variance was performed using R statistical software and means were separated using LSD at Probability level of 0.05. The analysis considered the test of ANOVA assumptions. Homogeneity of error variance was tested using Bartlett's test which proved that heterogeneity of error variance across locations. Therefore, the analysis was performed using adjustments using heterogeneous models (lme function of the library nlme) of R software.

Analysis of genotype x environment interaction and stability for the genotypes were done using both AMMI and GGE-biplot methods.

Results and Discussions

Analysis of Variance showed that significant variation was contributed by the testing environment to the total experimental variance whereas the genotype and genotype by environment interaction had the lower share of 3% and 14%, variations respectively (Table 1). The principal component analysis showed that the first two components explained 53% of the variation.

Table 1. Combined Analysis of Variance

Source of variation	DF	SS	MS	Variation %	AC. Variation %	F	Prob F
ENV	12	2730511103	227542592	83.27	83.27	48.15	$1.221e^{-14}$***
GEN	24	93911527	3912980	2.86	86.14	1.51	0.053340
ENV*GEN	288	454411674	1577818	13.86	100.00	0.59	1.000000
PC1	35	105104860	3002996	31.86	31.86	1.57	0.019160
PC2	33	72647611	2201443	22.02	53.88	1.15	0.253750
PC3	31	42555987	1372774	12.89	66.78	0.72	0.869720
Residuals	1025	2578599086	2581180				

Genotypes 6 and 8 are better performing than others with a yield advantage of 5.7% and 7.3%, respectively compared to the best standard check EH 1493 (Table 2). The grand mean of the trial yield is 3364.17 kg/ha and locations which have produced less than the overall mean were Adaba, Adet, Agarfa, Dinsho, Gassara, Kofele and Sinana whereas the best performing environments with higher grain yield than the grand mean were Alemata, Bekoji, Bore, Gedo, Goba and Shambu. Genotypes 6 and 8 have high yield than the standard checks and the grand mean and hence worthy selecting as candidate varieties for verification trial and hence selected to include as candidate varieties for release.

Table 2. Mean grain yield of genotypes combined across locations

Gen	Adet	Agarfa	Dinsho	Adaba	Sinana	Kofele	Gasera	Alemata	Bekoji	Bore	Gedo	Goba	Shambu	Mean
1	1803	791	1893	2708	2233	2286	1941	4378	4231	4225	4316	3597	3457	3021
2	761	1830	2229	1620	1914	2888	4500	5750	4122	3692	3604	3019	3932	3129
3	1211	1632	1907	1950	1974	2816	4011	4166	4843	4742	5155	3979	6312	3655
4	1477	1238	970	1552	2491	1596	2491	5285	3986	4975	5331	3238	3734	3084
5	608	786	1616	1864	2617	2892	1871	5306	4061	4092	4793	4183	3745	3141
6	**1806**	**1451**	**1111**	**2729**	**2827**	**2675**	**2672**	**5011**	**5008**	**6258**	**5151**	**3625**	**5828**	**3758**
7	867	1632	2258	1314	2051	1942	3437	5706	4699	4650	4984	3405	4312	3291
8	**1196**	**1669**	**1724**	**1662**	**2168**	**3273**	**3339**	**4843**	**5330**	**6133**	**5964**	**3491**	**5614**	**3820**
9	862	693	1807	1282	1616	2673	2948	4209	4235	3617	3830	3885	5060	3007
10	803	1143	1788	1144	1880	3030	2199	4416	4402	6317	4107	4029	5881	3358
11	820	1506	1463	2645	1979	2704	1761	5397	4267	5383	4794	3126	5104	3322
12	1214	1241	1645	1720	2397	2824	3590	5677	4417	4467	5075	2708	3138	3220
13	1175	1070	1289	1069	2543	3507	2965	5342	4687	5775	5093	3960	6105	3695
14	1217	1623	1353	1239	1943	3344	3197	6036	4451	3967	6331	4019	4807	3578
15	1294	1528	1209	2504	1706	2698	1980	4916	4877	5367	4789	2799	5518	3376
16	1352	654	1319	2583	2242	1571	2488	4339	4206	5108	4390	3032	3244	2899
17	889	810	1811	1761	2021	3053	2907	5133	5181	4825	5653	2459	5354	3507
18	1093	1195	1545	649	1721	3100	2801	5412	3820	4830	4278	3603	4067	3061
19	1445	968	1293	881	1939	3312	2115	5432	3799	2650	4974	3399	4582	3077
20	1057	727	1406	2022	1619	2939	2235	5972	3717	5542	5308	2882	5437	3327
21	1998	532	1265	2633	2558	2256	2026	4253	3487	7383	4151	4322	5283	3327
22	922	825	1748	1351	2316	2438	2291	4548	5145	6525	4971	4721	5128	3496
23	915	1376	2539	865	1929	4611	3210	4175	4677	3975	5113	4276	5776	3641
24	1234	1274	1866	1343	2452	2886	3751	5298	4896	4992	4090	4001	6583	3643
25	937	951	1703	2611	2660	2827	4050	4500	4359	5142	5023	4444	6007	3672
Mean	1158	1166	1630	1748	2152	2805	2831	**5020**	**4436**	**4985**	**4851**	**3608**	**4960**	**3364**

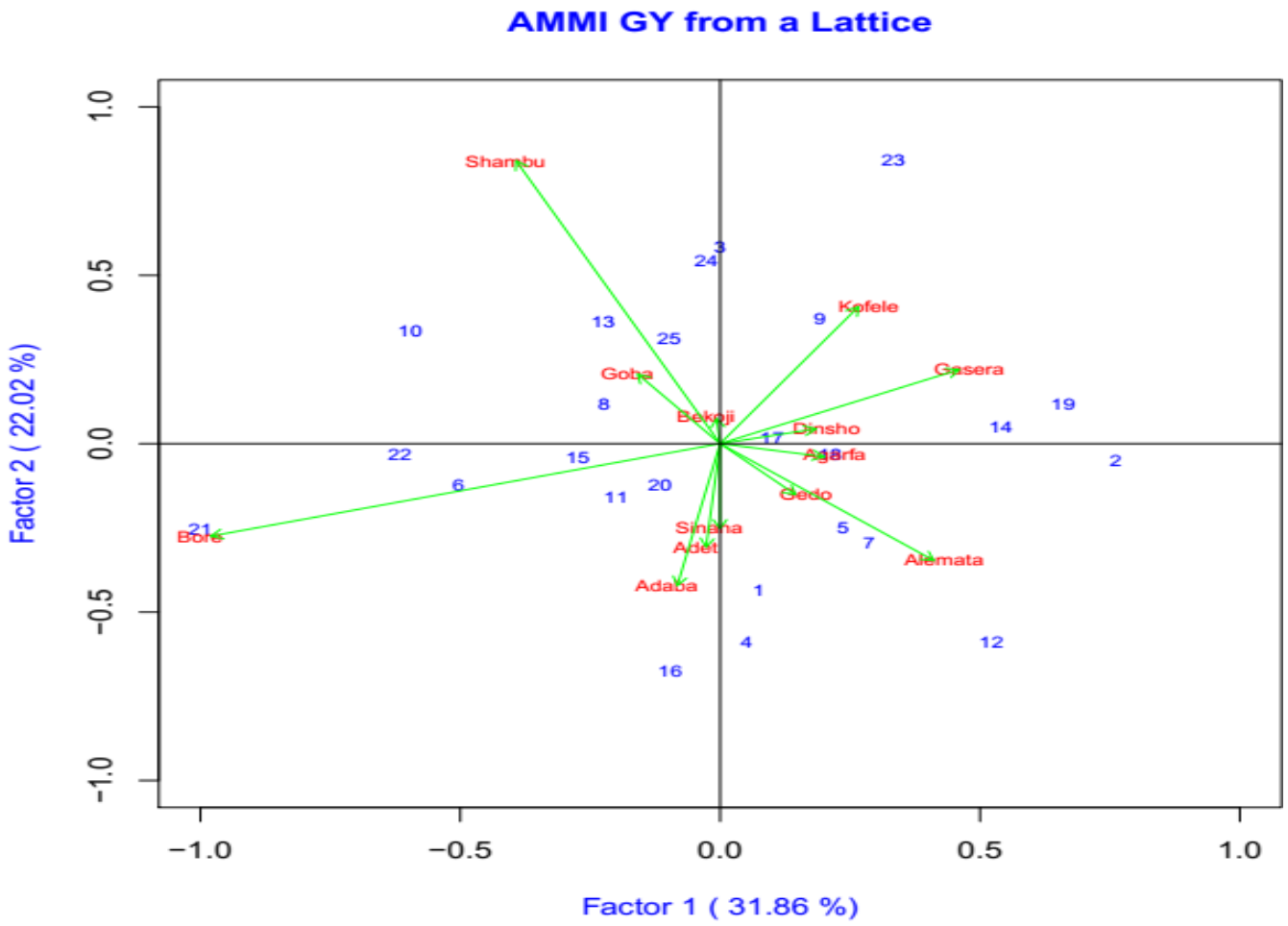
Table 3: Mean agronomic performance of the genotypes combined over years and locations

Genotypes	DTH	DTM	GFP	PH	TKW
242085	69	127	58	75.2	20.8
243223	72	126	55	91.7	23.8
243226	73	128	56	90.9	27.0
DERFA/CL128//PFC 88209	70	128	58	78.1	22.7
LACY/4/TOCTE//HIGO/LINO/3/PETUNIA 1	74	128	55	83.6	21.8
PENCO/CHEVRON-BAR//FEG53.16/3/LEGACY//PENCON/CHEVRON-BAR	**68**	**126**	**58**	**87.1**	**24.8**
P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1/6/M111/7/LEGACY/3/ SVANHALS-BAR/MSEL//AZAF/GOB 24 DH	69	126	57	80.9	18.7
P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1/6/M111/7/LEGACY/3/ SVANHALS-BAR/MSEL//AZAF/GOB 24 DH	**66**	**125**	**59**	**80.7**	**20.3**
PENCO/CHEVRON-BAR//FEG53.16/3/LEGACY//PENCON/CHEVRON-BAR	72	130	59	85.4	25.1
LIGNEE27/GERBEL/3/BOY-B*2/SURB//C12225.2D/4/BBSC/CONGONA	73	130	58	83.1	28.2
CAPUL/ESMERALDA	71	126	55	90.8	27.1
ENSINO/LEGACY	65	124	59	87.4	23.9
FRESA/M104	70	125	54	78.4	22.8
LA MOLINA96/6/P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA 1	71	127	56	77.6	25.5
LA MOLINA96/6/P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA 1	70	128	58	80.1	29.7
LA MOLINA96/LEGACY	70	128	58	79.6	23.4
CIRU/5/LEGACY/4/TOCTE//GOB/ HUMAI10/3/ATAH92/ALELI	68	125	57	82.9	20.8
PENCO/CHEVRON-BAR/3/ATACO/BERMINJO//HIGO/4/PENTUNIA1/5/LEGACY/4/ TOCTE//GOB/HUMAI10/3/ATAH92/ALELI	70	125	56	74.7	18.4
TRADITION//PENCO/CHEVRON-BAR	71	127	56	85.2	18.7
LA MOLINA96/GALCON-BAR	73	128	55	80.7	24.0
PENCO/CHEVRON/6/ P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1	69	126	56	81.3	25.2
DRUMMOND/STANDERBAR/6/ P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1	70	126	55	82.2	23.6
HB 1307	72	127	55	89.7	25.0
Cross 41/98	74	128	54	95.1	25.1
EH 1493	71	126	55	94.5	25.7
LSD		2.13	2.29	5.38	1.92

DTH= Days to heading, DTM= Days to maturity, GFP= Grain filling period (number of days), PH= Plant height (cm), TKW= thousand kernels weight (gm)

Genotype by Environment Interaction (GEI) and Stability Analysis

The AMMI model (Additive Main Effect and Multiplicative Interaction) showed that genotypes 17, 18, 20, 11 and 8 were near the origin, indicating that they are more stable than others (Figures 1 & 2). Genotypes 17 and 20 are more stable as compared to others and location Bekoji is near the origin and hence is the stable environment. The AMMI model also helps to classify environments similarly discriminating the genotypes. The environments that discriminate the genotypes in similar way are Kofele, Gasara, Dinsho, Agarfa, Gedo and Alemata. The other category of environments that similarly classify genotypes are Shambu, Goba, Bekoji, Bore, Sinana, Adet and Adaba. The mega-environments classified would enable alternative use of any of the environments in the category for variety evaluation without any loss of precision to screen genotypes. Based on the close similarity between environments, four mega environments were identified: the first contains Kofele, Gassara and Dinsho and the second consists of Shambu, Goba and Bekoji. The third mega environment had locations Sinana, Adet, Adaba and Bore whereas the fourth environment had Agarfa, Gedo and Alemata.



Figures 1: AMMI graph (PC1 Vs PC2) for grain yield

Acute angles (< 90) between location vectors show the similarity of genotype classification by the environments and obtuse angle (> 180) indicated discriminating ability of the environments in the opposite manner (Figure 2). This is also another view of the plot in which grain yield plotted in PC1 classify genotypes with acute angles as similar in performance and obtuse angles as dissimilar in their genotype discriminating power. Therefore, locations that have acute angles in the first cluster included Alemata, Gedo, Bekoji, Goba and Shambu while those in the second category included Gasera, kofele, Dinsho, Agarfa, Adet, Adaba and Sinana. Bore and Shambu are the environments with the longest vector from the biplot origin, demonstrating that they were with the most discriminating power against genotypes. Shambu and Bore are therefore the ideal environments to identify best performing genotypes. Alemata, Gedo and Bekoji are also good environments for variety identification since they have positive performance and high yielding potential.

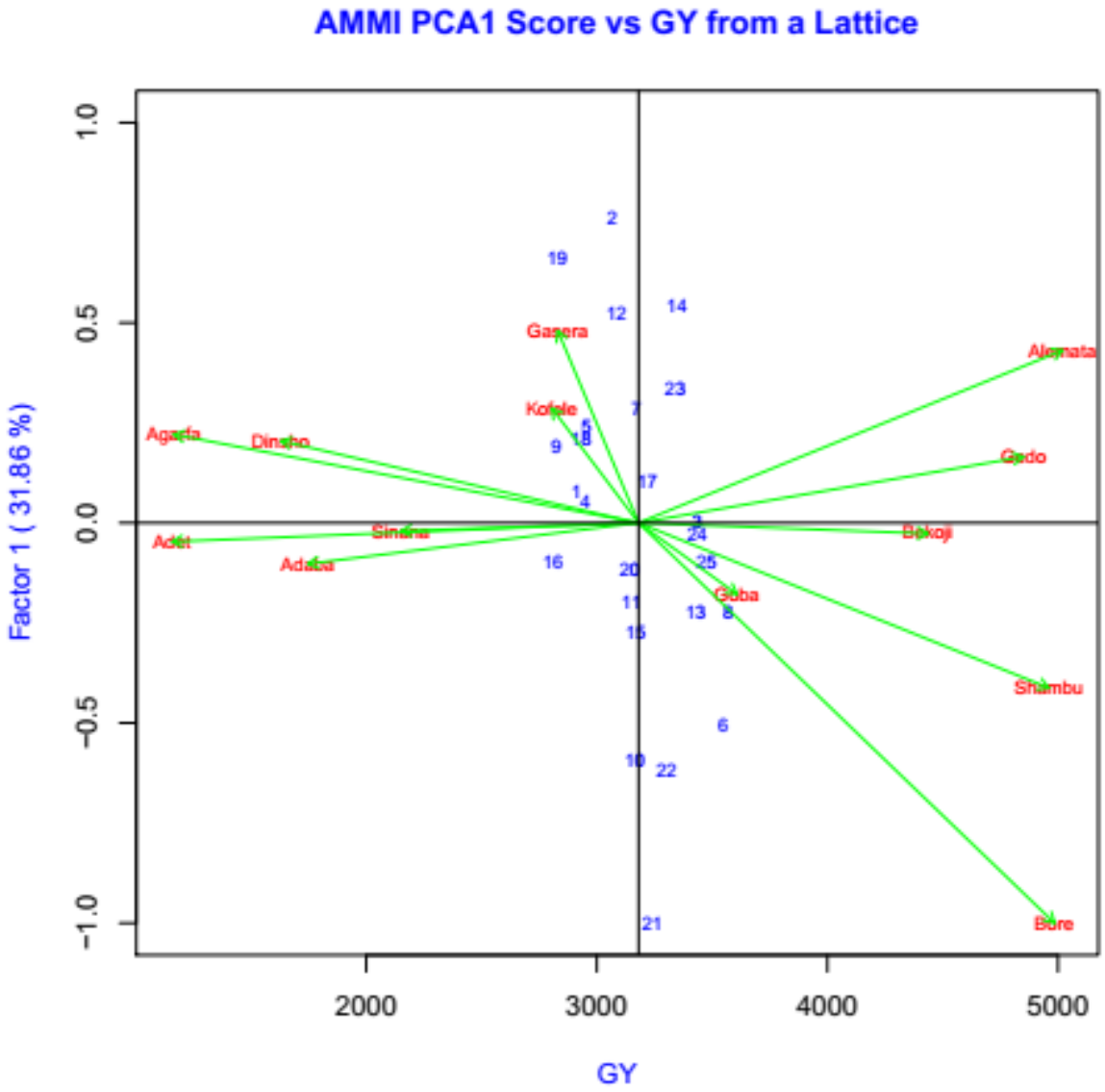


Figure 2: AMMI of grain yield in PC1

The GGE biplot (Genotype Main Effect plus Genotype x Environment Interaction) also known as the Site regression analysis (SREG), also called GGE, is a linear-bilinear model that removes the effect of location and expresses the answer only as a function of the effect of genotypes and the genotype by environment interaction (GEI). This model is recommended when the environments are the main source of variation in relation to the contributions of the genotypes and the GEI with respect to the total variability. In addition, as a difference with AMMI model, this technique allows the detection of GEI in terms of the crossover effect resulting from great changes in the ranking of the genotypes across the environments.

The SREG/GGE biplot method depicts genotype performance in an environment and when the genotype vector with an environment makes an acute angle, the genotype will have yield greater than the grand mean whereas in case of obtuse angle with the environment, the genotype yield would be less than the mean. This approach would help identify a stable genotype performance and hence a genotype which gives yield greater than the overall mean in almost all environments will be identified. Hence, Genotype 8 has yield greater than the

mean in almost all environments except in Alemata since the angle between the genotype 8 vector and each environments vector is ≤ 90 (Figure 3). This approach identifies the best genotype that is stable in yield performance across all environments and hence genotype 8 is the most stable and high yielding genotypes in almost all environments except at Alemata.

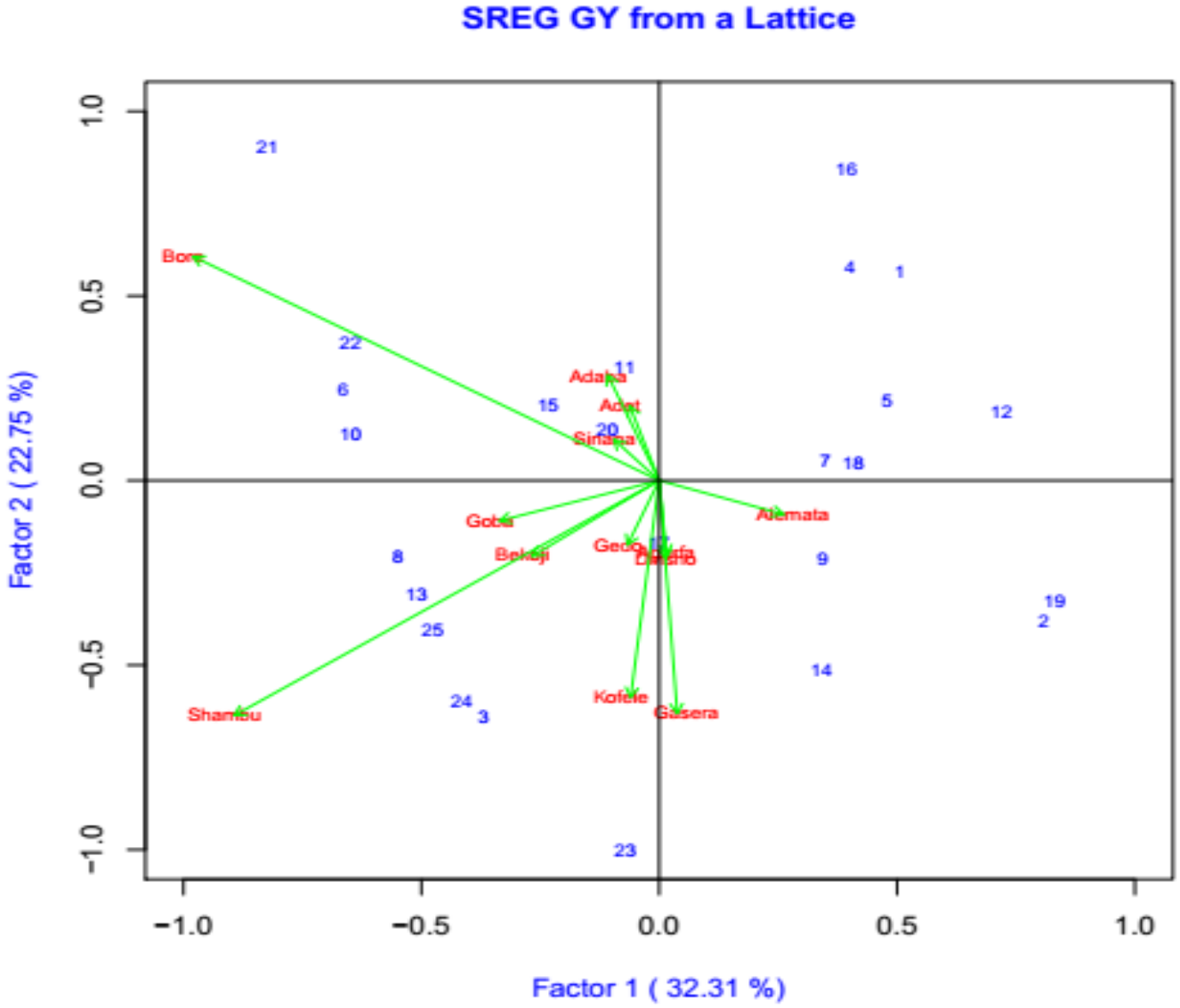


Figure 3. SREG or GGE Biplot of Grain yield

The SREG/GGE biplot technique also allows the determination of mega-environments, which means parts of the cultivation area of a species that show homogeneous environmental conditions, where the performance of certain genotypes is similar through the years. In each mega-environment, the effects of the GEI are limited or not significant. This method identified four mega environments (Figure 4) with the first category comprising of only Alemata while the second consisting of Adaba, Adet, Sinana and Bore. The third mega-environment contains only Goba and Bekoji while the fourth cluster includes Gedo, Dinsho, Kofele, Gasera and Agarfa.

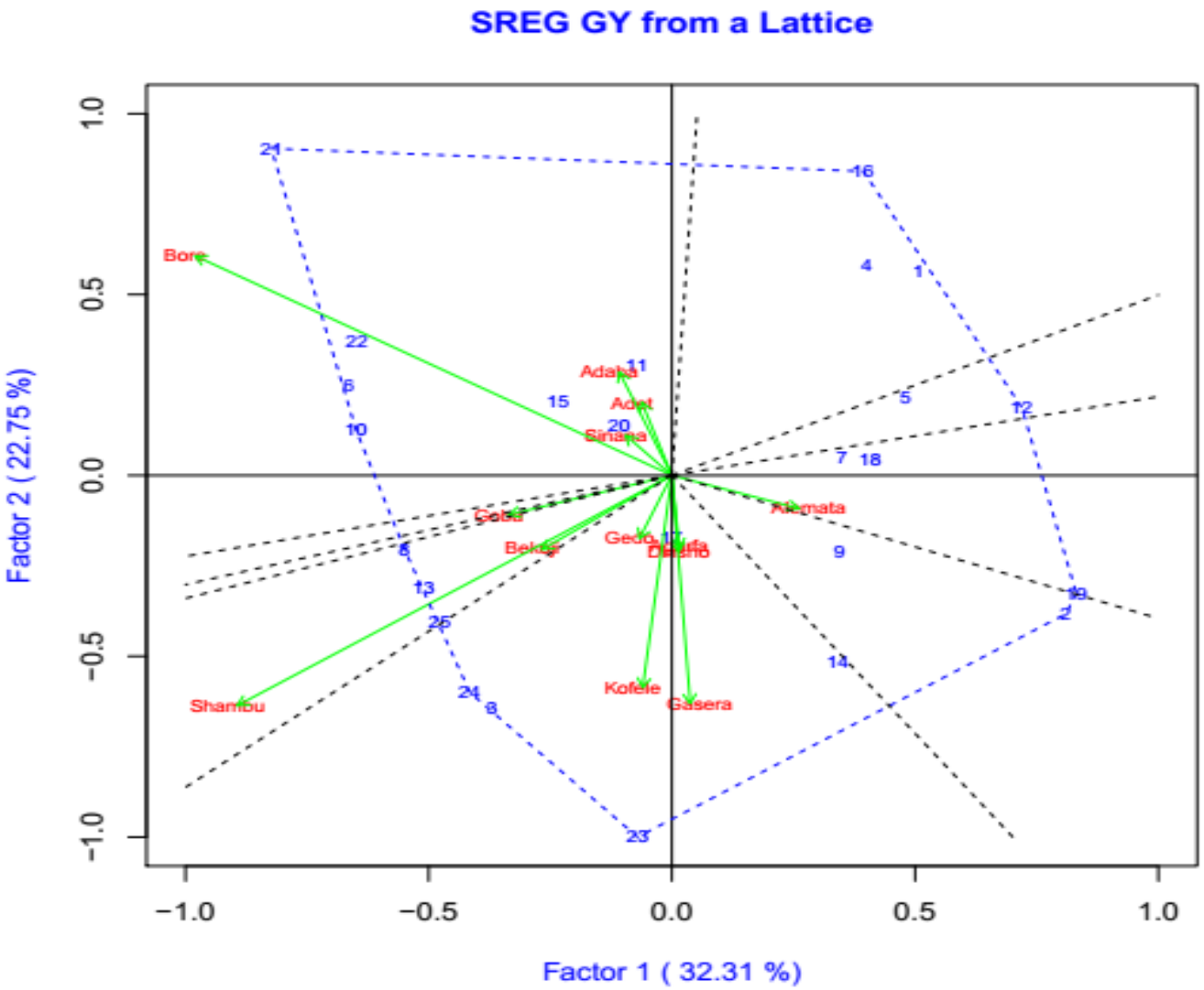


Figure 4. SREG/GGE Biplot for grain yield

The genotype discriminating power view of locations helps identify genotypes performing best in specific environments and hence locations with the longest vector form the biplot origin depicts the most discriminating environments. This approach helps to identify best performing genotypes. Shambu and Bore are the environments with longest vector from the biplot origin and hence declared the most genotype Discriminating environments (Figure 5). Alemata, Gedo and Bekoji are also the ideal environments with the genotype discriminating power. Genotypes 8 and 6 are those with the biggest average yield across all environments.

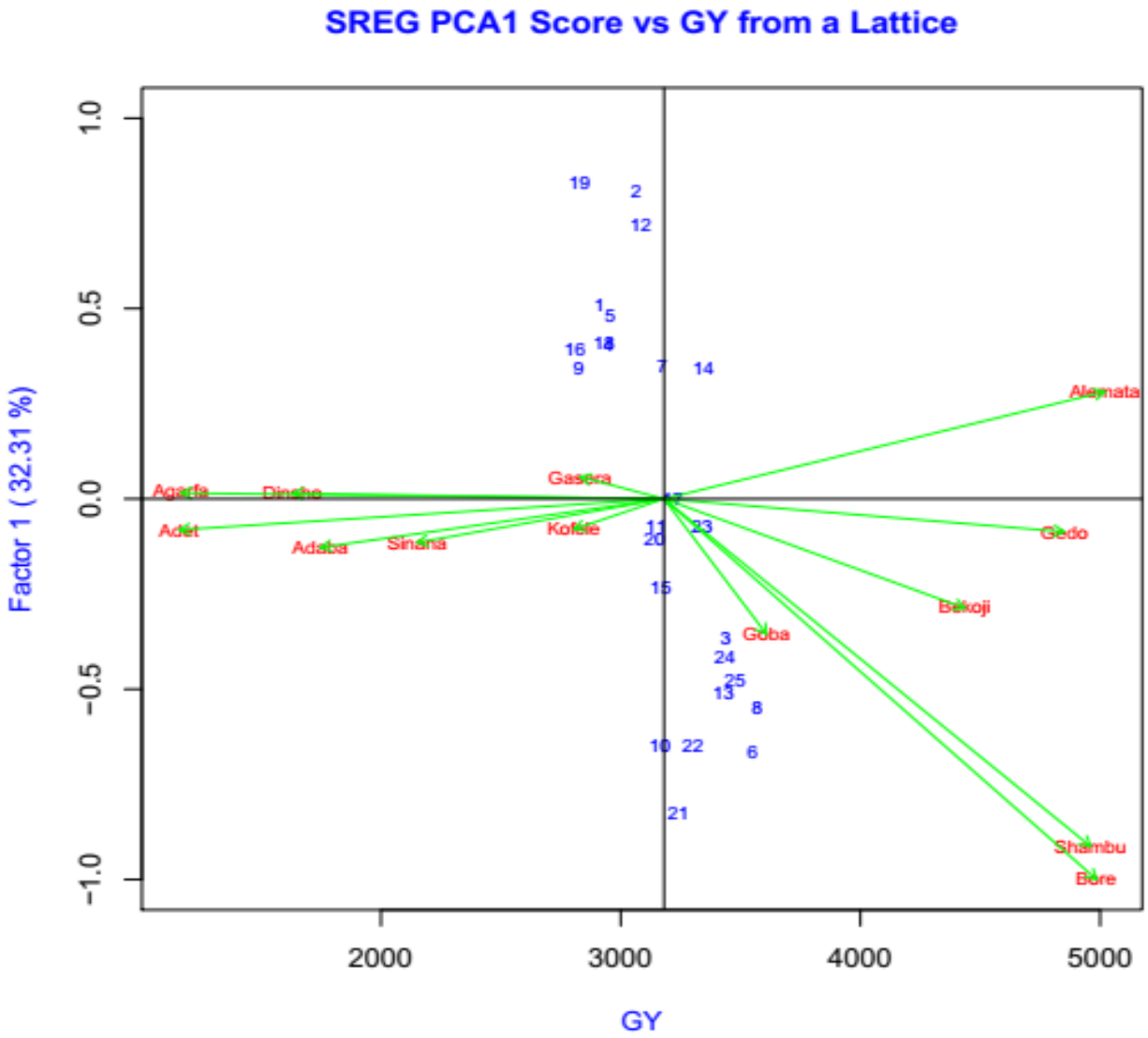


Figure 5. SREG/GGE biplot of grain yield in PCA1

The stability analysis indicates that genotypes with the smallest values of CV (%), Shukla's variance (σ^2), Perkins and Jinks (Dj), Mean square deviation (S^2d), Wricke's ecovalence (Wi), Superiority measure (Pi), Average Absolute Rank Difference of genotype in an environment (Si1) and Variance ranges of environments (Si2) are stable genotypes (Table 4). Genotypes with stability parameters of Perkins and Jinks (Bi) and Regression coefficient of Eberhart and Russel (bi) with values close to 1 are stable. On the other hand, genotypes with high R^2 (coefficient of determination) are considered stable. Based on these criteria, genotypes 8 and 6 are declared stable and with higher mean yield (Table 4).

Table 4. Stability parameters

GEN	*	*	Francis	Eberhart & Russell *		*	Shuckla	Perkins & Jinks *		Wricke's Ecovalence	Superiority Measure	Non parametric Nassar & Huehn *	
	Mean	Sd	CV (%)	bi	S^2di	R^2	ri^2	Bi	DJi	Wi	Pi	Si(1)	Si2
1	2912.244	1188.74	40.8187	0.7069	-705631	0.8334	458754.2	-0.2931	256780	5254181	1648613	1.09	56.67
10	3164.397	1832.418	57.9073	1.1283	-572612	0.8936	413396.1	0.1283	389798.8	4753428	931157	1.13	51.75
11	3149.987	1646.663	52.2752	1.0254	-707599	0.9139	238369.1	0.0254	254811.3	2821129	1044044	1.1	38.58
12	3085.564	1476.058	47.8375	0.8665	-516194	0.8123	473060.6	-0.1335	446217.1	5412124	1305893	1.18	39
13	3429.09	1887.634	55.0477	1.2076	-824960	0.9646	230232.8	0.2076	137450.3	2731306	579050	0.76	38
14	3348.039	1785.163	53.3197	1.0858	-517315	0.872	445191.4	0.0858	445095.3	5104449	940806	1.09	53
15	3168.013	1666.94	52.6178	1.0338	-678895	0.9065	268245.9	0.0338	283515.4	3150970	1015603	0.97	50.17
16	2809.782	1393.828	49.6063	0.8242	-589472	0.824	433616	-0.1758	372939.2	4976656	1693476	0.85	43.42
17	3219.744	1780.713	55.306	1.1195	-725533	0.9315	255440.2	0.1195	236877.9	3009595	916325	1.37	42.83
18	2931.821	1558.148	53.1461	0.9732	-748838	0.9194	197474.5	-0.0268	213572.5	2369653	1304411	1.04	32.92
19	2829.885	1549.682	54.7613	0.8958	-405697	0.7875	565349.7	-0.1042	556714	6430996	1803442	1.29	49.25
2	3066.308	1378.326	44.9507	0.7454	-318569	0.6893	790360.2	-0.2546	643841.4	8915111	1507088	1.59	86.42
20	3143.231	1865.34	59.3447	1.1734	-706693	0.9326	314659.4	0.1734	255717.4	3663374	961990	1.82	58.75
21	3242	1836.67	56.6524	1.0135	76619.76	0.7177	1018565	0.0135	1039031	11434496	1085967	1.72	99.58
22	3302.282	1919.955	58.1402	1.1939	-606013	0.9114	434276.9	0.1939	356398.1	4983952	827070	1.01	42.58
23	3341.128	1657.455	49.6076	0.9449	-261191	0.766	689281.1	-0.0551	701220	7799198	968011	1.37	69.17
24	3435.795	1741.806	50.6959	1.0731	-613362	0.8945	344302.1	0.0731	349049.3	3990630	728371	1.13	33.5
25	3477.846	1644.977	47.2987	1.011	-638463	0.8903	305916.5	0.011	323947.7	3566853	633527	0.94	36
3	3438.269	1616.252	47.0077	0.985	-607174	0.8753	337358.5	-0.015	355237.1	3913973	714329	1.41	45.1
4	2951.115	1587.087	53.7792	0.9684	-625753	0.8775	320826.9	-0.0316	336657.6	3731464	1430367	1.37	51.67
5	2956.321	1528.68	51.7089	0.9289	-631400	0.8702	325606.9	-0.0711	331011.2	3784235	1470169	1.4	52
6	**3550.205**	**1719.514**	**48.4342**	**1.0698**	**-679513**	**0.9123**	**277193.2**	**0.0698**	**282898.2**	**3249748**	**572757**	**1.13**	**50.5**
7	3173.487	1591.199	50.1404	0.9817	-678081	0.8971	266990.8	-0.0183	284329.8	3137113	1113007	1	48.94
8	**3569.705**	**1816.781**	**50.8944**	**1.1541**	**-786068**	**0.951**	**219354.2**	**0.1541**	**176343**	**2611205**	**446819**	**1.14**	**26.58**
9	2824.526	1442.61	51.0744	0.8898	-727714	0.8966	247789.4	-0.1102	234696.8	2925130	1570525	1.1	32.75

The analysis of Coefficient of Variation (CV) plotted on grain yield helped to classify genotypes as stable and high performing (Figure 6). The genotypes at the right corner are considered stable and are good performing. The most stable and high yielding environments found at the right corner are coloured in red. Genotypes coloured in red are high performing in yield and stable. Hence, genotypes 3, 6, 8, 23, 24 and 25 are high yielding with lower CV and hence stable. Among these, genotypes 6 and 8 are the most high yielding and stable genotypes.

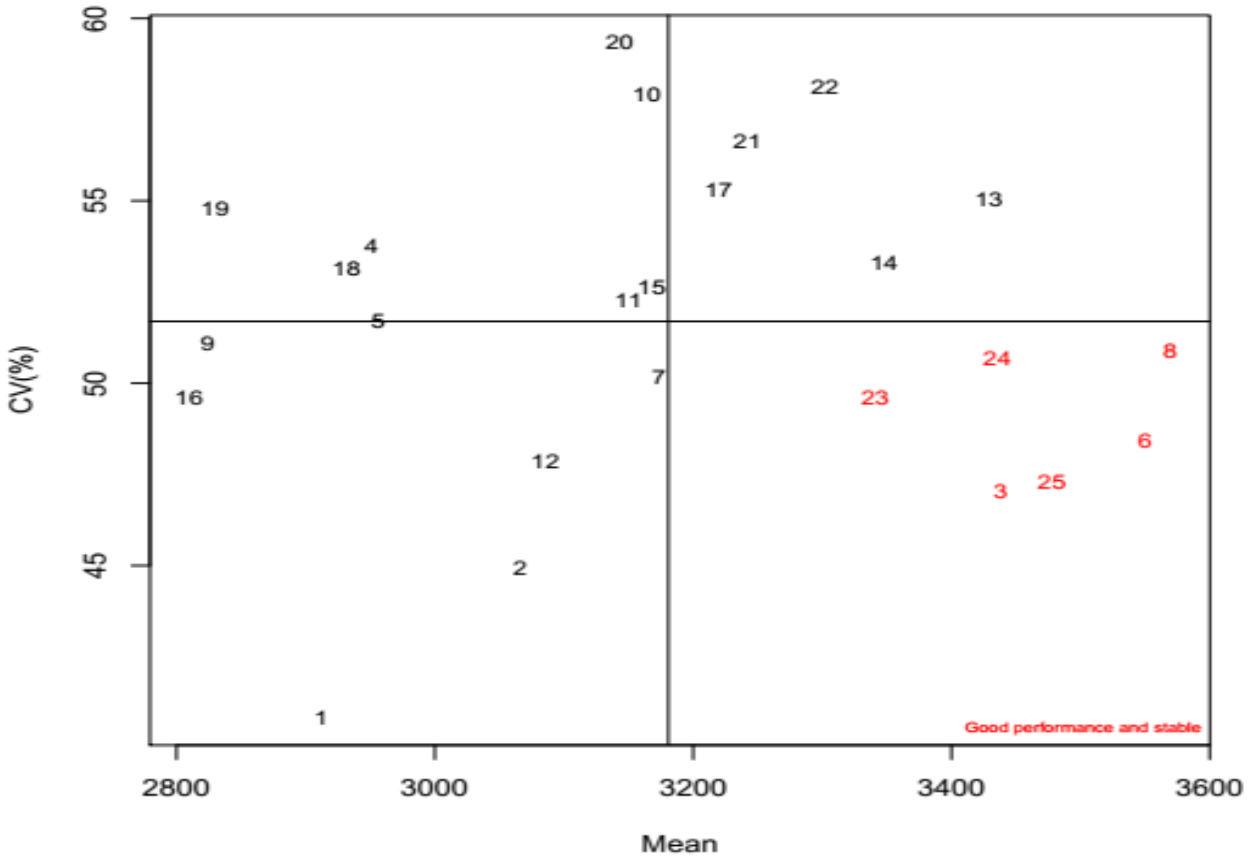


Figure 6: CV (%) of genotypes plotted against the mean

Conclusion

Genotype by environment interaction influences the selection of genotypes in multi-environment yield trails. This scenario will challenge the selection of superior genotypes that perform across all environments and need to be assessed. In case the Genotype by environment interaction is significant, appropriate statistical models need to be selected to classify mega environments and hence select genotypes performing best in the environments. Additive Main Effect and Multiplicative Interaction (AMMI) and Site Regression (SREG) or Genotype and Genotype by Environment Interaction (GGE) models have been used by breeding programs to evaluate the interaction effect on genotype selection in multi-environment yield trials. Different researchers have reviewed the efficiency of these models in evaluating the performance of the genotypes where most of the studies identified the complementarity of the two models for variety evaluation but some of them preferred the GGE model to better explain the interaction and help to efficiently select best performing genotypes than the AMMI model. In this study, the two models have been complementary in most cases to similarly evaluate the best performing genotypes with slight difference in some

cases. Since the main source of variation in this study is the environment and the contribution of genotype and the GEI to the total source of experimental variation is low, the use of GGE model is preferred to the AMMI model. The GGE model efficiently identifies best performing genotypes and classify mega environments and also explains which-won-where as well as the discriminative and representative view of the biplot. Different stability parameters were also used to identify stable genotypes. The genotype to be selected needs to be high performing in yield and stable across all environments for national programs to be effectively execute the wide adaptability approach of varietal release. Using the statistical models and stability parameters mentioned, the current study have identified Shambu and Bore as highly discriminative environments where we can easily identify genotypes that perform best while genotypes 6 and 8 were identified as high performing and stable across all environments and hence selected.

References

Annicchiarico, P. and M. Perenzin, 1994. Adaptation patterns and definition of macro-environments for selection and recommendation of common wheat genotypes in Italy. Plant Breeding. 113: 197-205.

Berhanu Bekele, Fekadu Alemayehu and Berhane Lakew. 2005. Food barley in Ethiopia. Pp 53-82. In: Grando, Stefania and Helena Gomez Macpherson (eds). 2005. Food Barley: Importance, uses and local knowledge. Proceedings of the international workshop on food barley improvement, 14-17. January 2002, Hammamet, Tunisia. ICARDA

Crossa, J. 1990. Statistical Analysis of Multi-location Trials. Advances in Agronomy, 44, 55-85.

Ding M, Tier B, Yan W. 2007. Application of GGE biplot analysis to evaluate Genotype (G), Environment (E) and G × E interaction on P. radiata: a case study. Paper presented to Australasian Forest Genetics Conference Breeding for Wood Quality, 1114 April 2007, Hobart, Tasmania, Australia.

Ding, M., Tier, B., and Yan, W. 2007. Application of GGE biplot analysis to evaluate genotype. Pages 11–14, Hobart, Tasmania, Australia.

Dixon, A.G.O. and E.N. Nukenine, 1997. Statistical analysis of cassava yield trials with the additive main effects and multiplicative interaction (AMMI) model. Afr. J. Root Tuber Crops, 3: 46-50.

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

Gauch, H.G. 1992. Statistical Analysis of Regional Yield Trials:AMMI Analysis of Factorial. Designs Elsevier, Netherlands,Amsterdam 256 pp.

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

Gauch, H.G. and Zobel R.W. 1988. Predictive and postdictive success of statistical analysis of yield trials. Theoretical and Applied Genetics 76: 1-10.

Gruneberg, W.J., K. Manrique, Z. Dapeng, and M. Hermann. 2005. Genotype environment interactions for a diverse set of sweet potato clones evaluated across varying eco-geographic conditions in Peru. Crop Sci. 45:2160–2171.

Kandus M., Almorza, D. BoggioRonceros, R., Salerno, J.C. 2010. Statistical models for evaluating the genotype-environment interaction in maize (Zea mays L.). International Journal of Experimental Botany, 79:39-46.

Kroonenberg, P. M. 1995. Introduction to biplots for G × E tables. *Department of Mathematics, Research Report*, 51.

Mitrovic B, Stanisavljevi D, Treski S, Stojakovic M, IvanovicM, Bekavac G, Rajkovic M (2012). Evaluation of experimental maize hybrids tested in multi-location trials using AMMI and GGE biplot analyses. Turkish Journal of Field Crops, 17: 35-40

Rad NM, Kadir MA, Rafii MY,Jaafar HZ, Naghavi MR, Ahmadi F. 2013. Genotype x 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: 956-961.

Samonte, SOP, Wilson LT, McClung AM, Medley JC. 2005. Targeting cultivars onto rice growing environments using AMMI and SREG GGE biplot analyses. Crop Science, 45(6): 2414-2424

Stojaković M, Ivanović M, Jocković Đ, Bekavac G, Purar B, Nastasić A, Stanisavljević D, Mitrović B, Treskić S, Laišić R. 2010. NS maize hybrids in production regions of Serbia. Field and Vegetable Crops Research, 47: 93-02.

Yan W, Kang MS, Ma B, Woods S Cornelius PL. 2007. GGE Biplot vs. AMMI Analysis of Genotype-by-Environment Data. Crop Science, 47: 641–653

Yan W. and Tinker, N. 2006. Biplot analysis of multi-location trail data: principles and applications. Canandian Journal of Plant Science 86:623-645.

Yan, W., and M.S. Kang, 2003. GGE Biplot analysis. A graphical toll for breeders, geneticists, and agronomists. CRC Press.

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

Zobel, R.W., M.J. Wright and H.G. Gauch, 1988. Statistical analysis of yield data. Agronomy Journal, 80: 388-393.

Genotype by Environment Interaction and Stability Analysis of Food Barley Genotypes in the Low Moisture Stressed Areas of Ethiopia

Girma Fana, Hiwot Sebsibe, Kassahun Tadese and Endashaw Tadese
Oromia Agricultural Research Institute, Sinana Agricultural Research Center, P.O.Box 208, Bale-Robe, Ethiopia

Abstract

*Twenty two malt barley genotypes obtained from international nurseries of the International Center for Agricultural Research in the Dry Areas (ICARDA) were evaluated across location (Robe, Adet, Sinana, Gasara, Selka, Kofele, Goba, Dodola, Gedo, Bekoji, Alemata, Shambu and Bore) for two years (2016-2018) with the objectives to identify high yielding and disease tolerant genotypes. The Analysis of Variance over locations and years showed that there is significant variation among test environments contributing 70% to the total variation compared to the 2% contribution by the genotypic effect. The Genotype by Environment Interaction had 10% share in the total variance. It was also found out that Dodola, Goba, Gedo, Bekoji, Alemata, Shambu and Bore are the ideal environments for malt barely production since they produced grain yield higher than the grand mean of 2775 kg/ha. Genotypes 6 (CHAMICOO/M111), 7(FNCI/3/LEGACY//PENCO/CHEVRON-BAR) and 17 (LIGNEE27/GERBEL/3/ BOY-B*2/SURB//C12225.2D/4/GLORIA-BAR/COM) were also identified as higher yielders across the environments. AMMI and GGE biplot methods the major parameters employed to classify the genotypes and environments main effect and the interaction. Different stability parameters were also employed to identify stable genotypes for wide adaptability. Bore, Shambu and Alemata were the most genotype discriminating environments and Bore has both the discriminative and most representativeness for malt barley variety evaluation. GGE biplot better explains the effect of the genotype by environment interaction and also is used for classifying mega environments. All of the stability parameters are in agreement with AMMI and GGE biplot to identify genotypes 6, 7and 17 as high yielding and stable genotypes whereas to identify Bore, Shambu and Alemata as high yielding environments with Bore as both the most representative and discriminative environment for malt barley variety evaluation which is a crucial decision tool for the national breeding program.*

Key words: AMMI, GGE biplot, low moisture, mega-environments, stability,

Introduction

Barley (Hordeum vulgare L.) is one of the most important crops in the world ranking fourth after Rice, Maize and wheat in terms of area coverage and tonnage. It is also one of the strategic crops for food security in Ethiopia ranking fifth after Tef, maize, wheat and sorghum (CSA, 2016). The favorable environmental condition in Ethiopia for optimum yield and quality is found in the cool highlands with elevations ranging from 2000-3000 masl. However, barley is also one of the few elastic crops which can grow from 1500 masl to 4000 maslwith no significant effect on its phenology and yield. It is more tolerant to drought and other stresses than other cereals and hence grown by farmers in the dry areas.

Barley production and consumption has a longstanding tradition in Ethiopia where the country is considered as the center of diversity or secondary origin of the crop with more than 15,000 accessions conserved in the gene bank.

High and stable yield performance under variable farming conditions is required for crop cultivars to become commercially successful (Karimizadeh et al, 2012). This presents the

challenge for breeders to develop such cultivars and for extension agronomists to effectively identify and recommend to farmers. Therefore, performance evaluation over a range of cropping environments, including unfavorable and/or stress ones, is required for this challenge to be met. Multi-environment trials (MET) are necessary to allow for estimating cultivar's genotypic value and it's consistency with the corresponding phenotypic value across environments. Conventionally the analysis of variance for MET data provides estimates of the genotype (G) and environment (E) main effects along with the corresponding genotype by environment interaction (GEI) effect. Increased GEI variance is associated with decreased correlation between genotypic and phenotypic cultivar values and thus ineffective in identification and selection of the desired genotypes (Comstock and Moll, 1963). According to Bernardo (2002) there are three approaches for coping with GEI. It could be ignored, reduced or exploited. When it is ignored, cultivar recommendation is based on the mean performance across all testing environments. In the other two cases, partitioning of the target population environments into homogeneous subgroups and/or stability analysis is required. Then cultivar recommendation is made separately for each sub-group (reduction) or for particular environments (exploitation). Several stability analysis methods have been proposed to address the GEI interaction and study each cultivar's performance relative to other cultivars in different environments. They are based either on joint regression or in principal components analysis (Bernardo, 2002).

The AMMI model has been suggested to be the efficient method to capture large GEI sum of squares and to classify the main and interaction effects. The AMMI model is convenient for graphical display although it lacks the inner product property which is the true biplot property (Zobel et al. 1988). It also lacks the ability to show the discriminative and representative view of a biplot which helps to clearly classify test environments. This led to the development of the Genotype plus Genotype by environment (G+GE) interaction (Gabriel, 1971; Yan et al., 2000) which accommodates the two sources of variation (Genotype main effect and Genotype by Environment interaction). The GGE biplot hence helps the analysis of mega-environments and recommending specific varieties for these mega-environments. The GGE biplot analysis is based on environment-centered principal component analysis (PCA), whereas AMMI analysis is established on double centered PCA (Kroonenberg, 1995). However, according to Yan and Tinker (2006), AMMI could be misleading if used for the purpose of "which-won-where" (i.e., identification of mega-environments as well as their wining genotypes). Several multi-environment trial studies have evaluated the similarity and difference between AMMI and GGE biplot methods and found different results. Few researchers suggested that AMMI is the best model in variety evaluation while others have recommended GGE biplot for variety evaluation across test environments. Still others have indicated the similarity and complementarity of the two models (Kandus et al. 2010; Stojaković et al., 2010; Samonte et al, 2005; Yan et al., 2007). Strong G × E interaction for quantitative traits such as grain yield can severely limit gain in selecting superior genotypes for improved cultivar development. For cultivars being selected for a large group of environments, evaluating stability of performance and range of adaptation has become increasingly important. Several stability parameters have been proposed to characterize yield stability when genotypes are tested across multiple environments, with each parameter giving different results. The current study was therefore designed with the objective to select high yielding and stable genotypes in the low moisture areas of Ethiopia.

Materials and Methods

The Barely National variety trial was conducted for two years (2016-2018) at different locations in the low moisture stressed areas of Ethiopia. The locations included Adet, Adola, Arjo, Asasa, Dhera, Dodola, Ginir, Goro, Mehoni and Sinana. The tested genotypes were obtained from the International Nurseries of ICARDA which included 22 genotypes along with three standard checks Gobe, Bentu and Robera. The design used was alpha lattice with three replications. The trial was laid out in alpha lattice design with three replications. All the recommended management practices at the respective test locations including weed management, fertilizer rate and seeding rates were employed. Statistical analysis employed analysis of variance (ANOVA) and Stability parameters were also analyzed to identify the stable genotypes using R statistical software and means were separated using Fisher's least significant difference (LSD) at probability level of 0.05. The homogeneity of error variance was tested using Bartlett's test to test the homogeneity of error variance between test locations.

Results and Discussions

Analysis of Variance (ANOVA)

Analysis of Variance (ANOVA) was performed for combined over locations and years effect on grain yield. The result showed that, much of the variation was due to environment and the genotypic difference is minimal. The total sum of squares were 44% explained by the location, 12% by Genotype: Location interaction, 11% by Location: year interaction and 8% by the Genotype main effect (Table 2). The main effects were all significant except the block effect and all of the interaction components were also significant. The error variance also contributed a significant amount (17%) to the total source of variation.

Table 1. Genotype name along with their pedigrees used in the study

Genotype code	Pedigree of the genotypes
1	244906
2	244919
3	SHEMIAL NO.3/MSEL
4	VMORALES
5	LIMON/BICHY2000/4/ALELI/3/ARUPO/K8755//MORA/5/MSEL
6	CHAMICOO/M111
7	FNCI/3/LEGACY//PENCO/CHEVRON-BAR
8	P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1/6/LEGACY//PENCO/CHEVRON-BAR
9	P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1/6/LEGACY//PENCO/CHEVRON-BAR
10	CABUYA/M111/7/TRADITION/6/P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA
11	SHYRI/GRIT//FN C1
12	P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1/6/CHNGA DU 89//PENCO/CHEVRON-BAR/3/CHAMICO/TOCTE/CONGONA-91
13	CANELA/C14196
14	LIGNEE527/GARBEL/3/BOY-B*2/SURB//C12225.2D/4/GLORIA-BAR/COM
15	SVANHALS-BAR/MSEL//AZAF/GOB24DH/3/DEFERA/DESCONNCIDA-BAR
16	LIGNEE27/GERBEL/3/BOY-B*2/SURB//C12225.2D/4/GLORIA-BAR/COM

17	LIGNEE27/GERBEL/3/BOY-B*2/SURB//C12225.2D/4/GLORIA-BAR/COM
18	LIGNEE27/GERBEL/3/BOY-B*2/SURB//C12225.2D/4/GLORIA-BAR/COM
19	FRES/M1004
20	FRES/LEGACY
21	SEN/5/LEGACY/4/TOCTE//GOB/HUMAI10/3/ATAH92/ALELI
22	PUEBLA/CORDO//TOCTE/3/FALCON-BAR
23	Gobe (Check)
24	Bentu (Check)
25	Robera (Check)

Table 2. Analysis of Variance (ANOVA) for grain yield combined locations and years

	Df	Sum Square	Mean Square	F value	Pr (>F)	% explained	TSS
Gen	24	209800000	8739642	16.04	< 2e-16***	8.0	
Loc	10	1165000000	116473201	213.72	< 2e-16***	44.2	
YR	1	25350000	25352232	46.5	1.77e-11***	1.0	
Blk	1	49280	49284	0.1	0.7637	0.002	
Gen:Loc	240	317700000	1323705	2.4	< 2e-16***	12.0	
Gen:YR	24	35200000	1466736	2.7	2.39e-05***	1.3	
Loc:YR	5	299700000	59945096	110.0	< 2e-16***	11.4	
Blk:Rep	2	5991000	2995291	5.5	0.00426**	0.2	
Gen:Loc:YR	120	94130000	784389	1.4	0.00267**	3.6	
Loc:YR:Rep	34	41160000	1210554	2.2	9.59e-05***	1.6	
Residuals	813	443100000	544972	-	-	16.8	
Total	1274	2637180280	-	-	-	100	

Gen= Genotype, Loc= Location, YR= year, Blk= Block, Rep= Replication, Df= Degrees of freedom, TSS= Total Sum of Squares

The overall mean performance combined over locations and years showed significant difference among the genotypes but none of the genotypes produced higher yield than the best standard check (Gobe). However, the yield of genotypes 8 and 9 are nearly equal with Gobe (Table 3). Locations such as Dodola, Mehoni, Goro, Asasa and Jimma are ideal environments for successful food barley production with yield greater than the grand mean of 2728 kg/ha whereas environments such as Adola, Adet, Arjo, Sinana, Ginir and Dhera are low yielding environments with relatively optimum yield in that increasing order. Ginir and Dhera produced grain yield only lower by 528 and 176 kg/ha than the grand mean and hence may be considered for optimum barley production.

Table 3. Least significant mean separation of grain yield across locations

Gen	Adola	Adet	Arjo	Sinana	Ginir	Dhera	Dodola	Mehoni	Goro	Asasa	Jimma	**Mean**
1	925	1809	1427	1497	1589	1347	2364	2095	2108	1518	2500	**1741**
2	775	1213	1133	1220	1235	929	1733	2781	2322	2593	3000	**1731**
3	758	796	2000	1599	1146	2896	3083	2372	2662	4842	5667	**2574**
4	675	1649	1098	1890	2630	2941	4298	3396	3559	4669	4500	**3008**
5	2642	453	2113	2287	2209	2835	2782	2864	3452	3349	5667	**2763**
6	2140	1973	1207	2118	2712	2984	2849	3468	3681	4273	5000	**2989**
7	617	1305	803	1706	1940	2666	2561	3802	3906	3880	5333	**2651**
8	**775**	**1472**	**2231**	**2274**	**3214**	**3822**	**3429**	**3769**	**4545**	**5172**	**5500**	**3405**
9	**992**	**1236**	**2272**	**2244**	**3424**	**3332**	**4895**	**3711**	**3981**	**4438**	**4333**	**3347**
10	628	834	1785	2074	2620	2665	2931	2789	3401	3687	5833	**2707**
11	1100	595	1452	2557	2108	2215	3372	3148	3856	4024	5167	**2766**
12	1017	2143	2266	1499	2026	2192	2694	4182	2238	3577	5667	**2687**
13	**1375**	**1463**	**2947**	**1988**	**2234**	**3140**	**2970**	**3474**	**4246**	**5202**	**5500**	**3150**
14	1083	1063	1558	1961	1632	1891	3344	3308	3241	3990	4500	**2570**
15	1617	868	574	1848	1130	2226	2595	3365	2639	3834	5000	**2394**
16	1142	1058	1169	2180	1195	2397	2529	3843	4094	4022	3500	**2547**
17	1275	1142	1062	1557	1474	2346	2957	2979	2973	4310	4333	**2472**
18	892	1390	1229	1774	1311	2414	3453	4038	2951	3769	4333	**2607**
19	1217	959	2073	2349	2861	3066	3184	2866	3830	3682	5000	**2888**
20	1108	1157	2372	2435	2336	2707	2644	2842	3482	3272	3667	**2603**
21	438	1963	1381	1866	1812	2366	2802	2733	3779	3853	4667	**2535**
22	1850	1860	2098	2772	1560	2748	3018	2541	3054	4171	4667	**2773**
23	**1425**	**951**	**3098**	**2127**	**3650**	**2994**	**3961**	**4468**	**4921**	**4568**	**4667**	**3447**
24	1067	477	1538	2098	3599	2217	2861	3645	4646	3259	4833	**2819**
25	1400	522	3066	2226	3365	2465	3461	3798	2931	3940	5000	**3025**
Mean	**1157**	**1214**	**1758**	**2006**	**2200**	**2552**	**3071**	**3291**	**3460**	**3916**	**4713**	**2728**

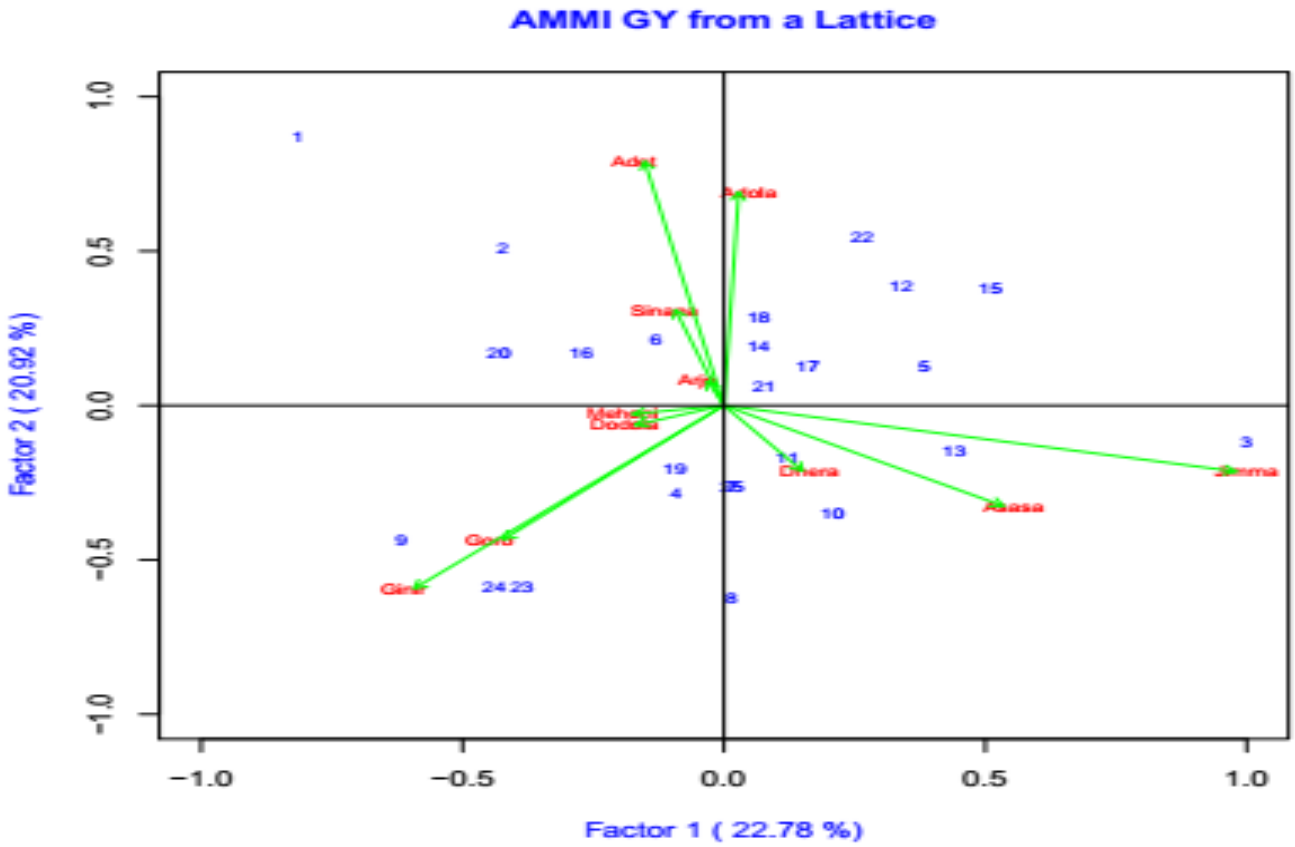
AMMI model

AMMI analysis showed significant variation among the growing environments, the genotypic effect and the interaction between the two (Table 4). The AMMI model explained that 44% of the variation was contributed by location, 8% by the genotype and 12% by the interaction. On the other hand, the residual error had less than 36% share in the total variation of the experiment. It also showed that the first three principal components were significant and explained 60% of the genotype by environment interaction.

Table 4. AMMI analysis for grain yield over locations and years

Source of variation	DF	SS	MS	% Variability	% Acc. Var.	F	P
ENV	10	1164732008	116473200.8	44	44	123.29	0.00000
GEN	24	209751419.6	8739642.48	8	52	9.25	0.00000
ENV*GEN	240	317689147.5	1323704.78	12	64	1.40	0.00028
Residuals	1000	944667173.8	944667.17	36	100	-	-
PC1	33	49506000.15	1500181.82	23	23	1.93	0.00148
PC2	31	45461603.89	1466503.35	21	44	1.89	0.00269
PC3	29	35484915.24	1223617.77	16	60	1.57	0.02884

The AMMI model usually presents the environmental and genotype scores of the first and second bilinear terms in a graph. The distance between two genotype vectors (their end points)
is indicative of the amount of interaction between the genotypes. The cosine of the angle between two genotype (or environment) vectors approximates the correlation between the genotypes (or environments) with respect to their interaction. Acute angles indicate positive correlation, whereas obtuse angles represent negative correlations. Perpendicularity of directions indicates a correlation of 0. The relative amounts of interaction for a particular genotype over environments can be obtained from orthogonal projections of the environmental vectors on the line determined by the direction of the corresponding genotype vector. Environmental vectors having the same direction as the genotype vectors have positive interactions (that is these environments favored these genotypes), whereas vectors in the opposite direction have negative interactions. The AMMI biplot shows that environments that classify genotypes in similar way are Adet, Adola, Sinana and Arjo since they have acute angles between their vectors (Figure 1). Mehoni, Dodola, Goro and Ginir also have similar genotype discriminating tendency. The third category of similar environments for genotype classification in similar way are Jimma, Asasa and Dhera. This analysis enables to discard any of the locations within a category with the same genotypes without any loss of precision to the test. This means that from the first class of locations Adet, Adola, Sinana and Arjo, one of the locations can represent the cluster with no loss of precision. Therefore, Adet may represent these locations to identify high performing genotypes. The locations Mehoni, Dodola, Goro and Ginir may also have one or more representative in variety evaluation with no precision loss. From the third cluster of locations also, either of the three locations can represent the cluster to identify high performing and stable genotypes. Therefore, based on the national program capacity and convenience, it is advisable to minimize the cost of variety evaluation with minimum selection of test environments. Locations Adet, Goro and Dhera can be representative of all of the clusters for variety evaluation with no precision loss in identifying the best performing genotypes with stable performance across locations.



Figures 1: AMMI graph (PC1 Vs PC2) for grain yield

Genotypes 8, 9, 13 and 23 have the largest average yield across the test environments and the stable genotypes found near the origin are 4, 7, 11, 14, 18 and 21 (Figure 2). Jimma is the most genotype discriminating environment followed by Asasa and Goro. Therefore, Jimma, Asasa and Goro are the ideal environments for identifying best performing genotypes for the moisture stress environments by the breeding program.

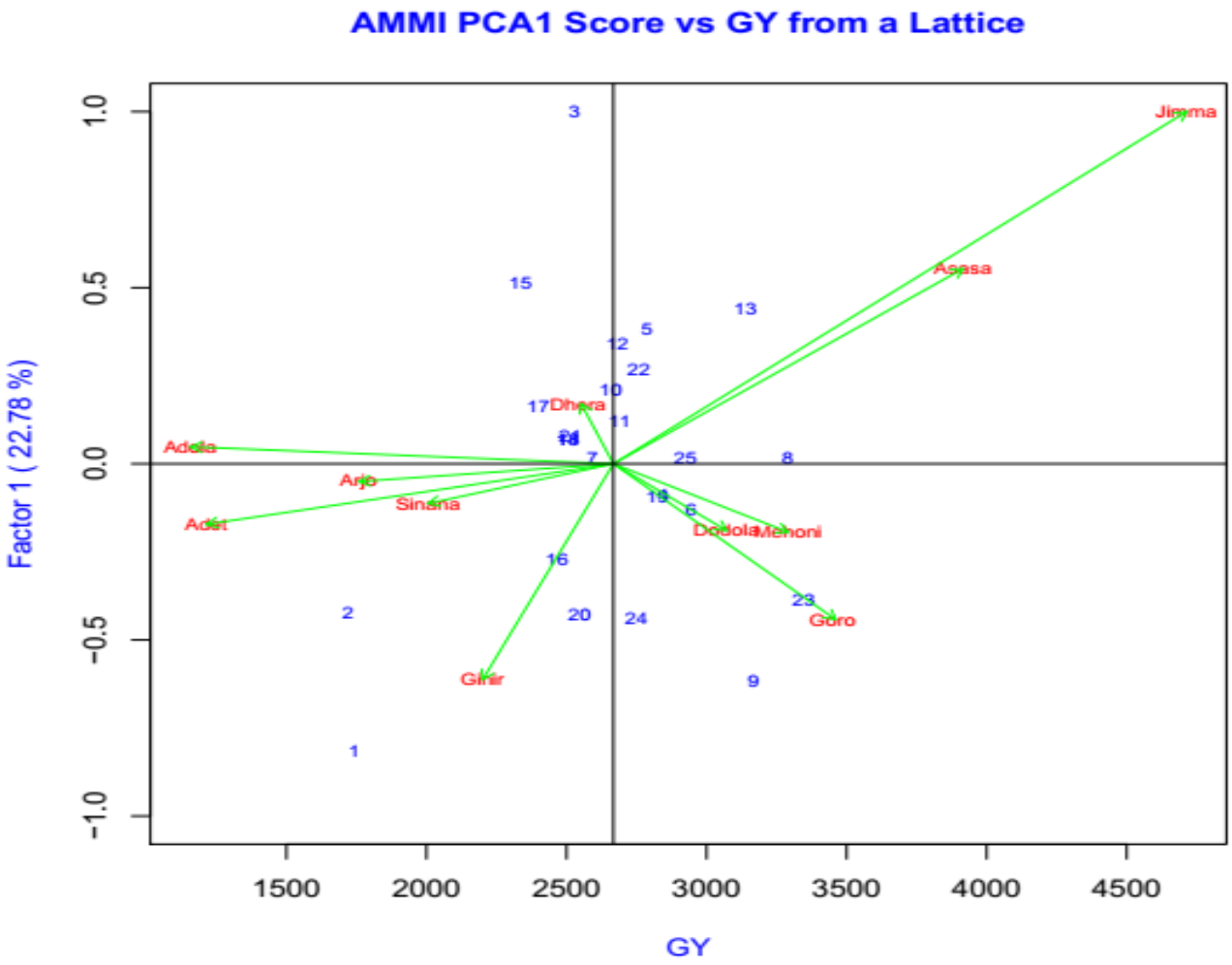


Figure 2.AMMI of grain yield in PC1

Site Regression (SREG) or GGE biplot model

Site regression analysis (GGE) allows the determination of mega-environments with similar environmental conditions. In each mega-environment, the effects of the Genotype by Environment Interaction (GEI) are limited or not significant. Hence, Genotype 8, 25, 13 and 11 have grain yield greater than the mean in almost all environments except at Adet since the angle between the genotypes vector and each environments vector is $< 90^0$ (Figure 3). The site regression model identified three major mega-environments. The first meg-environment consisted of Ginir, Goro, Dodola, Mehoni, Sinana, Arjo and Dhera; the second mega-environment contains Adola, Asasa and Jima and the third mega-environment category includes only Adet.

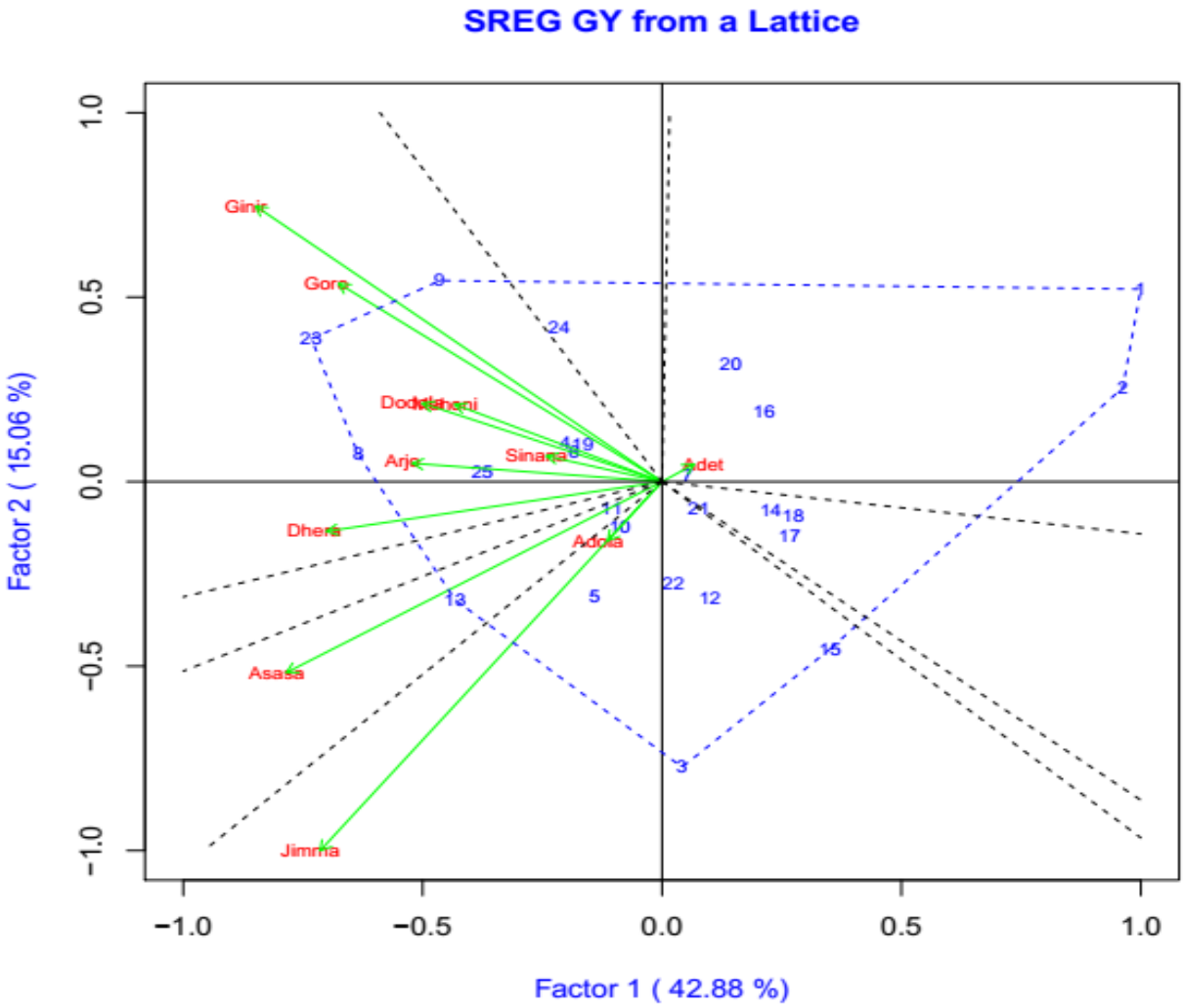


Figure 3: site regression (GGE) of grain yield

Acute angles (< 90^0) between location vectors show the similarity of genotype classification by the environments and obtuse angle (> 180^0) indicated discriminating ability of the environments in the opposite manner (Figure 4). The environment with the longest vector is with the most discriminating power against genotypes and hence Jimma, Asasa and Goro are the environments with the longest vector from the biplot origin which means they are the most genotype discriminating environments. It is also evident from the graph that genotypes 8, 9, 13 and 23 are the high yielding genotypes with highest average yield over all environments.

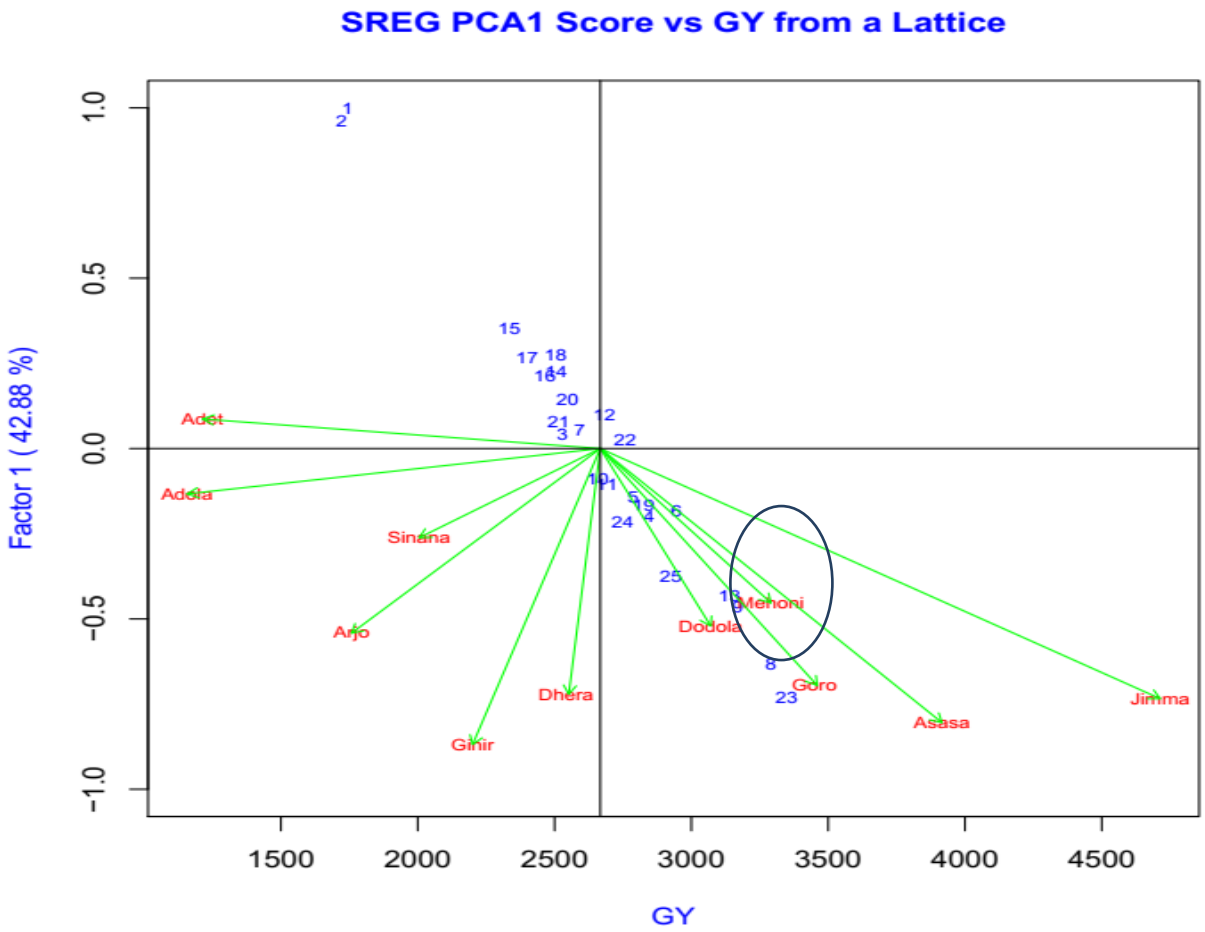


Figure 3. Discriminative and representative view of the biplot

The mean performance and stability can be viewed by plotting the stability parameters such as the CV against the mean yield. Figure 5 shows the CV plotted against the mean yield and hence genotypes with the highest mean and stability value (lower CV) are at the far right corner of the biplot. Genotypes 5, 6, 8, 9, 13, 19, 22, 23 and 25 are with lower CV and with higher mean yield. Therefore, based on evaluation by CV-yield plot, genotypes 8 and 13 are with good level of stability and mean yield compared to others.

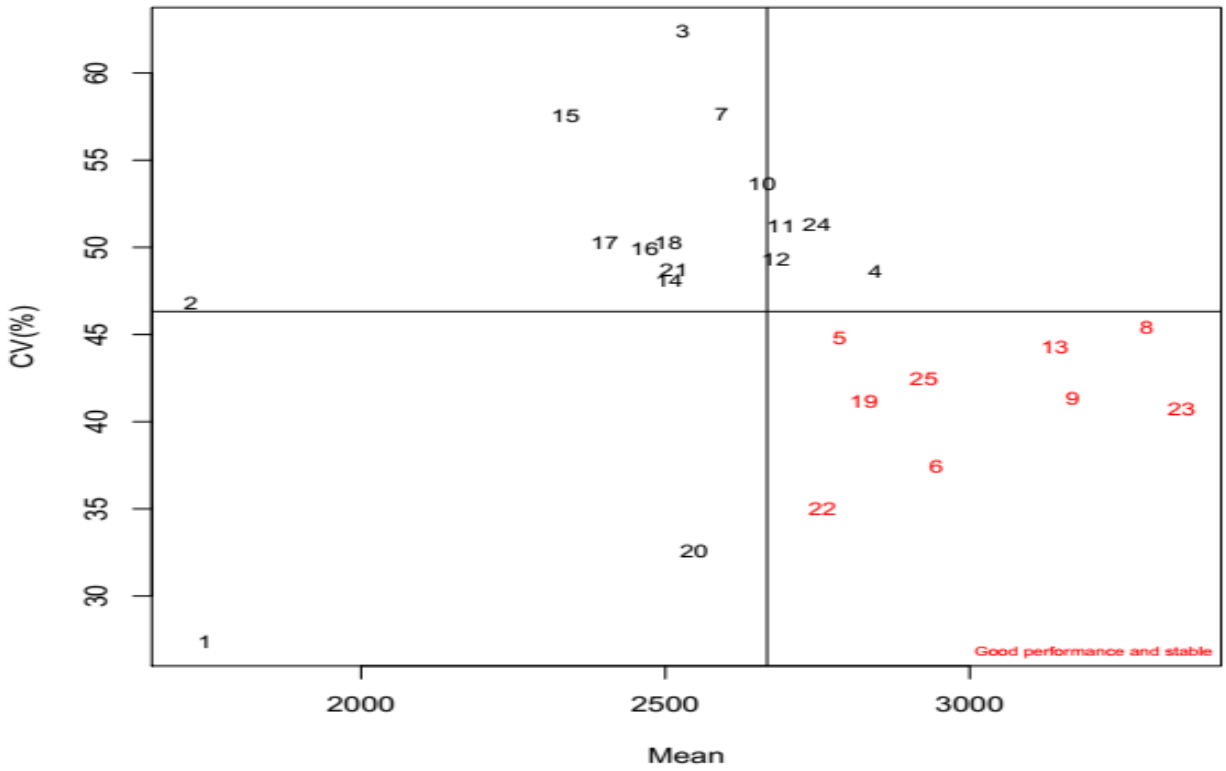


Figure 5: mean yield performance and stability view

Conclusions

The presence of significant genotype by environment Interaction (GEI) complicates the selection of stable and high yielding genotype over locations. Successful identification of appropriate genotypes that fit into stressful environment requires careful selection using appropriate statistical tools and models. There may be three decisions to cope with the GEI: it may be ignored, reduced or exploited. Combined analysis over years and locations considers as if there is no GEI and decision is made to identify high yielding and stable genotype for all locations. In this approach, Analysis of Variance (ANOVA) was employed and it identified the largest proportion of the total variance was contributed by the environment (69%) and the genotype contributed only 8% whereas the share of the GEI was 12%. ANOVA showed that locations such as Dodola, Mehoni, Goro, Asasa and Jimma are ideal low moisture stressed environments that can be used for optimum barley production while Adola, Adet Arjo and Sinana are low yielding environments. Ginir and Dhera are also environments with medium yield and hence can be used for optimum barley production. In reducing the effect of GEI, Additive Main Effect and Multiplicative Interaction (AMMI) and Genotype plus Genotype-by-Environment Interaction (GGE) biplot are the two common statistical models used. The decision to exploit the GEI requires specific recommendation of high yielding genotypes for specific locations which is very conservative view and not considered a practical decision especially for the national program. Most researchers have proposed GGE biplot method to better explain the GEI than the AMMI model and still others have witnessed that both methods complement each other in identifying high yielding and stable genotypes for wide adaptability. However for mega-environment classification, it is the argument of many researchers that GGE biplot method is the model of choice. According to GGE biplot, the first

mega-environment included locations Ginir, Goro, Dodola, Mehoni, Sinana, Arjo and Dhera whereas the second cluster contained Adola, Asasa and Jima and the third mega-environment category includes only Adet. Overall, using AMMI model identified Adet, Goro and Dhera as representative of the stress environments for variety evaluation. In the current study, AMMI, GGE biplot and other stability parameters have been used to identify stable and high yielding genotypes that are adaptable to wider environments and hence genotypes 8 and 13 are stable, high yielding and widely adaptable than other genotypes. The AMMI, GGE biplot and many stability parameters complemented each other to identify the same genotypes as high yielding and stable genotypes and selected for further breeding purpose.

References

Annicchiarico, P. and M. Perenzin, 1994. Adaptation patterns and definition of macro-environments for selection and recommendation of common wheat genotypes in Italy. Plant Breed. 113: 197-205.

Bernardo, R., 2002. Quantitative traits in plants. Stemma Press, 1938 BowsensLanne, Woodbury, MN 55125.

Crossa, J. 1990. Statistical Analysis of Multi-location Trials. Advances in Agronomy, 44, 55-85.

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

Kandus, M., Almorza, D. BoggioRonceros, R., Salerno, J.C. 2010. Statistical models for evaluating the genotype-environment interaction in maize (Zea mays L.). International Journal of Experimental Botany, 79:39-46.

Karimizadeh, R., M. Mohammadi, M.K. Shefazadeh, A.A. Mahmoodi, B. Rostami, F. Karimpour, 2012. Relationship Among and Repeatability of Ten Stability Indices for Grain Yield of Food Lentil Genotypes in Iran. Turkish Journal of Field Crops, 2012, 17(1): 51-61

Kroonenberg, P. M. 1995. Introduction to biplots for G × E tables. *Department of Mathematics, Research Report*, 51.

Samonte, SOP, Wilson LT, McClung AM, Medley JC. 2005. Targeting cultivars onto rice growing environments using AMMI and SREG GGE biplot analyses. Crop Science, 45(6): 2414-2424

Stojaković M, Ivanović M, Jocković Đ, Bekavac G, Purar B, Nastasić A, Stanisavljević D, Mitrović B, Treskić S, Laišić R. 2010. NS maize hybrids in production regions of Serbia. Field and Vegetable Crops Research, 47: 93-02.

Yan W, Kang MS, Ma B, Woods S Cornelius PL. 2007. GGE Biplot vs. AMMI Analysis of Genotype-by-Environment Data. Crop Science, 47: 641–653

Yan W. and Tinker, N. 2006. Biplot analysis of multi-location trail data: principles and applications. Can. J. Plant Sci. 86:623-645.

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

Zobel, R.W., M.J. Wright and H.G. Gauch, 1988. Statistical analysis of yield data. Agron. J., 80: 388-393.

Genotype by Environment Interaction and Stability Analysis of Malt Barley (*Hordeum vulgare* L.) Genotypes in the Highlands of Ethiopia

Girma Fana, Hiwot Sebsibe, Endashaw Tadese and Kassahun Tadese
Oromia Agricultural Research Institute, Sinana Agricultural Research Center, P.O.Box208, Bale-Robe, Ethiopia
Corresponding author: girmafana@yahoo.com , girmafana@gmail.com ; Tel: +251 912 000213

Abstract

A multi-environment malt barley yield trial was conducted across different malt barley growing environments in Ethiopia for two years 2016-2018. The test locations included Robe, Adet, Sinana, Gasara, Selka, Kofele, Goba, Dodola, Gedo, Bekoji, Alemata, Shambu and Bore. Bekoji and Bore have higher variance ratio than other locations. The Analysis of Variance over locations and years showed that there is significant variation among test environments which contributed 70% to the total variation compared to the 2% contribution by the genotypic effect. The Genotype by Environment Interaction had 10% share in the total variance. It was also found out that Dodola, Goba, Gedo, Bekoji, Alemata, Shambu and Bore are the ideal environments for malt barely production since they produced grain yield higher than the grand mean of 2775 kg/ha. Genotypes 6, 7 and 17 were also identified as higher yielders across the environments. AMMI and GGE biplot methods the major parameters employed to classify the genotypes and environments main effect and the interaction. Different stability parameters were also employed to identify stable genotypes for wide adaptability. Bore, Shambu and Alemata were the most genotype discriminating environments and Bore has both the discriminative and most representativeness for malt barley variety evaluation. GGE biplot better explains the effect of the genotype by environment interactions and also is used for classifying mega environments. All of the stability parameters are in agreement with AMMI and GGE biplot to identify genotypes 6, 7and 17 as high yielding and stable genotypes and also to identify Bore, Shambu and Alemata as high yielding environments with Bore as both the most representative and discriminative environment for malt barley variety evaluation which is a crucial decision tool for the national breeding program.

Key word: AMMI, GGE biplot, discriminative, representative, malt barley, stability. ,

Introduction

Barley (Hordeum vulgare L.) is one of the founder crops of the old world agriculture and was one of the first domesticated cereals. It is also a model experimental plant because of its short life cycle and morphological, physiological and genetic characteristics (Gebremedhin *et al.*, 2014). It is a cool-season crop that is adapted to high altitudes and grown in a wide range of agro-climatic regions under several production systems. At altitudes of about 3000 meters above sea level (masl) or above, it may be the only crop grown that provides food, beverages and other necessities to many millions of people. Barley grows best on well-drained soils and can tolerate higher levels of soil salinity than most other crops. It is believed to have been cultivated in Ethiopia as early as 3,000BC (Hailu and Leur, 1996).

Malt barley is becoming an important cash crop related with the current increasing industrial involvement in malting and beer making. Malt barley is estimated to cover 15% of the area allocated to the total barley production (National barley research strategy, 2016). The health

benefits of barley β-glucan include reduction of blood cholesterol and glucose and weight loss by increased satiety, and therefore, the control of heart disease and type-2 diabetes (Baik and Ullrich 2008). However, new findings revealed that cereal grains also contain many health-promoting components such as vitamins, minerals, essential fatty acids, phytochemicals and other bioactive food components, which include phenolic compounds (Dykes and Rooney 2007). Grain protein concentration is genetically controlled but easily affected by the environmental conditions; however genetic control was much greater than environmental control (Jummei *et al.*, 2003 and Shengguan *et al.*, 2013). This influence has been put at about 70% (Bleidere, 2008). The grain protein concentration decreases in newer varieties of malting barley due to increase in structural carbohydrates (Bulman *et al.*, 1993). The grain protein concentration shows a close relationship with other malt quality parameters indicating the need to select varieties with stable grain protein concentration (Shengguan *et. al.*, 2013). This varied response of barley yield and quality components to variety, environments and variety by environment interaction indicates the need to determine the response of specific varieties to these variables.

Several multi-environment trial studies have compared the AMMI and GGE biplot analyses to obtain an effective tool for analyzing GEI and have come out with differing results. Kandus et al. (2010) found the AMMI model was the best model to describe the GEI in maize. Stojaković et al. (2010) and Mitrovic et al. (2012) also found out that the models provided similar results. Moreover, (Rad et al., 2013) indicated that both models performed equally using data on bread wheat while, Samonte et al (2005) found the AMMI and GGE biplot analyses complementing one another. Contrary to these findings, Yan et al. (2007) compared the GGE biplot and AMMI analyses and concluded that the GGE biplot was superior to the AMMI biplot in mega-environment analysis and genotype evaluation. Different stability parameters have also been implemented to evaluate the genotypes performance across environments. The main objective of the present investigation is therefore to evaluate the genotype by environment interaction and stability performance of malt barley genotypes in the highlands of Ethiopia.

Materials and Methods

The multi-environment yield trial was conducted as national malt barely variety trial for two years (2016-2018) in highland barley growing areas of Ethiopia. The locations included Agarfa, Robe, Adet, Arjo, Adaba, Sinana, Gasara, Salka, Kofele, Dodola, Goba, Gedo, Bekoji, Alemata and Shambu. Twenty two genotypes obtained from international nurseries of the International Center for Agricultural Research in the Dry Areas (ICARDA) which were promising in desirable agronomic traits and yield parameters were evaluated along with three standard checks IBON 174/03, Bekoji-1 and Singitan. The trials were laid out in alpha lattice with three replications. The plot had an area of 1.2m x 2.5m with the total plot size of $3m^2$ consisting of 6 rows spaced 20cm apart. The central 4 rows were used as the total harvestable area for estimating yield per hectare. All agronomic recommendations for the specific areas were used according to the local recommendations. Data on agronomic and yield parameters were subjected to analysis using R statistical software. Analysis of Variance, Genotype by Environment Interaction and different stability parameters were analyzed and Least Significant means Differences (LSD) were separated using Fisher's Least Significant Difference at Probability level of 0.05.

Results and Discussions

Analysis of Variance (ANOVA)

The combined analysis of variance for grain yield over malt barley growing highlands of Ethiopia suggested a significant main effects (Genotype, Location and Year) and the interaction effect of genotype with the environment (with year and location) is also significant (Table 2). The ANOVA also depicted that out of the total variation in the experiment, 69.7% was explained by the location difference, 10.4% by the Genotype by Location interaction and 1.8% by the Genotype. The experimental error contributed 11.5% to the total experimental variation.

Table 1. Pedigree of the test genotypes

Genotype code	Pedigree
1	**AZAF//PENCO/CHEVRON-BAR**
2	**PFC88209//ATAH92/GOB**
3	**MN BRITE/4/TOCTE//GOB/HUMA/10/3/ ATAH92/ALELI**
4	**AR14**
5	**CANELA/BONITA//DEFRA**
6	**SARA1-BAR// PENCO/CHEVRON-BAR**
7	**CANELA//CLENI76/NE175-B**
8	**UN-G4604**
9	**CANELA/GOB89DH//CANELA/ GOB82DH/4/ARUPO/K8755//MORA/3/ALELI/5/SCARLETT**
10	**BICHY2000/SHENMAI NO.3**
11	**CANELA//DEFERA/DESCONOCIDA-BAR**
12	**BICHY2000//GOBHUMAI10**
13	**CANELA//DEFERA/CLE169**
14	**ALELI/SCOBA/3/ARUPO/K8755//MORA/4/FENCI**
15	**LEGACY/3/SAVHALS-BAR/MSEL//AZAF/GOBA24DH**
16	**245126**
17	**PENCO/CHEVRON-BAR//ATAH92/GOB**
18	**SHENMA NO.3/MSEL//CANELA**
19	**MSEL//DEFERA/CLE 169**
20	**ATAH92/2*M81//TOCTE/3/PENCO/ CHEVRON-BAR**
21	**SVANHALS-BAR/MSEL//AZAF/GOBB24DH/3/NE167/CLE176**
22	**E.ACACIA/DEFERA/3/SVANHALS-BAR/MSEL//AZAF/GOB24DH**
23(Check)	IBON 174/03
24(Check)	Bekoji-1
25(Check)	Singitan

Table 2. Combined Analysis of Variance for grain yield across different locations in Ethiopia

Source of variation	Df	Sum Squares	Mean Squares	F value	Pr (>F)	TSS explained %
Gen	24	75940000	3164373	6.236	0.0000000000000002	1.8
Loc	15	2947000000	196450723	387.125	0.0000000000000002	69.7
YR	1	29710000	29706420	58.539	0.0000000000000486	0.8
Blk	4	1438000	359541	0.709	0.0000000000000002	0.03
Rep	2	41660000	20828180	41.044	0.0000000000000002	0.98
Gen:Loc	360	439400000	1220566	2.405	0.0000000000000002	10.4
Gen:YR	24	12150000	506232	0.998	0.466298	0.29
Loc:YR	3	30060000	10019540	19.744	0.000000000000201	0.71
Blk:Rep	8	15230000	1903156	3.75	0.000245	0.36
Loc:Rep	30	125300000	4175226	8.228	0.0000000000000002	2.96
Gen:Loc:YR	72	27130000	376833	0.743	0.945149	0.64
Residuals	956	485100000	507460	-	-	11.47

The combined mean yield performance across locations showed that, Agarfa, Robe, Adet, Arjo, Adaba, Sinana, Gasara, Selka and Kofele are low yielding environments for malt barley production since they have produced less grain yield than the grand mean yield of 2775 kg/ha (Table 3). On the other hand, locations such as Dodola, Goba, Gedo, Bekoji, Alemata, Shambu and Bore are ideal environments for malt barley production since they produced grain yield higher than the grand mean. The most ideal location for malt barley production is Bore with an average yield of 5972 kg/ha followed by Shambu and Alemata. The result indicated that genotypes 6, 7 and 17 are high yielders over the test environments but not significantly higher than the best standard check IBON 174/03 (Genotype 23). IBON 174/03 is the highest yielder in Dodola, Alemata and Gedo whereas Genotype 6 is the highest yielder at Goba, Bekoji, Kofele and Shambu. Kofele showed a typical situation among the environments where the variability between the genotypes mean is very wide. The yield at Kofele ranged from the lowest yielding Genotype 20 with grain yield of 682 kg/ha to the highest yielding genotype 6 with grain yields of 4718 kg/ha. Gasara and Selka are also candidate locations with acceptable yield for some high yielding genotypes. Genotype 16 had 3677 kg/ha whereas genotype 20 produced 3117 kg/ha which are higher than the grand mean at these locations. Therefore, Gasara and Selka can be alternative locations for malt barley production.

Table 3. Grain yield performance of the genotypes across the locations

Geno-type	Agarfa	Robe	Adet	Arjo	Adaba	Sinana	Gasara	Selka	Kofele	Dodola	Goba	Gedo	Bekoji	Alemata	Shambu	Bore	Mean
1	640	1837	1809	2705	1040	1682	1723	1792	2818	2585	2965	4584	4137	4626	5949	7225	2974
2	668	1052	1213	1986	912	1938	1839	2380	2053	2162	2656	4272	3940	3945	5125	6692	2676
3	827	1032	796	609	1439	1502	1426	2062	2925	2964	2860	3359	3914	4738	5788	5058	2627
4	1786	1027	1649	482	1221	2382	1703	2797	2145	3773	3405	3756	3600	5605	3313	5208	2851
5	1287	1223	453	618	908	1553	2992	1967	2049	3359	2660	3340	3907	5378	5254	7583	2801
6	**1659**	**1158**	**1973**	**835**	**1173**	**2059**	**3162**	**1900**	**4718**	**3247**	**4110**	**2079**	**5314**	**5290**	**6054**	**6000**	**3273**
7	**1054**	**1408**	**1305**	**691**	**1618**	**2168**	**2306**	**1880**	**3188**	**2796**	**3790**	**4605**	**4888**	**4285**	**5783**	**6708**	**3106**
8	1405	1275	1472	2634	1111	1444	2021	1605	3465	3338	3278	4418	4038	4261	5512	5567	2947
9	1771	998	1236	506	1138	1309	1271	1965	3486	4020	2571	4145	4468	4129	4202	5133	2736
10	857	753	834	760	1107	1431	1689	1805	2573	3159	2512	3345	2877	2835	3871	6150	2327
11	500	1865	595	1305	1714	1223	1579	1417	3654	3192	2997	3573	3547	5047	4949	7383	2775
12	340	1162	2143	183	1755	1642	1936	2163	2255	2583	2951	4374	3497	3188	5496	5092	2572
13	1048	1542	1486	404	1402	1697	1669	1803	3025	2771	3133	3808	3597	4745	3952	6225	2675
14	1612	1512	1040	793	1400	1745	2038	2305	2628	3031	2964	4159	3660	4479	5140	6200	2805
15	800	1558	868	1812	1111	1885	2220	2195	2728	3059	3625	4264	4476	4747	5050	6558	3000
16	1903	1472	1058	2373	1059	1321	3677	1870	3477	2554	2816	4422	4002	4795	4903	4625	2851
17	**1438**	**1268**	**1142**	**2223**	**1564**	**2334**	**1859**	**2343**	**2220**	**3099**	**3424**	**4567**	**5024**	**5304**	**5782**	**5317**	**3139**
18	1122	1438	1390	429	1421	1836	2410	2527	1600	3652	3118	3976	4716	5171	4473	5842	2922
19	1447	1133	959	3089	1395	1916	1517	2125	2028	2754	3588	4831	3443	5161	5177	5350	2881
20	736	1343	1157	631	949	2444	2166	3117	682	3050	3186	4135	4325	4771	4500	4767	2748
21	602	927	1963	624	2510	1726	2728	1788	1280	2858	2988	3584	2873	4710	4729	5575	2595
22	590	793	1860	788	1363	1846	2172	2042	1325	2905	3627	3711	4057	5360	5697	6125	2835
23	**1745**	**1050**	**951**	**3331**	**1474**	**1664**	**2144**	**2262**	**1764**	**3671**	**2927**	**5270**	**5157**	**5828**	**5834**	**7217**	**3285**
24	1615	458	477	203	1045	1893	1252	2370	1436	3209	2959	4493	4664	4654	4759	5158	2669
25	1535	910	522	829	766	1860	1697	1945	834	3118	2436	3980	4212	4551	2714	6543	2504
MEAN	**1159**	**1208**	**1214**	**1234**	**1304**	**1780**	**2048**	**2097**	**2414**	**3076**	**3102**	**4042**	**4093**	**4704**	**4960**	**5972**	**2775**

AMMI analysis for grain yield

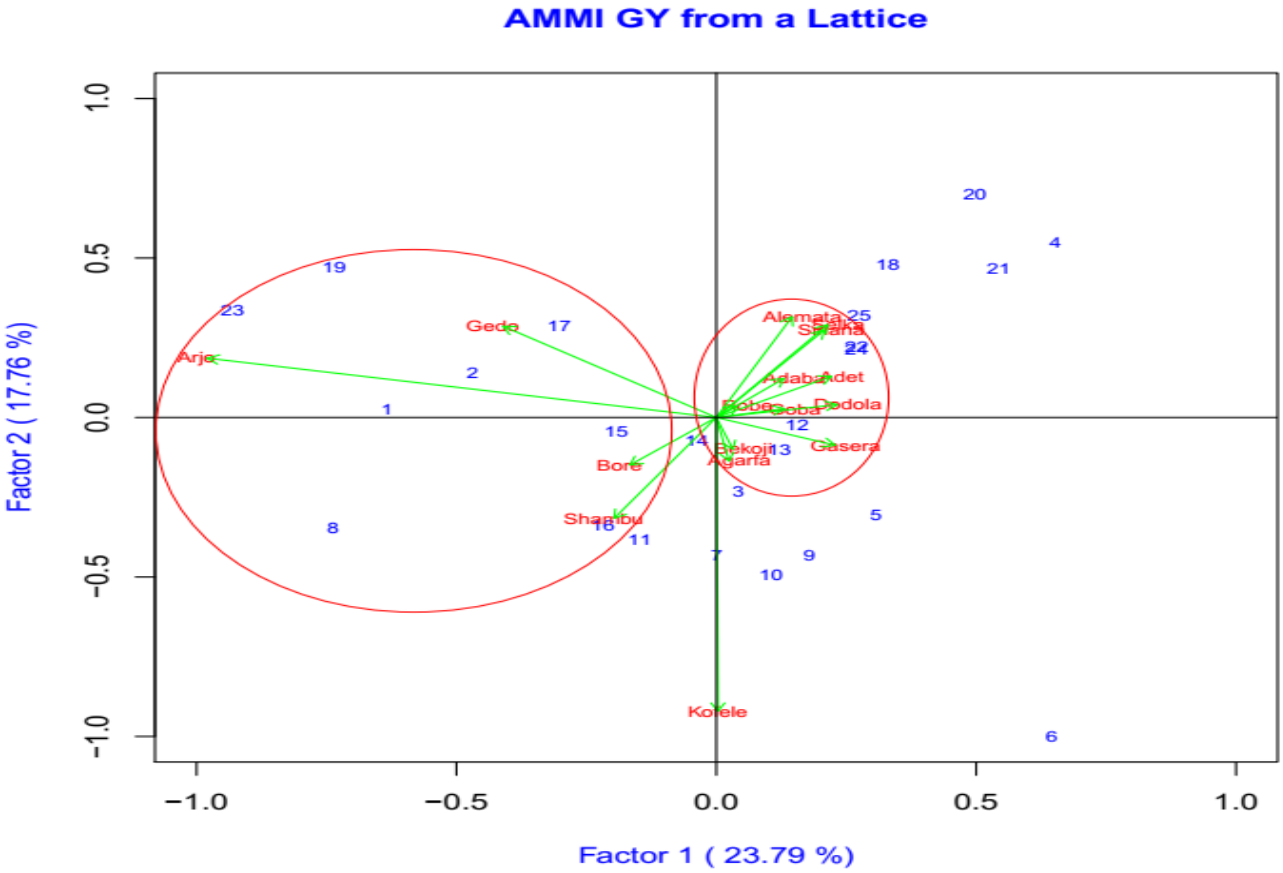
The AMMI method is used for three main purposes. The first is model diagnoses, AMMI is more appropriate in the initial statistical analysis of yield trials, because it provides an analytical tool of diagnosing other models as sub cases when these are better for particular data sets (Gauch, 1988). Secondly, AMMI clarifies the GE interaction and it summarizes patterns and relationships of genotypes and environments (Zobel et al., 1988; Crossa et al., 1990). The third use is to improve the accuracy of yield estimates. Out of the total variation, 73%, 2% and 11% is contributed by Environment, Genotype and GE interaction, respectively while the variance contributed by the residual error amounted to 14%. It is evident (Table 4) that the use of biplots to explain efficiently the interaction effect is very much limited, since the first two PCA axes explain only 42% of the total interaction variation. Hence it may not be advisable to conclude either on stability or simultaneous selection based on these two axes. It is evident that at least 4 axes must be retained for explaining stability or using the proposed simultaneous selection indices. Accordingly, the index values and stability values were calculated by retaining 4 PCA axes in the model (AMMI1-AMMI4) (Rao and Prabhakaran, 2005). The AMMI analysis showed that the first 6 PCA axes showed significance and could explain 84% of the GE interaction.

Table 4. AMMI Analysis for grain yield of malt barely genotypes in highlands of Ethiopia

Source	DF	SS	MS	% variability	% Acc. Variability	F	Probability
ENV	15	2946760843	196450723	72.5	72.5	37.66	0.0000
GEN	24	75944958	3164373	1.9	74.4	5.62	0.0000
ENV*GEN	360	439403642	1220566	10.8	85.2	2.16	0.0000
Residuals	1068	600841829	562586	14.8	100	-	0.0000
PC1	38	85945935.8	2261735.15	22.0	22.0	4.02	0.0000
PC2	36	77742225.2	2159506.26	19.9	41.9	3.84	0.0000
PC3	34	53988281.1	1587890.62	13.8	55.8	2.82	0.0000
PC4	32	44783217.5	1399475.55	11.5	67.3	2.49	0.0000
PC5	30	38081548.7	1269384.96	9.8	77.1	2.26	0.0001
PC6	28	27139085.3	969253.05	7.0	84.1	1.72	0.0116

AMMI model explains the GE interaction in biplots (PC1 and PC2) depicting the amount of mean yield and stability. Those genotypes that are located near the origin of the biplot are said to be stable across the environments and the environments that are similarly located around the origin of the plot is stable environment for all genotypes. AMMI model can also be used to classify mega environments but it needs curiosity to use the AMMI model for mega-environment classification since it has limitations such as the lack of inner product property. The AMMI model hence helps environments discriminate genotypes similarly if they have acute angles between their vectors. The environments that discriminate the genotypes in similar way are Gedo, Arjo, Bore and Shambu. Whereas the other category of environments that similarly classify genotypes are Bekoji, Agarfa, Gasara, and Kofele. Selka, Dodola, Adaba, Adet, Robe, Alemata, Sinana and Goba are also other environments that have close correlation to similarly categorize the genotypes.

Figures 1: AMMI graph (PC1 Vs PC2) for grain yield



Another view of the plot is the length of environment vector which represents its most discriminating power. The environment with the longest vector is hence Bore and Shambu are the environments with the longest vector from the biplot origin which means they are the most genotype discriminating environments. Genotypes 6, 7, 17 and 2 are high yielders. Locations Gedo, Shambu, Bekoji, Alemata and Bore are high yielding Environments with greater than 40 quintal per hectare.

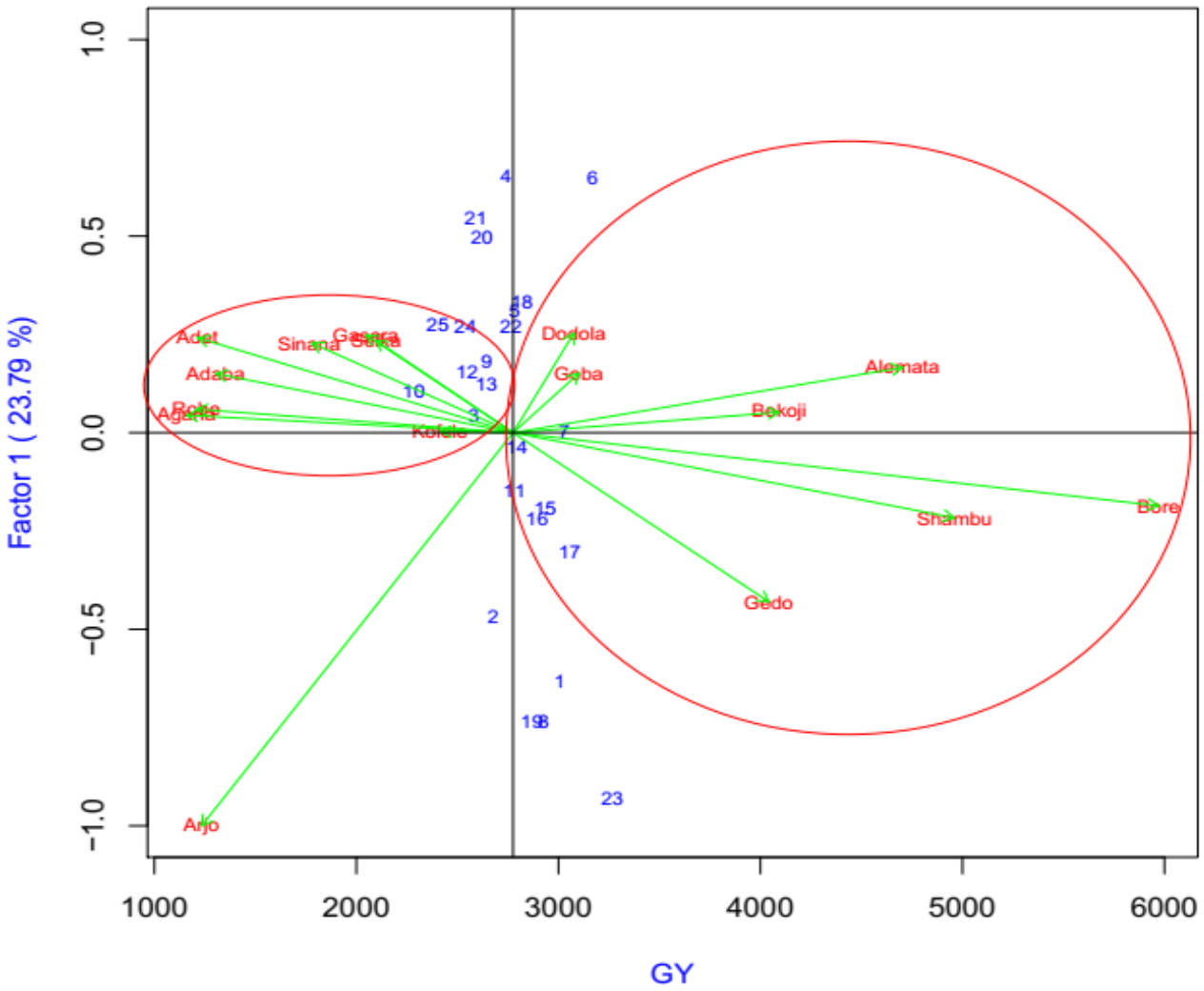


Figure 2: AMMI of grain yield in PC1

AMMI dependent stability parameters such as AMMI Stability Value (ASV) and Yield Stability Index (YSI) are also used to identify genotypes with higher mean yield and stability. The ASV shows genotypes with smaller values are stable and those with higher mean yield and YSI are also high yielding and stable. Genotypes 7 and 17 are with relatively lower ASV and hence stable while genotype 6 is with relatively higher ASV but higher mean yield (Table 5). The Yield Stability Index (YSI) combines stability and mean yield into a single parameter and hence genotypes with the first ranks (rYSI) are higher yielding and stable. Hence, genotypes 6, 7, 23 and 17 are with the 1 to 4 rank of YSI and hence are high yielding and stable.

Table 5. AMMI stability value (ASV) and Yield Stability Index (YSI) of malt barely genotypes

Genotype	ASV	rASV	Genotypes	YSI	rYSI	means
14	5.3	1	6	26	1	3634.47
15	7.3	2	7	9	2	3507.64
13	9.0	3	23	22	3	3469.65
2	10.6	4	17	14	4	3407.18
21	10.9	5	1	20	5	3395.95
22	11.2	6	15	8	6	3359.62
7	12.8	7	18	21	7	3251.77
19	12.9	8	5	29	8	3232.37
10	13.5	9	22	15	9	3207.46
17	15.3	10	8	26	10	3180.69
9	16.2	11	14	12	11	3170.01
12	17.3	12	16	32	12	3152.04
3	17.4	13	11	36	13	3143.45
18	17.9	14	19	22	14	3086.96
1	18.8	15	2	19	15	3081.56
8	21.3	16	4	34	16	3075.17
24	22.1	17	20	41	17	3044.79
4	22.8	18	13	21	18	3024.95
23	24.4	19	3	32	19	2975.17
16	24.8	20	12	32	20	2973.45
5	27.3	21	9	32	21	2926.37
25	34.3	22	21	27	22	2922.51
11	35.5	23	24	40	23	2898.6
20	38.6	24	25	46	24	2684.95
6	44.8	25	10	34	25	2639.08

Site Regression (SREG) or GGE biplot

Site regression analysis, also called GGE (Genotype Main Effect plus Genotype x Environment Interaction), is a linear-bilinear model that removes the effect of location and expresses the answer only as a function of the effect of genotypes and the GEI. This model is recommended when the environments are the main source of variation in relation to the contributions of the genotypes and the GEI with respect to the total variability. In addition, as a difference with AMMI model, this technique allows the detection of GEI in terms of the crossover effect resulting from great changes in the ranking of the genotypes across the environments. This technique allows the determination of mega-environments. In each mega-environment, the effects of the GEI are limited or not significant. The GGE biplot shows that genotype mean is higher than the grand mean in a specific environment if the environment vector is less than 90 degrees to the genotype vector. Hence, Genotype 8 and 17 have yield greater than the mean in almost all environments except in Adet, Sinana, Goba and Selka since the angle between the genotypes vector and each environments vector is less than 90 degrees (Figure 3).

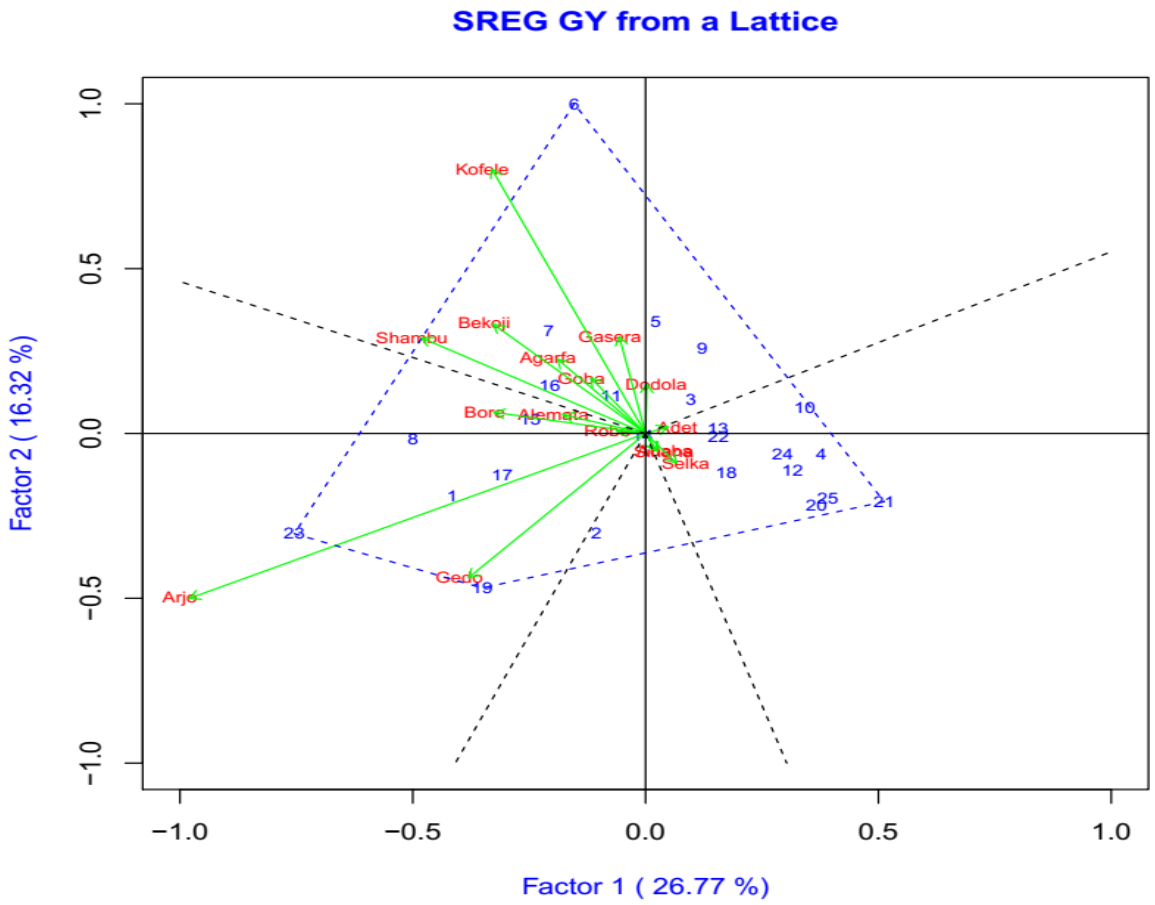


Figure 3: Site regression (GGE biplot) of Grain yield in PCA1

Another view of the GGE biplot is the discriminating and representative view in which the environments that have longest arm from the biplot origin are considered the most genotype discriminating environments. Bore, Shambu and Alemata are the environments with most genotype discriminating power in that order (Figure 4). On the other hand, environments with the acute angle with the average environmental axis are considered the most representative of all environments. Out of these environments, Bore is considered as both the most genotype discriminating and the most representative environment of the malt barley growing areas of the Ethiopian highlands. Genotypes 6, 7, 17 and 23 are those with the biggest average yield across all environments.

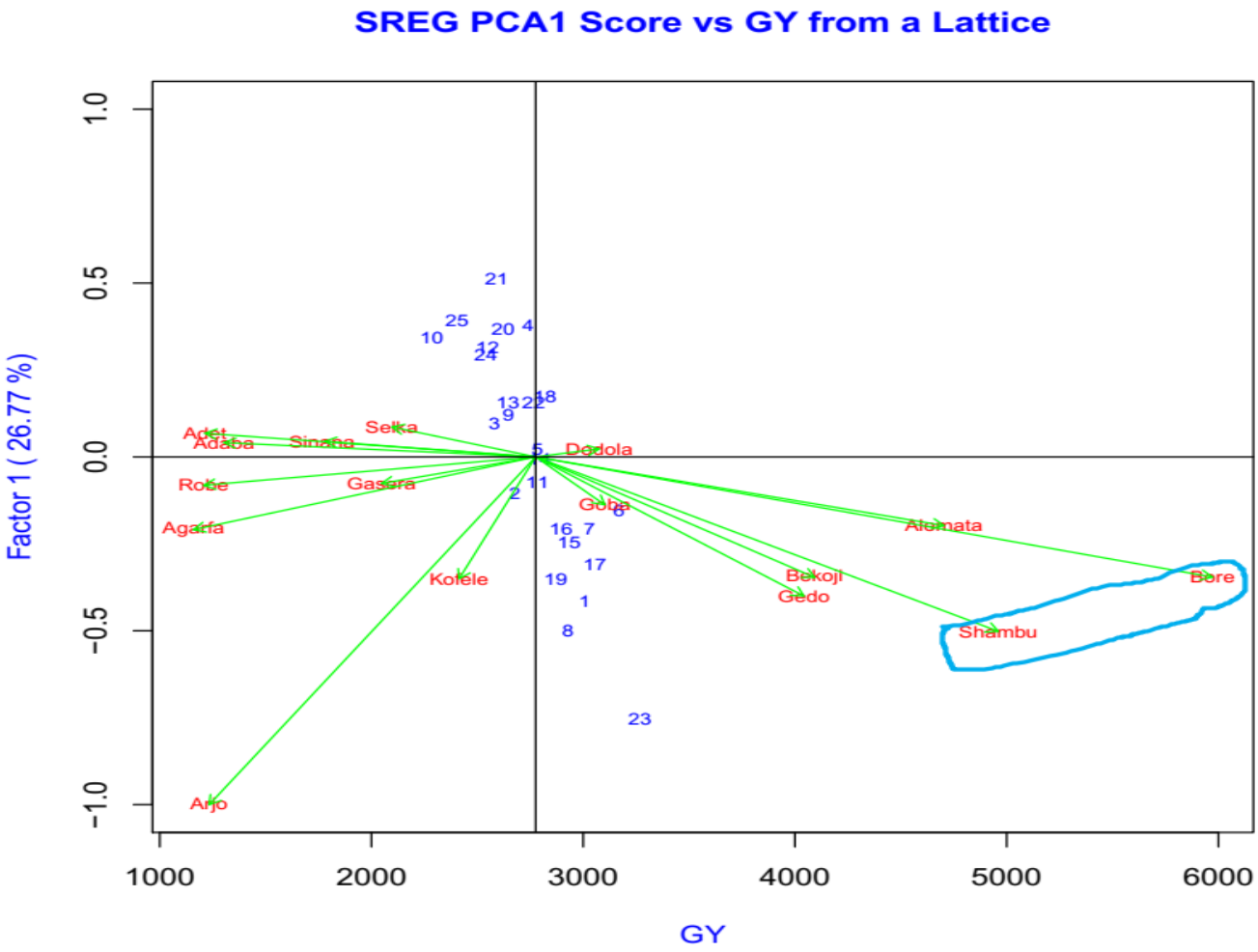


Figure 4: discriminative and representative view of the GGE biplot

Other Stability Parameters

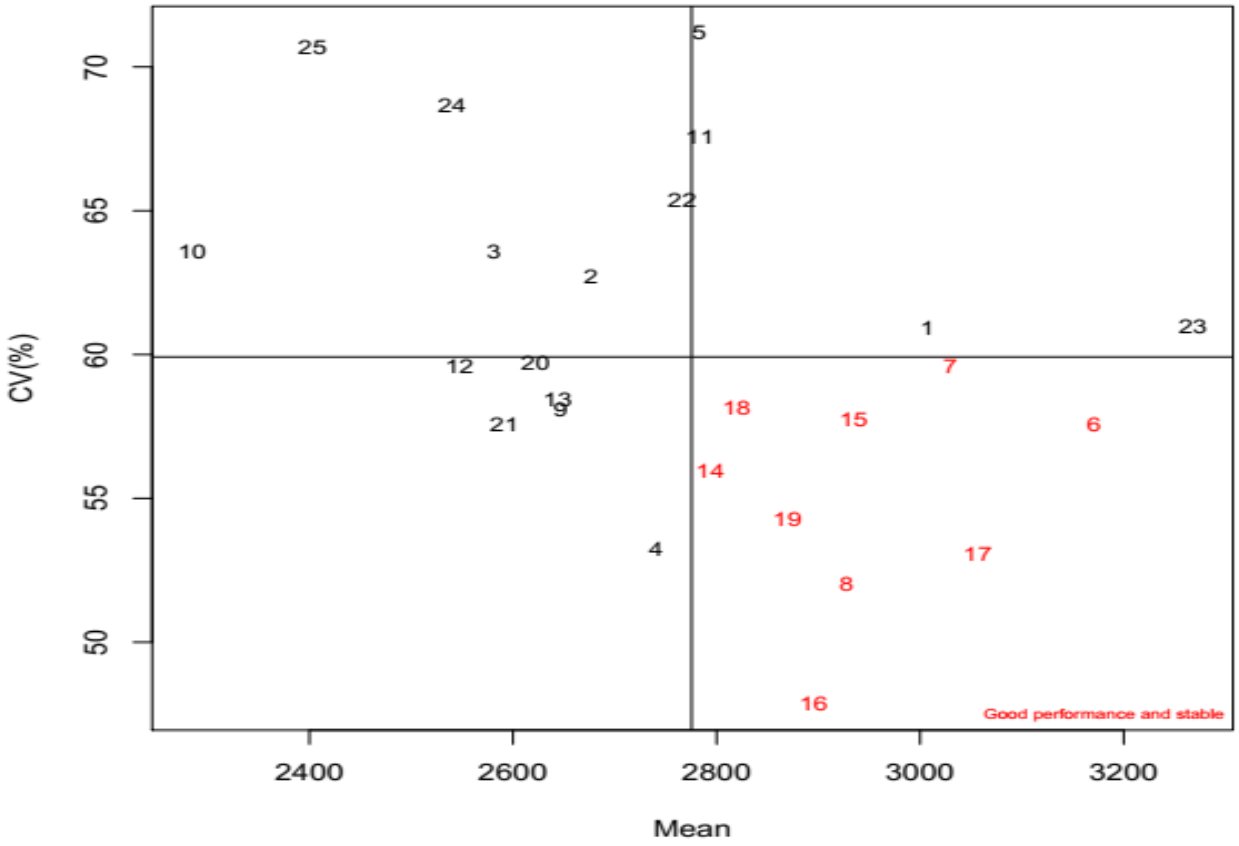
The stability analysis indicates that genotypes with the smallest values of CV (%), Shukla's variance (σ^2), Perkins and Jinks (Dj), Mean square deviation (S^2d), Wricke's Ecovalence (Wi), Superiority measure (Pi), Average Absolute Rank Difference of genotype in an environment (Si1) and Variance ranges of environments (Si2) are stable genotypes. Genotypes with stability parameters of Perkins and Jinks (Bi) and Regression coefficient of Eberhart and Russel (bi) values close to 1 are stable. On the other hand, genotypes with high R^2 (coefficient of determination) are considered stable. Based on these criteria, genotypes 6, 7 and 17 are declared stable and with higher mean yield (Table 4).

Table 6. Stability parameters

Francis				Eberhart & Russell			Shuckla	Perkins &Jinks		Wricke's Ecovalence	Superiority Measure	Non parametric Nassar & Huehn	
GEN	Mean	Sd	CV (%)	Bi	Sdi^2	R^2	ri2	Bi	DJi	Wi	Pi	Si(1)	Si2
1	3007.167	1831.148	60.8928	1.11	218998.8	0.892	409997.3	0.11	388130.7	5874546	651135.6	1.49	60.53
10	2284.813	1452.594	63.5761	0.8763	94379.09	0.8834	291990.3	-0.1237	263510.9	4246049	1644924	0.8	25.53
11	2783.708	1881.14	67.5768	1.1382	253030.1	0.8887	462982.1	0.1382	422161.9	6605736	900509.7	1.25	80.73
12	2547.469	1518.501	59.6082	0.8903	240075.7	0.8344	431206.6	-0.1097	409207.5	6167234	1408312	0.58	62
13	2644.188	1545.484	58.4484	0.9548	18893.06	0.9265	180438.3	-0.0452	188024.9	2706631	1102378	0.73	38.53
14	2794	1563.032	55.9424	0.9899	-99898.7	0.9736	54812.62	-0.0101	69233.17	972997.3	879144	0.66	15.27
15	2934.813	1693.701	57.7107	1.0729	-89472.1	0.9741	79149.56	0.0729	79659.73	1308847	641968.1	0.56	21.93
16	2895.417	1386.16	47.8743	0.7838	291790.9	0.7761	575230.5	-0.2162	460922.7	8154764	816129.7	1.13	68.47
17	3056.75	1621.596	53.0497	1.0002	46486.51	0.9235	203048.9	0.0002	215618	3018658	663539.5	0.62	21.73
18	2819.958	1639.716	58.1468	1.0141	37152.98	0.9284	194102.2	0.0141	206284.8	2895194	1004087	1.08	36.8
19	2869.458	1556.728	54.2516	0.9176	237582.8	0.8434	414829.9	-0.0824	406714.7	5941236	887025.2	0.83	46.6
2	2677.01	1678.465	62.6992	1.0344	66546.99	0.9219	226524	0.0344	235678.8	3342614	1010791	1.12	45.93
20	2622.354	1566.042	59.7189	0.9152	279970.5	0.8291	458870.2	-0.0848	449102.3	6548992	1450930	1.26	52.33
21	2591.552	1491.982	57.571	0.8754	222910.7	0.8356	422998.4	-0.1246	392042.6	6053962	1355584	0.92	54.53
22	2766.24	1808.341	65.3718	1.1223	58968.89	0.9349	255153.2	0.1223	228100.7	3737697	1062133	1.14	44.2
23	**3267.979**	**1992.082**	**60.9576**	**1.2068**	**294816.4**	**0.8909**	**567859.9**	**0.2068**	**463948**	**8053050**	**541393.6**	**0.81**	**50.4**
24	2540.417	1744.806	68.6819	1.0652	141746.9	0.9047	310905.3	0.0652	310878.8	4507076	1444325	1.5	59.67
25	2403.313	1698.44	70.6708	0.9918	363197.4	0.8278	524525.9	-0.0082	532329.3	7455040	1689289	0.78	42.73
3	2581.167	1641.595	63.5989	1.0147	40210.88	0.9275	197255.5	0.0147	209342.7	2938710	1200893	0.88	33.8
4	2740.844	1458.599	53.2172	0.8391	279382.5	0.8032	507663	-0.1609	448514.4	7222332	1260940	1.24	66.93
5	2783.24	1980.974	71.1751	1.2237	140884	0.9263	430862.6	0.2237	310015.8	6162487	1011403	0.91	63
6	**3170.708**	**1824.724**	**57.5494**	**1.006**	**766295.4**	**0.7378**	**933384.6**	**0.006**	**935427**	**13097290**	**752242**	**1.12**	**50.8**
7	**3029.552**	**1804.373**	**59.5591**	**1.127**	**15812.69**	**0.947**	**214496.8**	**0.127**	**184944**	**3176639**	**645745.9**	**0.78**	**38.33**
8	2927.76	1522.698	52.009	0.9209	109498	0.8878	283480.1	-0.0791	278629.8	4128608	669114.8	1.02	37.73
9	2646.729	1537.018	58.0724	0.9093	211849.4	0.8495	392530.7	-0.0907	380981.2	5633507	1188904	1.44	63.33

The plot of mean yield against coefficient of variation (CV) is also one of the stability indices in which genotypes that are with higher mean yield and lower coefficient of variation are considered stable and high yielding. Accordingly, Genotypes 6, 7, 8, 16 and 17 which are at the far right corner of the graph (in red) are good performing, high yielding and stable genotypes (Figure 5).

Figure 5: CV (%) of genotypes plotted against the mean



Conclusions

Malt barley is a sensitive crop which requires critical decision as to where to successfully grow for optimum yield and quality to the industrial requirement level. Optimum conditions that are needed for malt barley production for higher yield and required industrial quality need to be met by the growing environments and hence selection of the optimum growing environments is of paramount importance. Different environments and genotype selection criteria have been used in breeding program. Genotype selection over wide environments is not easy because of the genotype by environment interaction. The availability of Genotype by Environment (GE) interaction is hence hindrance to wide adaptability and need to be carefully observed and efficiently estimated. Among the parameters to estimate and separate the GE interaction are AMMI and GGE biplot. Other stability parameters were also employed to select high yielding and stable genotypes for determining wide adaptable genotypes. The current study aimed at analyzing the GE interaction and stability parameters for evaluating high yielding and stable malt barely genotypes. Analysis of Variance (ANOVA) showed significant variation among locations and genotypes. The effect of GE interaction was also significant. The contribution of environment (location) to the total variation was very high (70%) compared to the genotype (2%) and the GE interaction (10%). The GE interaction is

hence 5 times higher than the genotypic effect and hence poses significant pressure on widely adapted variety selection. The combined analysis over locations and years using ANOVA identified ideal environments that produced grain yield higher than the grand mean of 2775 kg/ha included locations such as Dodola, Goba, Gedo, Bekoji, Alemata, Shambu and Bore. AMMI model is one of the parameters to further exploit the GE interaction. The first 6 significant principal components expressed 84% of the GE interaction. AMMI was also the parameter used to discriminate genotypes. Environments having acute angles between their vectors in the biplot have similar genotypic discriminating power. The GGE biplot was used to classify mega environments and also used in discriminative and representative view of the biplot graph. Both AMMI and GGE biplot methods similarly categorized the mega-environments and identified genotypes 6, 7 and 17 as high yielding stable genotypes across all environments. Bore, Shambu and Alemata were identified as highly discriminating environments where we can easily identify high performing genotypes. Bekoji and Gedo can also be optional environments that can discriminate high performing genotypes. All the stability parameters were also in agreement with the AMMI and GGE biplot methods in identifying genotypes 6, 7 and 17 as the high yielding and stable genotypes that can be selected for verification in the next breeding stage.

Reference

Annicchiarico, P. and M. Perenzin, 1994. Adaptation patterns and definition of macro-environments for selection and recommendation of common wheat genotypes in Italy. Plant Breed. 113: 197-205.

Baik. B and Ullrich.S. 2008. Barley for food Characteristics, improvement, and renewed interest. Journal of Cereal Science, 48: 233–242.

Bleidere M., 2008.Genetic and environmental effect on the grain quality of spring barley.Latvian journal of agronomy 11:33-39

Bulman P., D. E. Mather and D. L. Smith 1993.Genetic improvement of spring barley cultivars in Eastern Canada. Euphytica 71:35-48

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

Dixon, A.G.O. and E.N. Nukenine, 1997. Statistical analysis of cassava yield trials with the additive main effects and multiplicative interaction (AMMI) model. Afr. J. Root Tuber Crops, 3: 46-50.

Dykes L., Rooney L.W. 2007. Phenolic compounds in cereal grains and their health benefits. Cereal Foods World, 52: 105–111.

Gauch HG. 1988. Model selection and validation for yield trials with interaction. Biometrics 44: 705-715.

Gebremedhin.W, Firew.M and Tesfye .B, 2014, Stability Analysis of food barley genotypes in northern Ethiopia, African Crop Science Journal, Vol. 22, No. 2, pp. 145 – 153

Gordana. S, Daniela .H, Kresimir. D, Ivan. A, Marija. V, Marijana. T and Alojzije. L, 2017. Evaluation of Total Phenolic Content and Antioxidant Activity of Malting and Hulless Barley Grain and Malt Extracts, Czech J. Food Sci., 35, 2017 (1): 73–78

Gupta M., Abu-Ghannam N., Gallaghar E. 2010. Barley for Brewing Characteristic Changes during Malting, Brewing and Applications of its By-Products. Comprehensive Reviews in Food Science and Food Safety, 9: 318–328.

Junmei W., Guoping Z., Jinxin C., Quiqnan S. and Feibo W. 2003.Genotypic and environmental variation in barley beta-amylase activity and its relation to protein content. Food Chemistry 83(2): pp163-165

Kandus M., Almorza, D. BoggioRonceros, R., Salerno, J.C. 2010. Statistical models for evaluating the genotype-environment interaction in maize (Zea mays L.). International Journal of Experimental Botany, 79:39-46.

Mitrovic B, Stanisavljevi D, Treski S, Stojakovic M, Ivanovic M, Bekavac G, Rajkovic M (2012). Evaluation of experimental maize hybrids tested in multi-location trials using AMMI and GGE biplot analyses. Turkish J. Field Crops, 17: 35-40

National Barley Research Strategy, 2016-2030. Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia.

Rad, NM, Kadir MA, Rafii MY, Jaafar HZ, Naghavi MR, Ahmadi F. 2013. Genotype x 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 Sci., 7: 956-961.

Rao AR and Prabhakaran VT (2005) Use of AMMI in simultaneous selection of genotypes for yield and stability. Indian Society Agricultural Statistics.59 (1): 76-82

Samonte, SOP, Wilson LT, McClung AM, Medley JC. 2005. Targeting cultivars onto rice growing environments using AMMI and SREG GGE biplot analyses. Crop Science, 45(6): 2414-2424

Shengguan C., G. Yu, X. Chen, Y. Huang, X. Jiang, G. Zhang and X. Jin 2013.Grain protein content variation and its association analysis in barley.BMC Plant Biology, 13:35 (doi: 10.1186/1471-2229-13-35).

Stojaković M., Ivanović M., Jocković Đ., Bekavac G., Purar B., Nastasić A., Stanisavljević D., Mitrović B., Treskić S., Laišić R. 2010. NS maize hybrids in production regions of Serbia. Field and Vegetable Crops Research, 47: 93-02.

Yan W., Kang M.S., Ma B., Woods S., Cornelius P.L. 2007. GGE Biplot Vs. AMMI Analysis of Genotype-by-Environment Data. Crop Science, 47: 641–653.

Zobel R.W., Wright M.J. and Gauch H.G. 1988. Statistical analysis of a yield trial. Agronomy Journal, 80: 388-393.

Correlation and Path Coefficient analysis on Yield and Yield Related Traits in Bread Wheat (*Triticum aestivum* L.) Genotypes in Mid Rift Valley of Oromia

Urgaya Balcha[1]*, Firew Mekbib[2], Dagnachew Lule[3]
[1]Oromia Agricultural Research Institute (OARI), Adami Tulu Agricultural Research Center, Batu, Ethiopia; [2]School of Plant Science, College of Agriculture and Environmental Science, Haramaya University, Dire Dawa, Ethiopia; [3]Oromia Agricultural Research Institute, Addis Ababa, Ethiopia.
***Corresponding author**: urgayab@gmail.com

Abstract
Thirty six bread wheat genotypes were tested in simple lattice design at Adami Tulu, East Shoa in 2017/18 main cropping season,. The overall objective was to assess the association among yield and yield contributing traits and identify traits that have the most direct and indirect effects on grain yield. Analysis of variance revealed that there was a significant difference among the thirty six bread wheat genotypes for most of the characters studied. Grain yield showed positive and highly significant ($P \leq 0.01$) genotypic and phenotypic correlation with biomass yield, harvest index and plant height. The results of path coefficient analysis at genotypic level revealed that, the biomass yield exerted the highest positive direct effect on grain yield followed by harvest index and spike length. Besides, biomass yield exerted the highest phenotypic direct effect on grain yield followed by awn length, spike length, days to maturity and number of spikelets per spike.Hence, biomass yield and harvest index could be used as the best indirect selection for yield improvement in bread wheat breeding program.

Key words: Bread wheat, Correlation, and Path Coefficient

Introduction
Bread wheat (*Triticum aestivum* L.) is a self-pollinating annual plant in the true grass family Gramineae (Poaceae) which is the largest cereal crop extensively grown as staple food sources in the world (Mollasadeghi and Shahryari, 2011). It is one of the most important and strategic cereal crop in the world and in Ethiopia in terms of production and utilization (Ranjana and Kumar, 2013). In Ethiopia, wheat is grown at an altitude ranging from 1500 to 3000 meters above sea level, between 6-16^{o}N latitude and 35-42^{o}E longitude. The most suitable agro ecological zones, however, fall between 1900 and 2700 meters above sea levels (Abu, 2012). The analysis of the relationship among yield atributing characters and their association with grain yield is essential to establish selection criteria. Correlation coefficient analysis is an important statistical method that can help wheat breeders in indirect selection of wheat for higher yield.To increase the yield, study of direct and indirect effects of yield components provides the basis for its successful breeding programme and hence the problem of yield increase can be more effectively tackled because of performance of yield components and selection for closely related characters (Birhanu et al., 2017) So far, limited information is generated on character associations between yield and yield contributing characters in bread wheat genotypes in Ethiopia particularly in Mid rift valley of Oromia.

Therefore, the objective of this study was to assess the association between yield and yield contributing traits and identify traits that have the most direct and indirect effects on grain yield.

Materials and Methods

Description of the Study Area

The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC) during 2017 cropping season. It has an altitude of 1650 meters above sea level and receives a bimodal average annual rainfall of 760.9 mm per annum with erratic distribution. The long-term mean minimum and the mean maximum temperatures are 12.6 and 27 ^{o}C, respectively. The pH of the soil is 7.88, having sandy loamy and andosol soil type with sand, clay and silt in proportion of 34, 48 and 18% respectively (ATARC, 1998).

Experimental Materials, Design and Management

In this experiment, 11 released bread wheat varieties and 25 advanced breeding lines, making a total of 36 genotypes which were obtained from Kulumsa Agricultural Research Center (KARC) were used for this experiment. The description of the genotypes used in this study were presented in Table 1.The experiment was arranged in 6x6 Simple Lattice Design. The plot size was 3m^2 (6 rows x 0.2m spacing x 2.5m length). The central four rows were harvested to estimate grain yield. The spacing between adjacent replications, blocks and plots were 1m, 0.5m and 0.5m, respectively. Sowing was done on July 13, 2017 by hand drilling and covered lightly with soil. Seeding rate of 150 kg ha^{-1} and fertilizer rate of 41 and 46 kgha^{-1} of N and P_2O_5 were used respectively. Weeding and other management practices were done as per the recommendation for wheat (MoARD, 2012).

Data collected on plot basis were days to heading, days to maturity, grain filling period, effective tillers per meter square, grain yield/ha (t ha^{-1}), 1000-kernel weight (g), biomass yields (g/plot) and harvest index. Ten plants randomly selected from the central four rows were used to collect characters such as plant height (cm), kernels per spike, spikelet per spike, peduncle length (cm), spike length (cm) and awn length (cm).

Four physiological data related to moisture stress tolerance such as relative leaf water contents (%), leaf water content (%), leaf area (cm^2) and chlorophyll content were collected as per the following formula.

Relative leaf water contents (%): Relative leaf water content (RLWC) was measured at flowering stage using Turner and Kramer (1980) method: $RWC\% = \frac{FW-DW}{TW-DW} X100$

Where, FW = fresh leaf weight; DW = dry weight (In Oven for 48 h); TW = tumescent weight.

Leaf water content (%): was calculated using Clarke and McCaig (1982) method:

$$LWC\% = \frac{FW - DW}{FW} X100$$

Where, FW = fresh leaf weight; DW = leaves placed in an oven at 50^{o} C for 24 h and re-weighed

Leaf area (cm^2): was calculated using the following equation (Birch et al., 1998 and Montgomery, 1911): Leaf area (cm^2) = maximum leaf length × leaf width× 0.75.

Chlorophyll content: A flag leaf per plant from 10 sample plants per plot was measured using portable chlorophyll meter Minolta SPAD- 502 at flowering (Mohammad et al., 2012). The averages of the SPAD values from sampled plants at flowering stage were used for analysis in each genotype similar to Moslem et al., (2013) and Mihratu (2014)

Table 1.Description of bread wheat genotypes evalauted in this study

No	Genotypes	Pedigree/selection history	Origin
1	K6290-Bulk	(AF.MAYOxGEM)Xromany	Kenya
2	Ogolcho (ETBW5520)	WORRAKATA/2*PASTOR	CIMMYT
3	BIKA	PASTOR//MXL7573/2*BAU/3/SOKOLL/WBLL1	CIMMYT
4	WANE (6130)	SOKOLL/EXCALIBUR	CIMMYT
5	Hawii (2501)	CHIL/PRL	CIMMYT
6	Pvon-76	VCM//CNO*S*/7C/3/KAL/BB	CIMMYT
7	Derselign	CI8154/2*FR	Mexico
8	Kakaba (Picaflor #1)	KRITATI//SERI/RAYON	CIMMYT
9	Gambo (Quaiu # 2)	BBAX/LR42//BABAX*/3/VIVITSI	CIMMYT
10	KINGBIRD	TAM-200/TUI/6/PAVON-F-76//CARIANCA-422/ANAHUAC-F-75/5/BOBWHITE/ CROW// BUCKBUCK/ PAVON-F-76/3/YECORA-F-70/4/TRAP-1.	CIMMYT
11	GALIL	not available	Israel
12	Advanced line (A1)	KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ/5/HUW234+LR34/PRINIA//PBW343*2/KUKUNA/3/ROLF07	CIMMYT
13	Advanced line (A2)	KACHU*2//WHEAR/SOKOLL	CIMMYT
14	Advanced line (A3)	PAURAQUE #1/3/PBW343*2/KUKUNA//PBW343*2/KUKUNA/4/BAJ #1	CIMMYT
15	Advanced line (A4)	WBLL1*2/BRAMBLING//SAAR/2*WAXWING/4/PBW343*2/KUKUNA//KRONSTAD F2004/3/PBW343*2/KUKUNA	CIMMYT
16	Advanced line (A5)	MELON//FILIN/MILAN/3/FILIN/4/PRINIA/PASTOR//HUITES/3/MILAN/OTUS//ATTILA/3*BCN/5/MELON//FILIN/MILAN/3/FILIN	CIMMYT
17	Advanced line (A6)	SOKOLL/3/PASTOR//HXL7573/2*BAU/4/WHEAR/SOKOLL	CIMMYT
18	Advanced line (A7)	MILAN//PRL/2*PASTOR/4/CROC_1/AE.SQUARROSA (213)//PGO/3/BAV92/5/PAURAQ	CIMMYT
19	Advanced line (A8)	FRANCOLIN #1/BAJ #1	CIMMYT
20	Advanced line (A9)	CROC_1/AE.SQUARROSA (205)//BORL95/3/PRL/SARA//TSI/VEE#5/4/FRET2*2/5/WHEAR/SOKOLL	CIMMYT
21	Advanced line (A10)	TILHI/SOKOLL*2//KINGBIRD #1	CIMMYT
22	Advanced line (A11)	SUP152/BAJ #1	CIMMYT
23	Advanced line (A12)	KACHU*2/3/ND643//2*PRL/2*PASTOR	CIMMYT
24	Advanced line (A13)	CHIBIA//PRLII/CM65531/3/MISR 2*2/4/HUW234+LR34/PRINIA//PBW343*2/KUKUNA/3/ROLF07	CIMMYT
25	Advanced line (A14)	PREMIO/2*BAVIS	CIMMYT
26	Advanced line (A15)	MILAN/KAUZ//PRINIA/3/BAV92/4/BAVIS	CIMMYT
27	Advanced line (A16)	CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/BAV92/4/BERKUT/5/BAVIS	CIMMYT
28	Advanced line (A17)	SHA7//PRL/VEE#6/3/FASAN/4/HAAS8446/2*FASAN/5/CBRD/KAUZ/6/MILAN/AMSEL/7/FRET2*2/KUKUNA/8/KINGBIRD #1	CIMMYT
29	Advanced line (A18)	NAVJ07/SHORTENED SR26 TRANSLOCATION/3/ATTILA/BAV92//PASTOR	CIMMYT
30	Advanced line (A19)	W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1*2/5/WHEAR/SOKOLL	CIMMYT
31	Advanced line (A20)	SERI.1B//KAUZ/HEVO/3/AMAD/4/ESDA/SHWA//BCN	ICARDA
32	Advanced line (A21)	ATTILA 50Y//ATTILA/BCN/3/PFAU/MILAN	ICARDA
33	Advanced line (A22)	SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN	ICARDA
34	Advanced line (A23)	KAUZ//ALTAR 84/AOS 3/KAUZ/3/ATTILA 50Y//ATTILA/BCN/4/PASTOR-6	ICARDA
35	Advanced line (A24)	ANGI-1	ICARDA
36	Advanced line (A25)	ENKOY/FLAG-5	ICARDA

Source: Kulumsa Agricultural Research Center

Data analysis

Analysis of variance (ANOVA)

The data collected for each trait were subjected to analysis of variance (ANOVA) for Simple lattice design. Analysis of variance was done using Proc lattice and Proc GLM procedures of SAS version 9.0, (SAS, 2002).The difference among treatment means was compared using DMRT at 5% probability levels.

Estimation of phenotypic and genotypic correlations

Phenotypic and genotypic correlations between yield and yield related traits were estimated using the method described by Miller et al. (1958).

$$rpxy = \frac{covpx.y}{\sqrt{\sigma^2 px.\sigma^2 py}}$$

Where, $rpxy$ = phenotypic correlation coefficient between character x and y

$covpxy$ = phenotypic covariance between character x and y;

$\sigma^2 px$ = phenotypic variance for character x; $\sigma^2 py$= phenotypic variance for character y

$$rgxy = \frac{covgx.y}{\sqrt{\sigma^2 gx.\sigma^2 gy}}$$

Where, rgxy=genotypic correlation coefficient between character x and y

covgxy= genotypic covariance between character x and y;

$\sigma^2 gx$ = genotypic variance for character x; and $\sigma^2 gy$= genotypic variance for character y

The coefficients of correlations at phenotypic level were tested for their significance by comparing the values of correlation coefficient with tabulated r-value at g-2 degree of freedom, where 'g' is number of genotypes. However, the coefficients of correlations at genotypic level were tested for their significance using the formula described by Robertson (1959).

$$t = \frac{rgxy}{SErgxy}$$

The calculated 't' values were compared with the tabulated 't' values at g-2 degree of freedom at 5% level of significance; where, g = number of genotypes, $rgxy$ = genotypic correlation coefficient and $SErgxy$ = standard error of genotypic correlation coefficient between character x and y which will be calculated as:

$$SErgxy = \sqrt{\frac{(1-r^2)2}{2H^2x.H^2y}}$$

Where:

$SErgxy$ = standard error of genotypic correlation coefficient between character x and y ;

H^2x = Heritability value of character x & H^2y = heritability value of character y

Path coefficient analysis

Path coefficient analysis was carried out to study the direct and indirect contributions of the traits to the associations. Days to heading, days to maturity, biomass yield per plot, harvest index, plant height, kernels number per spike, spikelets per spike, spike length, peduncle length and awn length were considered as predictor variables in a path analysis. Dewey and

Lu (1959) were used to estimate their direct effects (path coefficients) and indirect effects on grain yield which is the response (dependent) variable as follow.

$r_{ij} = p_{ij} + \sum r_{ik} P_{kj}$

Where rij = Mutual association between the independent variable 'i' and the dependent variable 'j' as measured by correlation coefficient.

pij = Components of direct effects of the independent variable (i) on dependent variable (j) as measured by the path coefficients; and

$\sum r_{ik} P_{kj}$ = Summation of components of indirect effects of independent trait (i) on the given dependent trait (j) via all other independent variables (k).

The contribution of the remaining unknown factor was measured as the residual factor. This will be calculated as: $\text{residual effect} = \sqrt{1 - R^2}$, where $R^2 = \sum p_{ij} r_{ij}$

Results and Discussions

Analysis of variance for 18 characters is presented in Table 2. The ANOVA indicated that, therewas significant differences among the test genotypes for all the studied traits except effective tiller per m^2, relative leaf water content (%) and leaf water content (%), The presence of these appreciable differences among the test genotypes for most of the characters studied implies that, there is huge potential variabilities to be exploited in future wheat improvement program.

Table 2 Mean squares of the 18 characters of 36 bread wheat genotypes evalauted at ATARC in 2017 cropping season.

Traits	Mean Squares			CV	± SE	Efficiency (%)	R^2
	Genotype(df=35)	Replication(df=1)	Error(df=25)				
DH	12.377^{**}	6.12^{ns}	3.86	3.87	1.39	101.22	0.870
DM	20.2^{**}	55.12^{**}	4.23	2.10	1.45	112.06	0.898
GFP	14.28^{*}	36.12^{*}	6.13	6.25	1.75	113.22	0.846
ETPM	7143.09^{ns}	2910.20^{ns}	5182.64	31.03	50.91	104.76	0.71
GY	1.14^{**}	10.89^{**}	0.331	14.41	0.41	193.69	0.893
TKW	16.64^{*}	2.88^{ns}	8.06	7.09	2.01	98.12	0.825
BY	100999.5^{*}	1034401.00^{*}	45361	16.29	150.60	167.10	0.853
HI	134.27^{**}	25.83^{ns}	53.16	11.82	5.16	53.158	0.809
PH	117.08^{**}	353.76^{ns}	26.83	7.14	3.66	162.1	0.894
NKPS	42.26^{**}	11.92^{ns}	11.86	8.91	2.44	108.4	0.863
NSPS	3.34^{**}	0.016^{ns}	0.45	3.94	0.48	126.93	0.938
PL	26.4^{**}	19.11^{ns}	4.85	7.94	1.56	125.09	0.910
SL	1.28^{**}	7.27^{**}	0.14	4.47	0.26	100.79	0.941
RLWC	113.37^{ns}	1231.32^{**}	87.91	11.00	6.63	93.97	0.76
LWC	21.84^{ns}	11.77^{ns}	14.87	5.39	2.73	100.25	0.72
LA	25.36^{**}	0.31^{ns}	9.16	21.36	2.14	99.25	0.843
CC	10.90^{*}	5.39^{ns}	5.19	4.47	1.61	133.28	0.841
AL	0.86^{**}	9.86^{**}	0.10	7.98	0.22	3.924	0.956

Key: *, ** & ns, significant at P≤0.05, P≤0.01 and non-significant, respectively; Df= degrees of freedom, CV= Coefficient of variation, SE= Standard Error, Efficiency(%)= Relative efficiency to Randomized complete block design, R^2 = Coefficient of determinations, DH=Days to heading(days), DM=Days to maturity(days), GFP= Grain filling Period(days), PH=Plant height (cm), SL=Spike length (cm), NSPS= No. of spikelet per spike,

NKPS= No. of kernel per spike^{-1}, TKW= Thousand kernel weight (g), BY=Biomass yield g plot^{-1}, HI=Harvest index, ETPM=Effective tiller per m^2, PL=Peduncle Length(cm), GY= Grain yield (t/ha), RLWC=Relative leaf water content (%), LWC= Leaf water content (%), LA= Leaf area(cm^2), CC= Chlorophyll content, and AL=Awn Length(cm)

Correlation of grain yield with other traits

Genotypic and phenotypic correlation coefficient estimates between each pairs of characters are presented in Table 3. At genotypic level, grain yield had positive and significant correlation with biomass yield, yield per plot (r=0.61), harvest index (r =0.5), plant height (r =0.46), days to heading (r= 0.34), number of kernels per spike (r=0.38), days to maturity (r=0.31), number of spikelets per spike (r =0.39), spike length (r =0.22), peduncle length (r=0.22) and awn length (r =0.20) . Similar to the present result, Adhiena (2015) reported high correlation of biomass yield per plot with grain yield, and Yonas (2015) grain yield with biomass yield and harvest index in bread wheat genotypes. Therefore, any improvement of those characters would result in substantial increment on grain yield. Traits such as thousand kernel weight (r=0.12), relative leaf water content (r=0.04), leaf area (r=0.01) and chlorophyll content (r=0.1) had showed positive non-significant correlation with yield per plot, demonstrating that the improvement of these traits would not affect the increment of grain yield. Similar result was also reported by Adhiena (2015). However, grain yield had non-significant and negative genotypic correlation with grain filling period (r=-0.16) and leaf water content (r=-0.01) showed that improvement of these traits would negatively affect the increment of grain yield.

At phenotypic level, grain yield showed positive and highly significant ($P \leq 0.01$) phenotypic correlation with biomass yield (r=0.75), harvest index (r=0.42), plant height (r=0.60), number of kernels per spike (r=0.30), peduncle length (r=0.40), spike length (r=0.31)and awn length (r=0.48), and significant ($P \leq 0.05$) phenotypic correlation with days to heading (r=0.25), days to maturity (r=0.29), and number of spikelets per spike (=0.27). In line with the present results, highly significant and positive phenotypic correlation of grain yield with biomass and harvest index was also reported by Yonas, 2015 and grain yield with biomass yield and tillers per plant was also reported by Adhiena, 2015.
Besides, grain yield had showed positive and non-significant phenotypic correlation ranging from r= 0.02 to 0.18 with grain filling period, effective tiller per meter square, thousand kernel weight, number of spikelets per spike, relative leaf water content, leaf water content and leaf area, showing that improvement of these traits would have an effect but not significant to improve grain yield. Association between any two traits or among various traits is of immense importance to make desired selection of combination of traits (Ahmad et al., 2003).

Table 3 Estimate of genotypic(above diagonal) and phenotypic (below diagonal) correlation coefficients for 18 traits of 36 bread wheat genotypes evaluated at ATARC in 2017 cropping season

Traits	DH	DM	GFP	ETPM	GY	TKW	BY	HI	PH	NKPS	NSPS	PL	SL	RLWC	LWC	LA	CC	AL
DH	1	0.50**	0.35*	0.04	0.34*	0.08	0.54**	-0.19	0.12	0.08	0.33*	-0.04	0.23	0.28	0.1	-0.32	0.2	0.09
DM	046**	1	0.60**	0.17	0.31*	-0.03	0.48	-0.33*	0.22	0.31	0.44**	0.07	0.28	0.26*	0.50**	-0.15	0.02	-0.09
GFP	-0.36**	0.64**	1	0.11	-0.16	-0.09	0.03	-0.19	0.12	0.25	0.16	0.11	0.08	0.05	0.45**	0.12	-0.27	-0.17
EYPM	0.02	0.16	0.1	1	-0.02	0.12	0.16	-0.17	0.27	-0.11	0.07	0.26	0.2	-0.13	-0.014	0.18	0.27	0.2
GY	0.25*	0.29*	0.12	0.03	1	0.13	0.61**	0.5**	0.46**	0.38*	0.39*	0.29*	0.22*	0.04	-0.01	0.01	0.1	0.20*
TKW	0.06	0.06	0.03	0.14	0.17	1	-0.17	0.32*	-0.1	0.2	0.04	0.39*	0.28	0.02	-0.08	-0.47	0.27	-0.44**
BY	0.35	0.51	0.26	0.11	0.75**	0	1	-0.34*	0.64**	0.21	0.21	0.56	0.19	0.19	0.17	0.23	-0.15	0.37*
HI	-0.15	-0.25*	-0.13	-0.07	0.42**	0.24*	0.24*	1	-0.13	0.29	0.07	0.2	0.08	-0.17	-0.23	-0.17	0.25	-0.11
PH	0.17	0.31**	0.19	0.24*	0.60**	0.03	0.70**	0.06	1	0.18	0.07	0.69**	0.31	0.11	0.2	0.17	0.06	0.26
NKPS	0.07	0.23	0.16	-0.02	0.30**	-0.21	0.19	0.22	0.23*	1	0.57**	0.06	0.41*	-0.09	-0.04	0.02	0.02	-0.1
NSPS	0.28*	0.41**	0.18	-0.05	0.27*	0	0.28*	-0.08	0.14	0.50**	1	0.11	0.56	0.04	0.03	-0.37*	0.02	-0.22
PL	-0.03	0.16	0.2	0.26*	0.40**	-0.26*	0.59**	-0.17	0.69**	0.14	-0.01	1	0.8	0.01	0.1	0.57**	-0.16	0.48**
SL	0.19	0.32**	0.16	0.23*	0.31**	0.22	0.28*	0.09	0.35**	0.32**	0.48**	0.14	1	0.11	0.03	0.28	0.41*	0.40*
RLWC	0.27*	0.34**	0.15	0.01	0.18	0.05	0.24*	0.09	0.14	-0.14	0.03	0.05	0.06	1	0.71	-0.26	-0.29	0.28
LWC	0.09	0.40**	0.34**	0.01	0.02	-0.01	0.13	-0.17	0.1	-0.1	-0.01	0.05*	0.01	0.65	1	-0.06	-0.08	0.09
LA	-0.25*	-0.1	0.1	0.19	0.04	-0.36**	0.22	-0.2	0.22	0.13	-0.30**	0.57**	-0.21	-0.24*	-0.04	1	-0.2	0.41*
CC	0.14	0.09	-0.28*	0.16	-0.15	0.15	-0.35**	0.2	-0.24*	-0.09	0.1	-0.27*	0.3	-0.17	-0.03	-0.25	1	-0.48**
AL	0.08	0.13	0.1	0	0.48**	-0.19	0.57**	-0.02	0.45**	0	0.07	0.54**	-0.1	0.34**	0.08	0.37**	-0.46**	1

Key: *and **, significant at P≤0.05 and, P≤0.01, respectively, and the rest are not significant. DH=Days to heading(days), DM=Days to maturity(days), GFP= Grain filling Period(days), PH=Plant height (cm)**,** SL=Spike length (cm),NSPS= No. of spikelet per spike**,** NKPS= No. of kernel per spike^{-1}**,** TKW= Thousand kernel weight (g),BY=Biomass yield g plot^{-1}**,** HI=Harvest index,ETPM=Effective tiller per m^2**,** PL=Peduncle Length(cm), GY= Grain yield (t ha^{-1}**), ,** RLWC=Relative leaf water content (%),LWC= Leaf water content (%),LA= Leaf area(cm^2),CC= Chlorophyll content,AL=Awn Length(cm).

Correlation coefficients among yield related traits

At genotypic level, days to heading had positive and highly significant association with days to maturity (r=0.5), grain filling period (r=0.35), biomass yield (r=54) and number of spikelets per spike (r=0.33). Similar to the present result, presence of highly significant association of days to heading with days to maturity on bread wheat was reported by Adhiena, 2015, Degewione et al. (2013), Ali et al. (2007) and Kumar et al. (2013).

Days to maturity showed significant correlation with traits such as grain filling period (r=0.60), number of spikelets per spike (r=0.44), relative leaf water content (%) (r=0.26) and leaf water content (%) (r=0.50). On the other hand, days to maturity had significant and negative correlation with harvest index (r=-0.33). This result is in close agreement with that of Adhiena (2015).The correlation between biomass yield and plant height was positive significant (r=0.64) and leaf area (cm^2) (r=0.37) .The association between plant height and peduncle length was also high (r=0.69). Grain filling period demonstrated significant association with leaf water content (%) (r=0.45) while, thousand kernel weight had positive and significant correlation with harvest index (r=0.32) and peduncle length (r=0.39). The correlation of plant height with peduncle length was maximum (r=0.69). Number of kernel per $spike^{-1}$ showed significant positive association with number of spikelet per spike (r=0.57) and spike length (r=0.41). Peduncle length had positive and significant correlation with both leaf area (r=0.57) and awn length (r=0.48) and leaf area had positive correlation with awn length (r=0.41).

.

At phenotypic level, days to heading had positive and highly significant association with days to maturity (0.46), number of spikelets per spike and relative leaf water content. Similarly Birhanu et al., (2017) reported that, days to heading showed positive and highly significant association with days to maturity.On the other hand , days to heading had negative and highly significant association with grain filling period (r=-0.36), and leaf area.

Days to maturity had positive and highly significant phenotypic association with grain filling period (r=0.64), plant height (r=0.31), number of spikelets per spike (r=0.41), spike length (r=0.32), relative leaf water content (r=0.34) and leaf water content (r=0.40) and negative and significant association with harvest index. Grain filling period had positive and highly significant phenotypic association with leaf water content (0.34), negative and significant association with days to maturity, chlorophyll content and non significant association with other traits.

Path coefficient analysis

Direct and indirect effects of various characters on grain yield at genotypic level

The results of path coefficient analysis at genotypic level (Table 4) revealed that the biomass yield exerted the highest positive direct effect (1.24) on grain yield followed by harvest index (0.83) and spike length (0.32). Similar results were also reported by Obsa (2014), Ali and Shakor (2012) and Peymaninia et al. (2012). In other cases, the highest negative direct effect was exerted by days to maturity (-0.25) followed by plant height (-0.24), number of spikelets per spike (-0.13), and days to heading (-0.12).

The direct effect of days to heading was negative (-0.12) however it had positive and significant genotypic correlation with grain yield. Similar result was also reported by Berhanu (2004) who reported negative direct effect of days to heading on grain yield. The highest positive indirect effect of days to heading was observed *via* biomass yield (0.67). The direct effect of days to maturity on grain yield per hectare was negative (-0.25), but days to maturity had positive and significant genotypic correlation with grain yield. Majunder et al. (2008), Desalegn (2012), and Degewione et al. (2013) had reported negative direct effect of days to maturity on grain yield. The highest positive indirect effect of days to maturity was scored *via* biomass yield (0.60). Therefore, direct selection through this trait will improve grain yield.
Number of kernels per spike had negative direct effect (-0.06) on grain yield but it had positive and significant genotypic correlation with grain yield. The indirect effect of number of kernels per spike was moderate *via* biomass yield (0.26) and low *via* spike length (0.13). Number of spikelets per spike had negative direct effect (-0.13) on grain yield and it had positive and significant genotypic correlation with grain yield. This is similar to the findings reported by Iftikhar et al. (2012). Biomass yield (1.24) exerted highest and positive direct effect on grain yield and it had positive and highly significant genotypic correlation. The highest indirect effect of biomass yield was exerted *via* plant height (0.80) followed by peduncle length (0.70), days to heading (0.67), days to maturity (0.60) and awn length (0.46), moderate *via* number of kernels per spike(0.26), number of spikelet's per spike (0.26) and spike length. This showed that, the correlation it had with grain yield was largely due to the direct effect. Therefore, direct selection through this trait will improve grain yield. A similar result was also reported by Adhiena (2015).

Harvest index (0.83) exerted high and positive direct effect on grain yield and it had positive and highly significant genotypic correlation with grain yield. The moderate indirect effect of harvest index was exerted *via* number of kernels per spike (0.24), and low indirect effect was exerted *via* peduncle length (0.17).

Plant height had negative direct effect (-0.24) on grain yield,however, it had positive and highly significant genotypic correlation with grain yield. This result contradicted with the results of some authors (Obsa, 2014; Solomon and Hanchinal, 2013), who reported positive direct effect of plant height on grain yield.The highest indirect effect of plant height was exerted *via* biomass yield (0.80), low *via* spike length (0.10) and negligible *via* harvest index (0.03). The peduncle length had negligible direct effect (0.00) on grain yield and it had positive and significant genotypic correlation. The indirect effect of peduncle length was high *via* biomass yield (0.70), moderate *via* spike length (0.25) and low *via* harvest index (0.17). Spike length (0.32) exerted positive direct effect on grain yield and it had shown positive and significant genotypic correlation. This result was in line with the finding of Obsa (2014), Adhiena (2015) and Iftikhar et al. (2012).The indirect effect of spike length was moderate *via* peduncle length (0.25), biomass yield (0.24), low *via* number of spikelet per spike (0.18) and number of kernels per spike (0.13). Residual effects (0.13) indicated that 10 characters included in the study explained 87% of the genotypic level of variability in grain yield. This further elaborate that the choice of yield attributing characters in the study was quite better, even if other characters are also needed to justify grain yield per hectare.

Table 4 Estimates of direct (bold and underlined diagonal) and indirect effects (off diagonal) of different traits on grain yield at genotypic level in 36 bread wheat genotypes tested at ATARC (2017)

Traits	DH	DM	BY	HI	PH	NKPS	NSPS	PL	SL	AL	r_g
DH	**-0.12**	0.01	0.67	-0.16	-0.03	0.00	-0.09	0.00	0.07	0.00	**0.34***
DM	-0.06	**-0.25**	0.60	0.06	-0.05	-0.02	-0.06	0.00	0.09	0.00	**0.31***
BY	-0.06	-0.15	**1.24**	-0.28	-0.16	-0.01	-0.03	0.00	0.06	0.00	**0.61****
HI	0.02	0.04	-0.42	**0.83**	0.03	-0.02	-0.01	0.00	0.03	0.00	**0.50****
PH	-0.01	-0.06	0.80	-0.11	**-0.24**	-0.01	-0.01	0.00	0.10	0.00	**0.46****
NKPS	-0.01	-0.07	0.26	0.24	-0.04	**-0.06**	-0.07	0.00	0.13	0.00	**0.38***
NSPS	-0.04	0.12	0.26	0.06	-0.02	-0.04	**-0.13**	0.00	0.18	0.00	**0.39***
PL	0.00	-0.14	0.70	0.17	-0.17	0.00	-0.01	**0.00**	0.25	-0.51	**0.29***
SL	-0.03	-0.2	0.24	0.07	-0.08	-0.03	-0.07	0.00	**0.32**	0.00	**0.22***
AL	-0.01	0.03	0.46	-0.09	-0.06	0.01	0.00	0.00	-0.13	**-0.01**	**0.20***

Key: Residual effect = 0.13, DH=Days to heading (days), DM=Days to maturity (days), PH=Plant height (cm)**,** SL=Spike length (cm),NSPS= No. of spikelet per spike**,** NKPS= No. of kernel per spike^{-1}**,** BY=Biomass yield g plot^{-1}**,** HI=Harvest index, PL=Peduncle length (cm), AL=Awn length (cm)

Direct and indirect effects of various characters on grain yield at phenotypic level

The results of path coefficient analysis at phenotypic level (Table 5) revealed that, the biomass yield (0.54) exerted highest direct effect on grain yield followed by awn length (0.41), spike length (0.38), days to maturity (0.36) and number of spikelets per spike (0.33) whereas the moderate positive direct effect was exerted by number of kernels per spike and lowest direct effect was exerted by harvest index (0.18) and peduncle length (0.13).. On the other hand, the highest negative direct effect was exerted by plant height (-0.14) followed by days to heading (-0.13). However they had shown positive and significant phenotypic correlation with grain yield. The lower positive indirect effect of days to heading on grain yield was scored *via* days to maturity (0.17), biomass yield (0.19) whereas negligible indirect effect was recorded *via* harvest index, plant height, number of kernel per spike, no of spikelet per spike, peduncle length, spike length, and awn length. Biomass yield (0.54) exerted highest and positive direct effect on grain yield and it had shown positive and highly significant phenotypic correlation with grain yield.

The highest indirect effect of biomass yield was exerted *via* plant height (0.38), peduncle length (0.32), awn length (0.31), moderate value was recorded *via* days to maturity, lower values were recorded *via* days to heading (0.19), grain filling period (0.14), harvest index (0.11), number of kernels per spike (0.10), number of spikelets per spike (0.15) and spike length (0.15). Harvest index (0.18) exerted positive direct effect on grain yield and it had shown positive and highly significant phenotypic correlation. Plant height (-0.14) had negative direct effect on grain yield, and also had positive and highly significant phenotypic correlation. The indirect effect of plant height had high value *via* biomass yield (0.38), low value *via* days to maturity (0.11), spike length (0.13) and awn length (0.18). Residual effects (0.25) indicated that 10 characters included in the study explained 75% of the phenotypic level of variability in grain yield. This further indicates that yield attributing traits chosen in the study were good.

Table 5 Estimates of direct (bold and underlined diagonal) and indirect effects (off diagonal) of different traits on grain yield at phenotypic level in 36 bread wheat genotypes tested at ATARC (2017)

Traits	DH	DM	BY	HI	PH	NKPS	NSPS	PL	SL	AL	Rp
DH	**-0.13**	0.01	0.19	-0.03	0.02	0.01	0.09	0.00	0.07	0.03	0.25*
DM	-0.06	**0.36**	0.28	-0.63	-0.04	0.05	0.14	0.02	0.12	0.05	0.29*
BY	-0.05	-0.23	**0.54**	0.04	-0.10	0.04	0.09	0.08	0.11	0.23	0.75**
HI	0.02	0.09	0.13	**0.18**	-0.01	0.04	-0.03	-0.02	0.03	-0.01	0.42**
PH	0.02	-0.17	0.38	0.01	**-0.14**	0.05	0.05	0.09	0.13	0.18	0.60**
NKPS	-0.01	-0.31	0.10	0.04	-0.03	**0.20**	0.17	0.02	0.12	0.00	0.30**
NSPS	-0.04	-0.45	0.15	-0.01	-0.02	0.10	**0.33**	0.00	0.18	0.03	0.27*
PL	0.00	-0.22	0.32	-0.03	-0.10	0.03	0.00	**0.13**	0.05	0.22	0.40**
SL	-0.03	-0.36	0.15	0.02	-0.05	0.06	0.16	0.02	**0.38**	-0.04	0.31**
AL	-0.01	-0.22	0.31	0.00	-0.06	0.00	0.02	0.07	-0.04	**0.41**	0.48**

Key: Residual effect= 0.25 where, DH=Days to heading (days), DM=Days to maturity (days), PH= Plant height (cm), SL=Spike length (cm), NSPS= No. of spikelet per spike, NKPS= No. of kernel per spike^{-1}, BY=Biomass yield g plot^{-1}, HI=Harvest index, PL=Peduncle Length (cm), AL=Awn length (cm).

Conclusions and recommendations

Grain yield showed positive and highly significant ($P \leq 0.01$ or $P \leq 0.05$) genotypic correlation with biomass yield, harvest index, plant height, days to heading and number of kernels per spike. At phenotypic level, grain yield showed positive and highly significant ($P \leq 0.05$ or $P \leq 0.01$) correlation with biomass yield, harvest index, plant height , number of kernels per spike, peduncle length, spike length, awn length, days to heading ,days to maturity and number of spikelets per spike. Path coefficient analysis at genotypic level revealed that the biomass yield exerted the highest positive direct effect on grain yield followed by harvest index and spike length, where as path analysis at phenotypic level revealed that biomass yield exerted highest direct effect on grain yield followed by awn length, spike length, days to maturity and number of spikelets per spike. Therefore, the present study revealed that, these traits that showed both positive correlation and direct effect on grain yield would help in improving grain yield in bread wheat breeding program serving as selection criteria.

References

Abu Tefera, 2012. Grain and feed annual report. Grain report number: ET1201, Addis Ababa, Ethiopia (Triticum aestivum. L.). Research in Plant Biology, 3(1): 33-36.

AdhienaMesele, 2015. Genetic Variability and Association among Seed Yield and Yield Related Traits in Bread Wheat (Triticum Aestivum L.) Genotypes in Ofla District, Northern Ethiopia. An MSc Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia.

Ahmed, H.M., Khan, B.M., Khan, S., Kisana, N.S. and Laghari, S. 2003. Path coefficient analysis in bread wheat. Asian Journal of Plant Sciences pp. 491-494.

Ali, I.H. and Shakor, E.F. 2012. Heritability, variability, genetic correlation and path analysis for quantitative traits in durum and bread wheat under dry farming conditions. MesoptamiaJournal of Agriculture, 40(4):27-39.

Ali, S., Shah, A.S., Hassnain, A., Shah, Z. and Munir, I. 2007. Genotypic variation for yield and morphological traits in wheat. Sarhad Journal of Agriculture, pp.23.

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

Berhanu Mamo, 2004. Genetic variability and character associations in bread wheat (Triticum aestivum L.) genotypes developed for semiarid areas. An MSc Thesis Presented to the School of Graduate Studies of Alemaya University, Ethiopia.

Birhanu, M., Sentayehu, A., Alemayehu, A., Dargicho, D. and Ermias, A. 2017. Correlation and Path Coefficient Studies of Yield and Yield Associated Traits in Bread Wheat (Triticum Aestivum L.) Genotypes. Advanced Plants Agricultural Research 6(5): 00226.

Clarke, J.M and McCaig, T.N. 1982. Excised leaf water retention capability as an indicator of drought resistance of Triticum genotypes. Canadian Journal of Plant Science, 6(2): 571-578.

Degewione A., Dejene T. and Sharif M., 2013. Genetic variability and traits association in bread wheat (Triticum aestivum L.) genotypes. International Research Journal of Agricultural Sciences, 1(2): 19-29

Desalegn Regasa, 2012. Genotype-Environment interaction and disease severity in bread wheat (Triticum aestivum L.) varieties in Borena and Guji Zone southern Ethiopia. An MSc Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia.

Iftikhar, R., Khaliq, I., Ijaz M. and Rashid, M.A.R. 2012. Association Analysis of Grain Yield in wheat for arthitecturing the desirable plant type. Indian Journal of Agricultural Research, 44(4):267-273.

Kumar , B., Singh, C.M., and Jaiswal K.K. 2013. Genetic variability, association and diversity studies in bread wheat (Triticum aestivum L.). The Bioscan, 8(1):143-147.

Majumder, D.A.N., Shamsuddin, A.K.M., Kabir, M.A. and Hassan, L. 2008. Genetic variability, correlated response and path analysis of yield and yield contributing traits of spring wheat. Journal of Bangladesh Agricultural University, 6 (2): 227 - 234.

MihratuAmanuel. 2014. Evaluation of Bread Wheat (Triticum aestivum L) Genotypes for Heat Tolerance at Middle Hawash, Ethiopia. An MSc Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia

Miller, P.A., Willias, H.F. and Consmtock, R.G. 1958. Estimate of genotypic and environmental variance in cotton and their implication in selection. Agronomy Journal, pp. 126-131.

MoARD (Ministry of Agriculture and Rural Development). 2012. Crop Variety Register. Addis Ababa, Ethiopia.

Mohammed, K.S., Mohammadi, M., Karimizadeh, R. and Mohammadinia. G.2012. Tolerance study on bread wheat genotypes under heat stress. Annals of Annual of Biological Research, 3(10):4786-4789.

Mollasadeghi, V. and Shahryari, R. 2011. Important morphological markers for improvement of yield in bread wheat. Advances Environmental Biology, 5(3): 538 – 542

Moslem, A., Ramezani, H.R., Bavei, V. and Talae, S. 2013. Effectiviness of canopy tempreture and chlorophyll content measurements at different plant growth stages for screening of drought tolerant wheat genotype. American Eurasian Journal of agriculture and environmental science, 13(10): 1325-1338.

Obsa Chimdesa, 2014. Genetic Variability Among Bread Wheat (Triticum Aestivum L.) Genotypes For Growth Characters, Yield And Yield Components In Bore District, Oromia Regional State. An MSc Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia.

Peymaninia, Y., Valizadeh, M., Shahryari, R., Ahmadizadeh, M. and Habibpour, M. 2012. Relationship among morpho-physiological traits in bread wheat against drought stress at presence of a leonardite derived humic fertilizer under greenhouse condition. InternationalResearch Journal of Applied Basic Science 3(4):822-830

Robertson, A. 1959. The sampling variance of the genetic correlation coefficients. Biometrics 15, 469–485.

SAS (Statistical Analysis System). 2002. Version 9.0 SAS Institute Inc Cary NC USA.

Solomon, G. and Hanchinal, R. 2013. Correlation and path analysis in yield and yield components in spring bread wheat (Triticum aestivum L.) genotypes under irrigated condition in Southern India. African Journal of Agricultural Research, 8(24): 3186-3192

Turner, N.C. and Kramer, P.J. 1980. Adaptation of plants to water and high temperature stress. [Proceedings of seminar held from November 6 to 10, 1978, at the Carnegie Institution of Washington, Department of Plant Biology, Stanford, California, USA].

Yonas Shimelis, 2015. Genetic Variability and Association of Grain Yield, Yield Components And Quality Traits In Durum Wheat(Triticum turgidum L. Var. Durum) Genotypes At Hera Liphitu, Southern Ethiopia. An MSc Thesis Presented to the School of Graduate Studies of Haramaya University, Ethiopia.

Grain Yield Stability and Agronomic Performance of Tef Genotypes in high lands of Western Oromia

Girma Chemeda[1]*, Chemeda Birhanu[1], Kebede Desalegn[1], Dagnachew Lule[2], Megersa Debela[1], Gudeta Badada[1], Megersa Kebede[1], Bodana Gudisa[1] and Fufa Anbasa[1]
[1]Bako Agricultural Research Center, P.O. Box 3, Bako, Ethiopia
[2]Oromia Agricultural Research Institute, P.O. Box 81256 Addis Ababa, Ethiopia
*Corresponding author: girmachemeda@yahoo.com

Abstract
Ethiopia is the center of both diversity and origin for Tef Eragrostis tef (Zucc.) Trotter, species and is the major Ethiopian cereal crop grown on about 3 million hectares annually. Thirteen tef genotypes were advanced to regional variety trial and tested in 2016 and 2017 cropping using Randomized Complete Block Design (RCBD) in multi-locations (Shambu, Gedo and Arjo sub sites). Agronomic managements were applied accordingly: 20cm between row spacing,10Kg ha^{-1} seed and 100/50 Kg ha^{-1} DAP/Urea. The combined analysis of variance across the three locations revealed that, there is highly significant ($p<0.01$) difference among the tested genotypes for plant height, panicle length, shoot biomass, lodging % and grain yield. Two best genotypes, viz. DZ-01-256 and DZ-01-1576 were found to be stable and high yielder with grain yield advantage of 37.13% and 25.05%, respectively over the standard check. The genotypes also showed low lodging percent across the tasted locations. The GGE biplot analysis revealed that, DZ-01-256 and DZ-01-1576 candidate genotypes were close to the concentric circle near to average environment axis, which indicates their adaptability across the test locations. Therefore, based on their high grain yield and agronomic performance, genotypes DZ-01-256 and DZ-01-1576 were promoted to variety verification trial to be evaluated for for possible release in these agroecologies.

Keywords: *Eragrostis tef*, Center of diversity, Gluten-free, Stability. ,

Introduction
Tef is C_4 self-pollinated, chasmogamous annual cereal (Ketema, 1997; Assefa K, 2015). It is enormously important crop to Ethiopia, both in terms of production and consumption. In terms of production, tef is the dominant cereal by area coverage and second only to maize in production and consumption (CSA, 2016/17). However, it has been historically neglected compared to other staple grain crops, yields are relatively low (around 1.26 tons ha $^{-1}$), and some farmers under certain conditions sustain high losses which result in reduced quantity of grain available to consumers (Ketema, 1997). Tef is mainly serve as staple food, majority of people are preferring grain of tef for consumptions by making Enjera and local beverage. In a country of over 90 million people, tef accounts for about 15% of all calories consumed (Lester and Bekele, 1981). It is highly nutritious, excellent in amino acid composition, its lysine content is higher than that of all cereals except rice and oats (Jansen *et al*., 1962), it has good mineral content and considerable amount of Iron content when compared with other cereal crops (Mengesha, 1965). Tef is free of protein known as gluten which found in wheat,

barley and rice, and can causes celiac disease by aberrant T-cell (Spaenij *et al*., 2005). The crop is not only important for grain consumption but also its straw is highly nutritious and more palatable for livestock compared to straw of other cereals crop especially during dry season.

Tef is a resilient crop adapted to diverse agro-ecologies, cropping systems, soil types and moisture regimes with reasonable tolerance to both low (especially terminal drought) and high (water logging) moisture stresses. Tef, therefore, is useful as a low-risk crop to farmers due to its high potential of adaptation to climate change and fluctuating environmental conditions (Balsamo *et al.,* 2005). It constitutes about 30% of the total acreage and 20% of the gross yearly grain production of cereals in Ethiopia followed by maize which accounts for about 21% of the acreage and 31% of the overall cereal grain production (CSA, 206/17). Nevertheless, until recently, tef was considered as "orphan" crop: one receiving no international attention regarding research on breeding, agronomic practices or other technologies applicable to smallholder farmers.

The most crucial bottlenecks constraining the productivity and production of tef in Ethiopia are: a) The small size of tef seed poses several problems during sowing, and indirectly during weeding and threshing b) Shattering is also causes significant yield loss in Tef production, c) Lodging is the major constraint to increase yield in tef, while a number of genetic and agronomic factors are involved, d) a limited attention has been paid to mechanization, processing and storage e) low yield potential of farmers' varieties under widespread cultivation; f) biotic stresses such as diseases, weeds and insect pests; iv) abiotic stresses such as drought, soil acidity, and low and high temperatures; g) the culture and labor-intensive nature of the tef husbandry; h) inadequate research investment to the improvement of the crop as it lacks global attention due to localized importance of the crop coupled with limited national attention; and i) weak seed and extension system (Tadasse, 1975, Bekabil *et al*.; 2011, Kebebew *et al.,* 2013).

Breeding methodology employed in tef is generally aimed at the development of high yielding and tolerant variety to diseases and adaptable to different agro-ecologies. Since genetic variation is basis for breeding, the development of tef variety is primarily depends on germplasm enhancement or utilization and conservation of the existed variation or creating variation. This germplam enhancement is through collection and characterization of indigenous germplasm, intra- and inter specific crossing and induced mutation techniques (Ketema, 1997). As tef is native to Ethiopia, the source of genetic variation for effective breeding is limited to landrace collections and crossing of selected parents from the landraces with little or no opportunities of introduction and acquisition of breeding materials and other germplasm from foreign sources (Lester and Bekele, 1981; Ketema, 1997). Therefore, the objective of this experiment was to evaluate and release high yielding, lodging and diseases tolerant tef varieties from landrace collections for tef growing areas of Western parts of the country

Materials and Methods

Thirteen tef genotypes developed through selection were tested under regional variety trial to evaluated in multi-location sites so as to see their adaptability, stability and yield potential in the main season during 2016-2017 cropping seasons. The experiment was conducted at Shambu, Gedo and Arjo sub site using Randomized Complete Block Design with three replications on a plot size of 2m x 2m ($4m^2$) each with 0.2m of row spacing. The distance between block was 1.5m and between plots was 1.0m. Fertilizer rate of 100/50 kg DAP/UREA at planting and 10 kg ha^{-1} of seed rate was used. Other agronomic practices were applied uniformly as required.

Data on days to emergence, days to maturity, panicle length, plant height, shoot biomass, lodging %, effective tillers, stand %, grain yield per plot were collected and subjected to statistical analysis using SAS statistical software.

Results and Discussions

The combined analysis of variance across the three locations revealed highly significant ($p<0.01$) difference among genotypes for plant height, panicle length, lodging % and grain yield-kg ha^{-1} and significant differences ($p<0.05$) for maturity date and shoot biomass (Table 1). Accession DZ-01-256 gave the highest grain yield (2309.22kg ha^{-1}) followed by accession DZ-01-1576 (2105.72 ha^{-1}). The standard check variety Kena gave 1683.92 kg ha^{-1}. The two candidate genotypes had yield advantage of 37.13% and 25.05%, over the standard check respectively (Table 1). In agreement with this finding; previous studies of Genotype x environment interaction on 22 tef genotypes at four locations in Southern regions of Ethiopia have indicated significant variations in grain yield for the tested genotypes (Ashamo and Belay, 2012). Similar study on phenotypic diversity in tef germplasm in a pot experiment using 124 single panicle sample collection showed substantial variability for traits such as plant height, panicle length, maturity, seed color, seed yield, lodging and panicle type (Malak-Haile *et al*.; 1965).

The combined analysis of variance for biomass depicted significant ($P<0.05$) difference among the tested genotypes. Accession DZ-01-256 gave the highest shoot biomass (15.80 ton ha^{-1}) followed by accession DZ-01-1118 (12.33 ton ha^{-1}). The standard check Kena gave a shoot biomass of 9.33 ton ha^{-1}.

The mean performance for lodging percent revealed that low percent for genotype DZ-01-256 (31.33%) followed by genotype DZ-01-383 (31.67%) and the standard check Kena showed (86%). The comparison of GGE biplot indicated that genotypes DZ-01-256 and DZ-01-1576 found to be stable and high yielder across the tasted locations of highlands of Western parts of the country with grain yield advantage of 37.13% and 25.05%, respectively over the check.

The GGE biplot analysis revealed that DZ-01-256 and DZ-01-1576 candidate genotypes were close to the concentric circle which indicates their potential wide adaptability across the three locations (Figure 1). Therefore, genotypes DZ-01-256 and DZ-01-1576 were promoted to Variety Verification Trial for evaluation and possible release.

Table 1. Mean grain yield(kg/ha) of tef genotypes across locations and years

Genotypes	Shambu		Gedo		Arjo			Ad.over
	2016/17	2017/18	2016/17	2017/18	2016/17	2017/18	Mean	check
DZ-01-1122	1800	1660	1822.33	1849.17	1618	1530.83	1713.39	
DZ-01-512	1840	1815	1957.67	1877.5	1609.33	1681.5	1796.83	
Local check	1690	1538.33	1963.67	1548.67	1568.67	1477.33	1631.11	
DZ-01-2014	1786.33	1689.17	1956.67	1643.33	1402.67	1495.67	1662.31	
Kena(Standard check)	1694.17	1650.83	1822.00	1856.5	1517	1563	1683.92	
DZ-01-61	1745	1883.33	1840.33	1646.67	1757.67	1845	1786.33	
DZ-01-513	2170	2166.67	1846.67	2028.17	1982	1895	2014.75	**19.65%**
DZ-01-1715	1593	1634.17	1865.33	1522.5	1694.67	1767.5	1679.53	
DZ-01-1108	1821.5	1909.17	1769.67	1719.17	1642.67	1544.167	1734.39	
DZ-01-1576	2267.5	2461.5	1990.17	2079.3	1893.33	1942.5	2105.72	**25.05%**
DZ-01-383	1960	1781.67	1765.83	1792.5	1702.67	1850.833	1808.92	
DZ-01-256	2450	2615	2307	2219.17	2036	2228.167	2309.22	**37.13%**
DZ-01-1118	1810	1869	1660	1680.83	1237	1654.167	1651.83	
Mean	**1755.07**	**1897.99**	**1889.79**	**1789.49**	**1306.49**	**1721.21**	**1813.71**	
CV%	**9.24**	**17.3**	**13.7**	**11.5**	**11.3**	**18.7**		
F test	**	**	**	**	**	**		
LSD 0.05	**240**	**224**	**178**	**167**	**174**	**189**		

Table 2. Mean grain yield and agronomic performance of 13 tef genotypes tested in regional variety trial combined over three locations for 2016/17 and 2017/18

Entry No.	Genotypes	PH(cm)	MD	PL(cm)	LOD%	ET	SBM(ton ha^{-1})	GY kg ha^{-1}
1	DZ-01-1122	88.33	116.67	28.27	43.33	6.20	10.60	1713.39
2	DZ-01-512	90.00	117.67	25.33	31.67	7.20	11.33	1796.83
3	Local	74.33	117.67	22.00	86.67	6.80	10.17	1631.11
4	DZ-01-2014	88.33	120.00	26.00	31.67	6.80	9.33	1662.31
5	Kena	88.00	117.67	23.73	86.00	6.13	9.33	1683.92
6	DZ-01-61	81.67	118.00	25.47	43.33	7.07	10.75	1786.33
7	DZ-01-513	96.67	117.00	30.60	31.67	6.07	10.50	2014.75
8	DZ-01-1715	81.00	119.33	23.07	33.33	6.4	9.00	1679.53
9	DZ-01-1108	92.00	120.67	30.87	35.00	6.93	10.16	1734.39
10	DZ-01-1576	86.67	118.67	31.07	40.00	6.47	9.30	2105.72
11	DZ-01-383	86.00	118.00	29.6	31.67	6.67	11.08	1808.92
12	DZ-01-256	106.00	119.67	37.53	31.33	6.87	13.80	2309.22
13	DZ-01-1118	78.00	119.67	22.13	38.33	6.47	12.33	1651.83
	Mean	**87.46**	**118.51**	**27.36**	**44.49**	**6.62**	**8.41**	**1813.71**
	CV %	**9.09**	**11.19**	**10.35**	**23.30**	**13.12**	**11.82**	**13.24**
	F test	**	*	**	**	**NS**	*	**
	LSD	1.34	**2.38**	**4.77**	**9.85**	**1.46**	**0.44**	**2.4**

Note: PH = plant height (cm), MD = maturity date, PL = panicle length (cm), LOD =lodging %, ET = effective tiller, SBM (kg) = shoot bio-mass, GY = grain yield (kg)

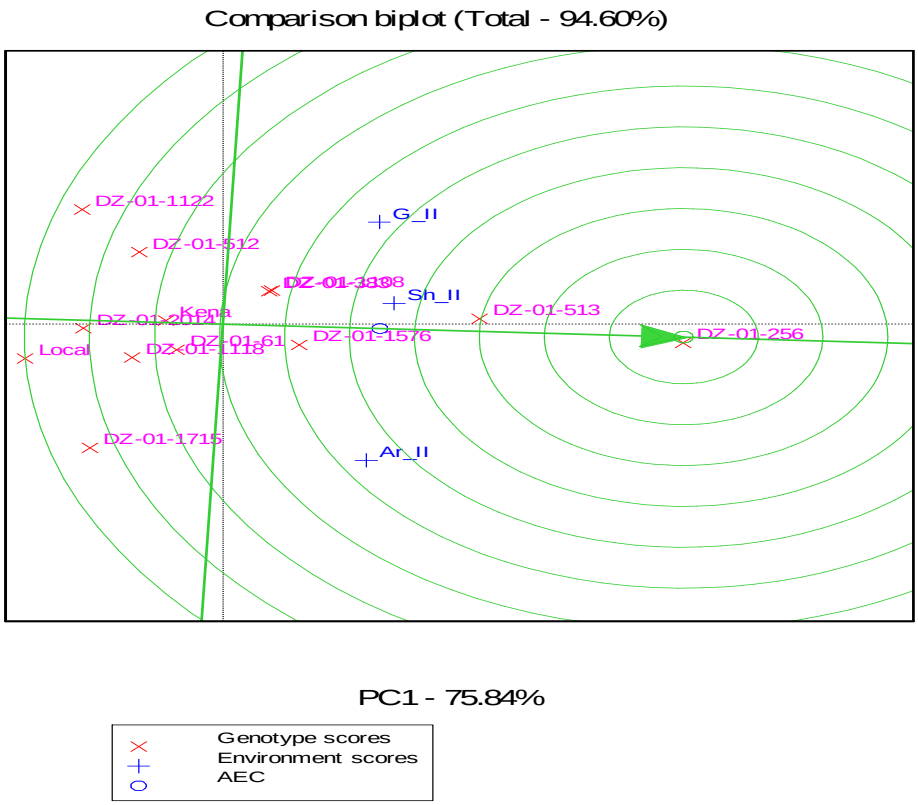


Fig.1 GGE bi-plot for stability test among tef genotypes

References

Assefa K, Cannarozzi G, Girma D, Kamies R, Chanyalew S, Plaza-Wüthrich S, Blösch R, Rindisbacher A, Rafudeen S and Tadele Z (2015) Genetic diversity in tef [Eragrostis tef (Zucc.) Trotter]. Front. Plant Sci. 6:177. doi: 10.3389/fpls.2015.00177Assefa K, Yu JK, Zeid M, Belay G, Tefera H, et al. (2011) Breeding tef [Eragrostis tef (Zucc.) Trotter]: conventional and molecular approaches. Plant Breeding 130: 1-9.

Bekabil F, Behute B, Simons R, Berhe T (2011) Strengthening Tef Value Chain: In Tef Improvement: Achievements and Prospects. Proceedings of Second International Workshop. November 7-9, 2011. Dreamland Hotel and Resort, Debre-Zeit, Ethiopia.

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

CSA (2016) Agricultural Sample Survey Statistical Bulletin Report on Area and Production of major crops. Addis Ababa, Ethiopia.

Jansen GR, Dimaio LR, Hause NL (1962) Amino acid composition and lysine supplementation of Teff Agric Food Chem 10: 62-64.

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

Ketema S (1997) Tef, Eragrostis tef (Zucc.) Trotter: Promoting the conservation and use of underutilized and neglected crops. International Plant Genetic Resources Institute 12.

Lester RN, Bekele E (1981) Amino acid composition of the Cereal Tef and Related species of Eragrostis (Gramineae). Amercan Association of Cereal Chemists, Inc 58: 113-115.

Mengesha M (1965) Chemical composition of Teff (Eragrostis tef) compared with that of wheat, barley and grain sorghum. Econ Bot 19: 268-273.

Spaenij-Dekking L, Kooy-Winkelaar Y, Koning F (2005) The Ethiopian Video S1 Root lodging of teff. cereal tef in celiac disease. New England Journal of Medicine 353: 1748-1749.

Tadasse E (1975) Tef (Eragrostis tef) cultivars: morphology and classification. Experimental Bulletin 66, Addis Ababa University, College of Agriculture, Ethiopia.

Grain Yield Stability Analysis of Recombinant Inbred Lines of Sesame in Western Oromia, Ethiopia

Chemeda Daba[1] and Solomon Bekele[1]
[1]Bako Agricultural Research Center P. O. Box 03, Bako, West Shewa, Ethiopia
Corresponding author:chemeda2012@gmail.com

Abstract
Evaluation of crop performances across different environments provides useful information on their adaptation and stability. The objective of the study was to assess stability and genotype x environment interaction effects on yield of sesame inbred lines. The treatment consisted of fifteen sesame genotypes grown in seven locations in western Oromia, Ethiopia during the 2017 main cropping season. The experiment was laid out in a randomized complete block design with three replications. The grain yield data were analysed using the methods of AMMI and GGE-biplot. For grain yield, G3 (EW002 x Obsa22-1) was the best followed by G8 (EW002 x Dicho 5-3) and G5 (Obsa x Dicho19-3). Genotype, G8 was the best stable genotype followed by G3 whereas G5 was adaptable to high potential environments. Genotype G1 (EW002 x Obsa 1-1) G2 (EW002 x Obsa22-1) and G13 (Dicho x EW006-9-1) were identified as potential for their high yield and disease resistance and they could be used for future sesame breeding program. Therefore, the current study identified three sesame genotypes for their high yield and stability and could be recommended for variety verification trial and possible release release for the studied environments and similary agroecologies.
Key words: AMMI, GGE- biplot, Sesame, Stability, Yield

Introduction
Evaluation of genotypic performances at a number of environments provides useful information on genotypic adaptation and stability (Crossa, 1990; Ceccarelli, 1996). Such a strategy provides the means for exploitation of genotype by environment interaction (GEI) as an advantage rather than considering it as a hindrance to crop variety development. Analysing the magnitude of GEI by proper techniques rather than neglecting them is useful for exploiting the opportunities and or limiting the disadvantages that these effects may cause ((Eisemann *et al*.,1990). Several statistical models have been proposed for studying the GEI effect and exploiting its advantage. The one mostly used statistical analyses is the additive main effects and multiplicative interaction (AMMI) model, the genotype main effect, and the genotype x environment interaction effect (GGE) model (Gauch, 2006).

AMMI model combines the analysis of variance, genotype and environment main effects with principal component analysis of GEI into a unified approach (Gauch and Zobel, 1996). However, the GGE biplot method, which is always close to the best AMMI model in most cases (Ma *et al*. 2004), was developed to use some of the functions of these methods jointly. Purchase et al. (2000) developed a quantitative stability value known as the AMMI stability value (ASV) to rank genotypes through the AMMI model. The developed ASV was considered to be the most appropriate single method to describe the stability of genotypes. . Gruneberg *et al*. (2005) showed that AMMI, as a multivariate tool was highly effective for the analysis of multi-environment trials (MET).

The GGE-biplot model provides breeders with a more complete and visual evaluation of all aspects of the data by creating a biplot that simultaneously represents mean performance and stability as well as identifying mega environments (Yan and Kang, 2003; Ding *et al*., 2007). For the research purpose of gaining accuracy AMMI and GGE are still equally useful (Gauch *et al*., 2008). Sesame (*Sesamum indicum* L.) is widely produced crop in Ethiopia. Breeding sesame to develop high-yielding varieties for the western part of the country was started in 2005. As a result, until the year 2017, four sesame varieties were released for the area and a number of recombinant inbred lines were developed. The information on GEI of these lines is required to recommend for production before releasing as a variety. Therefore, the objective of the study was to assess stability and genotype x environment interaction effects on yield of sesame in sesame inbred lines.

Materials and Methods

The planting materials consisted of fifteen sesame genotypes. The genotypes comprised of two released sesame varieties for western Ethiopia and thirteen recombinant inbred lines developed through hybridization (Table 1). These lines were selected based on their high yield, good agronomic characters and disease resistance/tolerance in western Ethiopia. The genotypes were grown in seven locations in 2017 main cropping season (Table 2). The genotypes and environments were given codes for ease of data handling and analysis (Table 3). The genotypes were planted from June 16 to 23 at different location in regional variety trial. The experiment was laid out in a randomized complete block design with three replications. The seed was drilled in each row at seeding rate of 5 kg ha^{-1} in plot consisting of 4 rows of 4 meter length with the spacing of 40 cm between rows. At planting, NPS (blended fertilizer) and 30 days after planting, Urea were applied at rate of 100 and 50 kg ha^{-1}, respectively. After planting, thinning was done to 10 cm spacing between plants. Hand weeding was done four times at a fort nightly interval starting two weeks after planting. The genotypes were harvested in early October. Seed yield per plot of the four rows were taken and reported in kg ha^{-1}.

Table 1. Description of 15 sesame genotypes evaluated in 7 locations in year 2017

No	Genotype	Category	**DF**	**DM**	**PH**	**BH**	**BP**	**CPP**
1	EW002 x Obsa 1-1	Inbred line	61	118.6	108.3	31.6	5.1	69.7
2	EW002 x Obsa16-1	Inbred line	59	119.7	107.7	30.9	5.6	64.2
3	EW002 x Obsa22-1	Inbred line	59	117.7	106.5	33.7	5.2	63.4
4	Obsa x Dicho19-11	In bred line	59	119.8	109.4	33.2	5.5	59.3
5	Obsa x Dicho19-3	Inbred line	60	119.5	108.0	37.7	5.1	57.0
6	OBSA x Dicho 27-1	Inbred line	58	117.3	108.3	38.9	5.1	53.7
7	EW002 x Dicho 1-1	Inbred line	60	117.1	101.6	31.1	5.4	77.0
8	EW002 x Dicho 5-3	In bred line	59	121.2	114.4	36.0	4.9	62.1
9	EW002 x Dicho 12-1	Inbred line	59	120.5	109.8	36.7	5.3	65.0
10	EW002 x Dicho 17-2	Inbred line	59	118.1	105.1	31.5	5.9	63.4
11	EW002 x EW006 (3-1)	Inbred line	59	118.9	106.1	30.7	5.6	64.6
12	Dicho x EW006 (9-1)	Inbred line	59	120.2	110.9	30.7	5.7	66.1
13	Dicho x EW006 (9-1)	Inbred line	59	122.0	113.5	36.8	5.0	64.8
14	Chalasa	Standard check	59	122.8	110.7	36.6	4.9	56.4
15	Walin	Standard check	55	120.2	106.4	36.9	4.7	61.4

DF=days to flowering, DM=days to maturity, PH=plant height, BH=branch height, BP=branches per plant, CPP=capsules per plant

Table 2. Description of test locations used for evaluation of sesame genotypes in East Wellega Zone

Location	Soil type	Altitude (masl)	District
Angar	Humic nitosol	1355	Gida- Ayana
Lugo	Humic nitosol	1386	Guto- Gida
Uke	Humic nitosol	1383	Guto- Gida
Wama	Humic nitosol	1436	Sibu-Sire
Bako	Nitosol	1597	Gobu –Sayo
Billo-Boshe	Humic nitosol	1635	Bilo-Boshe
Boneya	Nitosol	1610	Wayu –Tuka

Table 3. Genotypes and environments and their codes

No	Genotype	Genotype code	Environments	Env. code
1	EW002 x Obsa 1-1	G1	Angar	E1
2	EW002 x Obsa16-1	G2	Bako	E2
3	EW002 x Obsa22-1	G3	Boneya	E3
4	Obsa x Dicho19-11	G4	Billo-boshe	E4
5	Obsa x Dicho19-3	G5	Lugo	E5
6	OBSA x Dicho 27-1	G6	Uke	E6
7	EW002 x Dicho 1-1	G7	Wama	E7
8	EW002 x Dicho 5-3	G8		
9	EW002 x Dicho 12-1	G9		
10	EW002 x Dicho 17-2	G10		
11	EW002 x EW006 (3-1)	G11		
12	Dicho x EW006 (9-1)	G12		
13	Dicho x EW006 (9-1)	G13		
14	Chalasa (standard check)	G14		
15	Walin (standard check)	G15		

The AMMI model was used to estimate the magnitude of G x E interaction. The AMMI analysis and the IPCA were performed using Genstat 15th edition. The AMMI's stability value (ASV) was calculated to rank genotypes in terms of yield stability using the formula suggested by Purchase *et al*. (2000) as shown below.

AMMI Stability Value:

$$(ASV) = \sqrt{\left[\left(\frac{IPCA1SS}{IPCA2SS}\right)(IPCA1Score)\right]2 + (IPCA2Score)2}$$

Where: SS= sum of squares, IPCA1= Interaction principal component analysis axis one, IPCA2= Interaction principal component analysis axis two.

In general, an absolute stability value (ASV) was determined using a procedure that combines IPCA1 and IPCA 2. The GGE-biplot shows the first two principal components (PC1 and PC2, also referred to as primary and secondary effects, respectively) derived from subjecting environmental centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al*., 2000). For raw data of seed yield, biplots of the first two principal components were constructed using Genstat 15th edition and used to illustrate the relation among genotypes.

Results and Discussions

AMMI Analysis

The AMMI analyses of variance showed that, sesame grain yields were significantly affected by Environment, which explained 47.3% of the total (G + E + GEI) variation, whereas Genotype and GEI, which were significant ($P < 0.01$), accounted for 23.1% and 29.5%, respectively (Table 4).The significant effect of GEI on seed yield implied differential responses of the genotypes across the environments. According to Gauch and Zobel (1996, 1997), in normal multi-environment yield trials, environment accounts for about 80% of the total variation, while G and GEI each accounts for about 10%, which is in contrast to the results of the present study. Significant GEI complicates selection since the variety with the highest mean yield may not be the best genetically (Signor *et al*., 2001).

The magnitude of GEI sum of squares was close to the variation due to genotype as a main effect. This is in disagreement with the results of Yan and Kang (2003), who indicated that large GEI, relative to genotype effect suggests the possible existence of different mega-environments with different top-yielding genotypes. It was reported that multi-environment trial data may constitute a mixture of crossover and non-crossover types of GEI. Crossover type of GEI indicates change in the yield ranking of genotypes across environments and the non-crossover types of GEI shows a constant yield ranking of genotypes across environments (Matus-Cadiz *et al*., 2003).

The AMMI analysis partitioned the sum of squares of GEI into two interaction principal component axes (IPCA) and they were statistically significant. In this line, Zobel *et al.* (1988) proposed that two interaction principal component axes for AMMI model were sufficient for a predictive model. The results from the AMMI model showed that, the first IPCA captured 47.8% of the interaction sum of squares while the second explained 25.5% of the GEI sum of squares, respectively. The sum of squares for the two IPCAs cumulatively contributed to 73.3 % of the total GEI. In general, the model chosen by predictive criterion consists of two IPCA (Kaya *et al.*, 2002).

Table 4. Analysis of variance (ANOVA) for yield in different sesame genotypes tested across location in year 2017 main cropping season

Source	df	SS	MS	Total variation (%)	Variation% GxE explained	Cumulative Explained
Total	314	16947663	53973			
Treatments	104	10461132	100588			
Genotypes (G)	14	2423503	173107**	23.2		
Environments (E)	6	4949602	824934**	47.3		
Block	14	1148624	82045**			
Interactions (GEI)	84	3088027	36762**	29.5		
IPCA	19	1477971	77788**		47.8	47.8
IPCA	17	787655	46333*		25.5	73.3
Residuals	48	822401	17133			
Error	196	5337906	27234			

Mean yield (kg ha^{-1}), IPCA 1and 2 scores, ASV and ranks of 15 sesame genotypes based on mean grain yield and ASV values were presented in Table 5. For mean grain yield, G3 was ranked first followed by G8 and G5. The genotype G8 and G13 showed the lowest absolute scores for the IPCA1 and they were the most stable followed by G12. Genotype8 is the best one for its both high yield and stability. However, based on grain yield performance, G13 and G12 were ranked 5^{th} and 14^{th}, respectively. Genotype G1 and G10 followed by G5 were the top three with maximum absolute value of IPCA 1, indicating that they have high adaptability to specific environment. Among these three genotypes, only G5 has high grain yield that can be recommended to specific environment. Purchase (1997) reported that the IPCA scores of genotypes in the AMMI analysis are an indication of the stability of a genotype over environments. The greater the absolute value IPCA scores, the more specifically adapted a genotype is to a particular environment. The more IPCA2 scores approximate to zero, the more stable or adapted the genotype is over all environments sampled (Gauch and Zobel, 1996; Ferney *et al*., 2006). The more the IPCA score approximates to zero in absolute terms, the more stable or adapted the genotype is over all the environments sampled (Alberts, 2004). When IPCA2 was considered, G1 was the most stable followed by G14 and G15. Stability rank of genotypes varied for IPC1 to IPC2 indicating that the two IPCA have different values and meanings. Therefore, the other option is to calculate ASV to get estimated value between IPCA1 and IPCA2 scores as ASV was reported to produce a balance measurement between the two IPCA scores (Purchase, 1997).

Based on AMMI stability value (ASV) genotype G8, G12 and G7 were the best stable with the rank of first to third, respectively. Although G12 and G7 were the second and third stable genotype for ASV, they were ranked 14^{th} and 11^{th} for mean grain yield. As per the value of ASV the most unstable genotypes were G1, G10 and G5. It is to note that a genotype with low ASV values is considered more stable than a genotype with high ASV (Purchase, 1997).

Table 5. Mean yield (kg ha^{-1}), rank, IPCA 1and 2 scores,ASV and rank based on ASV of 15 sesame genotypes tested across seven locations of western Ethiopia during 2017

No	Genotype	Mean	Rank	IPCA[1]	IPCA[2]	ASV	Rank
1	EW002 x Obsa 1-1	670	6	-12.8874	0.0780	24.18	15
2	EW002 x Obsa16-1	638	7	3.6213	6.1776	9.2	5
3	EW002 x Obsa22-1	795	1	-5.7453	-6.9000	12.8	7
4	Obsa x Dicho19-11	584	10	-2.7994	-7.4304	9.09	4
5	Obsa x Dicho19-3	722	3	-9.2070	3.396	17.60	13
6	OBSA x Dicho 27-1	589	9	-4.7275	-9.7589	13.18	8
7	EW002 x Dicho 1-1	541	11	3.9073	2.9778	7.90	3
8	EW002 x Dicho 5-3	770	2	-1.7884	5.4860	6.43	1
9	EW002 x Dicho 12-1	527	13	7.3069	2.2387	13.80	9
10	EW002 x Dicho 17-2	541	11	11.1929	-8.7391	22.74	14
11	EW002 x EW006 (3-1)	622	8	6.9402	-3.6976	13.53	10
12	Dicho x EW006 (9-1)	520	14	2.2064	6.2204	7.40	2
13	Dicho x EW006 (9-1)	678	5	1.8429	9.3597	9.54	6
14	Chalasa (standard check)	519	12	7.8515	-1.1429	14.75	11
15	Walin (standard check)	690	4	-7.7144	1.7348	14.57	12

Mean seed yield (kg ha^{-1}) of 15 sesame genotypes tested in seven environments is shown in Table 6. For a crop to perform well, location mean can easily define whether the environment is favorable or not. The location mean observed ranged from the lowest of 453 (kg ha^{-1}) at E4 (Bilo-boshe) to the highest 794 kg ha^{-1} at E5 (Lugo) with a grand mean of 627 kg ha^{-1}. This indicated that Lugo was the best location for its high grain yield. At this location, G8 gave the maximum mean yield (1063kg ha^{-1}) while the minimum yield (600kg ha^{-1}) was recorded by G6. The mean of location showed that E1, E5 and E6 were rich; E7 and E3 were moderate and E2 and E4 were poor.

Genotype 3 (G3) was ranked first followed by G8 and G5 with mean grain yield of 795, 770 and 722 kg ha^{-1}, respectively. Genotype, G3 gave maximum grain yield at three locations viz., E1, E2 and E4 while genotype G8 showed maximum yield at E3 and E5 and G5 at E1. Genotypes G3, G8 and G5 being the top three high yielding and they were selected as candidate and were planted in variety verification trial in year 2018 main season. Genotype G1, G2 and G13 had high yield potential. Chemeda *et al*. (2017) had reported that the parents of these crosses had positive and high GCA for grain yield. Therefore, these lines have high potential that can be used as parent in future for sesame breeding.

In the present study, no genotype was ranked first at all locations indicating that there was rank changing of the genotypes. This differential yield ranking of the genotypes across the environments revealed that the G x E interaction effect was a crossover type (Matus-Cadiz *et al*., 2003). Based on mean seed yield, IPCA and ASV values, G8 was the best high yielding and stable genotype followed by G3. Genotype 5 was the third ranking genotype for its mean yield with specific adaptation to high potential environment. Genotype G1, G2 and G13 had mean grain yield more than the grand mean of which G1 was adapted to high potential environment.

Table 6. Mean seed yield (kgha^{-1}) of 15 sesame genotypes tested in seven environments

Genotype	**E1**	**E2**	**E3**	**E4**	**E5**	**E6**	**E7**	**Mean**
G1	906	668	453	340	734	993	598	670
G2	728	505	494	413	908	644	776	638
G3	1042	682	666	644	778	957	801	795
G4	646	435	570	511	627	795	504	584
G5	1040	576	575	403	930	878	651	722
G6	839	358	600	468	600	738	519	589
G7	569	444	538	311	720	558	647	541
G8	867	603	666	522	1063	908	758	770
G9	614	316	512	327	743	466	712	527
G10	619	278	481	628	640	436	706	541
G11	617	363	570	513	734	724	834	622
G12	450	444	313	373	809	678	576	520
G13	769	624	621	373	980	647	734	678
G14	527	390	445	514	732	503	520	519
G15	946	540	574	448	909	845	569	690
Mean	**745**	**482**	**539**	**453**	**794**	**718**	**660**	627

Comparison of Genotypes with GGE biplot

In the present study, genotype G8 (EW002 x Dicho 5-3) a high yielder located in concentric circle was a stable genotype for seed yield followed by G5 and G3 which are located in the next concentric circle. The low yielding genotype G12, G14, G10, G9, G7, G4 and G6 are undesirable because they are far away from the ideal genotype (Figure 1). An ideal genotype is a one that has both high mean seed yield and high stability; it is defined as a one that is the highest yielder in all test environments (Farshadfar *et al*., 2012). Although an ideal genotype may not exist in reality, it can be used as a reference for evaluating genotypes (Mitrovic *et al*., 2012). A genotype is desirable if it is closer to the ideal genotype (Yan and Hunt, 2002).

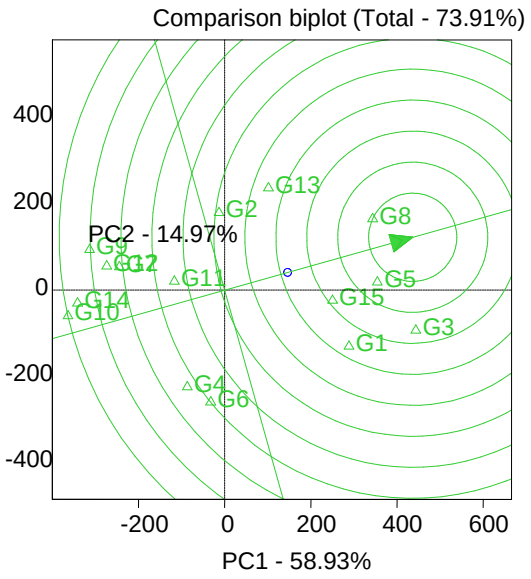


Figure.1. GGE–biplot based on genotype focused scaling for comparison of the genotypes

Conclusions and recommendations

The result of this study showed the presence and the type of GE interactions. Genotype G3 (EW002 x Obsa22-1) was the best for its grain yield followed by G8 (EW002 x Dicho 5-3) and G5 (Obsa x Dicho19-3) .Among the studied genotypes, G8 was the most stable for grain yield followed by G3.On the other hand, G5 is adapted to high potential environment. Thus, G8, G3 and G5 could be selected to be evaluated in verification trial for possible release.Genotypes such as G1 (EW002 x Obsa 1-1), G2 (EW002 x Obsa16-1) and G13 (Dicho x EW006 (9-1) were genotypes with high yielding potential that can be used as parents in future breeding programs. Environments viz., E1 (Angar), E5 (Lugo) and E6 (Uke) were identified as favorable test environments for sesame production.

References

Alberts, M. J. A. 2004. A comparison of statistical methods to describe Genotype x Environment interaction and yield stability in multi-location maize trials. MSc. Thesis. Department of Plant Sciences/Plant Breeding, University of the Free State, Bloemfontein, South Africa.

Ceccarelli, S. 1996. Positive interpretation of genotype by environment interaction in relation to sustainability and biodiversity. In: Cooper, M. and Hammer. G. L. (Eds) Plant Adaptation and Crop improvement .CAB International Wallingford, UK. pp. 467-486.

Chemeda Daba, Amsalu Ayana, Habtamu Zeleke and Aduna Wakjira.2017. Combining Ability for Seed Yield and Agronomic Traits of Sesame Genotypes (Sesamum indicum L.) from Western Ethiopia. Ethiop. J. Crop Sci,. 5(1):61-77

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

Ding, M., Tier, B. and Yan, W. 2007. Application of GGE- biplot analysis to evaluate genotypes (G) environment (E) and G x E interaction on P.radiata. Case study. Australian Forest Genetics Conference, 11-14 April 2007, the old wool store, Hobart, Tasmania, Australia.

Eisemann ,R.C. Cooper, M. and Woodruff, D.R. 1990.Beyond the analytical methodology , better interpretation and exploitation of GE interaction in Plant Breeding. In: Kang ,M.S. (ed)Genotype-by-Environment Interaction and Plant Breeding.Louisiana State University Agricultural Research. Baton Rouge, Louisiana, pp.108-177.

Farshadfar, E., Mohammadi, R., Aghaee, M. and Vaisi, Z. 2012. GGE-biplot analysis of genotype x environment interaction in wheat-barley disomic addition lines. Australian Journal of Crop Science, 6 (6): 1074- 1079.

Ferney G. B., Alexei, M. and Aigul, A. 2006. Evaluation of grain yield stability, in spring wheat from Kazakhstan and Siberia. Journal of Central European Agriculture, 7: 649-660.

Gauch, H. G. and Zobel, R. W. 1996. AMMI analysis of yield trials. In: Genotype by environment interaction. Kang & Gauch (Eds). CRC Press, Boca Raton, New York.

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

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

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.

Gruneberg W. J., Manrique K., Zhang, D. and Hermann, M. 2005. Genotype x environment interactions for a diverse set of sweet potato clones evaluated across varying ecographic conditions in Peru. Crop Science, 45: 2160-2171.

Kaya Y. K., Palta, E., Taner, S. 2002. Additive Main Effects and Multiplicative Interactions Analysis of Yield Performances in Bread Wheat Genotypes

Ma, B. L., Yan, W., Dwyer, L. M., Frégeau-Reid, J., Voldeng, H. D., Dion, Y. and Nass, H. 2004. Graphic analysis of genotype, environment, nitrogen fertilizer, and their interactions on spring wheat yield. Agronomy Journal, 96:169-180.

Matus-Cadiz, M. A., Hucl, P., Perron, C. E., and Tyler, R. T. 2003. Genotype x environment interaction for grain color in hard white spring wheat. Crop Science, 43: 219-226.

Mitrovic, B., Stanisavljevi, D., Treski, S., Stojakovic, M., Ivanovic, M., Bekavac G., Rajkovic, M. 2012. Evaluation of experimental Maize hybrids tested in Multi-location trials using AMMI and GGE biplot analysis. Turkish Journal of Field Crops., 17 (1): 35-40.

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

Purchase, J. L., Hatting, H. and Van Deventer, C. S. 2000. Genotype x Environment interaction of winter wheat (Triticum aestivum L.) in South Africa: II. Stability analysis of yield performance. South African Journal of Plant and Soil nutrition, 17: 101-107.

Signor, C. E., Dousse, S., Lorgeous, J., Denis, J. B., Bonhomme, R., Carolo P. and Charcosset, A. 2001. Interpretation of genotype x environment interactions for early maize hybrids over 12 years. Crop Science, 41: 663-669.

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

Yan, W. and Kang, M. S. 2003. GGE biplot analysis: a graphical tool for breeders, In: Kang M.S. (Ed.) Geneticists, and Agronomist. CRC Press, Boca Raton, FL, pp. 63-88.

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

Zobel, R. W., Wright, M. J. and Gauch, H. G. 1988. Statistical analysis of yield trial. Agronomy Journal, 80: 388-393.

Heritability and genetic advance for Quantitative Traits in Food Barley (*Hordeum Vulgare* L*)* Landraces

[1]Geleta Negash*, [2]Dagnachew Lule and [3]Zerihun Jaleta
[1]Haro Sebu Agricultural Research Center, P.O.Box 10, Haro Sebu, Ethiopia.
Corresponding author: Email: geleta2017@gmail.com
[2]Oromia Agricultural Research Institute, P.O. Box 81265, Addis Ababa, Ethiopia.
[3]Faculty of Agriculture, Department of plant science, Wollega University, Nekemte, Ethiopia

Abstract
Heritability and genetic advance are important factors to determine the success of selection in breeding programs. The aim of this study was to assess variability, heritability and genetic advance for grain yield and yield related quantitative traits of food barley landraces. One hundred barley landraces were laid out in10 x 10 simple lattice design with two replications in 2017 main cropping season at Sayo district of Mata research sub site. Components of Variances, broad sense heritability and genetic advance were calculated. Statistically significant variations were observed among genotypes for all quantitative traits considered in the present study. Genotypic coefficient of variation ranged from 4.99% for days to maturity to 32.24% for number of spikeletes per spike. Besides, broad sense heritability ranged from 12.14% for harvest index to 81.70% for number of spikeletes per spike. The highest genetic advance as percent of mean was recorded for number of spikeletes per spike (60.03%) and the least for harvest index (4.38%). Generally, the magnitude of genetic variability among the studied barley landraces showed great variations for the traits considered and thus, there is huge potential to improve food barely for those desirable traits through selection breeding.

Keywords: Barley (*Hordeum vulgare* L), Coefficient of Variation, Genetic advance, Heritability

Introduction
Barley (*Hordeum vulgare* L) (2n=2x=14) is one of the most important staple food crops in the highlands of Ethiopia. It is a cool season crop, the most dependable, early maturing cereal grain with relatively high-yield potential including in marginal areas where other cereal crops are not adapted (Martin and Leonard, 2010; Harlan, 2008). The major barley production areas of the world include Europe, the Mediterranean fringe of North Africa, Ethiopia and the Middle East, former USSR, China, India, Canada and USA (Horsley & Hochhalter, 2004). Ethiopia is the second largest barley producer in Africa, next to Morocco, accounting for about 25% of the total barley production in the continent (FAO, 2014). However, there is great yield gap between national average yield (2.11 tons ha^{-1}) (CSA, 2016/2017) and world average yield (5.5 tons ha^{-1}) (Birhanu *et al.*, 2005). This is due to different production constraints such as biotic and abiotic stresses, limited improved varieties for different production systems and agro-ecologies (Eshetu, 1986).

Genetic variability is the pre-requesite for plant breeding since proper management of diversity can produce permanent gain in the performance of plant and can safeguard against seasonal fluctuations (Sharma, 2004; Welsh, 2008). Phenotypic variation is the observable variation present in a character of a population, includes both genotypic and environmental components of variation and, as a result, its magnitude differs under different environmental

conditions (Singh, 2006). Heritability can be defined, in broad sense, as the proportion of the genotypic variability to the total variance (Allard, 2006). It refers to the portion of phenotypically expressed variation, within a given environment and it measures the degree to which a trait can be modified by selection (Christianson & Lewis, 2003). Heritability is a property not only of a character being studied but also of a population being sampled, of the environmental circumstance to which the individuals are subjected, and the way in which the phenotype is measured (Falconer & Mackay, 1996).

Estimates of heritability and genetic advance should be considered simultaneously because high heritability should not always associate with high genetic advance (Amin *et al.*, 2004). Hence, high heritability coupled with genetic advance is more dependable for selection breeding, but high heritability coupled with low genetic advance indicates the presence of non-additive gene action (Vimal and Vishwakarma, 2009). This study is, therefore, initiated for the systematic identification of heritable traits coupled with genetic advance and thus indicate the future appropriate barely breeding approaches.

Materials and methods

The experiment was conducted in 2017 main cropping season at Mata research sub-site of Haro Sabu Agricultural Research Center (HSARC), Western Oromia, Ethiopia. The experimental site is located at 8°53'33"N latitude and 34°80'11"E longitude and its elevation is 1900 meter above sea level. The soil types of the area is classified as 90% loam, 6% sand and 4% clay soil. Mean annual rainfall is 1219.15 mm. The minimum and maximum annual temperatures are 16.21 and 27.77 °C, respectively. A total of 100 food barley landraces, of which 97 were landraces (accessions) and two released food barely standard checks (HB 1307 and Abdane) and one local check were evaluated. The detal lists of the experimental materials is presented in Appendix 1.The experimental materials were arranged in 10 x 10 simple lattice design.Seed was drilled on 20 cm row spacing, 1.65-meter row length and 1meter spacing between each block was used. Seed rate of 85 kg ha^{-1} and a combination of UREA and DAP fertilizer was applied at the recommended rate of 50 and 100 kg ha^{-1}, respectively. DAP 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 half at tiller initiation or 35- 40 days after germination). All other agronomic practices were performed as per the recommendation for the crop.

Data collection

Data were collected both on plant basis and plot basis.

Ten plants were randomly selected before heading from each row and tagged with colored thread for plant-based data collection.

Plant based data collected: Peduncle length, grain weight per spike, plant height, spike length, spike weight per plant, number of spikelets per spike**,** productive and total tillers per plant, flag leaf length and awn length.

Plot based data collected: Days to heading, days to physiological maturity, thousand seed weight, grain yield, biological yield and harvest index

Statistical analysis

All collected agro-morphological traits were subjected to analysis of variance using Proc lattice and Proc GLM procedures of SAS version 9.2 (SAS, 2008). ANOVA was carried out following the ANOVA structure in dicated in table 1.

Table 1**:** The structure of ANOVA Table for Simple Lattice Design

Source of variation	DF	SS	MS	F-value	Pr>F
Replication	(r-1)	SSR	MSR		
Genotype					
-(Unadj.)	(k^2-1)	SSG_U	MSG_U		
-(adj.)	(k^2-1)	SSG_A	MSG_A		
Blocks within rep (adj.)	r(k-1)	SSB_A	MSB		
Error					
-Effective	(k-1) (rk-k-1)				
-RCB Design	(r-1) (k^2-1)				
-Intra block	(k-1) (rk-k-1)	SSE	MSE		
Total	(rk^2-1)	TSS			

Key: k =blocks, r = number of replications, G = genotype, MSR = mean square of replication, MSG_A = mean square of genotype adjusted, MSG_U = mean square of genotypes unadjusted, MSE = Environmental variance (error mean square) = $\sigma^2 e$

Analysis of phenotypic and genotypic coefficient of variation

Quantitative traits variances (phenotypic, genotypic and environmental variances) and their respective coefficient of variations were calculated following the formula suggested by Burton and DeVane (1953) as follows;

Genotypic Variance ($\sigma^2 g$): $\sigma^2 g = \frac{MSg - MSe}{r}$

Where MSg= mean square of genotypes, MSe = error mean square, r = number of replications.

Environmental Variance or error variance ($\sigma^2 e$): $\sigma^2 e = MSe$

Phenotypic Variance ($\sigma^2 p$): $\sigma^2 p = \sigma^2 g + \sigma^2 e$

Estimates of coefficient of variation were carried out as follows

Phenotypic Coefficient of Variation (PCV %): $PCV = \frac{\sqrt{\sigma^2 p}}{\bar{X}} x100$

Genotypic Coefficient Variation (GCV %):

$$GCV = \frac{\sqrt{\sigma^2 g}}{\bar{X}} x100$$

Environmental coefficient of variations (ECV%): $ECV = \frac{\sqrt{\sigma^2 e}}{\bar{x}}$ $ECV = \frac{\sqrt{\sigma^2 e}}{\bar{X}} x100$

Where $\bar{x}$= mean for the trait considered; $\sigma^2 p$=phenotypic variance; $\sigma^2 g$ =genotypic variance; $\sigma^2 e$= environmental variance, PCV (%) = Phenotypic coefficient of variation; GCV (%) = Genotypic coefficient of variation, ECV (%) = Environmental coefficient of variations.

Broad sense heritability (H^2) and genetic advances

Heritability (H^2): Heritability in broad sense for all characters was computed using the formula suggested by Falconer (1996) as follow;

$$H^2 = (\delta^2 g/\delta^2 p) \times 100$$

Where H^2 = heritability in broad sense $\delta^2 g$ = genotypic variance and $\delta^2 p$ = phenotypic variance.

Genetic advance under selection (GA): Expected genetic advance for each character assuming selection intensity at 5% (K =2.056) were computed using the formula suggested by Johnson *et al.* (1955b) as:

$$GA = k (\sqrt{\delta^2 p}) H^2$$

Where GA = expected genetic advance, k is constant (selection differential (K=2.056 at 5% selection intensity), $\sqrt{\delta^2 p}$ = is the square root of the phenotypic variance.

Genetic advance as percent of mean (GAM) was calculated to compare the extent of predicted advance of different traits under selection using the below indicated formula.

$$GAM = \frac{GA}{\overline{X}} X\ 100$$

Results and discussions

Analysis of Variance

Analysis of variance (ANOVA) showed highly significant differences ($P \leq 0.01$) among barely genotypes for days to heading, days to maturity, plant height, peduncle length, spike length, awn length, flag leaf length, productive tillers per plant, grain yield , grain weight per spike, spike weight per plant, number of spikeletes per spike, 1000-seed weight and biological yield (Table 2). Similarly, Alemayehu and Parlevliet (1997) reported significant variations among barley accessions for plant height, days to heading and thousand grain weight. Lakew *et al.* (1997) also reported significant variations among barley genotypes for spike length, seeds per spike, grain yield per spike, days to heading, days to maturity and plant height. Similar results were also reported by Berhane *et al.* (2006); Abebe and Bjornstad (2009); Dawit and Hailu (2009); PGRC/E (2011).

Variance components and coefficients of variation

The genotypic variance was found to be relatively greater than its corresponding environmental variance for days to heading, days to maturity, plant height, peduncle length, awn length, spike weight per plant, number of spikelets per spike and biomass yield (Table 3). This implied that, in the phenotypic expression of these traits, the effect of environmental factor is low as compared to the genetic component and so that selection will be more effective when the genetic variation in relation to environmental variation is high (Poehlman and Sleeper, 2005). Similarly, Ahmed *et al.* (2008) reported high level of genotypic variance for days to heading, days to maturity, spikelets per spike, grain per spike, plant height and biomass yield. In addition, both genotypic and phenotypic variances were observed to be reasonably greater than environmental variance for days to heading, days to maturity, plant height, peduncle length, awn length, number of spikelets per spike and biomass yield (Table 3) indicating, selections may be more effective and efficient upon these attributes and their phenotypic expressions would be a good indicator of genotypic potential. This estimate is in agreement with the finding of Ahmed *et al.* (2008).

Table 2: Analysis of variance (ANOVA) for quantitative traits of food barley accessions evaluated in the present study.

Traits	Source of Variation						Efficiency Relative to RCBD (%)
	Replications	Blocks within Replications	Treatments	Error Intra Block			
	DF=1	DF=18	DF=99	DF=81	R^2 (%)	CV%	
DH	33.62*	11.04	50.62**	7.83	89.79	4.63	102.07
DM	206.04**	13.15**	50.15**	8.21	90.04	3.12	103.85
PH	2288.26**	37.37**	134.18**	35.83	86.02	7.17	100.03
PDL	34.53*	6.03**	27.98**	5.77	87.2	16.92	103.04
SL	19.16**	1.19*	1.51**	0.64	80.6	9.52	106.56
AL	4.65*	1.3	7.02**	1.21	88.54	8.81	100.1
FLL	62.16**	7.38*	7.69**	3.73	76.86	12.99	108.07
PTPP	27.16**	1.01*	1.29**	0.58	79.77	16.88	105.33
TTPP	27.23**	1.05	1.09*	0.68	74.81	16.45	103.23
YLD	16.3**	0.36	1.25**	0.5	78.17	19.67	94.63
GWPS	0.37**	0.03	0.07**	0.03	77.74	16.73	99.11
SWPP	1.48**	0.04	0.13**	0.04	82.37	14.82	99.41
NSTPS	54.71*	10.82	72.90**	7.34	93.34	15.26	102.62
TSW	2751.34**	57.4	110.10**	54.24	76.9	23.8	100.06
BYLD	60.72**	1.4	8.37**	1.86	87.03	15.27	95.48
HI	10.95*	42.02*	58.47*	45.81	60.82	18.61	94.81

Key: *, ** indicated significance at 0.05 and 0.01 probability levels, respectively. DF= degree of freedom , RCBD=randomized complete block design, R^2= R- square, CV= Coefficient of variation, DH = days to heading, DM= days to maturity, PH=plant height, PDL= peduncle length, SL= spike length, AL =awn length, FLL =flag leaf length, PTPP =productive tillers per plant, TTPP=total tillers per plant, YLD = grain yield, GWPS =grain weight $spike^{1}$, SWPP, =spike weight $plant^{-1}$, NSTPS=number of spikeletes $spike^{-1}$, TSW =thousand seed weight, BYLD=biomass yield, HI=harvest index

On the other hand, considerable environmental influences were also observed for spike length, flag leaf length, productive tiller per plant, total tiller per plant, grain yield, grain weight per spike, thousand kernel weight and harvest index indicating the significant effect of environmental factors on the phenotypic expression of these traits. Kumar *et al*. (2001) and Ghimiray *et al.* (2000) stated the apparent variation is not only due to genotypes but also due to the influence of environment (Table 3).

Phenotypic coefficient of variation (PCV) and Genotypic coefficient of variation (GCV) values are considered as low (<10%), medium (10-20%) and high (>20%) (Deshmukh *et al.*, 1986). Accordingly, high phenotypic coefficient of variations (PCV) were observed for number of spikelets per spike (35.66%), 1000-seed weights (29.30%), peduncle length (28.95%), grain yield, (25.91%), biomass yield (25.33%), productive tillers per plant (21.44%), grain weight per spike (21.09%) and spike weight per plant (20. 97%) (Table 3). Chand *et al.* (2008) were also reported higher phenotypic coefficient of variation (PCV) for grain yield per plant and number of grains per spike in barley.

Similarly, high genotypic coefficient of variations (GCV) were recorded for number of spikelets per spike (32.24%), peduncle length (23.48%) and biomass yield (20.20%). This indicated that, the contribution of genotypic component was higher than environmental component in the expression of these phenotypic traits. Similarly, Jalata *et al.* (2010) and Chand *et al.* (2008) were also reported high values of GCV for grain yield and biomass yield.

The lowest GCV values were recorded for days to heading (7.66%), days to maturity (4.99%), plant height (8.39%), spike length (7.82%), flag leaf length (9.46%), total tiller per plant (9.02%) and harvest index (Table 3). Similarly, Assefa (2003) was also reported low GCV values for days to heading, days to maturity, plant height and the highest GCV values for grain yield per spike. On other hand, Andonov *et al*. (1979) were reported PCV value higher for grain yield per plant and number of grains per spike implying that environmental effect on the expression of phenotypic was low. Other authors were also reported high PCV and GCV for grain yield, biomass, harvest index, thousand seed weight and plant height in barley (Sharma *et al.,* 2005; Amsal *et al.,* 2006; Bekele *et al.,* 2008).

Broad sense heritability and genetic advance

Heritability values classified as very high (≥ 80%), moderately high (60-79%), Moderate (40-59%) and Low (≤ 40%) according to Singh, 2001. If heritability of a character is very high, selection for such characters could be very easy. The estimate of heritability (H^2) was ranged from 12.14% for harvest index to 81.70% for number of spikeletes per spike (Table 3). Moderately high heritability values were recorded for days to heading (73.21%), days to maturity (71.86%), peduncle length (65.81%), awn length (70.60%) and biomass yield (63. 64%). From breeding perspectives, effectiveness of a character is related to its onward transmission from the parent to the progeny (Raiz & Chowdhry, 2013).

Plant height (57.85%), spike length (40.47%), grain yield (42.86%) and spike weight per plant (52.94%) were recorded moderate heritability in broad sense. Similar findings were also reported by Khan *et al*. (2003) and Kumar *et al*. (2003). Heritability of a character will be computed for different genotypes and refers to a particular population under particular environmental circumstances (Dabholkar, 1992). Flag leaf length (34.68%), productive tillers per plant (37.97%), total tillers per plant (23.16%), grain weight per spike (40.00%), thousand seed weight (33.99%) and harvest index (12.14%) scored lower heritability values (Table 3). This revealed that, the environmental effect constitutes a major portion of the total phenotypic variation (Moghaddam *et al.*,1997). For traits with low heritability, selection may be considerably difficult or impractical due to the masking effect of the environment. Luzi-Kihupi (1998) reported high heritability estimates for plant height, number of filled grains per panicle, panicle length and 1000-grain weight in rice.

The estimates of genetic advance help in understanding the type of gene action involved in the expression of various polygenic characters. Expected genetic advance as percent of mean was categorized as low (<10%), moderate (10-20%), and high (>20%) (Johnson *et al.,* 1955b). Accordingly, number of spikelets per spike (60.03%), peduncle length (39.24%), biomass yield (33.20%), awn length (23.68%), grain yield (22.88%), spike weight per plant (22.87%) and thousand seed weight (20.51%) recorded high genetic advance as per cent of mean (Table 3). This result is in agreement with that of Jalata *et al.* (2010). The high values of genetic advance as percent of mean indicates the trait is governed by additive gene action, but low values are indicator of non-additive gene action (Singh and Narayanan, 1993).

High heritability together with high genetic advance is an important factor for predicting the resultant effect for selecting the best individual since the effectiveness of selection depends

upon genetic advance of the character selected along with heritability (Manju and. Sreelathakumary, 2002). Accordingly, days to heading, peduncle length, awn length, number of spikeletes per spike and biological yield showed high heritability accompanied with genetic advance as percent of mean (Table 3). High heritability coupled with high genetic coefficient of variation estimates the magnitude of genetic advance through phenotypic selection (Burton, 1952; Johnson *et al.*, 1955a). It is not necessarily true that, high estimates of heritability are always associated with high genetic gain (Ghuttai *et al.*, 2015). Low to moderate heritability and moderate to high genetic advance as percent of mean were recorded for grain yield, grain weight per spike, spike weight per plant and 1000-seed weight (Table 3). Similar results were also reported by Ehdaie and Waines (1989), Moghaddam *et al.* (1997), Chand *et al.* (2008), and Kahrizi *et al.* (2010).

Patterns of quantitative traits variation and their **values for breeding**

Wider ranges of variations were observed among food barley accessions for all quantitative Traits (Table 4). This variation is fundamental for effective selections and sustainable improvement of barley by combining the desirable traits. The analysis of variance (ANOVA) showed that variation among the accessions were significant for all the characters measured. This indicate the existence of high degree of genetic variation in the material to be exploited in breeding programs and reflected in the broad ranges observed for each character.

The mean values, ranges and variation of characters are presented in Table 4. Mean of days to heading ranged from 50 to 86 days (with an average of 60 days) (Wosene *et al.*,2015). Physiological maturity ranged from 82 to 111 days (with an average of 92 days). These variations offer great flexibility in developing improved varieties suitable for various agro-ecologies with variable length of growing period and also can be recommended for various cropping systems. Early maturing traits were desirable in areas where the terminal moisture stress is the limiting factors for barley production. It also guides breeders to develop a variety which can escape late season drought by improving traits which relate to days to maturity in the desired direction. Thomas and Fukai (1995) reported that, barley plant takes between 105-157 days to maturity. Total time to maturity depends on variety, location and planting date.

Similarly, plant height, peduncle length, awn length and flag leaf length were varied from 47 to 101cm (with an average of 84), 3 to 22cm (with an average of 14), 4 to 16cm (with an average of 13) and 10 to 22cm (with an average of 15), respectively (Table 4). Briggs (1978) reported barley stands from 60-120 cm tall. Number of productive and total tillers per plant ranged from 2 to 7 (with an average 5) and 3 to 7 (with an average 5), respectively. The variation in plant height, number of productive and total tillering capacity per plant indicate the possibility to develop resistant variety against lodging problems and varieties with variable biomass and grain yield. Similarly, Briggs (1978) and Gomez-Macpherson (2001) reported field grown barley plant typical produce 2-5 number of tillers per plant. Similar result reported by Grcíadel *et al.* (2003) that the magnitude of the difference in tillering was more affected by the environment. That means, at common seeding rates, a single plant usually develops from one to five stems but under favorable conditions it may have several times that number (Reid and Wiebe, 1979).

Table 3**:** Estimation of the different variance parameters, heritability and genetic advance for 16 traits of 100 food barley accessions

Characters	Range of mean	Mean ±SEM	Estimates of			PCV (%)	GCV (%)	ECV (%)	H^2 (%)	GA*	GAM (%)
			σ^2e	σ^2g	σ^2p						
DH	49.5-86	60.36±1.98	7.83	21.40	29.23	8.96	7.66	4.64	73.21	8.15	13.51
DM	82-111	91.80±2.03	8.21	20.97	29.18	5.88	4.99	3.12	71.86	8.00	8.71
PH	46.50-100.8	83.54±4.23	35.83	49.18	85.01	11.04	8.39	7.17	57.85	10.99	13.15
PDL	2.70-22.10	14.19±1.69	5.77	11.11	16.88	28.95	23.48	16.93	65.81	5.57	39.24
SL	5.63-10.93	8.43±0.57	0.64	0.44	1.08	12.30	7.82	9.49	40.47	0.86	10.25
AL	4.00-15.60	12.46±0.78	1.21	2.91	4.12	16.28	13.68	8.83	70.60	2.95	23.68
FLL	10.03-22.00	14.87±1.37	3.73	1.98	5.71	16.07	9.46	12.99	34.68	1.71	11.48
PTPP	2.31-6.53	4.51±0.54	0.58	0.36	0.94	21.44	13.21	16.89	37.97	0.76	16.77
TTPP	3.40-7.00	5.02±0.58	0.68	0.21	0.89	18.74	9.02	16.43	23.16	0.45	8.94
YLD	1.40-5.55	3.61±0.50	0.50	0.38	0.88	25.91	16.96	19.59	42.86	0.83	22.88
GWPS	0.40-1.75	1.06±0.12	0.03	0.02	0.05	21.09	13.34	16.34	40.00	0.18	17.38
SWPP	0.60-2.30	1.39±0.14	0.04	0.05	0.09	20.97	15.26	14.39	52.94	0.32	22.87
NSTPS	7.00-31.30	17.76±1.92	7.34	32.78	40.12	35.66	32.24	15.25	81.70	10.66	60.03
TSW	7.85-46.40	30.94±5.21	54.24	27.93	82.17	29.30	17.08	23.80	33.99	6.35	20.51
BYLD	3.60-14.25	8.93±0.96	1.86	3.26	5.12	25.33	20.20	15.27	63.64	2.96	33.20
HI	28.10-58.65	41.21±4.79	45.81	6.33	52.14	17.52	6.11	16.42	12.14	1.81	4.38

key: * The selection differential used was 2.06 at 5% selection intensity, DH = days to heading, DM= days to maturity, PH=plant height, PDL= peduncle length, SL=spike length, AL =awn length, FLL=flag leaf length, PTPP =productive tillers per plant, TTPP=total tillers per plant, YLD= grain yield GWPS =grain weight per spike, SWPP, =spike weight per plant, NSTPS=number of spikeletes per spike , TSW =thousand seed weight , BYLD =biomass yield , HI=harvest index, SEM= Standard error of the mean, σ^2g = Genotypic variance, σ^2e = Environmental variance, σ^2p = Phenotypic variance, H^2 (%)= Broad sense heritability, GCV (%) = Genotypic coefficient of variation, PCV (%) = Phenotypic coefficient of variation, ECV(%)= Environmental coefficient of variation, GA= Genetic advance, GAM (%)= Genetic advance as percent of mean.

Spike length is a character of considerable importance, as the larger spike is likely to produce more grains and eventually higher yield. Spike length ranges from 5.63 to 10.93 cm (with an average of 8.43). This variability was resulted from morphological character of the accessions such that the two-row barley had a relatively long spike as compared to the six-row barley (Eid, 2009; Xue *et al*., 2010). Grain yield, grain weight per spike, spike weight per plant and number of spikeletes per spike were ranged from 1.40 to 5.55 tons per hectare (with an average of 3.58), 0.40 to 1.75 gram (with an average 1.06 gram), 0.60 to 2.30 gram (with an average 1.39 gram) and 7.00 to 31.30 (with an average 17.76), respectively. Parameters like 1000-seed weight, biological yield and harvest index ranged between 7.85 to 46.40 gram (with an average 30.94 gram), 3.60 to 14.25 tons per hectare (with an average 8.93) and 28.10 to 58.65 % with an average of 41.21%, respectively (Table 4). Variation in grain yield, grain weight per spike, spike weight per plant and number of spikeletes per spike, 1000-seed weight, biological yield and harvest index implied that it is possible to create a variety with higher grain yield and/or other biological yields (Appendix 2).

Table 4: Summary of descriptive statistics of mean performances for 17 quantitative traits of 100 food barley accessions

characters	Minimum	Maximum	Mean	SE(±)	CV%	LSD 5%	Pr > F
DH	49.5	86	60.36	0.52	4.63	5.75	**
DM	82	111	91.8	0.53	3.12	5.99	**
PH	46.5	100.8	83.54	0.87	7.17	11.92	**
PDL	2.7	22.1	14.19	0.39	16.92	4.78	**
SL	5.63	10.93	8.43	0.09	9.52	1.71	**
AL	4	15.6	12.46	0.19	8.81	2.19	**
FLL	10.03	21.73	14.87	0.2	12.99	4.16	**
PTPP	2.31	6.53	4.51	0.08	16.88	1.61	**
TTPP	3.4	7	5.02	0.08	16.45	1.72	*
YLD	1.4	5.55	3.58	0.08	19.67	1.37	**
GWPS	0.4	1.75	1.06	0.02	16.73	0.35	**
SWPP	0.6	2.3	1.39	0.03	14.82	0.41	**
NSTPS	7	31.3	17.76	0.64	15.26	5.6	**
TSW	7.85	46.4	30.94	0.74	23.8	14.69	**
BYLD	3.6	14.25	8.93	0.22	15.27	2.64	**
HI	28.1	58.65	41.21	0.58	18.61	14.82	*

Key ; DH = days to heading, DM= days to maturity, PH=plant height, PDL= peduncle length ,SL=spike length, AL =awn length, FLL=flag leaf length, PTPP =productive tillers per plant, TTPP=total tillers per plant, YLD= grain yield, GWPS =grain weight per spike, SWPP, =spike weight per plant, NSTPS=number of spikeletes per spike , TSW =thousand seed weight , BYLD=biomass yield , HI=harvest index, CV=coefficient of variation, LSD = Least significant difference at 5% ,SE=standard error of mean,*, ** significance at 0.05 and 0.01 probability levels, respectively.

Conclusions and Recommendations

From the present study, it can be concluded that, there are comprehensive genetic variability among the studied materials with better agronomic performance that can provide basic breeding information and thus confident enough to expect genetic progress if further breeding activities are to be carried out. Accessions, such as Acc.No 3612, 202660, 241675, 202536, 219307,217176, 202661, 235652, 64344 and 242581 were found to be high yielder and most of these accessions were with better agronomic performance which are characterized for medium days to heading, days to maturity, plant height and productive tillers per plant and medium average grain yield. Hence, it is suggested that, these materials can be selected as the parents for future breeding program. However, the current study was conducted only at one location in one season, hence, further evaluation over-locations and seasons are very important to offer strong conclusions and suggestions.

References

Abebe, D. & Bjornstad, A. (2009). Phenotypic diversity of Ethiopian barleys in relation to geographical regions, altitudinal range, and agro-ecological zones: As an aid to germplasm collection and conservation strategy. *Hereditas,* 12(4), 17–29

Ahmed, Z., Ajamal, S. Munir, M. Zubair, M., & Massod, M. (2008). Genetic diversity for morpho-genetic traits in barley germplasm. *Pak. J.Bot*., 40(3), 1217-1224

Alemayehu, F., & Parlevliet, J. E. (1997). Variation between and within Ethiopian barley landraces. *Euphytica*, *94*(2), 183.

Allard, R.W. (1960). *Principles of Plant Breeding*, New York, John Willey and Sons Inc.

Amin, M.R., Barma, N.C.D., & Razzague M.A. (2004). Variability, heritability, genetic advance and correlation study in some quantitative character in durum wheat. *Rachis News Letter* 11(4)30-32.

Amsal, T., D.G. Tanner., & Getnet, G. (2006). Effect of genetic improvement of morph physiological character related to grain yield of barley in Ethiopia. *African Crop Sci. J*., 2(3), 247-255

Andonov, K. L., Sariev, B. S., & Zhundibaev, L. P. (1979). Structure of phenotypic variability in traits of spring barley. *Acta Agric. Shanghai*, *22*, 187-188.

Assefa, A. (2003). "Genetic variability and Breeding Potential of Barley (*Hordeum vulgare* L.) Landraces from North Shewa in Ethiopia," PhD Thesis, Faculty of natural and agricultural sciences university of Free State, Bloemfontein, South Africa.

Bekele, G., Solomon A., Balcha, Y., Desalegn D., &Temesgen K. (2008). Prospects and retrospect of barley germplasm in Ethiopia.

Berhane Lakew, Yitbarek Simane, Fekadu Alemayehu, Hailu Gebre, S. Grando, J.A.G. van Leur et al. (2006). Exploiting the diversity of barley landraces in Ethiopia. *Genet.Resour. Crop Evol*., 44(4),109-116.

Birhanu, L., Hailu, G., & Fekadu, A. (2005). Barley production in Ethiopia. Hailu Gabre and Joop Van Leur (eds.), Barley research in Ethiopia: Past Work and Future Prospects. Proceedings of the First Barley Research Review Workshop, 16-19 October 2008.Addis Ababa IAR/ICARDA.

Briggs, D.E. (1978). *Barley*. London, Chapman and Hall Ltd.

Burton, G.W. (1952). Quantitative inheritance in grasses. Proc. Int. Grassland Congr., 1(3),277-283.

Burton, G.W., & Devane, E.H. (1953). Genetic variability and heritability in soybean. *Agronomy J*., 45(1),478-481.

Chand, N., Vishwakarma, S. R., Verma, O. P., & Kumar, M. (2008). Worth of genetic parameters to sort out new elite barley lines over heterogeneous environments. *Barley genetics newsletter*, *38*, 10-13.

Christianson, M. N., & Lewis. C. F. (2003). *Breeding Plants for Less Favorable Environments*. New York, Chichester, Brisbane, Toronto, Singapore. A Wiley-Inter Science Publication, John Wiley and Sons.

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

Dabholkar, A.R. (1992). *Elements of Biometrical Genetics.* New Delhi, India, Concept Publishing Company.

Dawit Tadesse , & Hailu Mekbib. (2009). Barley Genetic Resource. 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.

Deshmukh, S. N., Basu, M. S., & Reddy, P. S. (1986). Genetic variability, character association and path coefficients of quantitative traits in Virginia bunch varieties of groundnut. *Indian Journal of Agricultural Sciences*, 56 (5), 515-518

Ehdaie, B., & Waines, J. G. (1989). Genetic variation, heritability and path-analysis in landraces of bread wheat from southwestern Iran. *Euphytica, 41*(3), 183-190.

Eid, M.H. (2009). Estimation of heritability and genetic advance of yield traits in wheat (*Triticum aestivum*L.) under drought condition. *International Journal of Genetics and Molecular Biology*, 1(7), 115-120

Eshetu Bekele. (1986). A review of research on diseases of barley, tef and wheat. In: Tsedeke Abate (eds). Proceedings of Symposium on First Ethiopian Crop Protection, Addis Ababa, Ethiopia. 4-7 February 1985, Institute of Agricultural Research.

Falconer, D.S., Trudy F., & Mackay. C. (1996). *Introduction to Quantitative Genetics*.4th ed., Malaysia. Longman Group Limited.

FAO (Food and Agriculture Organization) (2014). Food Balance Sheets FAOSTAT Database on Agriculture

Ghimiray, T.S., & Sarkar, K.K. (2000). Estimation of genetic parameters for some quantitative traits in wheat (*Triticum aestivum* L.) grown in terai soils of West Bengal. *Environmental and Ecol.*, 18(2), 338-340

Ghuttai, G., Mohammad, F., Khan, F.U., Khan, W.U., & Zafar Z. (2015). Genotypic differences and heritability for various polygenic traits in F5 wheat populations. *American Eurasian J. Agricultural and Environmental Science*, 15(10), 2039-2044

Gomez-Macpherson, H. (2001). *Hordeum vulgare*. http://ecoport.org/ep_plant=1232 & entity Type= PL*** & entity Display Category=full.

Grcíadel Moral, Luis, F., Belén García del Moral, José L., Molina-Cano, & Slafer, G.A. (2003). Yield stability and development in two-and six-rowed winter barleys under Mediterranean conditions. *Field crops research*, 81(2-3), 109-119

Harlan, J.R. (2008). *Evolution of Crop Plants*. New York. N.W Simmonds (eds.), University of Illinois Urbana Iii USA, Longman.

Horsley, R.D., & Hochhalter, M. (2004). Barley Agronomy. Encyclopedia of Grain Science, Wrigley, C., Corke, H., Walker, H. (eds.). Vol.1. Elsevier Academic press

Jalata, Z., Ayana, A., & Zeleke, H. (2010). Variability, heritability and genetic advance for some yield and yield related traits in Ethiopian barley (*Hordeum vulgare* L.) landraces and crosses. *Intl. Journal of Plant Breeding and Genetics*, *5*(1), 44-52

Johnson, H. W., Robinson, H. F., & Comstock, R. E. (1955a). Estimates of Genetic and Environmental Variability in Soybeans. *Agronomy journal, 47*(7), 314-318.

Johnson, H. W., Robinson, H. F., & Comstock, R. E. (1955b). Genotypic and Phenotypic Correlations in Soybeans and Their Implications in Selection. *Agronomy journal*, *47*(10), 477-483.

Kahrizi, D., Maniee, M., Mohammadi, R., & Cheghamirza, K. (2010). Estimation of genetic parameters related to morpho-agronomic traits of Durum Wheat (*Triticum turgidum* var. durum). *Biharean Biologist*, *4*(2), 93-97.

Khan, A.S., Ishtiaq, S., & Zulfiquar, A. (2003). Heritability of various morphological traits in wheat. *International Journal of Agriculture and Biology*,5(2),138-140.

Kumar, M.S., Chaudhary, H.B., & Desmukh, P.S. (2001). Genetic variability and association of morph physiological characters with grain yield in late sown wheat [*Triticum aestivum* (L) Em.]. Annals of Agricultural Research, 22(2), 217-220.

Kumar, S., Dwivedi, V. K., & Tyagi, N. (2003). Genetic variability in some metric traits and its contribution to yield in wheat. *Progressive Agriculture*, *39*(1/2), 152-153.

Lakew B., Semane Y., Fekadu A., Gebre H., Grando, S van Leur. J.A.G., & Ceccareli. S. (1997). "Exploiting the diversity of barley landraces in Ethiopia." Genetic resources and crop evolution ,44(3),109-116.

Luzi-Kihupi, A. (1998). Inter-relationship between yield and some selected agronomic characters in rice. *African Crop Science Journal*, 6(3),323-328.

Manju, P.R., & Sreelathakumary I. (2002). Genetic variability, heritability and genetic advance in hot chilli (*Capsicum chinense* JACQ.) *Journal of Tropical Agriculture*, 40, 4-6.

Martin, J.H., & Leonard, W.H. (2010). *Principles of Field Crops Production*.2nd ed. London, MacMillan Company.

Moghaddam, M., Ehdaie, B., & Waines, J. G. (1997). Genetic variation and interrelationships of agronomic characters in landraces of bread wheat from southeastern Iran. *Euphytica, 95*(3), 361-369.

PGRC/E. (2011). Ethiopia: Country report to the FAO international technical conference on plant genetic resource. Leipzig, Germany.

Poehlman, J.M., & Sleeper, D.A. (2005). *Breeding Field Crops*.4th ed. *Iowa State University Press, Ames*, 71.

Raiz, R., & Chowdhry, A. (2013). Estimation of variation and heritability of some physio orphic traits of wheat under drought condition, *Asian Journal of Plant Science*, 2(10), 748-755.

Reid, D.A., & Wiebe, G.A. (1979). Taxonomy, botany classification and world collection. Barley: Origin, botany, culture, winter hardiness, benetics, utilization, pests. USDA agric. Handbook.

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

Sharma, J. R. (2004). *Statistical and biometrical techniques in plant breeding*. New Delhi, New Age International(P) Limited Publishers.

Sharma, R.C., Yadav, D.J., & Slarma, R.K. (2005). Genetic variability and association of some yield components in winter nursery of barley. *Advances in plant Sci*. 8(1),95-99

Singh, P., & Narayanan, S.S. (1993). *Biometrical techniques in plant breeding*. New Delhi., Kalyani, Publishers

Singh, B.D. (2001). *Plant Breeding: Principles and methods*. New Delhi, Kalyani publishers.

Singh, B. D. (2006). *Plant breeding principles and methods*. Ludhiana, New Delhi, Kalyani Publishers.

Thomas & Fukai, S. (1995). Growth and yield response of barley and Chick pea to water stress under three environments in South east Queensland. I. Light inception, crop growth and grain yield. *Australia Journal of Agricultural Research* 46(1),17-33.

Vimal, S. C., & Vishwakarma, S. R. (2009). Heritability and genetic advance in barley under partially reclaimed saline sodic soil. *Rachis*, 17(1-2), 56- 61.

Welsh, J. R. (2008). *Fundamentals of Plant Genetics and Breeding.* New York, John Willey and Sons Inc.

Wosene, G., Berhane Lakew, Bettina I., Haussmann, G., & Karl, 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.* 7(8), 1-17.

Xue, D., Zhou, M., Zhang, X., Chen, S., Wei, K., Zeng. F., *et al.* (2010). Identification of QTLs for yield and yield components of barley under different growth conditions, *J. Zhejiang Univ. Sci.*, 11(9),169-176.

Appendices

Appendix:1 list of checks and 97 barley accessions collected from different regions of Ethiopia

Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)	Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)
1	64197	Amara	12-24-00-N	37-05-00-E	2090	26	64344	Oromiya	07-33-00-N	36-36-00-E	1880
2	3239	Amara	12-23-00-N	37-17-00-E	1830	27	64345	SNNP	07-10-00-N	36-21-00-E	2140
3	3240	Amara	12-18-00-N	37-10-00-E	1830	28	202536	Amara	12-47-00-N	37-40-00-E	1750
4	4560	Oromiya	09-10-00-N	35-42-00-E	1900	29	202537	Amara	12-47-00-N	37-40-00-E	1750
5	3465	Oromiya	08-57-00-N	37-46-00-E	1800	30	202538	Amara	12-47-00-N	37-40-00-E	1750
6	3583	SNNP	07-00-00-N	37-53-00-E	2140	31	202539	Amara	13-03-00-N	37-47-00-E	1810
7	3612	Oromiya	07-14-00-N	36-55-00-E	1810	32	202540	Amara	13-03-00-N	37-47-00-E	1810
8	3617	Oromiya	07-55-00-N	37-24-00-E	1890	33	202541	Amara	12-23-00-N	37-17-00-E	1830
9	3632	Oromiya	09-32-00-N	35-28-00-E	1800	34	202542	Amara	12-18-00-N	37-10-00-E	1830
10	3638	Amara	11-49-00-N	37-37-00-E	1780	35	202660	Oromiya	07-41-00-N	36-58-00-E	1810
11	3763	Amara	12-31-00-N	37-10-00-E	1870	36	202661	Oromiya	07-41-00-N	36-58-00-E	1810
12	3940	Oromiya	08-54-00-N	40-46-00-E	1830	37	202670	Oromiya	07-55-00-N	37-24-00-E	1890
13	3941	Oromiya	08-54-00-N	40-46-00-E	1890	38	202676	Amara	11-49-00-N	37-37-00-E	1780
14	3943	Oromiya	09-05-00-N	40-50-00-E	1870	39	202820	Oromiya	09-09-00-N	41-07-00-E	1910
15	235286	Tigray	13-38-00-N	39-17-00-E	1780	40	202536	Amara	12-47-00-N	37-40-00-E	1750
16	4193	Oromiya	09-02-00-N	40-44-00-E	1870	41	12970	SNNP	37-36-00-N	06-09-00-E	2150
17	4194	Oromiya	09-03-00-N	40-44-00-E	1840	42	212972	Oromiya	37-44-00-N	05-01-00-E	1850
18	4195	Oromiya	09-26-00-N	41-02-00-E	1800	43	217010	Amara	12-38-00-N	37-06-00-E	2090
19	202561	Oromiya	07-32-00-N	40-42-00-E	2090	44	217173	Oromiya	07-33-00-N	36-36-00-E	1880
20	239513	Oromiya	07-04-77-N	40-31-71-E	2050	45	217175	Oromiya	07-33-00-N	36-36-00-E	1880
21	64022	SNNP	06-53-00-N	37-48-00-E	2140	46	217176	SNNP	07-10-00-N	36-21-00-E	2140
22	64053	SNNP	06-12-00-N	37-35-00-E	2150	47	219151	Oromiya	09-19-00-N	41-03-00-E	2020
23	64248	SNNP	07-02-00-N	37-54-00-E	1900	48	219152	Oromiya	09-11-00-N	41-03-00-E	2100
24	64260	Oromiya	07-29-00-N	39-15-00-E	1910	49	219148	Oromiya	08-49-00-N	40-28-00-E	1800
25	237021	Amara	08-50-00-N	39-20-00-E	1750	50	219307	Oromiya	05-39-00-N	38-13-00-E	1880

Appendix:1 Continued…..

Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)	Entry code	Acc. No	Region	Latitude	Longitude	Altitude (m.a.s.l)
51	219311	Oromiya	04-52-00-N	38-05-00-E	1870	76	235274	Tigray	13-31-00-N	39-07-00-E	1620
52	219316	Oromiya	05-53-00-N	39-11-00-E	1820	77	235283	Tigray	13-38-00-N	39-15-00-E	1900
53	219317	Oromiya	05-44-00-N	39-20-00-E	1800	78	235284	Tigray	13-40-00-N	39-15-00-E	1840
54	220677	Amara	08-48-00-N	39-21-00-E	2000	79	233030	SNNP	05-58-00-N	37-17-00-E	2030
55	221312	SNNP	07-13-00-N	37-46-00-E	2130	80	235299	Tigray	13-23-00-N	39-21-00-E	1860
56	221313	SNNP	07-13-00-N	37-46-00-E	2130	81	235635	SNNP	05-17-00-N	37-39-00-E	2150
57	221324	SNNP	06-09-00-N	37-36-00-E	2150	82	235636	SNNP	05-17-00-N	37-39-00-E	2150
58	223192	Tigray	13-43-00-N	39-28-00-E	1930	83	235637	SNNP	05-17-00-N	37-39-00-E	2150
59	223194	Tigray	12-42-00-N	39-31-00-E	1940	84	235651	Oromiya	04-56-00-N	38-11-00-E	1780
60	225179	SNNP	06-57-00-N	37-51-00-E	2100	85	235652	Oromiya	04-56-00-N	38-11-00-E	1780
61	225992	Amara	12-22-00-N	37-17-00-E	1830	86	235654	Oromiya	05-28-00-N	38-15-00-E	1880
62	229997	Oromiya	06-64-00-N	39-01-00-E	1940	87	235746	Amara	12-24-00-N	37-07-00-E	1920
63	230614	Oromiya	07-01-00-N	40-29-00-E	1870	88	237021	Amara	08-50-00-N	39-20-00-E	1750
64	230620	Oromiya	07-05-00-N	40-36-00-E	1800	89	237022	Oromiya	08-50-00-N	39-00-00-E	1800
65	219307	Oromiya	05-39-00-N	38-13-00-E	1880	90	239514	Oromiya	07-09-00-N	40-40-88-E	2050
66	230622	Oromiya	07-05-00-N	40-36-00-E	1820	91	241675	Oromiya	07-17-36-N	38-22-98-E	1720
67	225176	SNNP	06-57-00-N	37-51-00-E	2100	92	242098	Amara	11-06-00-N	39-47-00-E	1760
68	230624	Oromiya	07-08-00-N	40-42-00-E	1800	93	242574	Tigray	13-52-10-N	39-35-24-E	1820
69	230628	Oromiya	07-11-00-N	40-44-00-E	1790	94	242581	Oromiya	07-00-00-N	40-27-40-E	1828
70	232372	Oromiya	09-22-00-N	41-47-00-E	2020	95	243182	Oromiya	07-00-00-N	40-27-40-E	1828
71	231223	Oromiya	08-35-00-N	39-53-00-E	1780	96	243184	Oromiya	06-59-44-N	40-28-04-E	1830
72	232373	Oromiya	09-22-00-N	41-47-00-E	2020	97	243614	Amara	10-39-00-N	36-38-00-E	1815
73	233028	SNNP	05-55-00-N	37-20-00-E	2050	98	HB1307	Oromiya			
74	234337	Tigray	14-05-00-N	38-57-00-E	1810	99	Abdane	Oromiya			
75	235264	Tigray	12-58-00-N	39-34-00-E	1850	100	Local	Oromiya	08-53-33-N	34-80-11-E	1700

Appendix 2: Mean for **agro-morphological** traits of food barley accessions tested in 2017 cropping season

code	Acc. No	DH	DM	PH	SL	AL	FLL	PTPP	YLDTH	GWPS	NSPS	TSW	BYLD	HI
1	64197	64.5^{e-h}	99^{b-e}	88.5^{b-s}	8.5^{d-x}	12.75^{e-s}	21.5^{a}	4.8^{b-s}	4.25^{a-m}	1.05^{e-k}	22.4^{j-x}	36.9^{a-m}	10.78^{b-s}	40.55^{b-p}
2	3239	52^{q-t}	82^{w}	78.1^{p-z}	7.65^{m-z}	12.3^{h-t}	12.7^{j-r}	5.55^{a-i}	3.5^{d-t}	0.8^{j-n}	15.4^{wx}	33.8^{a-p}	7.86^{r-z}	48.85^{a-i}
3	3240	77.5^{b}	111^{a}	82.5^{h-x}	7.75^{l-z}	11.75^{m-u}	21^{ab}	3.3^{s-x}	2.5^{q-x}	0.7^{l-n}	17.5^{t-x}	22^{n-w}	6.42^{d-r}	40.1^{b-p}
4	4560	59^{h-o}	83.5^{t-w}	88.3^{c-s}	7.75^{l-z}	14.3^{a-i}	12.15^{l-r}	4.15^{g-v}	3.7^{b-r}	1.05^{e-k}	23.5^{g-x}	29.3^{b-t}	9.40^{f-z}	41.2^{b-p}
5	3465	70.5^{cd}	100.5^{bc}	46.5^{d}	6.65^{az}	4.2^{x}	16.25^{d-m}	2.8^{vwx}	1.4^{x}	0.4^{o}	22.5^{j-x}	7.85^{w}	3.93^{r}	39.3^{c-p}
6	3583	60^{f-m}	91.5^{i-q}	83.5^{f-x}	9.80^{a-g}	15.6^{a}	15.2^{d-p}	4.2^{f-v}	4.4^{a-i}	1.05^{e-k}	23.5^{g-x}	34.6^{a-p}	11.4^{a-m}	39.1^{c-p}
7	3612	53^{p-t}	86.5^{q-w}	84^{f-w}	9.35^{b-m}	12.55^{f-t}	15.75^{d-o}	4.3^{d-v}	5.55^{a}	1.15^{c-i}	23.7^{g-w}	36.25^{a-n}	13.59^{ab}	39.65^{c-p}
8	3617	58.5^{i-p}	83.5^{t-w}	81.1^{j-y}	8.30^{e-z}	11.3^{p-u}	15^{d-q}	4.4^{d-v}	3.5^{d-t}	1^{f-l}	21.9^{j-x}	37.2^{a-l}	9.06^{j-z}	40.95^{b-p}
9	3632	51st	87^{o-w}	81.95^{h-x}	9.65^{a-i}	13.55^{a-o}	16^{d-o}	4.75^{b-t}	3.95^{b-p}	1^{f-l}	19.2^{o-x}	34.15^{a-p}	10.44^{c-v}	39.35^{c-p}
10	3638	53^{p-t}	91^{i-r}	75^{a-z}	8.3^{e-z}	13.75^{a-m}	12.05^{n-r}	5.25^{a-n}	2.7^{o-x}	0.65^{mno}	16.9^{u-x}	23.05^{j-v}	5.934^{j-r}	45.65^{a-m}
11	3763	61.5^{f-l}	95.5^{c-j}	81.2^{i-y}	9.1^{b-q}	14.1^{a-l}	12.5^{k-r}	3.6^{o-x}	3.75^{b-r}	1.05^{e-k}	27.3^{a-p}	14.55^{uvw}	9.03^{j-z}	40.15^{b-p}
12	3940	62^{e-l}	93.5^{e-m}	96^{a-e}	8.2^{g-z}	12^{k-u}	13.3^{g-r}	5.15^{a-o}	2.75^{n-x}	1.1^{d-j}	29^{a-m}	26.7^{c-u}	8.77^{k-z}	32.8^{k-p}
13	3941	64.5^{e-h}	93^{f-n}	87.2^{c-t}	7.5^{a-z}	11.7^{m-u}	14.8^{e-q}	4.25^{e-v}	4^{b-o}	1.45^{abc}	30.1^{a-j}	29.35^{b-t}	10.52^{c-u}	36.4^{f-p}
14	3943	63.5^{e-j}	96.5^{c-i}	92.2^{a-j}	7.7^{l-z}	12.6^{f-s}	16.1^{d-n}	3.55^{o-x}	2.9^{m-w}	1.3^{b-f}	24.9^{d-u}	25.2^{f-u}	7.75^{u-z}	36.7^{f-p}
15	235286	58.5^{i-p}	88.5^{l-u}	88.9^{a-q}	8.2^{f-z}	12.4^{g-t}	16.3^{d-l}	5.4^{a-l}	4.1^{b-n}	0.95^{g-m}	21.2^{m-x}	33.75^{a-p}	10.89^{b-p}	36.9^{f-p}
16	4193	63.5^{e-j}	98^{b-f}	89.2^{a-q}	8.1^{a-z}	12.2^{i-s}	20.8^{abc}	3.8^{l-x}	2.2^{t-x}	1.15^{c-i}	26.7^{b-q}	20.9^{o-w}	6.33^{g-r}	32.3^{l-p}
17	4194	65.5^{def}	98^{b-f}	84.3^{f-w}	7.1^{a-z}	13^{e-s}	15.3^{d-p}	2.5^{wx}	2.05^{vwx}	1.3^{b-f}	25.5^{d-t}	18.55^{q-w}	4.10^{qr}	40.55^{b-p}
18	4195	61.5^{f-l}	93^{f-n}	83.2^{f-x}	7.3^{a-z}	12.8^{e-s}	15.2^{d-p}	4.35^{d-v}	3.75^{b-r}	1^{f-l}	26.2^{c-s}	27.9^{b-u}	9.67^{e-z}	36.9^{f-p}
19	202561	61^{f-m}	84.5^{s-w}	80.9^{j-y}	8.35^{e-z}	12.95^{e-s}	11.9^{o-r}	4.95^{b-r}	3.9^{b-p}	0.95^{g-m}	23.6^{g-w}	28.45^{b-u}	9.27^{g-z}	40.65^{b-p}
20	239513	59.5^{h-n}	91.5^{i-q}	73.8^{a-z}	8.45^{e-y}	11.8^{m-u}	15.4^{d-o}	4.4^{d-v}	4.1^{b-n}	1.05^{e-k}	22^{j-x}	35.45^{a-o}	9.16^{h-z}	41.8^{b-p}
21	64022	62^{e-l}	96^{c-i}	88.6^{b-s}	11.1^{a}	15.2^{abc}	16.7^{c-j}	5.9^{a-d}	2.4^{r-x}	1.2^{b-h}	22.8^{i-x}	28.95^{b-u}	6.86^{z}	36.05^{f-p}
22	64053	61.5^{f-l}	90^{j-s}	79.4^{n-y}	8.05^{h-z}	13.2^{b-q}	16.4^{d-k}	5.45^{a-k}	3.25^{h-w}	1.3^{b-f}	25.6^{d-t}	32.1^{a-q}	8.73^{m-z}	42.1^{b-p}
23	64248	62^{e-l}	93.5^{e-m}	89.1^{a-p}	9.4^{a-l}	15.3^{ab}	15.7^{d-o}	5.05^{a-q}	4.2^{a-m}	1.35^{b-e}	26.9^{a-q}	31.3^{b-q}	10.85^{b-q}	39.1^{c-p}
24	64260	67.5^{cde}	100.5^{bc}	89.9^{a-q}	9.2^{b-o}	12.6^{f-s}	15.9^{d-o}	4.6^{c-t}	3.35^{f-w}	1.1^{d-j}	31.8^{a-g}	23.75^{i-u}	7.98^{p-z}	42.7^{b-p}
25	237021	61.5^{f-l}	95.5^{c-j}	88.7^{b-r}	10^{a-e}	14.25^{a-j}	16^{d-o}	5.75^{a-g}	4.3^{a-l}	1.2^{b-h}	23^{h-x}	40.45^{a-e}	11.63^{a-l}	38.2^{d-p}
26	64344	60.5^{f-n}	94.5^{e-k}	93.4^{a-h}	8.85^{c-u}	13.4^{b-p}	17.1^{b-i}	4.8^{b-s}	4.6^{a-h}	1.1^{d-j}	18.6^{q-x}	30.5^{b-s}	11.86^{a-j}	39.55^{c-p}
27	64345	62^{e-l}	96.5^{c-i}	76.7^{a-z}	8.8^{b-v}	12.95^{d-s}	15.9^{d-o}	4.1^{h-w}	3.05^{j-w}	1.1^{d-j}	22.4^{j-x}	35.55^{a-o}	6.80^{z}	43.15^{b-o}
28	202536	60.5^{f-n}	88.5^{l-u}	76.8^{a-z}	10.35^{ab}	13^{d-s}	17.5^{a-f}	5.8^{a-f}	4.8^{a-d}	1.25^{b-g}	19.5^{o-x}	46.4^{a}	10.96^{a-o}	45.05^{a-n}
29	202537	72^{bc}	101^{bc}	65.45^{abc}	9.55^{a-k}	13^{d-s}	17.4^{a-g}	2.95^{u-x}	1.5^{x}	0.95^{g-m}	31.7^{a-g}	9^{vw}	5.24^{o-r}	31^{m-p}
30	202538	60^{f-n}	85.5^{r-w}	79.1^{n-y}	8.8^{b-v}	11.65^{n-u}	14.8^{f-q}	4.25^{e-v}	2.95^{l-w}	0.95^{g-m}	25.5^{d-t}	32.55^{a-q}	9.49^{f-z}	30.65^{nop}
31	202539	59.5^{h-n}	88.5^{l-u}	72.4^{a-z}	9.3^{b-n}	12.4^{g-t}	13.8^{f-r}	4.5^{c-u}	3^{k-w}	0.95^{g-m}	19.1^{p-x}	31.05^{b-q}	6.91^{z}	42.95^{b-o}
32	202540	64.5^{e-h}	93.5^{e-m}	83.1^{g-x}	9.1^{b-q}	9.9^{uvw}	13.3^{g-r}	6.6^{a}	2.1^{u-x}	0.85^{i-n}	19.3^{o-x}	16.15^{s-w}	4.48^{pqr}	47.95^{a-j}
33	202541	60^{f-n}	93.5^{e-m}	92.7^{a-j}	8.2^{f-z}	13.2^{b-q}	16.4^{d-k}	4.1^{h-w}	3.3^{g-w}	0.9^{h-n}	24.4^{d-u}	28.85^{b-u}	6.86^{z}	46.75^{a-l}

code	Acc. No	DH	DM	PH	SL	AL	FLL	PTPP	YLDTH	GWPS	NSPS	TSW	BYLD	HI
34	202542	51.5^{r-t}	84.5^{s-w}	75.8^{a-z}	7.7^{l-z}	11.5^{n-u}	12.2^{l-r}	6.3^{ab}	3.1^{i-w}	0.85^{i-n}	19.2^{o-x}	36.4^{a-n}	5.79^{k-r}	53.2^{abc}
35	202660	59.5^{h-n}	91^{i-r}	90.8^{a-l}	10.25^{abc}	13.1^{d-r}	14.8^{e-q}	5.6^{a-i}	5^{ab}	1.15^{c-i}	23.6^{g-w}	37.3^{a-l}	9.83^{e-y}	50.4^{a-g}
36	202661	60.5^{f-n}	94.5^{e-k}	83.8^{f-w}	9.55^{a-k}	12.9^{d-s}	19.1^{a-d}	4.25^{e-v}	4.75^{a-e}	1.75^{a}	29.8^{a-l}	37.75^{a-h}	12.23^{a-g}	38.4^{c-p}
37	202670	60.5^{f-n}	96^{c-i}	100.3^{ab}	9.8^{a-g}	13.2^{b-q}	16.7^{c-j}	4^{i-w}	3.65^{b-r}	1.15^{c-i}	20.5^{n-x}	40.95^{a-d}	7.77^{u-z}	43.15^{b-o}
38	202676	63^{e-k}	92^{h-p}	95^{a-g}	9.1^{b-q}	11.7^{n-u}	12.8^{j-r}	5.5^{a-j}	3.25^{h-w}	1^{f-l}	22.7^{i-x}	34.05^{a-p}	8.14^{o-z}	39.55^{c-p}
39	202820	63^{e-k}	97.5^{b-g}	87.8^{e-s}	9.15^{b-p}	11.7^{n-u}	15.6^{d-o}	4.15^{g-v}	3.7^{b-r}	1.5^{ab}	29^{a-m}	36.25^{a-n}	10.41^{c-v}	35.7^{g-p}
40	202536	62^{e-l}	95.5^{c-j}	84.2^{e-w}	8.2^{f-z}	12.4^{g-t}	16^{d-o}	3.9^{j-x}	2.5^{q-x}	1.15^{c-i}	32.1^{a-f}	22.75^{l-v}	6.24^{i-r}	39.7^{c-p}
41	12970	62.5^{e-l}	91^{l-r}	78^{q-z}	10.2^{a-d}	4.45^{x}	12^{n-r}	3.9^{j-x}	2.75^{n-x}	0.6^{no}	18.2^{s-x}	21.15^{o-w}	6.52^{b-r}	40.8^{b-p}
42	212972	59^{h-o}	88^{m-v}	80^{l-y}	8.1^{g-z}	11.8^{n-u}	14.3^{f-r}	5.15^{a-o}	4.4^{a-j}	1.05^{e-k}	26.6^{b-r}	29.4^{b-t}	11.58^{a-l}	38.7^{c-p}
43	217010	60^{f-n}	90^{k-s}	78.65^{o-z}	7.6^{n-z}	13.45^{a-p}	17.1^{b-i}	4.45^{c-u}	4.35^{a-k}	1.2^{b-h}	34.2^{abc}	22.85^{k-v}	9.95^{d-y}	43.55^{b-o}
44	217173	63.5^{e-j}	99^{b-e}	91.9^{a-l}	8.7^{b-w}	11.4^{o-u}	17.2^{b-h}	3.45^{q-x}	2.9^{m-w}	1.3^{b-f}	26.3^{c-s}	25.3^{f-u}	7.52^{v-z}	38.75^{c-p}
45	217175	62.5^{e-l}	94^{e-l}	98.4^{abc}	8.6^{c-w}	14^{a-l}	13.4^{f-r}	5.1^{a-p}	3.75^{b-r}	1.05^{e-k}	22.7^{i-x}	33.2^{a-q}	10.81^{b-r}	34.2^{i-p}
46	217176	60^{f-n}	93.5^{e-m}	88.2^{e-s}	8.9^{b-t}	13.7^{a-m}	14.5^{g-r}	4.2^{f-v}	4.75^{a-e}	1.3^{b-f}	24.9^{d-u}	39.2^{a-g}	12.25^{a-f}	38.1^{e-p}
47	219151	59.5^{h-n}	90^{k-s}	86.85^{e-t}	9.5^{a-k}	15^{a-d}	13.7^{g-r}	5.25^{a-n}	3.9^{b-p}	1.1^{d-j}	21.7^{k-x}	36.8^{a-m}	9.33^{g-z}	38.15^{d-p}
48	219152	58.5^{i-p}	89.5^{k-s}	84.8^{e-v}	7.4^{a-z}	13.5^{a-o}	14.9^{e-q}	4.8^{b-s}	3.4^{e-v}	1.15^{c-i}	31^{a-i}	26.3^{d-u}	7.85^{s-z}	43.45^{b-o}
49	219148	62.5^{e-l}	93^{g-n}	90.5^{a-o}	8.3^{e-z}	11.8^{n-u}	13.9^{f-r}	4.2^{f-v}	3.8^{b-q}	1.2^{b-h}	22.9^{i-x}	39.7^{a-f}	12.08^{a-h}	31.35^{m-p}
50	219307	62.5^{e-l}	91^{i-r}	73.2^{a-z}	5.8^{a}	10.4^{tuv}	13.2^{h-r}	5.05^{a-q}	4.75^{a-e}	1.35^{b-e}	34.7^{ab}	26.2^{e-u}	12.03^{a-i}	38.05^{e-p}
51	219311	59.5^{h-n}	87.5^{n-w}	81.7^{h-y}	8.5^{d-x}	12.5^{f-t}	14.9^{e-q}	4.5^{c-u}	4.3^{a-l}	0.8^{j-n}	20.8^{m-x}	30.85^{b-r}	9.25^{h-z}	47.15^{a-k}
52	219316	53.5^{o-t}	86.5^{p-w}	83.6^{f-x}	7.65^{m-z}	14.4^{a-h}	14.25^{f-r}	5.05^{a-q}	4.05^{b-o}	1^{f-l}	19.7^{o-x}	40.1^{a-e}	10.69^{b-u}	39.55^{c-p}
53	219317	60.5^{f-n}	88.5^{l-u}	86.45^{e-u}	7.05^{a-z}	13.6^{a-n}	15.4^{d-o}	4.55^{c-u}	3.8^{b-q}	1.2^{b-h}	34.7^{ab}	24.55^{g-u}	7.94^{p-z}	50.85^{a-f}
54	220677	62.5^{e-l}	93.5^{e-m}	83.5^{f-x}	9.7^{a-h}	13.7^{a-m}	13.3^{g-r}	4^{i-w}	3.6^{c-s}	1.2^{b-h}	22.7^{i-x}	37.85^{a-i}	10.20^{c-w}	36.95^{f-p}
55	221312	61^{f-m}	93^{g-n}	80.5^{k-y}	9.3^{b-n}	11.9^{n-u}	13.3^{g-r}	4.25^{e-v}	4.35^{a-k}	0.9^{h-n}	23.7^{g-w}	31.4^{b-q}	12.86^{a-d}	35.2^{h-p}
56	221313	72^{bc}	103^{b}	90^{a-p}	7.75^{l-z}	12^{k-u}	15.5^{d-o}	3.15^{t-x}	2^{wx}	0.9^{h-n}	29^{a-m}	15.1^{t-w}	5.85^{j-r}	38.3^{d-p}
57	221324	58.5^{i-p}	83.5^{t-w}	95.1^{a-f}	7.7^{l-z}	4^{x}	14.8^{e-q}	3.5^{p-x}	3.25^{h-w}	0.9^{h-n}	20.8^{m-x}	33.45^{a-p}	8.31^{n-z}	38.8^{c-p}
58	223192	59^{i-o}	92^{g-p}	66.9^{a-z}	8.25^{f-z}	11.9^{n-u}	14.1^{e-r}	4.25^{e-v}	2.9^{m-w}	0.85^{i-n}	17.1^{u-x}	31.6^{b-q}	7.25^{xyz}	42.65^{b-p}
59	223194	60.5^{f-n}	88^{m-v}	82.6^{h-x}	8.9^{b-t}	12.8^{f-s}	14.8^{e-q}	5^{a-r}	4.3^{a-l}	1.05^{e-k}	32.2^{a-e}	22.5^{m-w}	9.51^{f-z}	49^{a-i}
60	225179	61^{f-l}	94.5^{d-k}	87.3^{e-t}	8.3^{e-z}	12.4^{g-t}	13.9^{f-r}	5.1^{a-l}	3.95^{b-p}	0.75^{k-n}	19.4^{o-x}	27.75^{b-u}	10.95^{a-o}	35.6^{g-p}
61	225992	49.5^{t}	82.5^{vw}	71.8^{a-z}	7.6^{n-z}	12.2^{i-t}	11^{qr}	4.35^{d-v}	3.35^{f-w}	0.9^{h-n}	15.2^{x}	40.5^{a-d}	6.57^{a-r}	52.95^{a-d}
62	229997	60.5^{f-n}	85.5^{r-w}	78.1^{p-z}	6.75^{ayz}	12.1^{j-t}	15.7^{d-o}	4.7^{b-t}	3.75^{b-r}	1^{f-l}	19^{p-x}	38.35^{a-i}	10.40^{c-v}	37.55^{e-p}
63	230614	58^{j-p}	88.5^{l-u}	89.7^{a-q}	8.8^{b-v}	14.6^{a-f}	14.2^{f-r}	5.55^{a-i}	4.1^{b-n}	1.4^{bcd}	26.3^{c-s}	37.65^{a-j}	9.14^{h-z}	49.8^{a-h}
64	230620	60.5^{f-n}	88.5^{l-u}	91.5^{a-m}	7.9^{j-z}	12.7^{e-s}	13.5^{f-r}	3.85^{k-x}	3.9^{b-p}	1.05^{e-k}	22.9^{i-x}	35.05^{a-p}	10.54^{c-u}	38.25^{d-p}
65	219307	62.5^{e-l}	91^{i-r}	100.8^{a}	9.5^{a-k}	13.4^{b-p}	16.6^{d-k}	5.35^{a-m}	3.4^{e-v}	1.2^{b-h}	22^{j-x}	27.3^{b-u}	12.51^{a-e}	28.1^{p}
66	230622	55.5^{m-s}	88^{m-v}	83.1^{g-x}	6.8^{a-z}	12.9^{d-s}	14.4^{f-r}	3.9^{j-x}	3.7^{b-r}	0.95^{g-m}	20.6^{n-x}	37.5^{a-k}	8.95^{k-z}	42.35^{b-p}

code	Acc. No	DH	DM	PH	SL	AL	FLL	PTPP	YLDTH	GWPS	NSPS	TSW	BYLD	HI

67	225176	60.5^{f-n}	89.5^{k-s}	93.1^{a-i}	8.45^{e-y}	12.7^{e-s}	13.6^{f-r}	4.5^{c-u}	3.55^{d-t}	1.1^{d-j}	28.6^{a-n}	26.05^{e-u}	9.37^{f-z}	36.5^{f-p}
68	230624	59^{h-o}	86.5^{p-w}	82.4^{h-x}	7.15^{a-z}	14^{a-l}	14.35^{f-r}	3.65^{n-x}	3.4^{e-v}	1.1^{d-j}	21.5^{l-x}	31.5^{b-q}	7.38^{w-z}	47.2^{a-k}
69	230628	59.5^{h-n}	90^{k-s}	86.5^{e-u}	8^{h-z}	13^{d-s}	13^{i-r}	3.9^{j-x}	3.45^{d-u}	1.1^{d-j}	23.6^{g-w}	33.3^{a-p}	8.32^{n-z}	43.15^{b-o}
70	232372	55^{n-t}	87^{o-w}	79.2^{n-y}	7.2^{a-z}	13.1^{d-r}	15.6^{d-o}	3.55^{o-x}	3.8^{b-q}	1.35^{b-e}	35.1^{a}	25.15^{f-u}	6.49^{c-r}	58.65^{a}
71	231223	61.5^{f-l}	94.5^{d-k}	93.5^{a-h}	9.9^{a-f}	11^{f-v}	15.9^{d-o}	4.45^{c-u}	3.3^{g-w}	0.95^{g-m}	19.5^{o-x}	20.75^{p-w}	7.53^{v-z}	45.6^{a-m}
72	232373	57^{l-r}	87.5^{n-w}	80^{l-y}	8.35^{e-z}	14.5^{a-g}	14.1^{f-r}	3.9^{j-x}	3.5^{d-t}	1.1^{d-j}	22.5^{j-x}	33^{a-q}	7.88^{f-z}	49.05^{a-h}
73	233028	61^{f-m}	94.5^{d-k}	74.1^{a-z}	7.9^{j-z}	11.8^{n-u}	13.3^{g-r}	3.5^{p-x}	3.55^{d-t}	1.05^{e-k}	21.7^{k-x}	31.85^{a-q}	9.03^{j-z}	40.7^{b-p}
74	234337	62^{e-l}	97^{c-h}	83.4^{g-x}	7.9^{j-z}	8^{w}	14.4^{f-r}	4.3^{d-v}	2.6^{p-x}	1.1^{d-j}	21.9^{j-x}	30.9^{b-r}	6.82^{z}	41.1^{b-p}
75	235264	49.5^{t}	91.5^{h-q}	63.3^{c}	7.6^{n-z}	10.9^{s-v}	12^{n-r}	6.05^{abc}	2.7^{o-x}	1^{f-l}	22.3^{j-x}	28.65^{b-u}	7.01^{yz}	40.8^{b-p}
76	235274	59.5^{h-n}	92.5^{f-o}	96.8^{a-c}	9.6^{a-j}	14^{a-l}	16.5^{d-k}	5.65^{a-h}	4.3^{a-l}	1^{f-l}	20.1^{o-x}	40.05^{a-e}	11.73^{a-k}	37.55^{e-p}
77	235283	57.5^{l-q}	89^{k-t}	69.8^{a-z}	8.15^{g-z}	11.5^{n-u}	12.1^{n-r}	4^{i-w}	3.6^{c-s}	0.85^{i-n}	20.6^{n-x}	32.75^{a-q}	7.38^{w-z}	48.45^{a-i}
78	235284	55.5^{m-s}	91^{i-r}	64.75^{bc}	8.1^{g-z}	11.1^{q-v}	12^{n-r}	4.75^{b-t}	4.45^{a-i}	0.9^{h-n}	18^{s-x}	40.7^{a-e}	9.98^{d-x}	46.75^{a-l}
79	233030	55.5^{m-s}	87.5^{n-w}	81.6^{h-y}	9.1^{b-q}	13.35^{b-p}	15.4^{d-o}	4.45^{c-u}	4.1^{b-n}	1.15^{c-i}	23.8^{f-v}	36.75^{a-m}	10.56^{c-u}	40.05^{c-p}
80	235299	58.5^{i-p}	88^{m-v}	67^{a-z}	9^{b-s}	11.5^{n-u}	14.5^{f-r}	5.8^{a-f}	3.8^{b-q}	0.9^{h-n}	19.9^{o-x}	33^{a-q}	7.51^{v-z}	54.9^{ab}
81	235635	61.5^{f-l}	91^{i-r}	82.2^{h-x}	8^{h-z}	12.5^{f-t}	10.5^{r}	4.35^{d-v}	3.5^{d-t}	1.2^{b-h}	29.9^{a-k}	26.8^{c-u}	6.39^{f-r}	52.05^{a-e}
82	235636	60^{f-n}	87.5^{n-w}	87.3^{c-t}	7.35^{a-z}	12.8^{e-s}	12.5^{k-r}	3.75^{m-x}	3.4^{e-v}	1.25^{b-g}	31.3^{a-h}	24.95^{g-u}	8.63^{m-z}	39.25^{c-p}
83	235637	60.5^{f-n}	88.5^{l-u}	88.4^{b-s}	8^{h-z}	12.8^{e-s}	15^{d-q}	4.65^{c-t}	4.35^{a-k}	1.05^{e-k}	24^{e-u}	41.3^{abc}	8.68^{i-z}	47.5^{a-k}
84	235651	60.5^{f-n}	90^{k-s}	79.6^{m-y}	9.05^{b-r}	13.5^{a-o}	16.15^{d-n}	5.85^{a-e}	3.5^{d-t}	0.85^{i-n}	18.7^{q-x}	36.75^{a-m}	7.09^{xyz}	46.7^{a-l}
85	235652	58^{j-p}	90^{k-s}	79.6^{m-y}	7.85^{k-z}	12^{k-t}	15.4^{d-o}	5.75^{a-h}	4.7^{a-f}	0.95^{g-m}	23^{h-x}	34^{a-p}	13.05^{abc}	35.25^{h-p}
86	235654	62.5^{e-l}	95.5^{c-j}	78^{q-z}	7.35^{a-z}	11.8^{n-u}	17^{b-i}	4.75^{b-t}	3.7^{b-r}	1.4^{bcd}	32.7^{a-d}	28.65^{b-u}	10.52^{c-u}	33.6^{j-p}
87	235746	63^{e-k}	94.5^{d-k}	92^{a-k}	7.45^{a-z}	12.1^{j-t}	16.5^{d-k}	3.65^{n-x}	3.35^{f-w}	1.05^{e-k}	30^{a-k}	24.35^{h-u}	7.98^{p-z}	37.3^{e-p}
88	237021	60^{f-n}	92^{g-p}	81.6^{h-y}	7.9^{k-z}	11.8^{n-u}	15^{d-q}	5.3^{a-t}	4^{b-o}	1^{f-l}	21^{m-x}	36.9^{a-m}	8.96^{j-z}	42.9^{b-p}
89	237022	59^{h-o}	93.5^{e-m}	92.1^{a-k}	10^{a-e}	11.6^{n-u}	18.95^{a-e}	4.7^{b-t}	4.3^{a-l}	1^{f-l}	20.6^{n-x}	39.1^{a-h}	13.92^{a}	29.9^{op}
90	239514	59^{h-o}	91^{i-r}	84.8^{e-v}	8^{h-z}	15.2^{abc}	11.2^{pqr}	5.45^{a-k}	3.8^{b-q}	1.05^{e-k}	18.3^{r-x}	29.85^{b-s}	8.73^{i-z}	41^{b-p}
91	241675	58^{j-p}	90^{k-s}	97.3^{a-d}	8.9^{b-t}	12.4^{g-t}	15.6^{d-o}	5.8^{a-f}	4.95^{abc}	1.4^{bcd}	27.2^{a-p}	37.05^{a-m}	11.25^{a-n}	44.3^{a-o}
92	242098	64^{e-i}	99^{b-e}	81.1^{j-y}	8.8^{b-t}	13.2^{b-q}	15.4^{d-o}	3.4^{r-x}	2.05^{xvw}	0.85^{i-n}	27.5^{a-o}	16.3^{r-w}	5.73^{l-r}	38.45^{c-p}
93	242574	65^{d-g}	96^{c-i}	75^{a-z}	7.2^{a-z}	9.1^{vw}	12.2^{l-r}	3.2^{s-x}	2.25^{s-x}	0.8^{j-n}	15.5^{vwx}	25.05^{f-u}	6.39^{f-r}	36.45^{f-p}
94	242581	55.5^{m-s}	88^{m-v}	72.8^{a-z}	7.9^{5i-z}	12.1^{j-t}	13.9^{f-r}	4.15^{g-v}	4.55^{a-h}	1^{f-l}	19.7^{o-x}	40.45^{a-e}	9.37^{f-z}	48.75^{a-i}
95	243182	51.5^{rst}	90^{k-s}	88.2^{c-s}	7.9^{k-z}	13.4^{b-p}	13.7^{f-r}	4^{i-w}	3.95^{b-p}	1.35^{b-e}	30.2^{a-j}	31.15^{b-q}	8.98^{j-z}	43.95^{a-o}
96	243184	55.5^{m-s}	88.5^{l-u}	90^{a-p}	7.6^{n-z}	12.9^{d-q}	14.8^{e-q}	4.6^{c-t}	3.95^{b-p}	0.9^{h-n}	19.9^{o-x}	36.25^{a-n}	8.08^{o-z}	48.6^{a-i}
97	243614	53.5^{o-t}	83^{uvw}	86.3^{e-u}	8.95^{b-s}	14^{a-l}	12.8^{j-r}	4.6^{c-t}	3.75^{b-r}	0.95^{g-m}	19.9^{o-x}	27.15^{b-u}	7.52^{v-z}	46.75^{a-l}
98	HB1307	86a	111^{a}	86.5^{c-u}	8.05^{h-z}	13.65^{a-n}	15.5^{d-o}	2.35^{x}	3^{k-w}	1.05^{e-k}	19.7^{o-x}	38.8^{a-h}	9.45^{f-z}	31.25^{m-p}
99	Abdane	62.$^{5e-l}$	100^{bcd}	89.5^{a-q}	8.85^{b-u}	12.75^{e-s}	16.5^{d-k}	4.75^{b-t}	3.05^{b-o}	0.9^{h-n}	20.2^{o-x}	33.7^{a-p}	9.76^{e-z}	41.25^{b-p}
100	L. check	50.5st	86^{q-w}	83.25^{f-x}	9.3^{b-n}	14.85^{a-e}	14.85^{e-q}	3.85^{k-x}	2.75^{n-x}	1^{f-l}	19.5^{o-x}	41.5^{ab}	10.77^{b-t}	42.45^{b-p}
	Minimum	**49.5**	**82**	**46.5**	**5.63**	**4**	**10.03**	**2.31**	**1.4**	**0.4**	**13.87**	**7.85**	**3.6**	**28.1**
	Maximum	**86**	**111**	**100.8**	**10.93**	**15.6**	**21.73**	**6.53**	**5.55**	**1.75**	**35.37**	**46.4**	**14.25**	**58.65**
	Mean	**60.36**	**91.8**	**83.54**	**8.43**	**12.46**	**14.87**	**4.51**	**3.58**	**1.06**	**23.68**	**30.94**	**8.93**	**41.21**
	SE(±)	**0.52**	**0.53**	**0.87**	**0.09**	**0.19**	**0.2**	**0.08**	**0.08**	**0.02**	**0.49**	**0.74**	**0.22**	**0.58**
	CV%	**4.63**	**3.12**	**7.17**	**9.52**	**8.81**	**12.99**	**16.88**	**19.67**	**16.73**	**16.24**	**23.8**	**15.27**	**18.61**
	LSD 5%	**5.75**	**5.99**	**11.92**	**1.71**	**2.19**	**4.16**	**1.61**	**1.37**	**0.35**	**8.35**	**14.69**	**2.64**	**14.82**

Evaluation of Ethiopian sorghum landraces for anthracnose (*Colletotrichum sublineolum* Henn.) resistance and agronomic traits

Girma Mengistu[a, b*], Hussein Shimelis[a], Mark Laing[a] and Dagnachew Lule[b]

[a]*University of KwaZulu-Natal, Private Bag X01, Scottsville 3209, Pietermaritzburg, South Africa,*
[b]*Oromia Agricultural Research Institute, P.O. Box 81265, Addis Ababa, Ethiopia*

*Corresponding author: germame2004@gmail.com

Abstract: Evaluation of sorghum accessions was done against sorghum anthracnose (*Colletotrichum sublineolum* Henn.) key fungal pathogens limiting sorghum production and still at epidemic level in western Ethiopia. The objective of this study was to assess the diverse sorghum collections and select anthracnose resistant and agronomically acceptable lines for further breeding. A total of 366 sorghum collections and three standard checks were evaluated during 2016 and 2017 cropping seasons at Bako under rain feed condition. Genotypes were artificially inoculated with virulent pathogen using a standard procedure. Accessions showed highly significant differences ($P < 0.01$) for anthracnose severity, relative area under disease progress curve and all agronomic traits considered in the study. Among the collections, 32 genotypes showed disease severity between 15 to 30% during both years suggesting their relative to moderate resistance for anthracnose disease. Higher disease severity was recorded in 2017 cropping season compared with 2016, which was mainly attributed to higher temperature and humidity in 2017. The following sorghum landraces: 71708, 210903, 74222, 73955, 74685, 74670, 74656, 74183, 234112, 69412, 226057, 214852, 71420, 71484, 200126, 71557, 75120, 71547, 220014, 228179, 16212, 16173, 16133, 69088, 238388, 16168 and 71570 showed relatively lower anthracnose severity and better agronomic performances and therefore, selected for future sorghum anthracnose resistant cultivar development subject to progeny test and continuous selection in the target production environments.

Keywords: disease severity; rAUDPC; resistance breeding; *Sorghum bicolor*,

Introduction

Sorghum anthracnose is caused by the fungal pathogen *Colletotrichum sublineolum* [Henn.] Sacc. & Trotter (formerly known as *C. graminicola* [Ces.] G.W. Wilson) (Sherriff *et al.*, 1995; Li *et a*l., 2013). It is the main cause of yield losses in susceptible sorghum (*Sorghum bicolor* [L.] Moench) varieties (Thakur and Mathur, 2000). The pathogen was first reported in Togo, West Africa in 1902 (Thakur and Mathur, 2000). Anthracnose disease is prevalent in most sorghum growing areas of the world (Crouch and Beirn, 2009; Prom *et al*., 2012; Tesso *et al*., 2012).

Disease infection and development is the highest in tropical and subtropical regions experiencing high temperature and humidity conditions (Mathur, 2002; Ngugi *et al*., 2002; Marley et al., 2005; Mehta *et al.*, 2005; Crouch and Beirn, 2009; Burrell *et al.*, 2015; Patil *et al.*, 2017). The disease is widely reported in sub-Saharan Africa encompassing the countries such as Kenya, Uganda and Ethiopia (Erpelding, 2010; Were and Ochuodho, 2012; Sserumaga *et al*., 2013). In Ethiopia anthracnose is the major problem in most sorghum

growing areas (Chala *et al*., 2010a; Chala *et al.,* 2010b). In Western Ethiopia, the disease is one of the most important sorghum production constraints as reported by farmers (Unpublished data).

Anthracnose is a foliar disease and its typical symptoms are associated with the occurrence of leaf blight and subsequent stem rot (Felderhoff *et al*., 2016). On susceptible sorghum genotypes symptoms are observed as small circular to elliptical spots with a diameter of <5 mm. Symptoms may appear as elongated red lesions with tan centers. In advanced growth stages, the fungus sporulates and acervuli are observed as black spots in the center of the lesion and coalescence leading to leaf senescence (Erpelding and Prom, 2004; Crouch and Beirn, 2009). Yield loss in sorghum due to anthracnose disease is estimated to be varying from 30-67% in susceptible varieties (Thomas *et al*., 1996; Mathur, 2002; Marley *et al*., 2005; Tesso *et al*., 2012). Sorghum anthracnose affects all plant parts including leaf, stem, panicle and grain (Crouch and Beirn, 2009). Anthracnose infected sorghum exhibits early flower abortion and reduced seed set, reduced seed weight and low seed density. Further, the disease causes premature drying and defoliation of leaves of sorghum plants leading to low grain yield (Mathur, 2002). Damage due to anthracnose disease is related with reduced photosynthesis efficiency and hence low grain yield response in susceptible sorghum varieties (Casela *et al*., 2001; Mathur, 2002; Mehta *et al.,* 2005; Crouch and Beirn, 2009).

C. sublineolum overwinters in soils through plant residue and seed. It survives as mycelium, acervuli, melanized hyphopodia, sclerotia and microsclerotia on sorghum and Johnsongrass [*Sorghum halepense* (L.) Pers.,] a wild relative of sorghum, (Crouch and Beirn, 2009). Various control options are suggested to minimize yield losses caused by anthracnose disease in sorghum. These includes use of fungicides, cultural practices, disease free seeds, crop rotation and host resistance (Mathur, 2002; Erpelding and Prom, 2004; Chala *et al*., 2010a; Silva *et al*., 2015). Developing sorghum cultivars with anthracnose resistance is the most sustainable, economic and environmentally friendly option to release varieties for resource-constrained farmers (Marley *et al*., 2005; Singh *et al*., 2006; Chala *et al*., 2010a; Li *et al*., 2013; Cuevas *et al.,* 2014). Effective fungicides are expensive, often ineffective, and crop residue management in crops such as sorghum are difficult to apply.

Host resistance can be achieved through incorporation of resistance genes into elite or the existing farmers-preferred susceptible genotypes. Disease severity, disease incidence, lesion size, and area under disease progress curve are the most common parameters used in the evaluation of sorghum genotypes for anthracnose resistance (Biruma *et al*., 2012; Chala and Tronsmo, 2012). Anthracnose resistance genes such as Cg1, Cs1A, Cs2A, SbLTP1, SbZnTF1, SbCDL1, SbDEFL1 and SbCK2 were reported with dominant or partially dominant gene action (Perumal *et al*., 2009; Biruma *et al*., 2012). These genes are reported to be non-durable in some sorghum genotypes (Buiate *et al*., 2010; Costa *et al*., 2015).

Due to the economic importance of sorghum anthracnose various national and international sorghum improvement programs are actively involved on pre-breeding and breeding of sorghum for anthracnose resistance (Belum *et al.,* 2007). However, some of the released varieties such as KSV 4 (BES) and IRAT 204 and elite lines such as IRAT 204 and 90 SN 7 were reportedly vulnerable to the disease (Marley *et al.,* 2001; Marley *et al.,* 2005). There is a

continued need to identify new sources of resistance through artificial and natural inoculation followed by genetic recombination and selection among available genetic stocks and landraces for breeding, disease management and to enhance sorghum productivity (Mbanga *et al.*, 2010; Prom *et al.*, 2012; Sharma *et al.*, 2012; Resende *et al.*, 2015).

In Ethiopia sorghum productivity is low, with the estimated national average yield of 2.53 t ha^{-1} (CSA, 2017). Anthracnose disease is the main biotic constraints limiting sorghum productivity in the country. Bako Agricultural Research Center (BARC) is one of the research centers in the Oromia Regional State of Ethiopia involved in developing sorghum genotypes for resistance against major diseases (anthracnose, leaf blight and grain mold) through integrated approach. Recently, BARC embarked on a dedicated sorghum resistance breeding program to develop anthracnose resistant varieties through incorporation of resistant genes into well-adapted sorghum genotypes for releases in the mid-altitude sub-humid agro-ecologies. Therefore, the objective of this study was to assess diverse sorghum collections and select anthracnose resistant and agronomically acceptable lines for further advanced breeding.

Materials and Methods

Study sites

The experiment was conducted during the 2016 and 2017 main cropping season at BARC in Ethiopia. The center is situated in Western Ethiopia in East Wollega Zone of the Oromia Regional State. It has a sub-humid agro-ecology with an altitude of 1650 meters above sea level (masl) and lies between 9º6’ north latitude and 37 º 09’ east longitudes. The soil type of the study site is nitosol. The center receives annual rainfall of 1,600 mm, mean maximum and minimum temperatures of 29 ºC and 13 ºC, in that order. The relative humidity ranges from 46 to 57 %. The center is a known hotspot area for sorghum anthracnose disease owing to higher temperatures and relative humidity. The main rainy season ranges from May to October with maximum rain received in July and August. Sometimes the rainfall extends from April to November. Weather data of the Center during the study period (2016 and 2017) is presented in Figure 1.

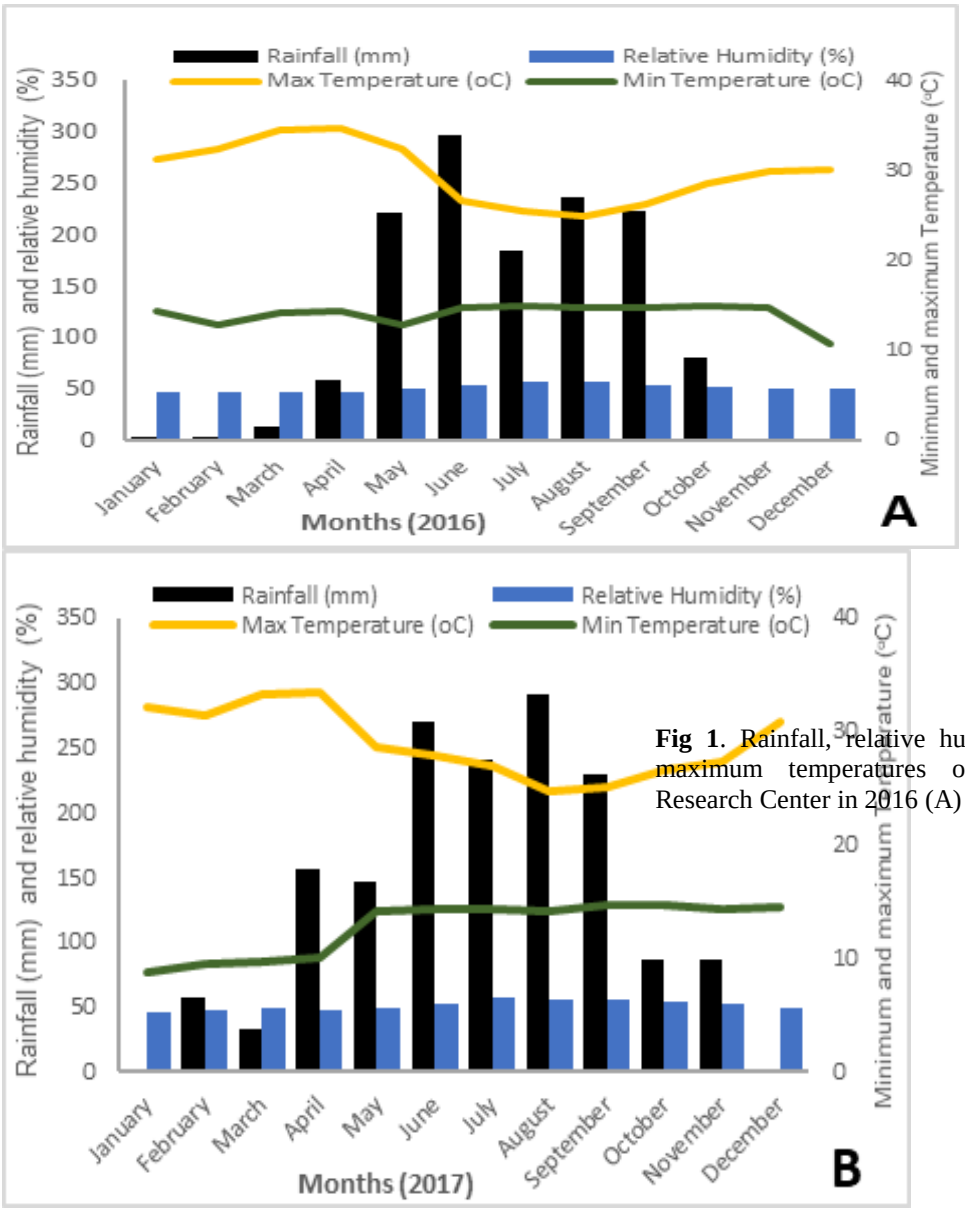


Fig 1. Rainfall, relative humidity, minimum and maximum temperatures of Bako Agricultural Research Center in 2016 (A) and 2017 (B)

Plant material

A total of 366 sorghum collections were used for the study (Table 1). The collections were obtained from various research centers and administrative regions in Ethiopia and USA. These included 363 landraces and 2 improved varieties. Improved sorghum variety referred to as 'Gemedi' released by BARC and variety 'Geremew' released by Melkassa Agricultural Research Center/Ethiopia and anthracnose susceptible check (BTx623) sourced from Texas A and M University, USA, were included in the study (Table 1).

Table 1. List of sorghum genotypes used in the study

Type of genotype	Source (administrative region or Research Center in Ethiopia)	No. of accessions	Name or designation
Landrace	Oromia Region	127	9110, 9116, 15830, 15832, 15877, 15890, 15897, 15904, 15908, 15914, 15932, 15935, 15956, 16113, 16116, 16133, 16135, 16152, 16162, 16163, 16168, 16171, 16173, 16176, 16177, 16180, 16206, 16208, 16212, 16213, 16440, 16450, 16451, 16477, 16487, 16489, 17518, 69534, 69540, 69553, 70282, 70471, 70704, 70842, 70859, 70943, 70967, 70998, 71044, 71110, 71137, 71154, 71165, 71168, 71169, 71177, 71194, 71319, 71334, 71337, 71363, 71372, 71374, 71392, 71395, 71466, 71500, 71502, 71503, 71507, 71513, 71516, 71524, 71544, 71545, 71546, 71547, 71548, 71549, 71550, 71551, 71553, 71555, 71556, 71557, 71558, 71559, 71560, 71562, 71563,75003,75004, 75006, 75114, 75115, 75118, 75119,75120, 75123, 75132, 75143, 75146, 75147, 200126, 200193, 200306, 200307, 200308, 208740, 211251, 213201, 214110, 223552, 223562, 228179, 228916, 228920, 228922, 234858, 237550, 237804, 241221, 241265, 241267, 241282, 241283, 245062
	Tigray Region	59	19613, 19619, 19621, 19641, 31309, 71420, 71424, 71425, 71476, 71479, 71480, 71484, 71489, , 71497, 73799, 73802, 73805, 73955, 73963, 73964, 74061, 74101, 74130, 74133, 74145, 74157, 74168, 74177, 74181, 74183, 74191, 74203, 74220, 74222, 74225, 74231, 74933, 207876, 220014, 234088, 234112, 235468, 237300, 238388, 238391, 238392, 238394, 238396, 238397, 238403, 238405, 238408, 238425, 238428, 238445, 238449, 238450, 242043, 243670
	Amhara Region	54	69252, 70376, 72443, 72467, 72477, 72520, 72524, 72526, 72616, 73037, 73041, 73048, 73045, 75274, 73079, 73049, 73095, 75455, 73074, 73042, 228115, 72474, 200539, 229887, 214845, 211237, 212640, 210971, 213354, 210949, 214852, 210945, 210974, 226057, 226054, 226047, 226048, 239179, 239180, 239197, 239188, 239184, 239194, 239187, 239154, 239219, 228112, 239182, 239250, 239228, 243657, 243650, 242052, 243645
	Gambela Region	39	69372, 69412, 70027, 70028, 70051, 71569, 71570, 71571, 71574, 71623, 71624, 71625, 71628, 71631, 71635, 71642, 71643, 71644, 71648, 71653, 71654, 71656, 71658, 71698, 71700, 71701, 71708, 71711, 71712, 71714, 71720, 74914, 200522, 201433, 206149, 206154, 211209, 211210, 222885
	SNNP Region	38	69088, 69178, 69326, 70161, 70187, 70636, 70795, 70874, 70891, 74649, 74651, 74653, 74656, 74663, 74665, 74666, 74670, 74681, 74685, 74686, 74687, 204622, 204626, 204631, 204633, 204636, 210903, 210906, 241706, 241708, 241709, 241715, 241720, 241721, 241722, 241723, 241725, 241728
	Dire Dawa City Administration	22	70742, 71161, 71180, 228840, 239114, 239115, 239116, 239117, 239118, 239119, 239123, 239124, 239125, 239126, 239127, 239129, 239131, 239132, 239133, 239134, 239135, 239137
	Afar Region	12	72564, 72998, 73003, 73006, 73007, 73008, 73019, 73026, 73643, 73645, 206212 and 206210
	Somali Region	8	70436, 70844, 70864, 231179, 231199, 231201, 231204, 231458
	Benishangul Gumuz Region	4	SC283-14, ETSL100375, PML981475, 29832
Released variety	Bako ARC	1	Gemedi
	Melkassa ARC	1	Geremew
	Texas A&M University/ USA	1	BTx623

SNNP= Southern Nations, Nationalities, and Peoples'
ARC=Agricultural Research Center

Experimental procedure

The accessions were planted on 27 May in 2016 and 16 May in 2017. The test genotypes were established using a 61 x 6 row by column incomplete block design with three replications. Each plot consisted of a single row of 2.1 m in length with inter-row and intra-row spacing of 0.75 m and 0.15 m, in that order.

Fertilizer was applied in the form of Urea and NPS each at the rate of 100 kg ha^{-1}. The Urea was applied in split (half at planting and the other half at a plant height of 0.60 m).

All the NPS was applied at planting. The experimental field was weeded at the right time and bird scaring was done avoid yield reduction.

Anthracnose inoculum preparation and inoculation

Based on preliminary evaluations, a single virulent anthracnose isolate sampled from Bako area was used for inoculation. Anthracnose inoculum preparation and inoculation was done according Prom *et al.* (2009). Briefly, infected tissue were taken from the susceptible sorghum leaves and surface disinfected by 10% Chlorox for four minutes and then thoroughly rinsed in distilled water. Then the tissue was plated on potato dextrose ager (PDA) in Petri dishes and incubated at room temperature for four days. Pure cultures were prepared by sub-culturing from the isolation plates. The cultures were incubated for 10 days to obtain sufficient growth.

Pure isolates of the fungus was inoculated on clean and sterilized sorghum seeds to multiply the fungus. Sorghum grain used for inoculation was prepared by washing followed soaking in water for 24 hr and then draining and autoclaving at 121 ºC for 30 min. Spores of pure cultures were gently harvested with sterilized spatula and added to the sterilized grains and incubated for 12 - 14 days in regulated light and temperature using growth chamber. The grains were mixed with a sterilized spatula every three to four days to facilitate complete colonization of the grains by the fungus.

Sorghum plants were inoculated during 45 to 50 days after planting by placing six *C. sublineolum* colonized sorghum grains into plant whorls. Inoculation was done during cloudy and afternoon to enhance infection. All plants within a row were inoculated with same amount pathogen load at the same time. To ensure further infection and higher disease pressure, susceptible check was planted as a spreader row between blocks perpendicular to the rows of test genotypes.

Data collection

Disease assessment

Disease severity (percentage of leaf area covered by anthracnose) was recorded five times at 10 days intervals starting from 14 days after inoculation. During this time there was a clear appearance of the disease symptoms. The final disease rating measured at 64 - 70 days after inoculation was referred to as final anthracnose severity (FAS). FAS was used to distinguish anthracnose reaction of genotypes based on level of severity. Five randomly tagged plants in each row were used for anthracnose disease data collection.

Disease severity for anthracnose was scored in percentage basis to calculate the diseases progress curve (AUDPC). The percentage of total leaf area of plants damaged by anthracnose were recorded following Chala and Tronsmo (2012).

The AUDPC were calculated for each sorghum accession based on Madden (2008) as follows:

$$\mathrm{AUDPC} = \sum_{i=1}^{n-1} [(X_i + X_{i+1})/2]\,(t_{i+1} - t_i)$$

Where, X=percent leaf area covered by anthracnose, t_i=time in days of the $_i^{th}$ assessment from the first assessment date and n=total number of assessments.

The AUDPC values were converted into relative area under disease progress curve (rAUDPC) as a ratio of the actual AUDPC of the sorghum accession to the AUDPC of susceptible landrace (Acc#239182) across the two cropping seasons.

Genotypes were classified into the following based on disease reaction following Chala and Tronsmo (2012): R= *resistant* (disease severity of 1–15%); MR = *moderately resistant* (16–30%); MS = *moderately susceptible* (31–45%); S = *susceptible* (46–60%) and HS = *highly susceptible* (>60%).

Yield and agronomic traits

Grain yield (t ha^{-1}) was harvested from net plot of 1.6 m^2 and adjusted to 12.5% moisture content latter converted into t ha^{-1}. Panicle length (cm), panicle width (cm), head weight (g) were measured from five randomly selected plants, thousand grain weights (g) were measured from a random sample of 1000 seeds of each accession.

Data analysis

Data collected in each year including grain yield, panicle length, panicle width, head weight and thousand grain weight were subjected to SAS computer software (SAS, 2002). Significant differences were detected among genotypes during each year that necessitated combined analysis of variance using the same software. Pearson correlation analysis was computed using SAS computer software (SAS, 2002) to estimate the relationship between final anthracnose severity (FAS), rAUDPC and agronomic traits.

Results and Discussion

Combined analysis of variance for disease and agronomic parameters

The combined analysis of variance for disease and agronomic parameters showed significant ($p<0.01$) differences among seasons, test genotypes and genotypes x season interaction for disease parameters and agronomic traits (Table 2).

Table 2. Mean squares for anthracnose disease and agronomic parameters of 366 sorghum genotypes assessed in 2016 and 2017 at Bako

		Disease parameters		Agronomic traits				
Source of variation	Df	FAS	rAUDPC	Panicle length (cm)	Panicle width (cm)	Head weight (g)	TSW (g)	Yield (ton ha^{-1})
Years	1	332**	55471**	387**	1710**	9ns	750**	103**
Replications in years	2	75ns	608**	5ns	15**	489**	1.2ns	0.1ns
Genotypes	365	928**	1098**	132**	30**	1359**	27**	5**
Genotypes x years	365	484**	556**	57**	20**	925**	22**	3**
Error	1397	29	46	5	2	90	2	0.2

DF=degree of freedom, FAS=Final anthracnose severity, rAUDPC= relative area under disease progress curve, TSW= Thousand seed weight, ** = highly significant and ns= non-significant

Mean responses of sorghum genotypes

Final anthracnose severity (FAS)

In 2016, only one genotype, 69088, scored a final anthracnose severity of 14% which is in the range of anthracnose resistance. Whereas, 32 landraces including the standard check (Gemedi) had disease severity of moderately resistance score ranging from 15 to 30%. The susceptible check, BTx623, showed 61.0 % and 62.7 % disease severity in 2016 and 2017, in that order (Table 3). About 62 landraces in 2016 and 40 in 2017 had higher anthracnose disease severity (data not shown) compared with the susceptible check (Table 3). In the present study anthracnose disease reaction varied from resistant to highly susceptible

among the tested lines (data not shown). Chala and Tronsmo (2012) observed genetic variation in response to anthracnose disease when evaluating 56 sorghum accessions conducted under natural infection. In line with the present study, different authors reported that Ethiopian sorghum landraces are good source of genetic variation for anthracnose resistance (Erpelding, 2008, 2009a; Prom *et al*., 2011; Chala and Tronsmo, 2012; Cuevas *et al.,* 2014).

In 2016 higher number of genotypes (130) showed moderately resistant reaction compared with 2017. In 2017 test season greater number of genotypes (174) displayed moderately susceptible reaction. Among the total sorghum genotypes tested in 2016 and 2017, 131 and 47 entries had resistant reactions, respectively (Figure 2). Higher anthracnose disease severity was observed in 2017 testing season than 2016 mainly attributed to the favourable weather condition for anthracnose disease infection and development. Relatively higher rainfall and relative humidity were recorded in 2017 than 2016 (Figure 1). In line with this finding Chala and Tronsmo (2012) reported that prolonged and higher rainfall and relative humidity favors anthracnose disease. It was noted that anthracnose disease severity showed faster increase on the susceptible genotypes (Figure 4) compared with resistant counterparts (Figure 3).

Relative area under disease progress curve **(rAUDPC)**

Highly significant ($P<0.001$) variation was observed among tested genotypes in both seasons. Lower rAUDPC value of 21.2% was obtained from landrace of 69088 followed by 73955, 74685 and 19621 with rAUDPC scores of 23.0%, 23.2% and 23.4%, respectively. The highest (93.8%) rAUDPC score was recorded from landrace of 239182. The standard checks Gemedi and Geremew showed rAUDPC values of 32.5% and 41.5%, respectively. BTx623, the variety used as anthracnose susceptible check, had higher rAUDPC value of 61.2% (Table 3). This finding of rAUDPC is within the range Chala and Tronsmo (2012).

Table 3. Mean final anthracnose severity (FAS), reaction type and relative area under disease progress curve (rAUDPC) of 32 selected sorghum genotypes and checks assessed for anthracnose resistance in 2016 and 2017 at Bako Agricultural Research Center in Ethiopia

Serial	Accession	FAS			Reaction type		rAUDPC		
No.	number/name	2016	2017	Mean	2016	2017	2016	2017	Mean
249	69088	14.0	25.0	19.5	R	MR	14.3	28.0	21.2
62	74685	16.3	20.7	18.5	MR	MR	15.7	30.7	23.2
232	16133	15.3	26.7	21.0	MR	MR	17.7	37.0	27.4
110	71547	16.7	27.7	22.2	MR	MR	22.7	31.7	27.2
28	71420	16.7	26.0	21.4	MR	MR	19.0	31.3	25.2
188	16173	18.0	25.7	21.9	MR	MR	22.0	34.0	28.0
270	19621	17.7	26.7	22.2	MR	MR	16.7	30.0	23.4
42	200126	18.3	27.3	22.8	MR	MR	20.7	36.0	28.4
291	223562	19.0	28.3	23.7	MR	MR	26.0	37.7	31.9
253	238388	19.0	28.0	23.5	MR	MR	21.3	35.3	28.3
293	16168	19.0	25.0	22.0	MR	MR	25.3	35.7	30.5
56	73955	19.3	23.3	21.3	MR	MR	16.3	29.7	23.0
11	71708	19.7	27.0	23.4	MR	MR	14.7	37.3	26.0
64	210903	20.0	26.3	23.2	MR	MR	16.0	38.7	27.4
61	75120	19.7	29.0	24.4	MR	MR	24.7	35.3	30.0
171	239126	20.0	30.0	25.0	MR	MR	19.7	39.7	29.7
311	75003	22.0	29.0	25.5	MR	MR	24.0	34.3	29.2
278	226057	22.0	28.0	25.0	MR	MR	25.7	39.7	32.7
154	228112	22.3	27.3	24.8	MR	MR	28.0	39.3	33.7
74	74656	23.3	25.3	24.3	MR	MR	22.7	42.0	32.4
55	74222	24.7	26.7	25.7	MR	MR	26.7	38.7	32.7
78	74183	25.3	26.0	25.7	MR	MR	32.3	29.7	31.0
174	16213	25.7	30.0	27.9	MR	MR	22.7	40.0	31.4
233	234112	25.7	25.0	25.4	MR	MR	29.0	31.7	30.4
250	69412	26.0	26.7	26.4	MR	MR	20.3	33.7	27.0
50	71571	26.7	29.3	28.0	MR	MR	34.0	38.7	36.4
183	16212	26.7	26.3	26.5	MR	MR	33.7	34.7	34.2
85	71562	26.3	29.0	27.7	MR	MR	28.0	37.7	32.9
114	220014	27.0	25.0	26.0	MR	MR	32.0	33.3	32.7
290	214852	26.7	27.3	27.0	MR	MR	30.0	37.7	33.9
30	71484	27.0	28.7	27.9	MR	MR	27.7	39.3	33.5
25	74651	27.7	28.0	27.9	MR	MR	29.3	30.3	29.8
299	Geremew	51.0	32.7	41.9	HS	S	38.0	45.3	41.7
366	Gemedi	28.0	26.7	27.4	MR	MR	33.0	32.0	32.5
365	BTx623	61.0	62.7	61.9	HS	HS	64.0	58.3	61.2
Mean		41.9	44.4				42.8	52.9	
SE		5.7	4.9				5.7	7.4	
LSD (5%)		9.2	7.9				9.2	11.8	
R^2 (%)		0.94	0.92				0.95	0.86	
CV (%)		13.6	11.1				13.4	13.9	
P Value		**	**				**	**	

R= Resistant, MR=Moderately resistant, HS= Highly susceptible, SE= standard error, LSD=Least Significant Difference, CV= Coefficient of variance, P = Probability, ** = highly significant at $p<0.01$

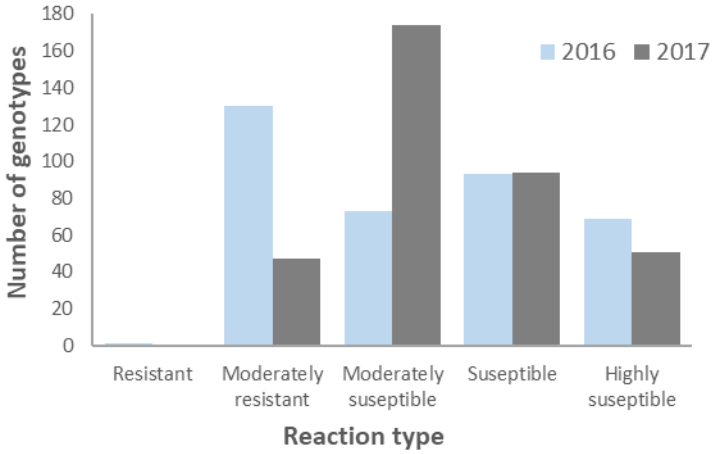


Fig 2. Classification of tested sorghum genotypes for anthracnose reaction type recorded in 2016 and 2017 at Bako

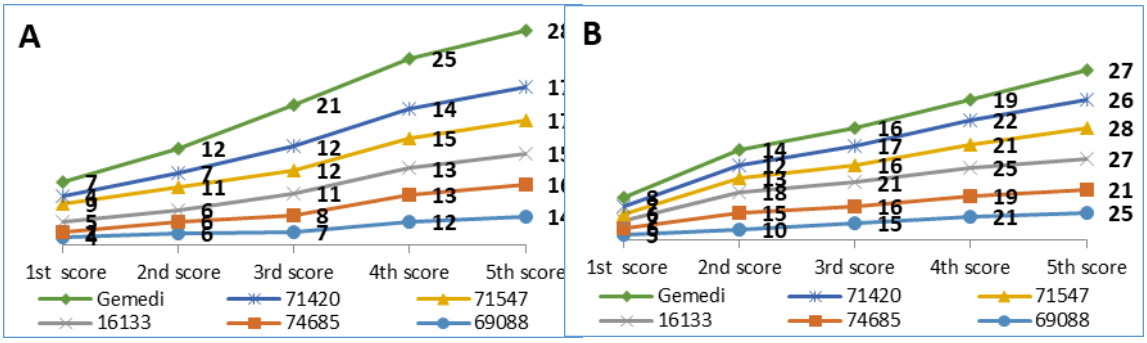


Fig 3. Disease severity scores for six selected moderately resistant accessions during 2016 (A) and 2017 (B)

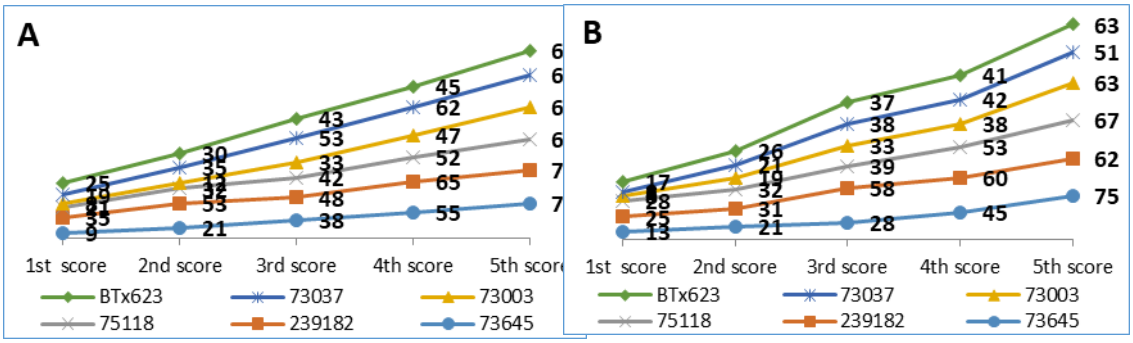


Fig 4. Disease severity scores for six selected susceptible and highly susceptible accessions during 2016 (A) and 2017 (B)

Grain yield and yield related traits

Highly significant (P<0.001) variation was observed among tested genotypes for yield and agronomic traits (Table 4). The mean grain yield of tested genotypes varied from 1.4 to 5.6 ton ha^{-1} for accessions 75120 and 223562, respectively with mean grain yield 3.0 ton ha^{-1}. Improved varieties used as standard checks such as Gemedi, Geremew and the susceptible check (BTx623) expressed grain yields of 2.0, 1.8 and 1.7 ton ha^{-1}, respectively. Longer panicle length of 32.3 cm was recorded from landrace of 69412, the wider panicle (16.6 cm) was recorded from landrace of 220014, head weight of 92.7 g for landrace 71484 and 1000 seed weight 25.1 g for landrace 74651 both in 2016 and 2017

(Table 4). Amare et al. (2015) reported similar results of the current finding of mean panicle length, head weight, grain yield, however, higher thousand seed weight 32.4 g.

Table 4. Mean head weight, panicle length, panicle width, 1000 seed weight and grain yield of 32 selected sorghum genotypes and checks assessed in 2016 and 2017 at Bako Agricultural Research Center in Ethiopia.

Serial	Accession	Head weight (g)			Panicle length (cm)			Panicle width (cm)			TSW (g)			Grain yield (ton ha^{-1})		
No.	number/name	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean	2016	2017	Mean
249	69088	83.3	90.3	86.8	30.1	30.6	30.4	11.4	10.0	10.7	21.9	23.7	22.8	1.7	1.8	1.8
62	74685	50.0	55.7	52.9	30.7	26.3	28.5	11.9	10.9	11.4	24.5	23.1	23.8	3.5	2.6	3.1
232	16133	72.0	90.7	81.4	25.1	18.5	21.8	17.1	8.0	12.6	22.5	21.1	21.8	3.0	2.7	2.9
110	71547	86.7	83.0	84.9	15.9	18.7	17.3	10.4	10.1	10.3	22.0	23.2	22.6	3.5	4.5	4.0
28	71420	53.0	46.3	49.7	22.1	23.2	22.7	9.9	7.5	8.7	20.2	17.7	19.0	2.3	1.4	1.9
188	16173	85.7	85.4	85.6	20.7	29.4	25.1	16.3	16.5	16.4	19.0	20.9	20.0	4.5	5.0	4.8
270	19621	64.7	43.7	54.2	24.3	20.3	22.3	8.3	6.9	7.6	23.3	20.4	21.9	4.4	1.5	3.0
42	200126	94.3	85.7	90.0	25.2	28.4	26.8	13.3	11.3	12.3	24.6	24.6	24.6	3.0	4.2	3.6
291	223562	91.3	84.0	87.7	20.3	26.3	23.3	9.8	9.9	9.9	23.1	25.3	24.2	6.3	4.3	5.3
253	238388	49.7	52.0	50.9	31.9	30.6	31.3	17.9	15.3	16.5	15.8	22.8	19.3	2.0	2.1	2.1
293	16168	53.0	54.0	53.5	24.5	22.1	23.3	12.5	11.3	11.9	25.3	20.0	22.7	3.1	3.2	3.2
56	73955	53.7	72.0	62.9	24.9	24.5	24.7	11.7	8.2	10.0	20.4	21.4	20.9	2.6	3.4	3.0
11	71708	92.7	90.7	91.7	30.6	30.3	30.5	12.3	14.0	13.2	22.5	26.2	24.4	4.6	5.4	5.0
64	210903	76.3	74.0	75.2	24.5	26.2	25.4	14.4	11.0	12.7	21.2	19.8	20.5	3.7	3.9	3.8
61	75120	45.3	55.0	50.2	27.6	26.0	26.8	9.1	7.1	8.1	23.1	22.9	23.0	1.5	1.3	1.4
171	239126	67.0	87.7	77.4	24.8	25.2	25.0	10.6	10.7	10.7	19.3	19.7	19.5	2.8	4.7	3.8
311	75003	26.7	35.7	31.2	31.7	27.9	29.8	12.7	14.5	13.6	20.9	20.4	20.7	2.7	4.3	3.5
278	226057	67.3	70.7	69.0	24.7	24.0	24.4	11.4	7.9	9.7	24.8	19.6	22.2	2.1	2.9	2.5
154	228112	51.3	51.7	51.5	23.6	28.7	26.2	11.3	13.9	12.6	22.6	22.8	22.7	3.3	4.2	3.8
74	74656	69.3	71.0	70.2	22.2	25.6	23.9	12.4	11.9	12.2	27.9	21.5	24.7	2.4	1.3	1.9
55	74222	44.7	63.0	53.9	20.9	30.3	25.6	10.5	9.2	9.9	25.6	23.3	24.5	3.6	4.5	4.1
78	74183	54.0	59.7	56.9	21.5	21.6	21.6	10.6	11.6	11.1	24.1	20.7	22.4	2.2	2.6	2.4
174	16213	56.3	54.7	55.5	22.9	26.8	24.9	12.1	7.5	9.8	18.5	18.2	18.4	1.5	3.9	2.7
233	234112	74.0	72.7	73.4	27.0	30.2	28.6	10.4	10.2	10.3	24.3	19.0	21.7	3.6	1.6	2.6
250	69412	69.7	54.7	62.2	34.7	29.9	32.3	13.7	9.1	11.4	24.0	25.5	24.8	4.2	3.2	3.7
50	71571	52.0	66.3	59.2	30.7	27.2	29.0	7.9	8.1	8.0	19.4	18.7	19.1	4.9	3.2	4.1
183	16212	69.3	68.3	68.8	33.0	30.9	32.0	15.7	13.3	14.5	22.0	18.5	20.3	2.3	2.8	2.6
85	71562	66.0	68.0	67.0	23.7	28.4	26.1	7.5	7.0	7.3	22.6	21.5	22.1	2.3	2.9	2.6
114	220014	72.0	73.7	72.9	30.9	27.5	29.2	20.5	12.6	16.6	21.1	21.8	21.5	4.4	4.1	4.3
290	214852	65.7	61.7	63.7	21.6	22.6	22.1	9.5	8.6	9.1	23.2	25.7	24.5	3.1	3.8	3.5
30	71484	97.0	88.3	92.7	24.9	27.7	26.3	10.8	11.9	11.4	25.5	22.4	24.0	2.2	2.9	2.6
25	74651	53.3	54.9	54.1	15.4	16.6	16.0	8.8	9.5	9.2	24.6	25.6	25.1	2.6	3.5	3.1
299	Geremew	58.0	75.0	66.5	23.8	29.2	26.5	7.9	8.8	8.4	24.9	20.5	22.7	1.7	1.8	1.8
366	Gemedi	63.0	69.7	66.4	31.7	30.5	31.1	10.1	10.0	10.1	20.6	21.8	21.2	1.9	2.1	2.0
365	BTx623	54.3	48.0	51.2	13.7	19.2	16.5	7.7	10.5	9.1	22.9	20.3	21.6	1.5	1.9	1.7
Mean		59.5	59.6		24.0	24.8		11.4	9.6		22.6	21.4		2.8	3.2	
SE		7.7	10.9		2.0	2.5		1.2	1.4		0.7	1.8		0.3	0.5	
LSD (5%)		12.3	17.4		3.2	4.1		2.0	2.3		1.2	2.9		0.6	0.9	
R^2 (%)		0.90	0.86		0.93	0.89		0.92	0.83		0.96	0.80		0.94	0.90	
CV (%)		12.9	18.2		8.2	10.2		10.8	15		3.2	8.6		12.4	16.3	
P Value		**	**		**	**		**	**		**	**		**	**	

TSW= Thousand seed weight, SE= Standard error, LSD=Least Significant Difference, CV=Coefficient of variation, P = Probability, ** = highly significant at p<0.01

Association between disease parameters and agronomic traits

Correlation analysis between disease parameters and agronomic traits indicated highly significant (p<0.01) associations for most variables (Tables 5). The highest positive correlation (0.87, p<0.01) was observed between FAS and rAUDPC during both years. Significant and positive relationship (p<0.01) were recorded between grain yield and panicle length (r=0.18), panicle width (r=0.13) and head weight (r=0.20). There were significant (p<0.01) and negative correlation between rAUDPC and yield (r=-0.23), head weight (-0.19), panicle length (-0.27) and panicle width (-0.22) suggesting that anthracnose disease had marked negative effect on grain yield and its components.

Further, grain yield had negative and significant (p<0.01) correlation with final anthracnose severity (r=-0.19) in 2016 (Table 5). The above trends were evident in both years except minor discrepancies. Overall, positive and significant correlation was observed between FAS and rAUDPC, but these two parameters correlated negatively and

significantly with the others agronomic parameters (Table 5). In line with the present findings, Tesso *et al.* (2011) reported thousand seed weight, panicle width and head weight had positive correlations with grain yield. Conversely, the authors reported negative correlation between panicle length and grain yield opposed to the current findings.

Table 5. Pair-wise Pearson correlation coefficients describing association of sorghum agronomic and anthracnose disease parameters when assessing 366 sorghum genotypes in 2016 (lower diagonal) and 2017 (upper diagonal) at Bako Agricultural Research Center in Ethiopia

Parameters	Panicle length	Panicle width	Head weight	TSW	Yield	FAS	rAUDPC
Panicle length	1	0.16**	0.16**	0.12*	0.27**	-0.22**	-0.26**
Panicle width	0.33**	1	0.17**	0.18**	0.14**	-0.10ns	-0.10*
Head weight	0.15**	0.02ns	1	0.12*	0.24**	-0.10ns	-0.12*
TSW	0.01ns	0.01ns	0.10*	1	0.17**	-0.11*	-0.13*
Yield	0.18**	0.13**	0.20**	0.16**	1	-0.22**	-0.19**
FAS	-0.25**	-0.19**	-0.16**	-0.07ns	-0.19**	1	0.87**
rAUDPC	-0.27**	-0.22**	-0.19**	-0.10ns	-0.23**	0.87**	1

TSW= Thousand seed weight, FAS=Final anthracnose severity, rAUDPC= relative area under disease progress curve, ** = highly significant ($p<0.01$), * = significant ($p<0.05$), ns= non significant

Conclusion

Even though there are different sorghum anthracnose disease management options practiced to control the disease, developing anthracnose resistance sorghum cultivar plays a greater role in boosting sorghum production and productivity. In this study about 27 sorghum landraces such as 71708, 210903, 74222, 73955, 74685, 74670, 74656, 74183, 234112, 69412, 226057, 214852, 71420, 71484, 200126, 71557, 75120, 71547, 220014, 228179, 16212, 16173, 16133, 69088, 238388, 16168 and 71570 were selected because of their relatively lower disease severity and better agronomic performances. The selected lines are useful for future sorghum anthracnose resistant cultivar development subject to progeny test and continuous selection in the target production environments.

References

Amare, K., H. Zeleke, and G. Bultosa. 2015. Variability for yield, yield related traits and association among traits of sorghum (*Sorghum bicolor* (L.) Moench) varieties in Wollo, Ethiopia. Journal of Plant Breeding and Crop Science 7: 125-133.

Belum, V. S. R., S. Ramesh, S. T. Borikar, and S. K. Hussain. 2007. ICRISAT–Indian NARS partnership sorghum improvement research: Strategies and impacts. Current Science 92: 909-915.

Biruma, M., T. Martin, I. Fridborg, P. Okori, and C. Dixelius. 2012. Two loci in sorghum with NB-LRR encoding genes confer resistance to *Colletotrichum sublineolum*. Theoretical and Applied Genetics 124: 1005-1015.

Buiate, E. A. S., E. A. SOUZA, L. Vaillancourt, I. Resende, and U. P. Klink. 2010. Evaluation of resistance in sorghum genotypes to the causal agent of anthracnose. Crop Breeding and Applied Biotechnology 10: 166-172.

Burrell, A. M., A. Sharma, N. Y. Patil, S. D. Collins, W. F. Anderson, W. L. Rooney, and P. E. Klein. 2015. Sequencing of an anthracnose-resistant sorghum genotype and mapping of a major QTL reveal strong candidate genes for anthracnose resistance. Crop Science 55: 790-799.

Casela, C. R., F. G. Santos, and A. S. Ferreira. 2001. Reaction of sorghum genotypes to the anthracnose fungus *Colletotrichum graminicola*. Fitopatologia Brasileira 26: 197-200.

Chala, A., T. Alemu, L. K. Prom, and A. M. Tronsmo. 2010a. Effect of host genotypes and weather variables on the severity and temporal dynamics of sorghum anthracnose in Ethiopia. Plant Pathology Journal (Faisalabad) 9: 39-46.

Chala, A., M. B. Brurberg, and A. M. Tronsmo. 2010b. Incidence and severity of sorghum anthracnose in Ethiopia. Plant Pathology Journal (Faisalabad) 9: 23-30.

Chala, A., and A. M. Tronsmo. 2012. Evaluation of Ethiopian sorghum accessions for resistance against Colletotrichum sublineolum. European Journal of Plant Pathology 132: 179-189.

Costa, R. V., L. Zambolim, L. V. Cota, D. D. Silva, D. F. Parreira, F. E. Lanza, and A. G. C. Souza. 2015. Pathotypes of *Colletotrichum sublineolum* in Response to Sorghum Populations with Different Levels of Genetic Diversity in Sete Lagoas-MG. Journal of Phytopathology 163: 543-553.

CSA (2017) Agricultural sample survey. Report on area and production of major crops, Volume I (Meher season, private peasant holding), Addis Ababa.

Crouch, J. A., and L. A. Beirn. 2009. Anthracnose of cereals and grasses. Fungal Diversity 39: 19.

Cuevas, H. E., L. K. Prom, and J. E. Erpelding. 2014. Inheritance and molecular mapping of anthracnose resistance genes present in sorghum line SC112-14. Molecular Breeding 34: 1943-1953.

Erpelding, J. E. 2008. Sorghum germplasm resistance to anthracnose. American Journal of Plant Sciences and Biotechnology 2: 42-46.

Erpelding, J. E. 2009a. Anthracnose disease response for photoperiod-insensitive Ethiopian germplasm from the US sorghum collection. World Journal of Agricultural Sciences 5: 707-713.

Erpelding, J. E. 2009b. Anthracnose disease response for photoperiod-insensitive Ethiopian germplasm from the US sorghum collection. World Journal of Agricultural Science 5: 707-713.

Erpelding, J. E. 2010. Anthracnose disease response in the Burundi sorghum germplasm collection. Agriculture and Biology Journal of North America 1: 1119-1125.

Erpelding, J. E., and L. K. Prom. 2004. Evaluation of Malian sorghum germplasm for resistance against anthracnose. Plant Pathology Journal 3: 65-71.

Felderhoff, T., L. McIntyre, A. Saballos, and W. Vermerris. 2016. Using Genotyping by Sequencing To Map Two Novel Anthracnose Resistance Loci in *Sorghum bicolor*. G3: Genes| Genomes| Genetics: g3. 116.030510.

Li, L., F. Zhu, H. Liu, A. Chu, and C. Lo. 2013. Isolation and expression analysis of defense-related genes in sorghum–*Colletotrichum sublineolum* interaction. Physiological and Molecular Plant Pathology 84: 123-130.

Madden, L. V., Hughes, G., & van den Bosch, F. 2008. The study of plant disease epidemics. Minnesota: The American Phytopathology Society.

Marley, P. S., M. Diourte, A. Neya, and F. W. Rattunde. 2005. Sorghum anthracnose and sustainable management strategies in West and Central Africa. Journal of Sustainable Agriculture 25: 43-56.

Marley, P. S., K. A. Elemo, D. A. Aba, I. Onu, and I. Akintayo. 2001. Reactions of Sorghum Genotypes to Anthracnose and Grey Leaf Spot Diseases Under Sudan and Sahel Savanna Field Conditions of Nigeria. Journal of Sustainable Agriculture 18: 105-116.

Mathur, K., R. P. Thakur, A. Neya, P. S. Marley, C. R. Casela and L. U. Rosewich. 2002. Sorghum anthracnose–Problem and Management Strategies. In J. Leslie, (ed.) Sorghum and Millets Pathology 2000: Pp. 211-220.

Mbanga, J., O. Chifamba, and S. DUBE. 2010. Effect of Method of İnoculation, Moisture and Seedling Age on Foliar Anthracnose Development in Two Varieties of *Sorghum bicolar* (Kadoma 332 and Marapansi). Journal of Agro Crop Science 1: 12-18.

Mehta, P. J., C. C. Wiltse, W. L. Rooney, S. D. Collins, R. A. Frederiksen, D. E. Hess, M. Chisi, and D. O. TeBeest. 2005. Classification and inheritance of genetic resistance to anthracnose in sorghum. Field Crops Research 93: 1-9.

Ngugi, H. K., S. B. King, G. O. Abayo, and Y. V. R. Reddy. 2002. Prevalence, incidence, and severity of sorghum diseases in western Kenya. Plant Disease 86: 65-70.

Patil, N. Y., R. R. Klein, C. L. Williams, S. D. Collins, J. E. Knoll, A. M. Burrell, W. F. Anderson, W. L. Rooney, and P. E. Klein. 2017. Quantitative Trait Loci Associated with Anthracnose Resistance in Sorghum. Crop Science 57: 877-890.

Perumal, R., M. A. Menz, P. J. Mehta, S. Katilé, L. A. Gutierrez-Rojas, R. R. Klein, P. E. Klein, L. K. Prom, J. A. Schlueter, and W. L. Rooney. 2009. Molecular mapping of Cg1, a gene for resistance to anthracnose (*Colletotrichum sublineolum*) in sorghum. Euphytica 165: 597-606.

Prom, L. K., J. Erpelding, R. Perumal, T. Isakeit, and H. Cuevas. 2011. Response of sorghum accessions from four African countries against *Colletotrichum sublineolum*, causal agent of sorghum anthracnose. American Journal of Plant Sciences 3: 125-129.

Prom, L. K., R. Perumal, S. R. Erattaimuthu, C. R. Little, E. G. No, J. E. Erpelding, W. L. Rooney, G. N. Odvody, and C. W. Magill. 2012. Genetic diversity and pathotype determination of *Colletotrichum sublineolum* isolates causing anthracnose in sorghum. European Journal of Plant Pathology 133: 671-685.

Prom, L. K., R. Perumal, J. E. Erpelding, T. Isakeit, N. Montes-Garcia, and C. W. Magill. 2009. A pictorial technique for mass screening of sorghum germplasm for anthracnose (*Colletotrichum sublineolum*) resistance. The Open Agriculture Journal 3: 20-25.

Resende, R. S., C. A. Milagres, D. Rezende, C. E. Aucique-Perez, and F. Á. Rodrigues. 2015. Bioprospecting of Saprobe Fungi from the Semi-Arid North-East of Brazil for the Control of Anthracnose on Sorghum. Journal of Phytopathology 163: 787-794.

Sharma, R., H. D. Upadhyaya, S. V. Manjunatha, V. P. Rao, and R. P. Thakur. 2012. Resistance to foliar diseases in a mini-core collection of sorghum germplasm. Plant Disease 96: 1629-1633.

Sherriff, C., M. J. Whelan, G. M. Arnold, and J. A. Bailey. 1995. rDNA sequence analysis confirms the distinction between *Colletotrichum graminicola* and *C. sublineolum*. Mycological Research 99: 475-478.

Silva, D. D., R. V. Costa, L. V. Cota, J. E. F. Figueiredo, C. R. Casela, and F. E. Lanza. 2015. Genotype rotation for leaf anthracnose disease management in sorghum. Crop Protection 67: 145-150.

Singh, M., K. Chaudhary, and K. S. Boora. 2006. RAPD-based SCAR marker SCA 12 linked to recessive gene conferring resistance to anthracnose in sorghum [*Sorghum bicolor* (L.) Moench]. Theoretical and Applied Genetics 114: 187-192.

Sserumaga, J. P., M. Biruma, A. Akwero, P. Okori, and R. Edema. 2013. Prevalence of sorghum anthracnose in different agroecologies of Uganda. Uganda Journal of Agricultural Sciences 14: 125-135.

Tesso, T., R. Perumal, C. R. Little, A. Adeyanju, G. L. Radwan, L. K. Prom, and C. W. Magill. 2012. Sorghum pathology and biotechnology-a fungal disease perspective:

Part II. Anthracnose, stalk rot, and downy mildew. European Journal of Plant Science and Biotechnology 6: 31-44.

Tesso, T., A. Tirfessa, and H. Mohammed. 2011. Association between morphological traits and yield components in the durra sorghums of Ethiopia. Hereditas 148: 98-109.

Thakur, R. P., and K. Mathur. 2000. Anthracnose. In: Compendium of Sorghum Diseases. (Eds. R. A. Frederiksen and G. N. Odvody). The American Phytopathological Society, St Paul, MN, USA, pp: 10-12.

Thomas, M. D., I. Sissoko, and M. Sacko. 1996. Development of leaf anthracnose and its effect on yield and grain weight of sorghum in West Africa. Plant Disease 80: 151-153.

Were, J. O., and J. O. Ochuodho. 2012. Morphogenetic diversity of Colletotrichum species infecting *Sorghum bicolor* in the lake basin regions of Kenya. International Journal of Agronomy & Agricultural Rresearch 2: 1-7.

Effects Of NPS Fertilizer Rates on Yield and Yield Traits of Maize Varieties at Bako, Western Ethiopia

[1*]Hailu Feyisa, [1]Fufa Anbessa, [1]Megersa Debela and [1]Gudeta Bedada
[1]Bako Agricultural Research Center, P.O.Box 3, Bako, West Shewa, Ethiopia.
Corresponding author: thailufeyisa@gmail.com

Abstract

Maize productivity is constrained by the application of blanket recommended DAP and urea fertilizers. However, since 2015 cropping season an effort has been made to replace the use of DAP and urea fertilizers to more balanced form of NPS fertilizer which is also blanket. To this end, this experiment was conducted on three farmers' field around Bako, Western Oromia, in 2016 and 2017 main cropping season to determine the optimum NPS fertilizer rate for maize varieties in the study area. Two maize varieties (BH661 and BHQPY545) were used as a test varieties and six rates of NPS fertilizer (0, 25, 50, 75, 100 and 125 NPS kg ha^{-1}) and one previously recommended N & P_2O_5 used as check were laid out in factorial RCBD with three replication. The result revealed that fertilizer application significantly affected grain yield, above ground biomass yield and plant height while no significant effect on thousand kernel weight and harvest index. Significant grain yield differences were observed between treatments for BH661 varieties, whereas, significant differences were observed only between control treatment and the rest rate of fertilizers applied for BHQPY545 varieties. Maximum grain yield increment was observed in the interval between 25 to 50 kg NPS ha^{-1} rate, but small increment of grain yield was observed beyond this intervals. There was also strong relationship between applied NPS fertilizer and grain observed (R^2= 0.86 and 0.90) for maize cultivar BH661 and BHQPY545 correspondingly. Based on obtained results, application of 100 kg NPS ha^{-1} on maize variety of BHQPY545 had the highest net benefit ETB 43394.30 ha^{-1} with an acceptable marginal rate of return (MRR) of 456.3%. In conclusion, application of 100 kg NPS ha^{-1} fertilizer with maize cultivar BHQPY545 is agronomically and economically feasible and hence recommended for the end users.

Key words*:* BH-661, BHQPY-545, NPS

Introduction

Maize has been considered globally as the most important agricultural grain crop which is stable food in many countries and feed to livestock. It is estimated that by 2050 the demand for maize in developing countries will be double, and by 2025 maize will have become the crop with the greatest production globally (FARA, 2009).

In Ethiopia, cereal crops production cover nearly 81.3%. Of this maize covered about 17% (2,135,571 ha) and 27% (78,471,746 quintals) of grain yields (CSA, 2017). It is the major stable food crop leading all other cereals in terms of production and productivity. Approximately 88% maize produced in Ethiopia is consumed at home as food, both as green and dry grain (Tsedeke *et al*., 2015). No other cereal crop produced reaches to this level in terms of retention for home consumption (Moti *et al*., 2015). For smallholder farmers in maize-based systems, their perception on own food security status is directly related to the amount of maize harvest they produced in a given year, which is again related to maize productivity influenced by factors such as varieties used and crop management efforts put forth. Despite tremendous yield potential, maize productivity

remains low. Current national average grain yield of maize in Ethiopia is about 3.7 t ha^{-1} (CSA, 2016/17). This is very low compared to developed countries average grain yield of 10.3 t ha^{-1} in USA, 9.7 in Germany and 5.2 t ha^{-1} is world average (FAOSTAT, 2012). Although, low yields of this crop was attributes of several factors, nutrient management is found the key element that contributed to low productivity of maize in Ethiopia (CIMMYT, 2004).

Plant nutrient deficiency is one of the foremost problems hamper the development of an economically successful agriculture (Fageria and Baligar, 2005). Higgs *et al*. (2002) is pointed out that some 30 to 50% of the rise in world food production since the 1950s attributed to utilization of fertilizer. Nevertheless, many farmers refine from applying fertilizer because of rising costs, uncertainty about the economic returns to fertilizing crops and lack of knowledge as to which type and rates are appropriate (Hopkins *et al*., 2008).

Over the past 40 years, soil fertility management in Ethiopia focused on the application of DAP and UREA. However, since 2015 cropping season an effort has been made to replace the use of DAP and UREA fertilizers to more balanced form of NPS fertilizer on soil test-based fertilizer recommendation. This new more balanced NPS fertilizer was introduced directly to replace the recommended DAP while UREA is recommended to be used as basal fertilizer. However, this new recommended blend formula fertilizer is still blanket.

Moreover, 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 sulfur in different types of soils in addition to mining by different crops as result of continues cultivation of land (Murashkina *et al*., 2006). Recently different fertilizers produced in factory by blending different nutrients is used to replace adding two or more fertilizers to the soils by the crop producers to supply different nutrients for the crop, save resources and economy of the farmers. Hence, the current research was initiated to address the objectives of determining the optimum NPS fertilizer rate for maize varieties in the study area.

Materials and Methods

Description of the study area

The experiment was conducted on three farmers' fields in Bako-Tibe district of West Shewa zone of Oromia regional state, Ethiopia in 2016 and 2017 main cropping season (Fig. 1). The area lie between 8’59'31" N to 9'01'16" N latitude and 37'13'29 E to 37°21'’’E longitude and at altitude range of 1727 to 1778 meter above sea level. Mean annual rainfall is 1265 to 1293 mm with unimodal distribution (MBARC, 2014). The experimental area is characterized by warm and humid climate with mean minimum, mean maximum and average air temperatures of 14, 28.5 and 21.2^{o}c to 13.4, 28.49 and 20.95°c, respectively (WWW.IQQO.ORG). The soil type is brown clay loam Nitisols and Alfiso (Mesfin, 1998).

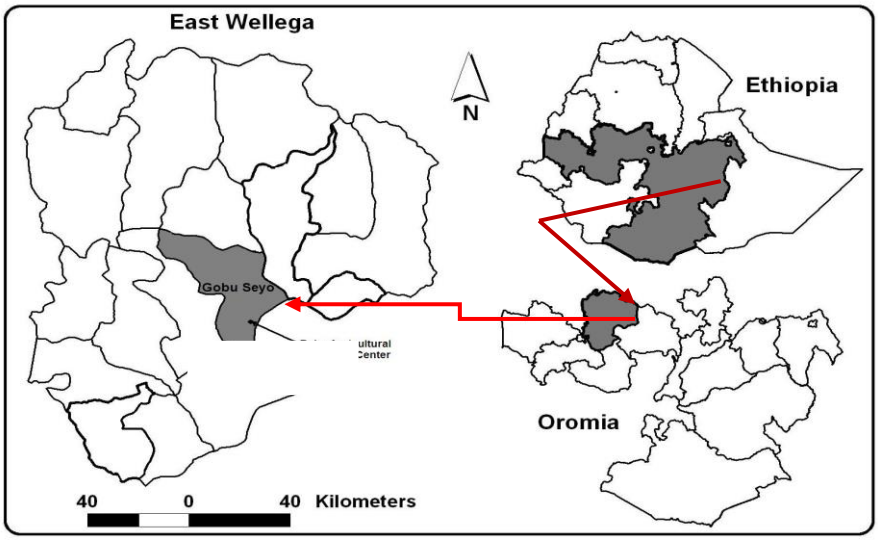


Figure 1: Study district in East Wallaga Zone of Oromia, Ethiopia.

Experimental materials

Variety: The maize varieties BH-661 and BHQPY-545 which is a three and single cross hybrid respectively released by Bako National Maize Research Center in 2011 and 2008 correspondingly, were used as a test crops. The hybrid maize variety BH-661 can be grown in a range of 1600-2200 m above sea level and requires an annual rainfall of 1000-1500 mm with uniform distribution in its growing periods. It needs 180 days to maturity, having a white kernel. Its yield potential varies between 9.5 and 12 t ha^{-1} at research field and 68.5 t ha^{-1} at farmers' field. While BHQPY-545 variety grown in a range of 1000-1800 m above sea level and it requires an annual rainfall of 500-1000 mm. It requires 144 days to maturity, having a yellow kernel. It has yield potential ranges from 8.0-9.5 t ha^{-1} at research field and 5.5-6.5t ha^{-1} at farmers field (Adfris *et al*, 2015). These cultivars perform better if planted during mid of May to mid-June.

Fertilizer: NPS blended fertilizer was applied at different rates as constituted in the treatments, while previously recommended N (92 kg N ha^{-1}) and phosphorus (46 kg P_2O_5 ha^{-1}) fertilizers in the form of UREA and DAP were used as check.

Experimental Design and Treatments

For this experiment, two maize varieties BH-661 and BHQPY-545 were used as test crops. The treatment consisted of six NPS fertilizer rates (0, 25, 50, 75, 100 and 125 kg NPS ha^{-1}) and one previously recommended N and P_2O_5 was included. The experiment was laid out in a factorial arrangement of randomized block design (RCBD) with three replications. The total number of treatment was 14. The size of each plot was 5.1 m x 4.5 m (22.95 m^2) and the distance between adjacent plots and blocks were kept at 1.0 and 1.5 m respectively. The distance between rows and plants in the plot was 75 cm and 30 cm respectively. Each plot consisted of six rows. The recommended nitrogen 92 kg ha^{-1} was used similarly for all plots in the form of UREA which applied half at time of planting and the rest half applied at 35 days after planting.

All field activities were also carried out following standard production practices. The trail was planted on June 6th in 2016 and June 8th in 2017 in hand made rows by placing one seeds per hill. All other agronomic management practices were applied uniformly as per the recommendation for maize in the area. At the time of harvesting, the maize was

harvested by excluding two border rows from each side. A net plot size for each plot was 2.25 m x 5.1 m (11.475 m^2).

Finally, biomass yield, grain yield, plant height, harvest index, and other important agronomic traits were collected. Grain yield was adjusted to standard moisture content to 12.5% as described as follows: adjusted yield = actual yield x 100-M ÷ 100 - D, where *M* and *D* are measured and standard moisture contents, respectively.

Costs that vary among treatments were also assessed using the CIMMYT partial budget analysis (CIMMYT, 1988). The cost of NPS, DAP, seed, the cost of labour required for the application of fertilizer, and cost for shelling were estimated by assessing the current local market prices. The price of NPS (1199.00 ETB 100 kg^{-1}), DAP (1468.00 ETB 100 kg^{-1}), daily labors (35 ETB per one person day based on governments' current scale in the study area), the price of seed (BH-661 cultivar 21.60 ETB kg^{-1} and BHQPY-545 cultivar 29.50 ETB kg^{-1}), and the cost of maize shelling (100 ETB t ha^{-1}) were considered to get the total cost that vary among the treatments. Time elapsed during NPS application for some plots of each treatment was recorded to calculate daily labor required for one hectare. One person per day was estimated based on eight working hours per day. The two maize varieties, BH-661and BHQPY-545 grain yield was valued at an average open market price of ETB 5.00 and 7.00 kg^{-1}, respectively at Bako. However, other non-varied costs were not included since all agronomic managements were equally and uniformly applied to each experimental plot. Before calculating gross revenue, maize grain yields obtained from each experimental plot were adjusted down by 10%. Finally, gross revenue was calculated as total yield obtained multiplied by field price that farmers receive for the sale of the crop. The net benefit and the marginal rate of return (MRR) were also calculated as per standard manual ((CIMMYT, 1988).

Lastly, combined analysis of variance across season were carried out using Gen Stat 15th Edition software, and the Duncan's multiple range tests at 5 % probability level was used for comparing treatment means (Duncan, 1955). Pearson's regression analysis were performed to observe relationship between different variables as affected by different levels of nitrogen fertilizer applications on different Maize varieties.

Results and Discussion

Mean grain yield and yield components of Maize

The result of combined analysis showed that mean grain yield, dry biomass yield and plant height were significantly($P<0.01$) affected by applied NPS rates in 2016 and 2017 seasons (Table 1). Even though main effects of NPS rates did not show significant variation to all parameters, there were highly significant effects due to the various applications of NPS rates.

As depicted in Table 2, the highest grain yields of 7.6 t ha^{-1} followed by 7.3 t ha^{-1} were obtained from BH-661 when 125 and 50 kg NPS ha^{-1}, respectively applied, but both are statistically at par. However, maximum grain yield of 7.2 t ha^{-1} followed by 7.0 t ha^{-1} were recorded when 100 and 125 kg NPS ha^{-1}, respectively applied for BHQPY-545 variety. Additionally, the highest above ground dry biomass yield (27.6 t ha^{-1} for BH-661 and 22.4 t ha^{-1} for BHQPY 545) of maize was recorded from application of pervious recommended practice and 50 kg NPS ha^{-1}, respectively. On the other hand, minimum value of grain yield, dry biomass and harvest index were obtained from control treatments in 2016 and 2017 cropping season.

Table 1: Analysis of variance for phenological growth, grain yield and yield components of maize under different rate of NPS fertilizer, and the interaction effects in 2016 and 2017 at Bako, Western Ethiopia.

Source of variation	df	PH (m)	GY (t ha^{-1})	DB (t ha^{-1})	HI (%)	TKW (g)
			MS			
NPS	6	0.87**	36.97**	298.96**	35.42^{ns}	1101.2^{ns}
Var.	1	20.81**	9.045**	906.30**	1248.06**	237632.1**
Frm	2	2.13**	53.867**	422.623**	551.56**	3206.00*
Yr	1	0.56**	91.17**	6673.28**	15275.31**	28594.2**
NPS x Var	6	0.022^{ns}	1.19*	2.34**	55.61*	641.1^{ns}
NPS x Frm	12	0 .04*	0.48^{ns}	7.52^{ns}	43.68*	1334.5^{ns}
NPS x Var x Frm	12	0.017^{ns}	1.08^{s}*	24.51*	26.38^{ns}	2045.6*
NPS x Var x Frm x Yr	12	0.01^{ns}	1.512**	18.49*	48.68*	2061.00*
Replication	2	0.201 **	8.034**	104.04**	20.36^{ns}	2128.5^{ns}
Residual	166	0.020	0.501	9.783	23.62	962.1

* and ** significant at 5% and 1% probability level, MS= Mean square, Var= Variety of maize (BH-661 & BHQPY-545), PH= plant height, GY= Grain yield, DB= Above ground dry biomass, HI= Harvest index and TKW= 1000 kernel weight, Frm= farmers & Rep= replication

There was also statistically higher grain yield performance obtained in 2017 than 2016 main season (Figure 2 (a) and (b)). In 2017 season, the amount and the distribution of rainfall during the growing period the crop were much optimum than in 2016. The cumulative rainfall in the entire growing period, particularly from mid-June to September was considerably higher in the 2017 than in 2016 (Figure 3). Moreover, the daily rainfall distribution, particularly from June to August, was erratic and sometimes heavy rain, causing high runoff and even leading to leaching occurred in 2016.

Table 2: The overall mean effects of NPS fertilizer rates on mean grain yield, dry biomass yield, harvest index, thousand kernel weight and, plant height of maize varieties grown at Bako, Western Ethiopia in 2016 & 2017 cropping season

Treatments		GY (t ha^{-1})	DB (t ha^{-1})	HI (%)	TKW (g)	PH (m)
NPS level (kg ha^{-1})	Maize cultivar					
0	BH-661	4.7	17.9	33.0	335	2.7
25	BH-661	6.3	24.1	33.3	335	3.0
50	BH-661	7.3	25.1	35.8	349	3.1
75	BH-661	7.0	25.2	34.1	352	3.1
100	BH-661	7.2	26.3	33.7	343	3.1
125	BH-661	7.6	25.9	36.5	340	3.2
RP	BH-661	7.2	27.6	32.8	339	3.1
0	BHQPY-545	4.1	14.9	37.1	267	2.1
25	BHQPY-545	6.3	20.1	39.8	285	2.4
50	BHQPY-545	6.4	22.4	35.7	290	2.5
75	BHQPY-545	6.9	21.7	38.7	277	2.5
100	BHQPY-545	7.2	22.0	40.9	281	2.5
125	BHQPY-545	7.0	22.1	39.4	285	2.6
RP	BHQPY-545	6.9	22.2	38.8	278	2.5
LSD (5%)			1.15	5.04	7.83	NS NS
CV (%)			10.8	13.8	13.3	10.0 5.2

NS= Non-significant difference at 5 % probability level, DB= Above ground dry biomass, HI= Harvest index, TKW= thousands kernel weight and PH = Plant height.

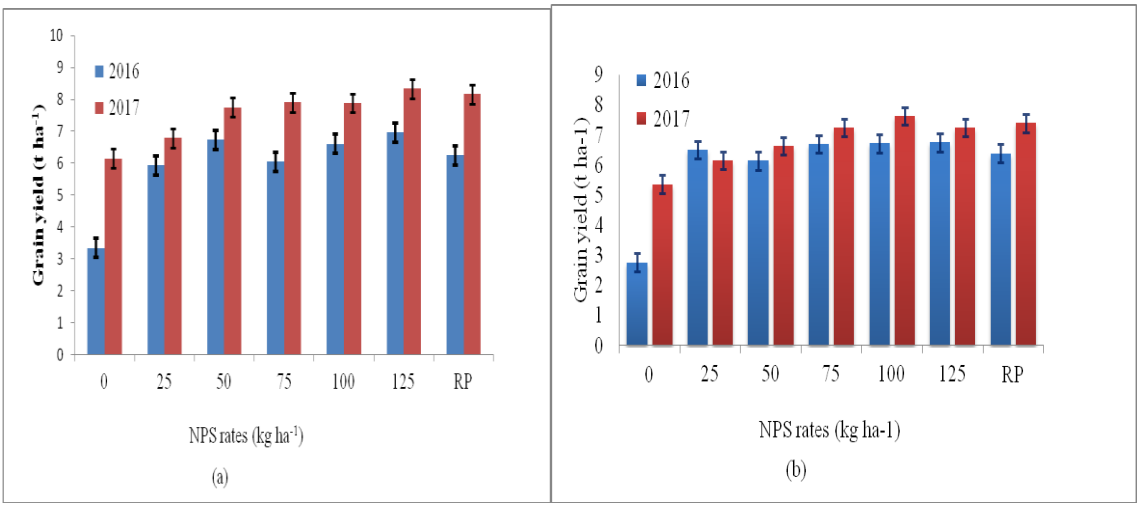


Figure 2: The effects of NPS on grain yield of maize variety BH-661 (a) and BHQPY-545 (b) in the 2016 and 2017 at Bako, Western Ethiopia

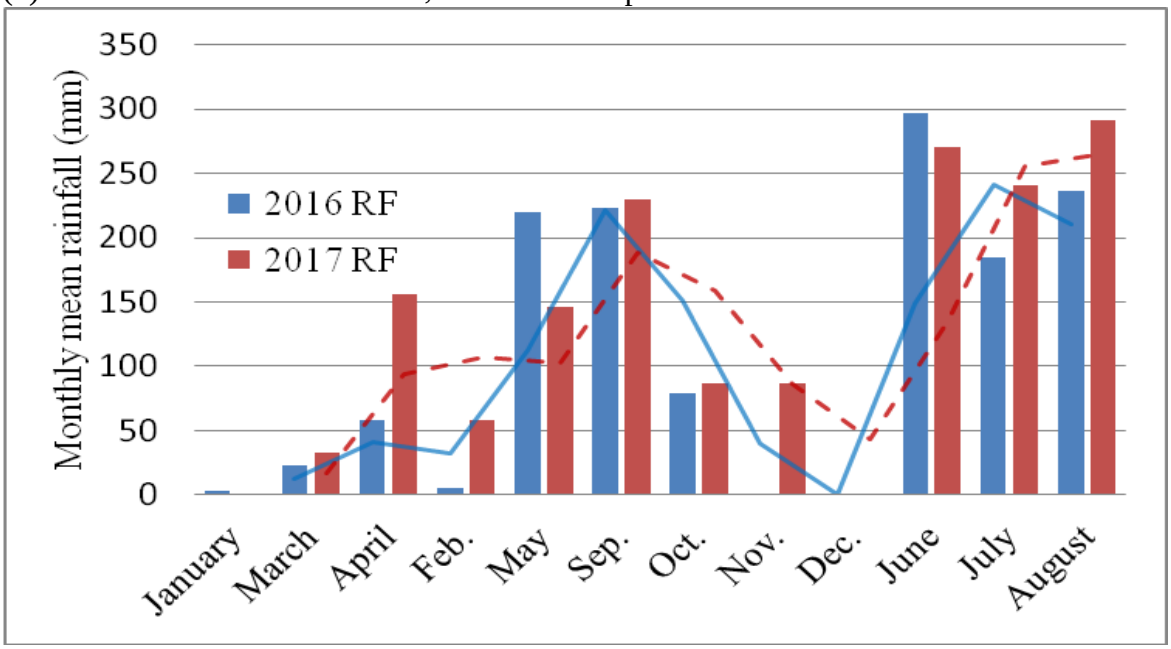


Figure 3: Mean monthly rainfall in the 2016 and 2017 at Bako, Western Ethiopia.

Grain Yield of Maize on Farmer's field

Mean grain yield of maize varieties (BH-661 & BHQPY-545) was significantly ($P<0.01$) increased with applied NPS fertilizer rate from control to 50 kg NPS ha^{-1} and it declined beyond that and again rise at 125 kg NPS ha^{-1} in all farms (Tables 3 and 4). Similarly, Torbert *et al.* (2001) reported that grain yield was increased with increasing nitrogen fertilizer up to 168 kg ha^{-1} in wet years. All applied NPS rates yielded significantly more than the check (0 kg ha^{-1}). The mean grain yield of maize varieties (BH-661 & BHQPY-545) was varied among farms. This might be due to variations among farmers field in soil fertility status and management practices applied. Similarly Raun *et al.* (2009) reported indigenous soil N across the landscape can vary several-fold, resulting in very different N recommendations depending on the location within the field.

The heterogeneity of smallholder farmers field were contributed much in yield variations of maize with similar NPS rate application in the soil during planting. A highly variable amount

of plant nutrient was required to bring any given subplot of corn within a farmer's field to maximum yield (Schmidt *et al*., 2002). Similarly Vanlauwe *et al.* (2014) found house-hold typologies based on resource endowments are useful for exploring and designing appropriate technologies congruent with those endowments. They further stated within farms variability caused by the different levels of land use intensity and the ability of farmers to apply inputs (crop residues, manure, refuse, fertilizer) to some fields (homestead), yet exploiting others (distant fields). Differences in soil variability between farms that vary in resource endowment are attributable to differential soil management between farms and fields over time (Tittonell *et al*., 2012). Wibawa *et al.* (1993); and Penny (1996) reported within-field yield variation is typically attributed to variability in soil texture, changes in landscape position, cropping history, soil physical and chemical properties and nutrient availability across fields. This indeed the need site based management fertilizer for maize production by maintain maize production levels, while reducing inorganic fertilizer input applied.

Table 3: Effects of NPS rates on mean grain yield of maize (BH-661) conducted on farmers' field around Bako-Tibe district, Western Ethiopia

NPS level (kg ha-^{1})	Farm-1	Farm-2	Farm-3	Mean
0	5.5	3.5	5.2	4.7
25	6.7	5.7	6.7	6.3
50	7.5	7.2	7.1	7.3
75	7.5	6.6	6.9	7.0
100	8.4	6.6	6.7	7.2
125	8.5	6.9	7.5	7.6
RP	8.3	6.5	6.9	7.2
LSD (5%)	0.77	0.37	0.87	
CV (%)	9.1	11.2	11.2	

Table 4: Effects of NPS rates on mean grain yield of maize (BHQPY-545) conducted on farmers' field around Bako-Tibe district, Western Ethiopia.

NPS level (kg ha-^{1})	Farm-1	Farm-2	Farm-3	Mean
0	5.0	2.9	4.3	4.1
25	7.3	5.3	6.4	6.3
50	7.5	5.0	6.7	6.4
75	7.8	6.0	7.1	6.9
100	8.1	6.1	7.4	7.2
125	7.5	5.9	7.5	7.0
RP	7.2	6.3	7.2	6.9
LSD (5%)	0.77	0.37	0.87	
CV (%)	9.1	11.2	11.2	

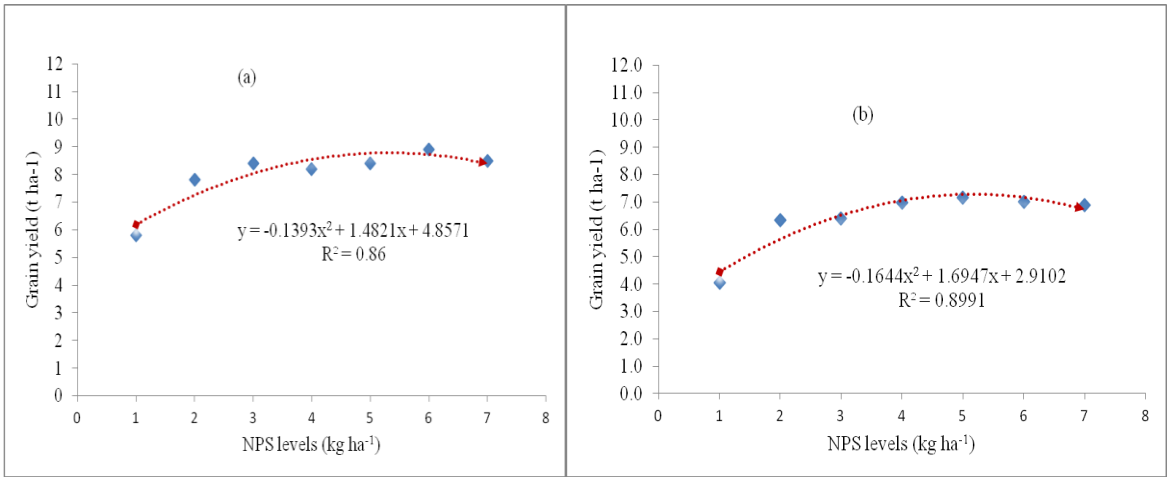


Figure 4: NPS fertilizer rate vs. grain yield of maize variety BH-661 (a) and BHQPY-545 (b) in the 2016 and 2017 at Bako, Western Ethiopia.

There were also strong relationships between the applied NPS fertilizer and grain yield of maize varieties (BH-661 and BHQPY-545) observed. As indicated in Figure 4 (a) and (b) a higher relationship between applied NPS fertilizers and grain yield of maize cultivars was observed. A strong relationship between applied NPS fertilizer and grain were observed (R^2= 0.86 and 0.90) for maize cultivar BH-661 and BHQPY-545 correspondingly, resulted in a good relationship between applied NPS fertilizer and harvested grain yields. As the NPS level increase maize grain yields become higher. It can be noted that mean grain yield peaked between 25-100 kg NPS ha^{-1}, implying that greater nutrient utilization is achieved at 25-100 kg NPS ha^{-1}.

Effects NPS rate on economic feasibility of maize production

The results of economic analysis for nutrient management are indicated in (Table 5). The highest net benefit of 43394.3 ETB ha^{-1} with an acceptable marginal rate of return (MRR) of 456.3% was obtained from use of 100 kg NPS ha^{-1} on BHQPY-545 maize varieties, followed by net benefit of ETB 41844.1 with MRR 775.6% that was achieved from application of 75 kg NPS ha^{-1} on the same maize variety, which implies a very high increase in farmers' income with a simple improvement in crop managements. For BH-661 maize varieties the highest net benefit of ETB 27404 were obtained from 25 kg NPS ha^{-1}. The minimum net benefit was obtained from the control treatments for both maize varieties. In conclusion, application of 100 kg NPS ha^{-1} fertilizer with BHQPY-545 maize cultivar is agronomically and economically feasible.

Table 5: Partial budget analysis for NPS fertilizer rates on maize at Bako, Western Ethiopia

Treatments		Av. GY (t ha^{-1})	Adj. GY (t ha^{-1})	TVC (ETB)	Gross benefit (ETB)	Net benefit (ETB)	D.A	MRR (%)
NPS rates (Kg ha^{-1})	Maize varieties							
0	BHQPY-545	4.1	3.69	411.69	25830	25418.3	-	-
0	BH-661	4.7	4.23	471.24	21150	20678.8	D	-
25	BH-661	6.3	5.67	945.99	28350	27404.0	-	371.6
25	BHQPY-545	6.3	5.67	946.44	39690	38743.6	-	-
50	BHQPY-545	6.4	5.76	1266.19	40320	39053.8	-	97.0
50	BH-661	7.3	6.57	1355.74	32850	31494.3	D	-
75	BHQPY-545	6.9	6.21	1625.94	43470	41844.1	-	775.6

75	BH-661	7.0	6.30	1635.49	31500	29864.5	D	-
100	BH-661	7.2	6.48	1965.24	32400	30434.8		-
100	BHQPY-545	7.2	6.48	1965.69	45360	43394.3	-	456.3
RP	BHQPY-545	6.9	6.21	2204.69	43470	41265.3	D	-
RP	BH-661	7.2	6.48	2234.24	32400	30165.8	D	-
125	BHQPY-545	7.0	6.30	2255.44	44100	41844.6		-
125	BH-661	7.6	6.84	2314.99	34200	31885.0	D	-

Av.GY= Average grain yield, Adj.GY= Adjusted grain yield to 10%, TVC= Total Variable Costs, D.A = Dominance analysis, D= Dominated and MRR= Marginal Rate of Return.

Conclusion and Recommendation

Application of balanced fertilizers is the basis to produce more crop output from existing land under cultivation and nutrient needs of crops is according to their physiological requirements and expected yields. Different fertilizers produced in factory by blending different nutrients are used to replace adding two or more fertilizers. To this point, it is critical to replace the previous DAP fertilizer with newly manufactured NPS fertilizers. Thus, application of 100 kg NPS ha^{-1} on BHQPY-545 had the highest net benefit ETB 43394.30 ha^{-1} with an acceptable MRR of 456.3%. In conclusion, application of 100 kg NPS ha^{-1} fertilizer on maize variety BHQPY-545 is agronomically and economically feasible and hence recommended for the end users.

References

Adefris Teklewold, Dagne Wegary, Abraham Tadesse, Birhanu Tadesse, Kassahun Bantte, Friesen, D. K. and Prasanna B.M., 2015. Quality Protein Maize (QPM): A Guide to the Technology and Its Promotion in Ethiopia. CIMMYT: Addis Ababa, Ethiopia.

International Maize and Wheat Improvement Center, (CIMMYT), 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, DF. 79p.

International Maize and Wheat Improvement Centre (CIMMYT), 2004. Global trends influencing CIMMYT's future. Prepared by the Global Trends Task Force in support of strategic planning at CIMMYT. Mexico, D.F.: CIMMYT.

Central Statistical Agency,(CSA), 2017. Agricultural Sample survey: report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin, (1). Addis Ababa

Central Statistical Agency,(CSA), 2016/17. Agricultural Sample survey Volume I: Report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin 584. April, 2017; Addis Ababa, Ethiopia.

Duncan, D. B., 1955. Multiple range and multiple F tests. *Biometrics* 11: 1-42.

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

Food and Agriculture Organization Corporate Statistical Database (FAOSTA), 2012. FAOSTAT data 2012. FAO.

Forum for Agricultural Research in Africa (FARA), 2009. Networking Support Function 3: Regional Policies & Markets. Patterns of Change in Maize Production in Africa, Implications for Maize Policy Development. Ministerial Policy Brief Series (№ 3).

Higgs, B., Johnston, A. E., Salter J.L. and Dawson C. J., 2002. Some aspects of achieving phosphorus use in agriculture. Journal of Environmental Quality. 29: 80–87.

Hopkins, B. G., Rosen, C. J., Shuffler A. K and Taysom, T.W, 2008b. Enhanced efficiency fertilizers for improved nutrient management of potato. University of Idaho, Aberdeen.

MBARC, 2014. Meteorological data of Bako area for 1960-2014," Bako, Oromia, Ethiopia

Mesfin, A., 1998. Nature and Management of Ethiopian Soils, Alemaya university of Agriculture, Ethiopia, pp: 272.

Moti Jaleta, Menale Kassie and Paswel Marenya, 2015. Impact of Improved Maize Variety Adoption on Household Food Security in Ethiopia: An Endogenous Switching Regression Approach. Agriculture in an interconnected world.

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 Vally, California. The 18th world Congress of soil science at Philadelphia, Pennsylvania, USA.

Penny, D.C., 1996. Yield and nutrient mapping for site specific fertilizer management. Communications in Soil Science and Plant Analysis, 27: 1265-1279.

Raun, W.R, I. Ortiz-Monasterio and J.B. Solie, 2009. Temporally and spatially dependent nitrogen management for diverse environments. Section II, Making of wheat crop, pp. 203-214.

Schmidt, J.P., A.J. DeJoia, R.B. Ferguson, R.K. Taylor, R.K. Young and J.L. Havlin, 2002. Corn yield response to nitrogen at multiple in-field locations. Agronomy Journal, 94: 798-806.

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

Tsedeke Abate, Bekele Shiferaw, Abebe Menkir, DagneWegar, Yilma Kebede, Kindie Tesfaye, Menale Kassie, Gezahegn Bogale, Berhanu Tadesse and Tolera Keno, 2015. Factors that transformed maize productivity in Ethiopia. Food Sec. 7:965-981.

Torbert, H.A., K.N. Potter and J.E. Morrison, 2001. Tillage system, fertilizer nitrogen rate and timining effect on corn yields in the Texas Black land prairie. Agronomy Journal.

Vanlauwe, B., D. Coyne, J. Gockowski, S. Hauser, J. Huising, C. Masso, G. Nziguheba, M. Schut and P. Van Asten, 2014. Sustainable intensification and the African smallholder farmer. Current Opinion in Environmental Sustainability, 8: 15-22.

Wibawa, W.D., D.L. Diludlu, L.J. Swenson, D.G. Hopkins and W.C. Dahunke, 1993. Variable fertilizer application based on yield goal and soil map unit. Journal of Production Agriculture, 6: 165-166.

Effect of Vermicompost and Nitrogen Rate on Yield and Yield Components of Tomato (*Lycopersicum esculentum* L) at Harari People Regional State, Eastern Ethiopia

**Gebisa Benti, Alemayehu Biri, Fikadu Tadesse, Gezu Degefa and Mohammed Jafar*
Oromia Agricultural Research Institute/Fedis Agricultural Research Center
Corresponding author: Gebisa Benti, bantiig@gmail.com

Abstract

*Availability of insufficient amount of nutrients are among the main factors which constrained productivity of the tomato. This experiment was conducted in Sofi district, Harari People Regional State, Ethiopia in 2016 and 2017 cropping season to investigate the effect of vermicompost and nitrogen rate on yield and yield components of tomato. Experimental treatments were vermicompost rate (0, 1.4, 2.8 and 4.2 t ha^{-1}) and nitrogen rate (0, 50, 100 and 150 kg ha^{-1}). A total of 16 treatments were laid out in Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. Melkashola Variety was used for the experiment. The result showed that plant height was significantly (P<0.05) influenced by the application of vermicompost while number of branches, number of clusters, number of fruits, average fruit weight and fruit yield were significantly (P<0.05) affected due to the interaction effect of vermicompost and nitrogen. The highest plant height was recorded at 2.8 t ha^{-1} of vermicompost whereas the lowest was for the rest rates. Maximum number of clusters, number of fruits and fruit yield were obtained at combined application of 2.8 t ha^{-1} of vermicompost with 100 kg ha^{-1} N while maximum number of branches and average fruit weight were recorded at 2.8t ha^{-1} of vermicompost with 150 kg ha-1 N, and 4.2t ha^{-1} of vermicompost with 50 kg ha^{-1} N. Maximum economic return (*461,606 birr ha^{-1}*) was also recorded at 2.8 t ha^{-1} and 100 kg ha^{-1} vermicompost and nitrogen, respectively with acceptable marginal rate of return. In general, the combination of vermicompost and nitrogen at 2.8 t ha^{-1} and 100 kg ha^{-1} was the best combination for the study area.*

Keywords: Melkashola, Nitrogen, Tomato, Vermicompost

Introduction

Tomato (*Solanum lycopersicum*) is one of the important vegetable crops grown throughout the world and ranks next to the potato and sweet potato in terms of area, but ranks first as a processing crop (FAO, 2010). The cultivated area under tomato was 4100 hectares with a total production in Ethiopia of 51000 metric tons (FAO, 2016). Tomato is grown in the summer and winter seasons in Ethiopia; however, production varies in various regions due to varieties, seasons, and climatic conditions, planting time, management practices and soil properties (Gabal *et al*., 1984; and Nandwani, 2014).

Most soils in Africa are poor compared with other parts of the world (Bationo *et al*, 2006). African soil nutrient balances are often negative due to a low level of fertilizer inputs, and soil nutrient depletion is a major reason for decreasing or stagnation of agricultural productivity (Sanchez, 1997). Mbah (2006) asserts that soil fertility is a major overriding constraint that affects all aspects of crop production. As is the case in other regions in Africa, local farmers use inadequate nutrient inputs, inappropriate quality and inefficient

combinations of fertilizers, which in the end prove to be very costly (Palm, 1997). A consequence of this trend is a deeply unbalanced soil nutrient composition that ultimately leads to a reduction in crop yield potential (Tonfack *et al.*, 2009). Nutrients, when in adequate quantity, increases fruit quality, fruit size, colour, and fruit taste of tomato (Azad, 2000).

The organic production system aims at supporting and sustaining healthy ecosystems, soil, farmers, food production, the community, and the economy. Reduction and elimination of the adverse effects of synthetic fertilizers and pesticides on human health and the environment is a strong indicator that organic agriculture is gaining worldwide attention (Aksoy, 2001; Chowdhury, 2004). Organic fertilizers are environmentally friendly, since they are from organic sources (Oyewole *et al*., 2012). The current global scenario firmly emphasizes the need to adopt eco-friendly agricultural practices for sustainable food production.

Organic fertilizer; vermicompost are produced through the interaction between earthworm and microorganism by the breakdown of organic wastes. It is a stabilized, finely-divided peat-like material with a low C: N ratio and high water holding capacity that constitute a source of plant nutrition which is released gradually through mineralization whenever the plant needs it (Mathivanan *et al*., 2012). Earlier work by Theunissen *et al*. (2010) on the growth and nutrient status of vegetables have revealed a positive effect on plant nutrition, photosynthesis, chlorophyll content and nutrient content of different plant components namely roots, shoots and fruits. Biochemical changes in the degradation of organic matter are carried out by microorganisms through enzymatic digestion, enrichment by nitrogen excrement and transport of inorganic and organic materials. Earthworms play a vital role in plant growth and productivity. The ability of some species of earthworm to consume and breakdown a wide range of organic residues such as sewage sludge, animal wastes, crop residues and industrial refuse is well known (Dominguez *et al*., 1997; Edwards *et al*., 1985; Kaushik and Garg, 2003).

The use of organic amendments such as traditional thermophili composts has been recognized generally as an effective means for improving soil aggregation, structure and fertility, increasing microbial diversity and populations improving the moisture holding capacity of soils, increasing the soil Cation Exchange Capacity (CEC) and increasing crop yield (Marinari *et al*., 2000). Vermicompost contains most nutrients in plant-available forms such as nitrates, phosphates and exchangeable calcium and soluble potassium (Orozco *et al*., 1996). Recycling bio-waste of different resources in the form of compost can be an alternative to meet the increasing demands for organic manures; this will also help to reduce environmental pollution arising out of accumulated bio-wastes (Kumar, 2005). Bio-wastes could be recycled by adopting simple and suitable techniques in compost making and preparing enriched manure. These improved technologies not only reduce the quantity but also improve the quality of compost with better plant nutrients (Jagadeesan, 2005).

There is accumulating scientific evidence that vermicompost can influence the growth and productivity of plants significantly (Edward, 1998). The study conducted by Tomati and Galli (1995) and Atiyeh *et al*. (2000) showed that growth and yield parameters such as leaf area, dry shoot weights and weight of fruits were significantly affected by applying vermicompost. Maynard (1995) reported that tomato yields in field soils amended with

compost were significantly greater than those in the untreated plots. The available nutrient status of soil was greatly enhanced by the application of vermicompost as an organic source (Prabha *et al*., 2007). Despite the beneficial effects on growth and yield of plants, higher metal concentration in the compost may be a problem and limit its utilization (Jordao *et al*., 2006). Vermicompost enhanced phosphorous concentration and uptake in soil, increasing the solubilisation of phosphorous either by microorganism activation with excretion of organic acids likes citric, glutamic, tartaric, succinic, lactic, oxalic, malic and fumaric (Sainz *et al*., 1998).

Nitrogen is the most limiting nutrient to crop production (Pionke *et al*., 1990). Like many vegetables, tomato is often heavily fertilized. Large amounts of nitrogen are often lost to leaching below the root-zone of vegetable crops (Pionke *et al*., 1990). Nitrogen deficiency can seriously decrease yield and crop quality. The nitrogen composition of plant tissue has important nutritional consequences, since plants are a major source of proteins in human diet (Below, 1995). Nitrogen is also a constituent of a large number of important compounds found in living cells, such as (enzymes) amino acids and nucleic acids (RNA and DNA) (Lea and Lee gold, 1993). Hence, nitrogen is critical in improving growth, yield and quality of vegetable crops.

In Eastern Ethiopia, vegetable crops, especially tomato is produced in both season in winter and summer under irrigation and rain fed. Heavy doses of chemical fertilizers in irrigation and pesticides are being used by the farmers to get a better yield of various field crops. These chemical fertilizers and pesticides decreased soil fertility and caused health problems to the consumers. Due to adverse effects of chemical fertilizers, interest has been stimulated for the use of organic manures. (Follet *et al.,* 1981). However, in the study area; there is no information related to recent research work into the effects of vermicompost, nitrogen fertilizer and their combined effect utilization on vegetable crops, particularly on tomato. Therefore, the main aim of this study was to determine the effects of different rates of vermicompost and nitrogen fertilizer in combination with nitrogen rate on yield and yield parameters of tomato under field conditions.

Materials and methods

Experimental Site

The Experiment was conducted in Harar People Regional State, Sofi district in Harawe on farmers land. The district was geographically lies at an altitude of 1300-1800 meters above sea level. The mean annual rainfall of the district was 400 mm and maximum and minimum rain fall is 500 mm and 300 mm, respectively. Like some part of Ethiopia, Sofi district was characterized by the bimodal rainfall pattern. . The first season was characterized by the short rainy season (*Belg*), which extends from March to May, while the second season which is the most important main rainy season (*Meher*) extends from July to October. The dry-spell period was extends from June to July and based on its duration, it may affect crop growth. The minimum and maximum temperature of the area was 25 ^{0}C and 35 ^{0}C, respectively with the annual average of 30 ^{0}C (Harari BoA, 2016, unpublished).

Experimental Treatments and Design

For this experiment, tomato variety "Melkashola" was used as a test crop which was potentially produced by the farmers' in the area. The experimental treatments consisted of four vermicompost rate (0, 1.4, 2.8 and 4.2 tons/ha) and four nitrogen fertilizer rates (0, 50, 100 and 150 kg N ha^{-1}). A total of 16 treatments were laid out in Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. Each treatment combination was assigned randomly to experimental units within a block. The plant and row spacing of 30 cm and 70 cm, respectively, was used for all treatments. A plot size of 2.1 m in width and 2.1m in length were used. Each plot consisted of four rows and about eight plants were planted per row. Data were recorded from the two central rows of each plot.

Experimental Procedures

The experimental field was cultivated to a depth of 25-30 cm by a tractor. The experimental plots were harrowed to a fine tilth manually before planting. The land was leveled well and seeds of tomato were sown in rows of 10 cm on well prepared seed bed of 1 x 10 m and the beds were covered with light soil and mulching grasses until emergence. The beds were supplied with supplementary irrigation during the shortage of rainfall. Finally, hardened, healthy and uniform seedlings of pencil size were transplanted at 3 to 5 leaves developed. All cultural practices were conducted as per recommendation of the area and each and every data planned to be collected were taken on time by using data record sheet. The nitrogen fertilizer (N) was applied uniformly in the form of UREA whereas phosphorus (P) in the form of Triple Super phosphate (TSP) during sowing of the seed on nursery.

Earthworms were collected from Haramaya University for this experiment. Vermicompost was prepared by feeding earthworms with different weeds and cow dung through wetting with water frequently. These inputs were estimated to the cost of vermicompost preparation. Vermicompost was applied to the field according to specified rate before transplanting seedlings into the field. Nitrogen was applied at two equal splits (3 weeks after transplanting and the rest half 6 weeks after transplanting) as basal application according to the rate specified in the treatments. All treatments were randomly assigned to the experimental plots.

Data Analysis and management

Data collected

Morphological data like plant height (cm), number of branch per plant, number of cluster per plant, number of fruit per cluster, number of fruits per plant, yield per hectare, average fruit weight were collected. Plant height was measured using ruler from the base of the plant to the tip of the shoots from ten plants of the central rows. The average number of branches was counted from 10 plants. The numbers of fruit clusters were counted from 10 plants of the central rows. The average numbers of fruits per cluster were also counted from 10 plants. All fruits harvested were counted to estimate the number of fruits per plant. The average fruit weight was weighted from ten fruits which harvested from central rows of the plots. The average fruit weight was expressed in gram. During harvesting, all harvest cycle fruits were weighted by using digital balance and expressed in tons per hectare.

Statistical data analysis

Data were subjected to analysis of variance using Gen-STAT Statistical Software package. Means that differed significantly were separated using the LSD (Least Significant Difference) test at 5% level of significance.

Result and discussion

Soil Chemical Properties

The analysis of soil sample collected from experimental site indicated that the soil is sandy clay loam in texture and moderately basic in reaction with 8 pH (Table 1). According to Bruce and Rayment (1982) range, the soil was medium in total nitrogen (0.171%). Similarly, according to Olsen *et al*. (1954), the experimental site had low available phosphorus (2.893 mg kg^{-1} soil). According to Emerson (1991) range of organic matter content of soil, the experimental soil had moderate organic matter (2.277) contents. This moderate content of organic matter indicated that moderate soil structural condition, moderate structural stability. According to Metson (1961), the soil of the experimental site had low cation exchange capacity (7.13 cmol kg^{-1} soil) and high in exchangeable potassium (9.026 cmol (+) kg^{-1} soil) (Table 1).

Vermicompost was made from cattle dung and different plant residues. As the result indicated in the table (1), the physical texture of the compost was clay loam. The pH of the compost was mildly alkaline (7.7). The pH of vermicompost from different wastes have also been reported like sheep manure- 8.6 (Gutierrez-Miceli *et al*., 2007), sewage sludge-7.2 (Masciandaro *et al*., 2000). Vermicompost contained very high total nitrogen, available phosphorous, exchangeable potassium, organic carbon and CEC as indicated in the result (Table 1)

Table 1. Soil and vermicompost physical and chemical properties of the experimental site (Harawe)

Samples	pH	CEC	OC	Mg^{2+}	Ca^{2+}	Exch.Na	Exch.K	Avail P	TN	Texture
Soil	8	7.13	1.324	9.36	8.963	0.399	9.026	2.893	0.17	Sandy clay loam
Vermicompost	7.7	27.83	8.157	29.954	18.55	0.403	35.429	39.262	0.58	clay loam

pH (soil to water ratio 1:2.5), CEC (cation exchangeable capacity: meq 100 g^{-1} soil), OC (Organic carbon:%), Mg^{2+} (Magnesium: cmol (+) kg^{-1} soil), Ca^{2+} (Calcium: cmol (+) kg^{-1} soil), Exch. Na (Exchangeable Sodium: cmol (+) kg^{-1} soil), Exch. K (Exchangeable Potassium: cmol (+) kg^{-1} soil), Avail. P (Available phosphorous: mg kg^{-1} soil), TN (Total Nitrogen: %).

Plant height and number of branches

The result revealed that vermicompost significantly ($P<0.05$) affected plant height (Figure 1). Increasing vermicompost from nil to 2.8 t ha^{-1} linearly increased plant height though it was statistically at par. Plant height starts to decline beyond 2.8 t ha^{-1} vermicompost. Thus, application of 2.8 t ha^{-1} vermicompost recorded the highest plant height (72.32 cm) while the lowest value (66.48 cm) was at 4.2 t ha^{-1}. In line with current result, Kashem et *al*. (2015) stated that application of vermicompost at (20 t ha^{-1}) and NPK fertilizer (200 kg

ha^{-1}) showed an increment of 36.34 cm and 23.34 cm of shoot length respectively, as compared to control. They revealed that vermicompost dose of 20 t ha^{-1} resulted in maximum plant height of 52.67 cm. On the other hand, number of branches were significantly ($P<0.05$) affected due to combined application of vermicompost and nitrogen fertilizer. The highest number of branches was recorded at 2.8 t ha^{-1} vermicompost with 150 kg ha^{-1} nitrogen while the lowest was recorded at 2.8 t ha^{-1} with 0 kg ha^{-1} nitrogen (Table 2). Plant growth parameters such as shoot length, root length, number of leaves, fresh weight and dry weights were better in vermicompost treated plants rather than the control plant (Vaidyanathan and Vijayalakshmi, 2017).

Clusters and fruits per plant

Clusters and fruits per plant were significantly ($P<0.05$) affected due to the interaction effect of vermicompost and nitrogen application. Combined application of vermicompost with nitrogen at the rate of 2.8 t ha^{-1} and 100 kg ha^{-1} recorded the highest number of cluster (16.9) and fruits per plant (51.4) while the lowest value was observed at control treatment (Tables 2 and 3). Increasing application of vermicompost from nil to 2.8 t ha^{-1} linearly increased fruit clusters at application of 100 kg ha^{-1} nitrogen. Application of vermicompost and nitrogen at 2.8 t ha^{-1} and 100 kg ha^{-1}, respectively, resulted in an increment of about 55 % fruit clusters and 50.6% fruits per plant respectively over the control treatments. This result was in agreement with the study of Ogundare *et al*.,2015 who reported that the number of fruits per plant, fruit yield per plant, fruit yield per plot and tomato yield were significantly affected by combined use of organic and inorganic fertilizer.

Average fruit weight and fruit yield

The result revealed that average fruit weight and fruit yield were significantly ($P<0.05$) affected due to the interaction effect of vermicompost and nitrogen fertilizer. The highest average fruit weight (74.9 g) was recorded at combined application of 4.2 t ha^{-1} vermicompost and 50 kg ha^{-1} nitrogen while lowest value was recorded from control treatment. On the other hand, the highest fruit yield (65.3t ha^{-1}) was recorded at combined application 2.8 t ha^{-1} vermicompost and 100 kg ha^{-1} nitrogen fertilizer. The result revealed that combined application of 2.8 t ha^{-1} vermicompost and 100 kg ha^{-1} nitrogen resulted in an increment of 54.7% to 56.7% fruit yield as compared to combined application of 0 kg ha^{-1} vermicompost with all the rest nitrogen rates (Table 4). These results were in agreement with Kashem *et al*., 2015 who reported that application of cow manure vermicompost had significantly influenced all the studied growth parameters and fruits yield of tomato plant rather than inorganic nitrogen fertilizer. This indicated that, vermicompost plays a major role in improving growth and yield of different field crops, vegetables, flowers and fruits (Lekshmanaswamy, 2014).

Table 2. Interaction effect of vermicompost and nitrogen rate on branches and fruit clusters per plant over the two years (2016 and 2017)

	Branches				Clusters			
	Nitrogen (kg ha-1)							
Vermi compost (t ha^{-1})	0	50	100	150	0	50	100	150
0	5.9ab	5.6ab	5.2ab	6.0ab	7.60e	10.0c-e	10.7b-e	10.3c-e
1.4	5.2ab	6.3ab	6.2ab	6.4ab	8.5de	10.7b-e	13.2a-c	9.2c-e
2.8	4.80b	5.7ab	5.8ab	6.80a	12.1b-d	12.0b-d	16.90a	14.6ab
4.2	5.7ab	6.2ab	5.3ab	6.2ab	8.7de	9.7c-e	10.1c-e	10.9b-e
LSD (0.05)		1.46				3.48		
CV (%)		21.8				27.7		

Table 3. Interaction effect of vermicompost and nitrogen fertilizer on fruit weight and number of fruits per plant for the 2016 and 2017

	Average Fruit weight(g)				Fruits per plant			
	Nitrogen (kg/ha)							
Vermi Compost (t ha^{-1})	0	50	100	150	0	50	100	150
0	42.90f	65.3a-c	53.8b-f	61.4a-d	25.40f	26.4ef	27.6d-f	27.6d-f
1.4	46.0ef	66.6a-c	56.5b-e	61.5a-d	28.5d-f	36.1b-f	39.2b-d	37.7b-f
2.8	48.7d-f	67.7ab	56.8b-e	62.0a-d	27.6d-f	38.3b-e	**51.40a**	48.3ab
4.2	52.9c-f	**74.90a**	58.4b-e	62.2a-d	28.6d-f	32.2c-f	41.1a-c	37.5b-f
LSD (0.05)		11.89				10.662		
CV (%)		17.70				26.800		

Table 4. Interaction effect of vermicompost and nitrogen fertilizer on fruit yield over the two years (2016 and 2017)

	Fruit yield (t ha^{-1})			
Vermi compost (t ha^{-1})	0	50	100	150
0	29.60b	29.6b	28.70b	28.30b
1.4	31.20b	45.9ab	53.5ab	40.3ab
2.8	45.9ab	44.9ab	**65.30a**	54.5ab
4.2	30.6ab	33.70b	50.8ab	48.5ab
LSD (0.05)	25.09		52.800	

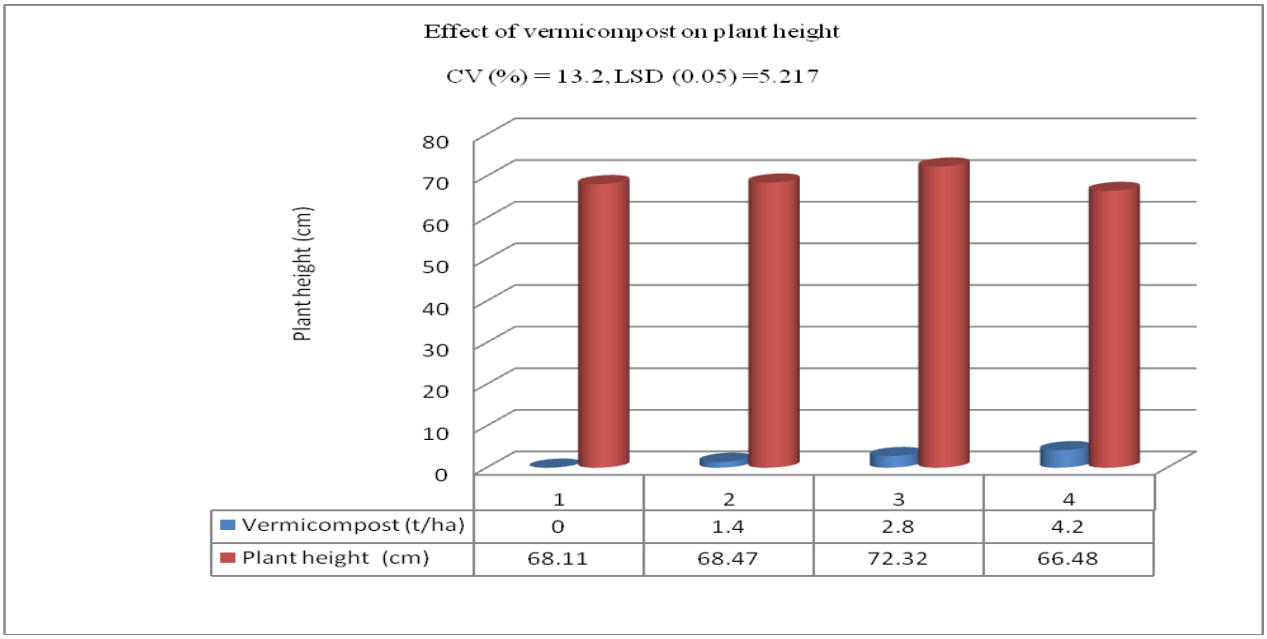


Figure 1. Effect of vermicompost on plant height of tomato

Partial cost analysis

The partial budget analysis was conducted based on the average price fluctuation of tomato in two years. An average tomato price was 8 birr kg^{-1}. The total variable costs were the combinations of fertilizer, vermicompost (crop residues, water, cow dung) and labor costs. The combined application of vermicompost and nitrogen at 2.8 t ha^{-1} and 100 kg ha^{-1}, respectively, resulted maximum net return (461,606 birr ha^{-1}) with acceptable marginal rate of return. Application of nitrogen without vermicompost recorded the lowest net returns in all treatments.

Table 5. Partial budget analysis of vermicompost and nitrogen applied on tomato

(Vermi + N)	UFY (kg ha^{-1})	AFY (kg ha^{-1})	GR (birr ha^{-1})	TVC (birr ha^{-1})	NR (birr ha^{-1})	MRR (%)
0 – 0	29610	26649	213192	2894	210298	
0 – 50	29600	26640	213120	5074	208046	D
0 – 100	28700	25830	206640	5654	200986	D
1.4 – 00	31200	28080	224640	5944	218696	6107
0 - 150	28300	25470	203760	6234	197526	D
1.4 - 50	45900	41310	330480	6544	323936	40777
1.4 - 100	53500	48150	385200	7104	378096	9671
2.8 - 00	45900	41310	330480	7394	323086	D
1.4 - 150	40300	36270	290160	7684	282476	D
2.8 - 50	44900	40410	323280	7974	315306	11321
2.8 - 100	65300	58770	470160	8554	461606	25224
4.2 - 00	30600	27540	220320	8904	211416	D
2.8 - 150	54500	49050	392400	9134	383266	74717
4.2 - 50	33700	30330	242640	9484	233156	D
4.2 - 100	50800	45720	365760	10064	355696	21128
4.2 - 150	48500	43650	349200	10644	338556	D

Note: UFY=Unadjusted Fruit Yield , AFY Adjusted Fruit Yield=, GR= Gross return, TVC= Total Variable Cost, NR= Net Return, MRR=Marginal rate of Return,

Conclusion

The experiment was conducted for two consecutive cropping season to determine the effect of Vermicompost and nitrogen fertilizer rate on tomato yield and yield parameters. The mean annual rainfall of the district is 400 mm and maximum and minimum rain fall is 500 mm and 300 m m. The district geographically lies at an altitude of 1300-1800 meters above sea level.

The soil analysis showed deficiency in phosphorous, moderate in total nitrogen and organic matter and low in CEC. Therefore, the soil of the area needs additions of nutrients for the optimum growth of the crop. The result over the two years revealed that there were significant differences among treatments for plant height due to the application of vermicompost. Similarly, there were also significant differences among the treatments for number of branches, number of clusters, fruits per plant, average fruit weight and fruit yield due to the interaction effect of vermicompost and nitrogen.

Generally, application of vermicompost at 2.8 t ha^{-1} and nitrogen at 100 kg ha^{-1} resulted in highest number of branches, number of clusters, number of fruit per plant, fruit yieldand the highest economic return (461,606 birr ha^{-1}) with acceptable marginal rate of return. The combined application of 2.8 t ha^{-1} vermicompost and 100 kg ha^{-1} nitrogen were resulted 2.2 times net return than control (0 N and 0 vermicompost) treatments. Therefore, application of 2.8 t ha^{-1} vermicompost and 100 kg ha^{-1} nitrogen was recommended for tomato production to the study area and similar agro-ecology.

REFERENCES

Aksoy, U. Ecological farming. II. In Proceedings of the Ecological Farming Symposium, Antalya, Turkey,14–16 December 2001.

Atiyeh, R.M., Arancon, N, Edwards, C.A and Metzger, T.D. 2000. Influence of earthworm processed pig mature on the growth and yield of greenhouse tomatoes. Sci. Direst, 75:175-180.

Azad, A.K. 2000. Effects of plant spacing, source of nutrients and mulching on growth and yield of cabbage. M. Sc. Thesis. Department of Horticulture, Bangladesh Agriculture University Mymensingh, pp. 15-40.

Azarmi R., Ziveh P. S and Satari M.R. 2008. Effect of vermicompost on growth, yield and nutrition status of tomato (*Lycopersicon esculentum*).*Pakistan Journal of Biological Sciences*, 11(14):1797-1802.

Bationo A., Hartemink A., Lungu O., Naimi M., Okoth P., Smaling E., Thiombiano L. (2006). African soils: their productivity & profitability of fertilizer use, Background papers prepared for the African fertilizer summit, Abuja, Nigeria, 25 p.

Below FE. 1995. Nitrogen metabolism and crop productivity. p. 385. *In:* Mohammed P.1995. (Eds.). Handbook of plant and crop physiology. Marcel Decker, Inc. New York.

Bruce, R. C., and Rayment, G. E. 1982. Analytical methods and interpretations used by the Agricultural Chemistry Branch for Soil and Land Use Surveys. Queens land Department of Primary Industries. Bulletin QB8 (2004), Indooroopilly, Queensland. chemical fertilizers. Les. Envis. Newsl. 2004, 7, 4–5.

Chowdhury R (1997). Effects of chemical fertilizers on the surrounding environment and the alternative to the Dominguez, J., Edwards, C. A. & Sulber, S.. A comparison of

vermicomposting & composting methods to process animal wastes. Biocycle, 38:57– 59.

Edwards, C. A. , Burrows, I., Fletcher, K. E. and Jones, B. A. 1985. The use of earthworms for composting farm waste. In: Composting Agricultural and Other waste, Gasser, J. K. R. (eds). Elsevier, London and New York, ISBN: 0-85334 - 357-8, pp: 229-241.

Edwards, C. A. 1998. The use of earthworm in the breakdown and management of Organic wastes. In:earthworm ecology. Edwards, C.A (eds). CRC press LLC, Boca Raton, F1, ISBN:)84931819X, PP:327-354.

Emerson, W. W. 1991. Structural decline of soil, assessment and prevention. *Australian Journal of Soil Research,* 29: 905–922.

FAO. 2016. *Production Year Book.* Food and Agriculture Organization of United Nations, Rome, Italy

Follet, R., R. Donahue and L. Murphy, 1981. Soil and Soil Amendments. Prentice hall :Inc., New Jersey.

Food and Agriculture Organization (FAO). Production Year Book; Food and Agriculture Organization of the United Nations: Rome, Italy, 2010; Volume 53, pp. 132–133.

Gabal, M.R.; Abd-Allah, I.M.; Hass, F.M.; Hassannen, S. Evaluation of some American tomato cultivars grown for early summer production in Egypt. Ann. Agric. Sci. Moshtohor J. 1984, 22, 487–500.

Gutiérrez-Miceli F., J. Santiago-Boraz, JAM Molina, C.C. Nafat, M. Abdul-Archila, M.A.O. Llaven, R. Rincón-Rosales and L. Dendooven, 2007. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato (*Lycopersicum esculentum*). Bioresour. Technol., 98: 2781-2786.

Gutierrez-Miceli, F.A., Santiago-Boraz, J., Molina, J.A, Nafate, C.C, Rincon-Rosales, R. and Dendooven, L. 2007. Vermicompost as a soil supplement to improve growth, yield and fruit quality of tomato. Bioresour. Technol. 98:2781-2786.

Jagadeesan, G. (2005). "Resource Recovery of Farm Refuse", Proceedings – UGC sponsored National Seminar on Waste–Disposal Man agemen t an d Utilisation , Department of Mechanical Engineering Faculty of Engineering and Technology, Annamalai University, Annamalai nagar, India. 22-23.

Jordao, C.P, Nascentes, C.C., Cecon, P.R., Fontes, R.L.F., and Pereira, J.L. 2006. Heavy metal availability in soil amended with composed urban solid wastes. Environ. Monitoring Assess, 112: 309-326.

Kashem, M.A., Sarker, A., Hossain, I. and Islam, M.S. 2015. Comparison of the Effect of Vermicompost and Inorganic Fertilizers on Vegetative Growth and Fruit Production of Tomato (*Solanum lycopersicum* L.). *Open Journal of Soil Science*, 5, 53-58. http://dx.doi.org/10.4236/ojss.2015.52006.

Kaushik, P. and Garge, V.K. 3003. Vermicomposting of mixed solid textile mill sludge and cow dung with the epigeic earthworm *Eisenia foetida*. Bioresour. Technol., 90: 311 - 316.

Kumar, A., (2005). "Verms and Vermitechnology", A.P.H Publishing Corporation, New Delhi.5,71.

Lea JP, Leegood CR. 1993. Plant biochemistry and molecular biology. John Wiley and Sons Ltd. Pp.155-180.

Lekshmanaswamy M. Effect of vermicompost on *Jatropha curcas* growth. SIR J Biol Environ Sci, 2014; 1(1): 13-16.

Marinari, S., Masciandaro, G., Ceccanti, B. and Grero, S. 2000. Influence of organic and mineral fertilizers on soil biological and physical properties. Bioresour. Technol.72:9-17.

Masciandaro, G., Ceccanti, B., Roachi, V. and Bauer, C. 2000. Kinetic parameters of dehydrogenase in the assessment of the response of soil to vermicompost and inorganic fertilizers. Biology and Fertility of Soils. 32: 479-483.

Mathivanan S, Chidambaram AL A, Sundaramoorthy P, Kalaikandhan R. Effect of vermicompost on germination and biochemical constituents of ground nut (*Arachis hypogea* L.) seedling. Int J Res Biol Sci, 2012; 2(2): 54-59.

Maynard, A.A. 1995. Cumulative effect of annual additions of MSW compost on the yield of field grown tomatoes. Compost Sci. util., 3:47-54.

Mbah, C. N. (2006). Influence of organic wastes on plant growth parameters and nutrient uptake by maize (Zea mays L.). *Nigerian Journal of Soil Science, 16*(1), 104-108.

Metson, A. J. 1961. Methods of chemical analysis for soil survey samples. Soil BUREAu Bulletin No. 12, New Zealand Department of Scientific and Industrial Research, pp. 168–175. (Government Printer: Wellington, New Zealand.).

Nandwani, D. Growth and yield response of four tomato cultivars in the US Virgin Islands. J. Agric. Univ. Puerto Rico 2014, 97, 181–184.

Olsen, S.R.; Cole, C.V.; Watanabe, F.S. and Deen, L.A. 1954. Estimation of available P in soils by extraction with sodium bicarbonate. USDA. Circ 939: 1-19.

Orozco, F. H., Cegarra, J., Trujillo, L. M. and Roig, A. 1996. Vermicomposting of coffee pulp using the earthworm *Eisenia fetida*: effects on C and N contents and the availability of nutrients. Biol. Ferti.Soils, 22: 162 - 166.

Oyewole, C.; Opaluwa, H.; Omale, R. Response of tomato (Lycopersicon esculentum) growth and yield to rates of mineral and poultry manure application in the Guinea Savanna Agro-ecological Zone in Nigeria. J. Biol. Agric. Healthc. 2012, 2, 44–56.

Palm, C. A., Myers, R. J. K., & Nandwa, S. M. (1997). Combined use of organic and inorganic nutrient sources for soil fertility maintenance and replenishment. *In* R. J. Buresh, P. A. Sanchez, & F. G. Calhoun (Eds.), *Replenishing soil fertility in Africa* (pp.193-218). Madison, WI, USA: Soil Science Society of America (SSSA).

Pionke HB, Sharma ML, Hirschberg KJ. 1990. Impact of irrigated horticulture on nitrate concentration in ground water. *Agriculture, Ecosystems and Environment* 32,199-122.

Prabha, K.P., Loretta, Y.L., Usha, R. K. 2007. An experimental study of vermi-biowaste composting for agricultural soil improvement. Bioresour. Technol., 99: 1672-1681.

Sainz, M.T., Taboada-Castro, M. T. and Vilarino, A. 1998. Growth, mineral nutrition and mycorrhizal colonization of red clover and cicumber plants grown in a soil amended with composted urban waste. Plant Soil, 205: 85 - 92.

Sanchez P.A., Shepherd K.D., Soule M.J., Place F.M., Buresh R.J., Izac A.-M.N., Mokwunye A.U., Kwesiga F.R., Ndiritu C.G., Woomer P.L. (1997). Soil fertility replenishment in Africa. An investment in natural resource capital, in: Buresh R.J.,

Theunissen J, Ndakidemi PA, Laubscher CP. Potential of Vermicompost produced from plant waste on the growth and nutrient status in vegetable production. Intl J Phys Sci, 2010; 5: 1964-1973.

Tomati, U. and Galli, E. 1995. Earthworm, soil fertility and plant productivity. Acta Zoologica Fennica, 196:11-14.

Tonfack, L.B.; Bernadac, A.; Youmbi, E.; Mbouapouognigni, V.P.; Ngueguim, M.; Akoa, M. Impact of organic and inorganic fertilizers on tomato vigor, yield and fruit composition under tropical andosol soil conditions. Fruits 2009, 64, 167–177.

Vaidyanathan, G. and Vijayalakshmi, A. 2017. Effect of vermicompost on growth and yield of tomato. *European Journal of Pharmaceutical and Medical Research, 2017,4(9), 653-656.* www.ejpmr.com

Effects of Intra-row Spacing and N Fertilizer Application on Yield and Yield Components of Tomato(*Lycopersicon esculentum* L.)

**Gebisa Benti, Gezu Degafa, Adugna Hunduma, Habte Birhanu and Mohammed Jafar*
Oromia Agricultural Research Institute/Fedis Agricultural Research Center
Corresponding author: bantiig@gmail.com

Abstract

*Improper plant spacing and nitrogen fertilizer are among the main factors which constrained productivity of the tomato. Due to this gap the experiment was proposed and conducted in Sofi district, Harari People Regional State, Ethiopia in 2016 and 2017 cropping season to investigate the effect of intra-row spacing and nitrogen fertilizer on yield and yield components of tomato. Experimental treatments were nitrogen rates (0, 39, 69 and 99 kg ha^{-1}) and intra-row spacing (25, 30, 35 and 40 cm). A total of 16 treatments were arranged in randomized complete block design with three replications. Melkashola variety was used for the experiment. The results revealed that there were significant (P<0.05) differences for plant height, number of branches, fruit clusters per plant, number of fruits per plant due to nitrogen application. Increasing nitrogen rate from nil to 69 kg ha^{-1} increased all these parameters. Average fruit weight and fruit yield were significantly (P<0.05) affected due to the interaction effect of nitrogen and intra-row spacing. The highest fruit weight was recorded at 39 kg N ha^{-1} and 40 cm intra-row spacing while the lowest were at 0 N and 40 cm intra-row spacing. The highest fruit yield was recorded at 69 kg ha^{-1} N and 30 cm intra-row spacing while the lowest was at 0 N and 40 cm intra-row spacing. In conclusion, the application of 69 kg N ha^{-1}and 30 cm intra-row spacing recorded highest fruit yield with highest economic returns (*270,330 *birr ha^{-1}). Based on fruit yield and economic return, combination of 69 kg N ha^{-1} and 30 cm intra-row spacing was recommended for the study area and similar agro-ecology.*

Keywords: Intra-row, Melkashola, Nitrogen, Spacing, Tomato

Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the most important fruity vegetables, which due to high nutrient value, is in the second rank in regards level under cultivation and consumption (Daneshvar, 2000). It is also among the most important vegetable crops in Ethiopia. The total production of this crop in the country has shown a marked increase (Lemma *et al*., 1992) since it became the most profitable crop providing a higher income to small scale farmers compared to other vegetable crops. However, tomato production is highly constrained by several factors especially in developing nations like Ethiopia. The national average of tomato fruit yield in Ethiopia is often low (125 q/ha) compared even to the neighboring African countries like Kenya (164 q/ha) (FAO, 2004). In Ethiopia, farmers get lower yield mainly due to diseases and pests as well as due to sub-optimal fertilization. Mehla *et al*., (2000) and Pandey *et al.* (1996) reported that fruit yield in tomato is highly influenced by the N and P fertilizers rates applied. Similarly, Sherma *et al*. (1999) also reported average fruit weight of tomato to have been influenced by the amount of N and P fertilizers rates applied.

Improper plant spacing is also among the notable reasons of low productivity of this crop. Lemma *et al*.-(1992) reported that plant spacing greatly influenced fruit yield in both fresh

market and processing tomatoes. Likewise, Godfrey-Sam-Aggrey *et al*.(1985) and Mehla *et al*.(2000) also reported yield parameters of tomato have been affected by spacing.

The two main management practices which greatly influence tomato fruit yield are spacing and fertilizer application (Abdel-Mawgoud *et al*., 2007). Closer spacing resulted in higher yield, less cracked fruits per plants (Adani *et al*., 1998). Wider spacing on the other hand led to increase in fruit yield per plant with bigger fruits and more cracked fruits per plant. Since spacing requirement of tomato depends on soil type and its inherent fertility (Lemma *et al*., 1992) and the type of cultivars (Mehla *et al*., 2000), the use of blanket recommendation would be inappropriate and it would be indispensable to identify appropriate recommendation for specific soil types and cultivars grown in the region. Farmers in the study area grow tomato traditionally even without the row planting and they are not using appropriate fertilizer rate. As a result of this, adequate levels of nutrients are very vital to increase the production and yield of tomato. In view of inconsistent and inadequate results concerning the combination of these two management production practices, field trial was conducted with the objectives to determine the optimum intra-row spacing and N fertilizer rate for tomato under eastern Hararghe zone.

Materials and methods

Experimental Site

The experiment was conducted in Harar People Regional State, Sofi district in Harawe on farmers land. The district was geographically lies at an altitude of 1300-1800 meters above sea level. The mean annual rainfall of the district was 400 mm and maximum and minimum rain fall is 500 mm and 300 mm, respectively. Like some part of Ethiopia, Sofi district was characterized by the bimodal rainfall pattern. The first season was characterized by the short rainy season (*Belg*), which extends from March to May, while the second season which is the most important main rainy season (*Meher*) extends from July to October. The dry-spell period was extends from June to July and based on its duration, it may affect crop growth. The minimum and maximum temperature of the area was 25 ^{0}C and 35 ^{0}C, respectively with the annual average of 30 ^{0}C (Harari BoA, 2016, unpublished).

Experimental Treatments and Design

For this experiment, tomato variety "Melkashola" was used as a test crop which was potentially produced by the farmers' in the area. The experimental treatments consisted of four intra-row spacing (25, 30, 35 and 40 cm) and four fertilizer rates (0, 39, 69 and 99 kg N/ha). A total of 16 treatments were laid out in Randomized Complete Block Design (RCBD) in factorial arrangement with three replications. Each treatment combination was assigned randomly to experimental units within a block. The row spacing of 70 cm was used for all treatments. Spacing between blocks and each plot were 1m, respectively. Based on the intra-row spacing specified, the plant populations were 57143, 47619, 40816 and 35714 plants per hectare, respectively.

Experimental Procedures

The experimental field was cultivated to a depth of 25 cm by a tractor. The experimental plots were harrowed to a fine tilth manually before planting. The land was leveled well and seeds of tomato were sown in rows of 10 cm on well prepared seed bed of 1 x 10 m and the beds were covered with light soil and mulching grasses until emergence. The beds were supplied with supplementary irrigation during the shortage of rainfall. Finally, hardened, healthy and uniform seedlings of pencil size were transplanted at 3 to 5 leaves

developed. All cultural practices were conducted as per recommendation of the area and each and every data planned to be collected were taken on time by using data record sheet. The nitrogen fertilizer (N) was applied in the form of UREA whereas phosphorus (P) in the form of Triple Super phosphate (TSP) during sowing of the seed on nursery. Nitrogen was applied at two equal splits (3 weeks after transplanting and the rest half at 6 weeks after transplanting) as basal application according to the rate specified in the treatments. Hand weeding and hoeing were carried out three times sequentially at seedling establishment, flowering and fruit setting. Mancozeb was applied before flowering to protect blight. All treatments were randomly assigned to the experimental plots.

Data Analysis and Management

Data collected

Data were collected from plant height (cm), number of branch per plant, number of cluster per plant, number of fruit per cluster, number of fruits per plant, yield per hectare, average fruit weight. Plant height was measured using ruler from the base of the plant to the tip of the shoots from ten plants of the central rows. The average numbers of branches were counted from 10 plants. The numbers of fruits per clusters were counted from 10 plants of the central rows. The average numbers of fruits per cluster were also counted from 10 plants. All fruits harvested were counted to estimate the number of fruits per plant. The average fruit weight was weighted from ten fruits which harvested from central rows of the plots. The average fruit weight was expressed in gram. During harvesting, all harvest cycle fruits were weighted by using digital balance and expressed in tons per hectare.

Statistical data analysis

Data were subjected to analysis of variance using Gen-STAT Statistical Software package. Means that differed significantly were separated using the LSD (Least Significant Difference) test at 5% level of significance.

Results and discussion

Soil Chemical and Physical Properties

Analysis of soil sample indicated that the soil was sandy clay loam in texture and moderately basic at pH of 8 (Table 1). According to Bruce and Rayment (1982) range, the soil was medium in total nitrogen (0.171%). Similarly, according to Olsen *et al*. (1954), the experimental site had low available phosphorus (2.893 mg kg^{-1} soil). According to Emerson (1991) the range of organic matter content was moderate (2.277) contents. This moderate content of organic matter indicated that moderate soil structural condition, moderate structural stability. According to Metson (1961), the soil of the experimental site had low cation exchange capacity (7.13 cmol kg^{-1} soil) and high in exchangeable potassium (9.026 cmol (+) kg^{-1} soil), pH (soil to water ratio 1:2.5), CEC (cation exchangeable capacity: meq 100 g^{-1} soil), OC (Organic carbon:%), Mg^{2+} (Magnesium: cmol (+) kg^{-1} soil), Ca^{2+} (Calcium: cmol (+) kg^{-1} soil), Exch. Na (Exchangeable Sodium: cmol (+) kg^{-1} soil), Exch. K (Exchangeable Potassium: cmol (+) kg^{-1} soil), Avail. P (Available phosphorous: mg kg^{-1} soil), TN (Total Nitrogen: %) (Table 1).

Table 1. Soil chemical properties of Expermenta site, Sofi district, Harari People Regional State, 2017

Sample	pH	CEC	OC	Mg^{2+}	Ca^{2+}	Exch.Na	Exch. K	Avail. P	TN	Texture
Soil	8	7.13	1.324	9.36	8.963	0.399	9.026	2.893	0.171	Clay loam

Plant height and Number of branches

Plant height was significantly (P<0.05) affected by the application of nitrogen and intra-row spacing. Number of branches were significantly (P<0.05) affected due to nitrogen application, but did not due to intra-row spacing. Application of nitrogen at 99 kg ha^{-1} increased plant height by 13.6% over with out application of nitrogen. However, application of nitrogen at 69 and 99 kg ha^{-1} statistically non significant.The maximum value of plant height was recorded at intra-row spacing of 40cm. Plant height increased with decreased spacing in tomato. Intra-row spacing of 35 and 40 cm were statistically not different on plant height. Increasing nitrogen application from 0 to 99 kg ha^{-1} linearly increased tomato branches. The highest branches were recorded at nitrogen rate of 99 kg ha^{-1}, however, application of nitrogen at 39, 69 and 99 kg ha^{-1} statistically parity. Application of Nitrogen at 99 kg ha^{-1} increased tomato branches by about 28.9 % over with out nitrogen application. The result of current study was in line with that of Ogundare *et al*. (2015) who reported that as UREA rate increased, plant height also increased. Increasing UREA rate increased plant height and number of branches per plant. Similar to this study Ogundare *et al*. (2015) also reported that the number of branches and leaves increased with increased rate of UREA. Plots amended with UREA fertilizer were significantly better than the control in terms of plant height and number of branches.

Fruit Yield and Yield Components

Fruit clusters and fruits per plant

Fruit clusters and fruits per plant were significantly (P<0.05) affected by application of nitrogen while intra-row spacing did no significant difference on both parameters. The highest fruit clusters were recorded at 69 kg ha^{-1} nitrogen application, however, application of nitrogen at 39, 69 and 99 kg ha^{-1} were statistically not different. Application of nitrogen at 69 kg ha^{-1} increased fruit clusters by about 22.8% over the control treatment.The lowest numbers of fruits per plant were recorded in control treatment. Application of nitrogen at 39, 69 and 99 kg ha^{-1} did not showed significant difference on number of fruits per plant. The lowest fruit clusters and fruits per plant were recorded from control treatment. According to Ogundare *et al*., (2015), the highest increase was observed in plots treated with 108.6 kg UREA, while the control plots recorded the least value of fruit length, fruit weight, and number of fruits per plant and fruit yield per hectare.

Average fruit weight and fruit yield

Average fruit weight and fruit yield were significantly (P<0.05) affected due to the interaction effect of nitrogen application and plant intra-row spacing. The highest fruit weight was recorded at 39 kg N ha^{-1} and 40 cm intra-row spacing while the lowest were at 0 N and 40 cm intra-row spacing. The highest fruit yield was recorded at 69 kg N ha^{-1} and 30 cm intra-row spacing while the lowest was at 0 N and 40 cm intra-row spacing. According to Tesfaye Balemi (2008), a plant spacing of 80 cm x 30 cm resulted in the highest mean total fruit yield (78.6 kg $plot^{-1}$) whereas spacing of 100 cm x 30 cm gave the

lowest mean total fruit yield (67.6 kg plot^{-1}). Teerapolvichitra (1983) also reported the highest marketable fruit yield at closer spacing than at wider spacing, which supports the present finding. However, Godfrey-Sam-Aggrey *et al*., (1985) and Mehla *et al*., (2000) reported increased marketable fruit yield at wider spacing which contradicts with the present finding. In contrast to the present study, Kirimi *et al*., (2011) reported that nitrogen had no significant effect on marketable fruits in both seasons while spacing significantly affected the number of marketable fruits in both seasons. Warner *et al*., (2004) stated that fertilizer N above 100 kg N ha^{-1} increased yields of green fruit, but little increase in marketable yield was obtained with N rates above 150 kg ha^{-1}. In this study, tomato fruit yield was significantly affected due to the interaction effect of nitrogen and intra-row spacing which recorded the highest fruit yield at 69 kg ha^{-1} and 30cm intra row spacing.

Table 2. Effect of nitrogen rate and intra-row spacing on growth, yield and yield component of tomato over the two years at Sofi district, Harari People Regional State, 2016 and 2017.

Nitrogen (kg/ha)	Plant height (cm)	Branches per plant	Clusters per plant	Fruits per cluster	No of fruits per plant
0	57.470c	3.960b	6.910b	3.071	18.79b
39	60.07bc	4.55ab	7.72ab	3.227	27.15a
69	64.34ab	4.63ab	8.950a	3.175	28.83a
99	66.510a	5.570a	8.04ab	3.306	28.16a
LSD(0.05)	4.4170	1.2980	1.7070	NS	7.460
Intra spacing (cm)					
25	61.42ab	4.752	7.948	3.281	29.98
30	59.010b	4.410	7.771	3.123	23.42
35	62.10ab	4.425	8.029	3.048	23.87
40	65.860a	5.123	7.873	3.327	25.66
LSD(0.05)	4.6680	NS	NS	NS	NS
CV (%)	12.4000	48.4	37.7	20.8	50.6

Table 3. Interaction effect of nitrogen rate and intra row spacing on average fruit weight (g) at Sofi district, Harari People Regional State 2016 and 2017

	Intra-row spacing-(cm)			
N rate (kg/ha)	25	30	35	40
0	52.53a-e	48.52cde	48.10cde	42.7300e
39	49.28c-e	55.28a-d	56.92abc	62.3200a
69	47.06c-e	44.180de	52.89a-e	59.12abc
99	50.20b-e	49.08cde	48.04cde	61.450ab
LSD (0.05) =10.349,		CV (%) = 17.4		

Table 4. Interaction effect of nitrogen and intra-row spacing on fruit yield (tons/ha)-over the two years at Sofi district, Harari People Regional State ,2016 and 2017

	Intra-row spacing (cm)			
Nitrogen	25	30	35	40
0	25.0ab	21.9ab	21.a0b	18.80b
39	33.2ab	33.5ab	27.3ab	23.9ab
69	29.7ab	38.10a	28.2ab	26.8ab
99	31.5ab	23.5ab	29.2ab	23.0ab
LSD(0.05) = 14.28		CV(%) 45.8		

Partial Budget Analysis

Application of nitrogen rate at 69 kg ha^{-1} and intra-row spacing of 30 cm recorded maximum net return followed by combination of nitrogen and intra-row spacing at 39 kg ha^{-1} and 30 cm, and 39 kg ha^{-1} and 25 cm, respectively, from tomato production. The lowest net returns were obtained at 0 N in all treatment combinations.

Table 5. Partical budget analysis of Nitrogen fertilizer and intra-row spacing of tomato, at Sofi district, Harari People Regional State 2016 and 2017.

(Spacing + N)	UFY (kg ha^{-1})	AFY (kg ha^{-1})	GR (birr ha^{-1})	TVC (birr ha^{-1})	NR (birr ha^{-1})	MRR (%)
40 - 0	18747	16872	134976	2170	132806	
35 - 0	20990	18891	151128	2480	148648	5110
40 - 39	23931	21538	172304	2622	169682	14813
30 - 0	21857	19671	157368	2894	154474	D
35 - 39	27250	24525	196200	2932	193268	102089
40 - 69	26758	24083	192664	2970	189694	D
35 - 69	28160	25344	202752	3280	199472	3154
40 - 99	22990	20691	165528	3318	162210	D
30 - 39	33458	30113	240904	3346	237558	269100
25 - 0	25025	22523	180184	3472	176712	D
35 - 99	29227	26304	210432	3628	206804	19290
30 - 69	38058	34253	274024	3694	270330	96252
25 - 39	33203	29883	239064	3924	235140	D
30 - 99	23458	21112	168896	4032	164864	D
25 - 69	29678	26711	213688	4272	209416	18563
25 - 99	31538	28385	227080	4620	222460	3748

N =Nitrogen, UFY=Unadjusted Fruit Yield, AFY=Adjusted Fruit Yield, GR=Gross Return, TVC=Total Variable Cost, NR=Net Return, MRR=Marginal Rate of Return, D=Dominated treatments

Conclusion

The experiment was conducted for two consecutive cropping season to determine the effect of intra-row spacing and nitrogen fertilizer rate on tomato yield and yield parameters. The results indicated that there was significant diffreance among treatments for plant height, branches per plant, clusters per plant and number of fruits per plant due to the application of nitrogen. There was an interaction effect of nitrogen application and intra-row spacing on average fruit weight and fruit yield. The highest fruit weight was obtained by the application of 39 kg ha^{-1} N at intra-row spacing of 40 cm while fruit yield was at 69 kg ha^{-1} N and 30 cm intra-row spacing. In conclusion, application of 69 kg N $ha^{-1}$and intra-row spacing at 30 cm, recorded highest fruit yield with highest economic returns (270,330 birr ha^{-1}). Based on fruit yield and economic return, combination of 69 kg N ha^{-1} and 30 cm intra-row spacing was recommended for the study area and similar agro-ecology.

REFERENCES

Abdel-Mawgoud NHM, Greadly E, Helmy YI, Singer SM. Responses of tomato plants to different rates of humic-based fertilizer and NPK fertilization. J. Appl. Sci. Res. 2007;3(2):169-174.

Bruce, R. C., and Rayment, G. E. 1982. Analytical methods and interpretations used by the Agricultural Chemistry Branch for Soil and Land Use Surveys. Queens land Department of Primary Industries. Bulletin QB8 (2004), Indooroopilly, Queensland. chemical fertilizers. Les. Envis. Newsl. 2004, 7, 4–5.

Daneshvar, M.H. 2000. Vegetables growing. Shahid-Chamran University Press, Persian.

Emerson, W. W. 1991. Structural decline of soil, assessment and prevention. *Australian Journal of Soil Research*, 29: 905–922.

Food and Agriculture Organization (FAO). 2004. Production year book.

Godfrey-Sam-Aggrey and Bereke Tsehi (eds.). Proceedings of the First Ethiopian Horticultural Workshop. pp236-249.

Godfrey-Sam-Aggrey, W. Turuwork A. and Tadelle A. 1985. Review of Tomato Research in Ethiopia and Proposal for future Research and Development direction. *In:* Kirimi, J.K, Itulya, F.M. and Mwaja, V.N. 2011. Effects of nitrogen and spacing on fruit yield of tomato. African Journal of Horticultural Sciences, 5:50-60.

Lemma, D., Yayeh, Z. and Herath, E. 1992. Agronomic Studies in Tomato and Capsicum. *In*: Herath and Lemma (eds.). Horticulture Research and Development in Ethiopia: Proceedings of the Second National Horticultural Workshops of Ethiopia. 1-3 December. Addis Ababa, Ethiopia. pp 153-163.

Mehla, C.P., Srivastava, V.K., Jage, S., Mangat, R., Singh, J. and Ram, M. 2000. Response of tomato varities to N and P fertilization and spacing. Indian Jornal of Agricultural Research. 34 (3): 182-184.

Metson, A. J. 1961. Methods of chemical analysis for soil survey samples. Soil BUREAu Bulletin No. 12, New Zealand Department of Scientific and Industrial Research, pp. 168–175. (Government Printer: Wellington, New Zealand.).

Ogundare, S.K., Oloniruha, J.A., Ayodele, F.G. and Bello, I.A. (2015) Effect of different spacing and UREA application rates on fruit nutrient composition, growth and yield of tomato in derived Savannah vegetation of Kogi State, Nigeria. *American Journal of Plant Sciences*, **6**, 2227-2233.

Olsen, S.R.; Cole, C.V.; Watanabe, F.S. and Deen, L.A. 1954. Estimation of available P in soils by extraction with sodium bicarbonate. USDA. Circ 939: 1-19.

Pandey, R.P, Solanki, P.N, Saraf R.K and Parihar, M.S. 1996. Effect of Nitrogen and Phosphorus on growth and yield of tomato varieties. Punjab Vegetable Grower. 31: 1-5. Report. pp 1-4.

Sharma, K.C., Singh, A.K. and Sharma, S.K. 1999. Studies on Nitrogen and Phosphorus requirement of tomato hybrids. Annals of Agricultural Research. 20 (4): 339-402.

Teerapolvichitra, P. 1983. Effect of Plant Population Density on Tomato. ARC Training.

Tesfaye Balemi. 2008. Response of tomato cultivars differing in growth habit to nitrogen and

phosphorus fertilizers and spacing on vertisol in Ethiopia. Acta Agriculturae Slovenica, 91 - 1, str. 103 - 119, DOI: 10.2478/v10014-008-0011-8.

COFFEE RESEARCH

Isolation, Identification and Characterization of *Colletotrichum kahawae* from Infected Green Coffee Berry in Arsi, Southeastern Ethiopia

Hika Bersisa[1], Mashilla Dejene[2] and Eshetu Derso[2]
[1]Mechara Agricultural Research Center, Mechara, Ethiopia
[2]School of Plant Sciences, Haramaya University, Ethiopia
[2]Ethiopian Agricultural Research Institute, Addis Abeba, Ethiopia
Corresponding Author: hikbersisa@gmail.com, Tel: +251 (0) 917794867

Abstract
Colletotrichum kahawae is a causal pathogen of coffee berry disease (CBD). It was reported in Ethiopia for the first time in 1971and spread to all major coffee-producing regions within very short period. It was prevalent in most coffee growing areas of Ethiopia and has been characterized in morpho-cultural attributes. However, characterization of *C. kahawae* in Arsi is lacking. Therefore, present study was conducted to characterize the pathogen isolates for their morpho-cultural attributes. Attributes selected for isolates characterization were conducted following recent procedures and methods with few modifications. Accordingly, five representative isolates of *C. kahawae* and one of *C. gloeosprioides* were isolated and identified from infected green coffee berry. Morphological characters (colony color, radial growth rate and texture) and cultural characteristic (conidial shape, size and sporulation capacity) were used to characterize *C. kahawae*. There were significant variations among isolates in their morpho-cultural features. Four colony colors (light gray, dark gray, gray and dim gray) were identified. Conidia production capacity varied from 7.5×10^5 – 1.44×10^6, while conidial size varied among and within isolates ranging from 10.5 to 15.5 µm and 2.78 to 3.83 µm for length and width, respectively. More than 50% of conidial shape frequency of each isolate was under conidial shape of type 1 except isolate Shk9. Except conidial size, other Morpho-cultural attributes were used for identification of *C. kahawae*. Therefore, except conidial size one can be use remaining morpho-cultural attributes of C. kahawae for diagnosis or as identification tools. This is not to mean traditional characterization is enough for diagnosis. Since it has limit diagnosis and identification among and within pathogen species, further study should be undertaken via molecular tools.

Keywords: C. kahawae, conidial, colony, Morpho-cultural features

Introduction
Colletotrichum kahawae is a causal pathogen of coffee berry disease. It was reported in Ethiopia for the first time in 1971 by Mulinge (1972). Then the disease spread to all major coffee producing regions within very short period except to the lower altitudes, i.e. it has spread and found in all coffee producing areas in which it is favored by environmental conditions. From the range of Colletotrichum spp. that are isolated from coffee plants, four groups were initially described based on their morphological traits, namely *C. coffeanum* mycelial, *C. coffeanum* acervuli, *C. coffeanum* Pink and the CBD strain. The three former groups were later recognized as *C. gloeosporioides* Penz and *C. acutatum* Simmonds, and proved to be non-pathogenic in green coffee berries (Gibbs, 1969; Hindorf, 1970). Only

the fourth group was able to infect both wounded and unwounded green berries and was formerly referred to as *C. coffeanum* (Hindorf, 1970).

Colletotrichum coffeanum was described in 1901 based on Colletotrichum isolated from coffee in Brazil (Freeman, 1998) where CBD does not exist, and was probably synonymous with *C. gloeosporioides*, which occurs as a saprophyte or weak pathogen of ripe berries and damaged coffee tissue worldwide (Freeman, 1998). Several authors attempted to amend this anomaly but it was not until 1993 that Waller and Bridge described *C. kahawae* as the causal agent of CBD and as a distinct species based on morphological, cultural and biochemical characters (Waller, 1993) and more recently on multi-locus datasets (Prihastuti et al., 2009).
Traditional approaches of identification of species belonging to the genus Colletotrichum as well as other filamentous fungi have always relied on morphological characteristics (colony color, size and shape of conidia, presence or absence of setae and teleomorph, pathogenicity and cultural criteria (Sutton, 1992; Agrios, 2005). Similarly, according to Kilambo *et al.* (2013), identification of *C. kahawae* has been based on morphological and cultural characteristics, such as conidial morphology and pigmentation.
CBD is prevalent in most coffee growing areas of Ethiopia and the casual pathogen was also characterized based on morpho-cultural features. However, *C. kahawae* was not characterized in Arsi Zone, Oromia, Ethiopia. Therefore, present study was conducted to characterize *C. kahawae* isolates from this zone for their morpho-cultural attributes.

Materials and Methods

Description of the study area

Laboratory experiment was conducted in Plant Pathology Laboratory of School of Plant Sciences, Haramaya University in 2017. Haramaya University was established in 1954 at Haramaya, Oromia Regional State, Eastern Ethiopia.

Sample collection and techniques used

One sample from each fourty one farms visited (a total of fourty one samples) were collected. From each farm 40 green coffee berries (1640 in total) affected by CBD with active lesions were collected. The collected berries were placed in sterilized paper bags and sandwiched between newspapers and kept in a cool box for the pathogen to be viable for successful subsequent isolation. Samples were transported to Plant Pathology Laboratory of School of Plant Sciences, Haramaya University. Samples were maintained at 4^{o}C for further analysis.

Isolation and identification of *C. kahawae*

Colletotrichum kahawae was isolated from the diseased coffee berries with active CBD lesions using the method described by Kilimbo *et al.* (2013), Emana (2014), Abdi and Abu (2015) and Fredrick *et al.* (2017). The infected coffee berries with active lesions (sunken and dark lesions) were selected for fungal isolation. The diseased berries were surface-sterilized with 5% sodium hypochlorite (NaOCl) solution for 3 minutes and then rinsed with sterilized distilled water twice for one minute. Sterilized berries were placed on sterilized tissue paper for drying. Totally 30 coffee berries were used and arranged in three replications, i.e. 10 coffee berries per sample were plated on potato dextrose agar (PDA) incubated at 25°C for 5 - 7 days.

For the purpose of fungal identification, advanced mycelia were transferred aseptically to freshly prepared potato dextrose agar PDA. The advanced mycelium was taken from the

margin of ten-day-old culture by using sterile scalpel. These all activities were done under air-flow laminar hood to reduce contamination arising from airborne micro-organisms (laboratory weeds). Preliminary confirmatory tests of colony texture of *C. kahawae* isolates on PDA was made based on mycological color chart developed by Rayner (1970). Eventually identification of the pathogen was done under compound microscope.

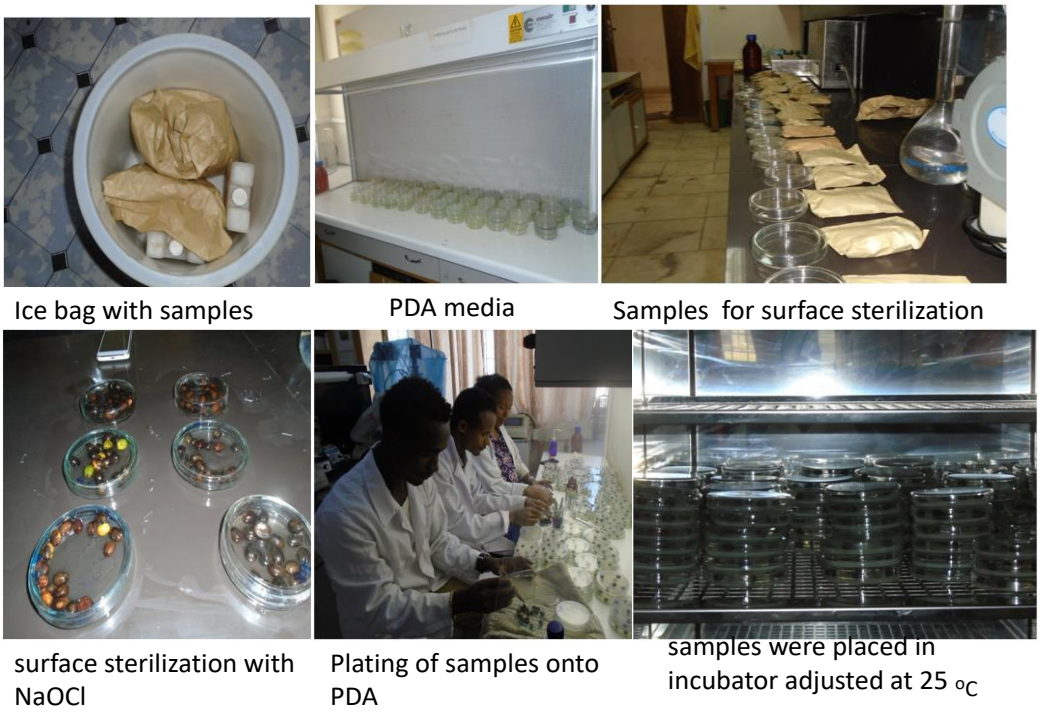


Figure 1. Isolation and identification of *C. kahawae* from infected coffee berry.

Morphological characterization of *C. kahawae*

Colony (mycelial) radial growth: Cultures of 5 *C. kahawae* isolates were inoculated on PDA. Hyphal tip of each isolate was placed at the center of 15 ml PDA dispensed in a 90 mm diameter sterilized Petri dish with three replications (Emana, 2014). Mycelial (colony) radial growth (mm per 24 hr) of each isolate was measured manually with ruler. Colony diameter was measured from two perpendicular planes on the reverse side of the Petri-dishes.

Colony color of *C. kahawae* isolates: Colony (mycelia) color on front side and types of pigments from the reverse side of each *C. kahawae* isolate were determined using PDA and MEA using RGB color chart (Rayner, 1970; Anonymous, 2005; Kilimbo et al., 2013; Emana, 2014). Colony texture (aerial mycelial growth) of *C. kahawae* isolates: Following procedure employed by Arega (2006) and Emana (2014), vigor of aerial mycelial growth was determined as dense, irregular (scarce) or very scarce type by observing on top side of colony on 10-day-old culture grown on PDA and malt extract agar (MEA).

Cultural characterization of *C. kahawae* isolates

Conidial size: The isolates were incubated on PDA medium at 25^{o}C for 7 days, replicated three times per isolate (Arega, 2006). All types of shapes and most frequent sizes were included at random to minimize further measurement biasedness. Conidial size (length and width) was calculated from 100 conidia per isolate. More conidia were measured for those isolates which had more variable shapes of conidia. Length and width of conidia were

measured with ocular micrometer (µm), which was fitted into 10x eyepiece and adjusted at 40x objective of the compound microscope.

Sporulation capacity: Ten-day-old cultures of each *C. kahawae* isolate incubated on PDA was washed by flooding with 10 ml sterile distilled water, rubbed with sterile scalpel and transferred to 50 mL sterile beaker and thoroughly stirred for 10-15 minutes with magnetic stirrer to extract the spores from the interwoven mycelia and then filtered into another sterile beaker through double layer cheese cloth. The number of conidia per milliliter was counted using haemocytometer under compound microscope. The results were determined for each isolate as the average number of conidia per milliliter after taking nine haemocytometer counts (Arega, 2006).

Conidial shape: Frequency of conidial shapes was computed from 14-day-old cultures of *C. kahawae* isolates incubated on PDA (Arega, 2006). Conidial shape of representative *C. kahawae* isolates were described using ocular compound microscope and the most frequent five conidial shapes which were standardized and used by Hindorf (1973) and Tefestewold (1995) for Colletotrichum spp. characterization. The frequency of each shape was computed from 100 conidia per isolate.

Experimental design, treatments and data analysis:
Experiment was conducted in laboratory under Completely Randomized Design (CRD) with three replications. General fungal growth medium, PDA and MEA used as constant variable while coffee CBD isolates were as a treatment. Data was analyzed using GenStat software version 16 (Duncan's Multiple Range Test).

Results and Discussion

Isolation and identification of *C. kahawae* and related species
Five representative isolates of *C. kahawae* and one *C. gloeosporioides* were obtained (Table 1). Those isolates identified as *C. kahawae* were recognized by producing dark grey cottony colony, oval conidial morphology and slow growth rate. Five representative *C. kahawae* isolates were isolated from infected green coffee berries sampled from Chole (one isolate), Gololcha (two isolates) and Shanan Kolu (two isolates), while one *C. gloeosporioides* isolate was obtained from infected green berries samples from Gololcha.

Table 1. Colletotrichum species detected from infected coffee berries

Isolates code	Garden coffee locality	Pathogenicity	Species
Cho41	Chole	＋	*C. Kahawae*
Go33	Gololcha	＋	*C. Kahawae*
Go34	Gololcha	＋	*C. Kahawae*
Go38	Gololcha	－	*C. gloeosporioides*
Shk9	Shanan Kolu	＋	*C. Kahawae*
Shk10	Shanan Kolu	＋	*C. Kahawae*

Note: + and － stand for pathogenic and non pathogenic of Colletotrichum spp. isolates to coffee berry

Frequency of coffee berry contaminants and fungal occurrence

A total of 41 coffee samples were collected from 41 farms of Arsi garden coffee. From the collected samples, four types of fungal species (*C. kahawae*, *F. lateritium*, Aternaria spp. and Phoma spp.) were isolated and identified (Table 2). Coffee berries were invaded more by *C. kahawae* (87.23%), followed by *F. lateritium* (9.13%), Phoma spp. (2.13%) and Aternaria spp. (1.5%). Abdi and Abu (2015) have isolated three kinds of fungal species namely *C. kahawae*, *F. lateritium* and Phoma spp. However, present study demonstrats Aternaria spp. as an additional fungal species. The coffee berry samples collected from Shanan-Kolu was highly infected compared to Chole and Gololcha districts. Abdi and Abu (2015) observed similar variations in infection level in the coffee berry samples collected from Abaya, Bule-Hora and Kercha districts.

Table 2. Frequency of fungal species from infected coffee berries

Districts	Fungal species	% of berry infected by CBD and other fungal spp.
Chole	*C. kahawae*	87.2
	F. lateritium	7.4
	Aternaria spp.	1.9
	Phoma spp.	3.5
Gololcha	*C. kahawae*	91.2
	F. lateritium	6.3
	Aternaria spp.	1.3
	Phoma spp.	1.2
Shanan Kolu	*C. kahawae*	83.3
	F. lateritium	13.7
	Aternaria spp.	1.3
	Phoma spp.	1.7

Morphological characterization of *C. kahawae*

Mycelial radial growth rate: There was significant ($p \leq 0.05$) difference among isolates in their radial colony growth rate on PDA medium (Table 3). Mean radial colony growth rate of isolates ranged between 3.721 and 7.751 mm in 24 hrs on PDA medium. High (7.751 mm in 24 hrs) and low (3.72 mm in 24 hrs) radial growth rate of mycelium was recorded in isolates sampled from Gololcha (Go33) and Shanan Kolu (Shk9), respectively. The result of the present study is in agreement with the previous works related with cultural features of the pathogen. *C. kahawae* isolates from Hararghe showed different mycelial radial growth rate among themselves that ranged between 17.35 to 59.59 mm in 24 hrs (Emana, 2014). Abdi and Abu (2015) presented a similar report on *C. kahawae* isolates from Borena and Guji Zones. Nguyen *et al.* (2010) and Kilimbo *et al.* (2013) also conducted a similar study in Vietnam and Tanzania, respectively. Arga (2006) also characterized *C. kahawae* isolates from the Ethiopian forest coffee for their mycelial radial growth. Arega (2006) also reported on substrate growth preference habit of *C. kahawae* isolates. Accordingly, the author demonstrated that the isolates showed higher mycelia radial growth rate on MEA than on PDA medium due to presence of peptone in MEA. According to Arega (2006), this shows the ability of *C. kahawae* to colonize coffee berry easily by decomposing peptone found in the cell wall of the coffee berry by releasing peptidase enzyme.

On the contrary, Tefestewold and Mengistu (1989) earlier reported 6.75 and 6.5 mm in 24 hrs growth rates on PDA and MEA media, respectively. Similarly, the recent report showed that mean radial colony (mycelial) growth rate of *C. kahawae* isolates varied on MEA and PDA, i.e. 4.05 and 5.35 mm in 24hrs, respectively (Emana, 2014). The variation among radial growth rates of the isolates indicated their preference for substrate utilization and temperature under which they were cultivated.

Table 3. Mean radial growth rate of *C. kahawae* isolates from Arsi Zone

Isolates	Means	f	P
Go33	7.751a	39.93	0.001
Go34	6.229b		
Cho41	6.062bc		
Shk10	5.476c		
Shk9	3.721d		
LSD (0.05)	0.3199		
CV (%)	7.000		

Note: the same letters indicates none significant difference among the isolates.

Colony texture (mycelia aerial growth): Colony textures of *C. kahawae* isolates were classified into dense (regular) and scarce (irregular) colony types. About 80 and 20% of the isolates continually indicated dense and irregular (scarce) types of aerial mycelia growth on PDA medium, respectively, while 60 and 40% of the isolates constantly indicated dense and irregular (scarce) types of aerial mycelial growth on MEA medium, respectively (Table 4). More percentage of these isolates indicated good (regular) aerial mycelial growth on PDA medium than on MEA medium. Based on this result it can be concluded that *C. kahawae* isolates indicated consistent aerial mycelial growth on PDA medium than on MEA medium in dense or irregular (scarce) types. Similar results were obtained by Arega (2006) for *C. kahawae* isolates collected from Ethiopian forest coffee and by Berhanu (2014) for *C. kahawae* isolate sampled from Hararghe.

According to Berhanu (2014), among Hararghe *C. kahawae* isolates tested for their aerial mycelia growth (vigor), 65 and 90% showed consistently dense aerial mycelia growth on both potato dextrose agar (PDA) and malt extract (MEA) media, respectively; whereas 30 and 5% isolates revealed irregular (scarce) and 5% revealed very scarce aerial mycelia growth on both PDA and MEA, respectively. Similarly, Tefestewold (1995) and Zeru *et al.* (2009) also reported differences in aerial mycelial growth among *C. kahawae* isolates from Kaffa and Illubabor on PDA medium. This variation scientifically showed the existence of genetic variability within the same fungal species and existence of variability on the utilization of different substrates.

Table 4. Colony texture of C. kahawae isolates on PDA and MEA

Isolates code	Aerial mycelial growth (vigor)	
	PDA	MEA
Cho41	Dense	Dense
Go33	Dense	Dense
Go34	Dense	Scarce
Shk9	Scarce	Dense
Shk10	Dense	Scarce

Colony color of the isolates: There was a variation among the isolates collected on their colony color. Based on the color observed in this study, colony color of the isolates is grouped into 4 classes (light gray, dark gray, gray and dim gray) mycelium (Table 5; figure 2). These groups were made based on the observation from the front side of the culture plate on both PDA and MEA media, while in previous study Arega (2006) classified them in to three groups of colony color (light-gray, dark-gray and gray). Emana (2014) categorized *C. kahawae* isolates from Hararghe into four types of colony color (light gray, dark gray, gray and white mycelia). Abdi and Abu (2015) reported that young colony *C. kahawae* from Borena and Guji Zones produced grey, becoming grey to dark, olivaceous grey, and dark greenish in reverse side of plates.

These all mycelia of C. kahawae had cottony appearance, including the present result. Sixty percent (three isolates), 20% (one isolate) and 20% (one isolate) of isolates had dark gray, gray and light gray cottony mycelia on PDA medium, respectively, while on MEA medium they produced 60% (three isolates), 20% (one isolate) and 20% (one isolate) of dark gray cottony, dark cottony and dim gray cottony colonies, respectively. However, the non-pathogenic isolate, *C. gloeosporioides* produced whitish cottony and pale whitish to pinkish cottony mycelium on both PDA and MEA, respectively.

The reverse side of culture plate of *C. kahawae* isolates showed different pigments. Several researchers reported diverse colony color in both obverse and reverse side of mycelia of *C. kahawae* isolates obtained from different ecologies (Arega, 2006; Emana, 2014; Abdi and Abu, 2015). Likewise the obverse side, the reverse side of the culture plate produced three types of pigments, viz. dark olive green, dark brown and dim gray. On the PDA medium, 40, 40 and 20% of reverse side of the mycelium of the isolates were dark olive green, dark brown and dim gray, respectively, while on MEA medium, 80 and 20% of reverse side of the mycelium of the isolates were dark olive green and dim gray, respectively. The observed differences among isolates may be related to genetic variability, ecology and utilization of different substrates.

Table 5. Colony colors of *C. kahawae* isolates

Isolates	Colony color on Media			
	PDA		MEA	
	Observed side	Reverse side	Observed side	Reverse side
Cho41	Dark gray cottony	Dark olive green	Dark gray cottony	Dark olive green
Go33	Dark gray cottony	Dark olive green	Gray cottony	Dark olive green
Go34	Dark gray cottony	Dark brown	Dark gray cottony	Dim gray
Go38	Whitish cottony	Pale white	Pale white cottony	Yellowish
Shk9	Light grey cottony	Dim gray	Dim gray cottony	Dark olive green
Shk10	Gray cottony	Dark brown	Dark gray cottony	Dark olive green

Figure 2. Colony color of Colletotrichum species via front and reverse side.

Cultural Characterization of C. kahawae Isolates

Sporulation capacity: Conidial production on 10-day-old mono-conidial cultures showed significant ($p < 0.05$) differences among isolates. Conidial production ranged between $7.5x10^5$ and $1.44x10^6$ conidia mL^{-1} by isolate Shk9 and Go33, respectively. The highest (1.44×10^6 conidia mL^{-1}) number of conidia was produced by isolate Go33, followed by Go34 (1.31×10^6 conidia mL^{-1}), Shk10 (1.02×10^6 conidia mL^{-1}), Cho41 (7.8×10^5 conidia mL^{-1}) and Shk9 (7.5×10^5 conidia mL^{-1}) (Table 6)

In a previous study, Tefestewold (1995) observed 1.2-5.2 x 10^5 conidia mL^{-1} and 6.84-17.20 x 10^6 conidia mL^{-1} production from six isolates of *C. kahawae* on PDA medium and GCA (green coffee seed extract agar). Arega (2006) also reported the existence of considerable variation in conidia production among *C. kahawae* isolates that ranged between 6.84 $x10^6$ to 1.720 x 10^7 conidia mL^{-1}. According to this author, conidia production varied between 2.593 x 10^5 (by isolate Y70 from Yayu) and 2.532 $x10^6$ conidia mL^{-1} (by isolate S60 from Sheko). *Colletotrichum kahawae* from Hararghe Zones showed significant variation on their capacity to produce conidial quantity (Emana, 2014). In the same study the mean conidia production capacity of *C. kahawae* isolates ranged between 3.953 $x10^5$ conidia mL^{-1} produced by isolate Bo3 from Boke and 2.6085 x 10^6 conidia per milliliter produced by isolate B2 from Bedeno. Previous and current studies demonstrates that *C. kahawae* isolates sampled from high elevation with low temperature produced large number of conidia as compared with isolates collected from midland to highland. In another way, the finding indicates that *C. kahawae* isolates prefer low temperature and high moisture rather than high elevation context.

Conidial size: Conidial size varied among and within isolates. All isolates had variable mean conidia length and width ranged between 10.5 - 15.5 and 2.78 - 3.83 µm, respectively (Table 6). The average conidial length and width of isolates were 13.224 and 3.526 µm, respectively. The longest and the shortest conidial length was measured on isolate Shk10 and Go34, respectively, while the widest and narrowest conidial width was recorded in isolate Go33 and Shk10, respectively. Tefestewold (1995) reported that *C. kahawae* isolates had variable mean conidial length that ranged between 13.5 and 19.3 µm and mean conidia width between 2.9 and 5.2 µm. Arega (2006) also reported that *C. kahawae* isolates had variable mean conidial length and width that ranged between 12.7-15.5 and 3.6-4.8 µm, respectively. The average conidial length and width of isolates were 14.10 and 4.21 µm, respectively (Arega, 2006). Kilimbo et al. (2013) reported variability of *C. kahawae* isolates related to their conidial size sampled from different countries of African continent. According to the same auothors, the average size of conidia was 14.10 x 4.21 µm, while conidial width and length ranged between 3.6 – 4.8 µm and 12.7 – 15.5 µm, respectively (Kilimbo *et al.*, 2013).

In the present study, all isolates indicated variable conidial length and width, even within one isolate, and the observations fit with the findings of previous authors. Talhinhas *et al.* (2005) indicated variability in conidial size within and among strains when studying the diversity of Colletotrichum species in olive anthracnose and concluded that it is difficult to distinguish fungal strains using spore size. Similar to his observation, the result of present study indicates the presence of high variability in spore/conidial size among and within *C. kahawae* isolates.

Table 6. Conidial size and sporulation capacity of C. kahawae isolates.

Isolates	Conidial size (L ×W, µm)	Spore production capacity (×10,000 conidia mL^{-1})
Cho41	L 12.7 × W 3.67b	78c
Go33	L 15.5 × W 3.83a	102b
Go34	L 10.5 × W 3.57c	144a
Shk9	L 12.8 × W 3.78b	75c
Shk10	L 14. 7 × W 2.78c	131a
f	31.14	32.57
p	0.001	0.001
LSD (0.05)	4.683	15.78
CV (%)	5.5	8.7

Note: the same letters indicate non significance among isolates.

Conidial shape: The conidial shapes of isolates were variable. About 45-72% of the conidia of the isolates had conidial shape of type 1. More than 53% of conidia of each isolate fall under conidial shape of type 1 except isolate Shk9. However, isolate Shk9 produced almost type 1 and 2 conidia shapes. Isolate Shk41, Go34 and Shk10 produced all types of conidial shapes but predominantly shape type 1 (Table 7). Hindorf (1970) also reported conidial shape variability of *C. kahawae* isolates. The five types of conidial shapes described by Hindorf (1973) and Tefestewold (1995) were frequently observed or encountered in different proportions in each isolate examined. *C. kahawae* isolates from Ethiopian forest coffee showed variable conidial shapes (Arega, 2006). In the same study,

about 49-88% conidia showed conidial shape type 1. More than 55% of conidial shape frequency of each isolate lied under conidial shape type1 except isolates B53, Y75 and G80 (Arega, 2006). It was found that some isolates produced almost type 1 and 2 conidial shapes in equal proportion, while few isolates produced all types of conidial shapes but predominantly type 1 (Arega, 2006).

Emana (2014) also reported conidial shape variability among and within *C. kahawae* isolates collected from Hararghe Zones. In the same study, more than 50% of conidial shape was categorized under conidial shape type 1. According to (Emana, 2014), some isolates produced almost type 1 and 2 conidia shapes in equal proportions, while the others produced all types of conidial shapes except type 5, and few of them produced all types of conidial shapes but most of them produced dominantly type 1.

Table 7. Frequencies of different kinds of conidia shapes produced by C. kahawae isolates

Isolates code	% of conidia per shape type				
	1^x	2	3	4	5
CHO41	72	13	10	5	0
Go33	70	14	9	7	0
Go34	81	9	5	3	2
Shk9	45	39	9	7	0
Shk10	53	28	12	3	4

Note: 1^x = cylindrical and round at both ends, 2 = cylindrical acute at one and round at the other end, 3 = clavate-round at both ends starts attenuating from ¼ of its length, 4 = reniform or kidney-shaped, 5 = oblong-elliptical, types.

Conclusion

Colletotrichum species sampled from Arsi Zone coffee growing areas are divided into six representative isolates (Five *C. kahawae* and one *C. gloeosporioides*) depending on their colony morphology and growth rate. *C. kahawae* isolates were characterized for their colony color, radial growth rate and texture in case of morphological characteristics, while conidial shape, size and sporulation capacity in case of cultural characteristic. Accordingly, *C. kahawae* isolates significantly varied from each other with their Morpho-cultural attributes. However, conidial size varied among and within isolates. Thus, conidial size can not be used as identification and diagnostic tool. Except conidial size, other Morpho-cultural attributes can be used as identification and diagnostic tools for *C. kahawae*. Such traditional characterization is not enough for diagnosis since it has limitations in diagnosis and identification among and within pathogen species particularly on genetic variability. Thus, it should be supported by molecular analysis.

References

Abdi Mohammed and Abu Jambo. 2015. Importance and Characterization of Coffee Berry Disease (Colletotrichum kahawae) in Borena and Guji Zones, Southern Ethiopia. Journal of Plant Pathology and Microbiology, 6: pp302.

Agrios, G. 2005. Plant Pathology, 5th Edition. San Diego, California, USA: Academic Press, Inc. 948 pp.

Arega Zeru. 2006. Diversity of Arabica coffee populations in afromontane rainforests of Ethiopia in relation to Colletotrichum kahawae and Gibberella xylarioides. MSc Thesis, Addis Ababa University. Addis Ababa, Ethiopia, 99 pp.

Berhanu Tamiru. 2014. Coffee berry disease (Colletotrichum kahawae): Status, pathogenic variability and reactions of coffee landraces in Hararghe, Eastern Ethiopia. International Journal of Plant Breeding and Crop Science, 2(1): 038-042.

Emana, B. 2014. Distribution assessment and pathogenicity test of coffee berry disease (Colletotrichum kahawae) in Hararghe, Ethiopia. International Journal of Plant Breeding and Crop Science, 2(1): 038-042.

Fredrick, N., Owaka, M., Chrispine, O. and Elijah, K. 2017. Pathogenicity of Colletotrichum kahawae in Kenya. International Journal of Science and Research, 6 (5): 1-4.

Freeman, S. 1998. Characterization of Colletotrichum species responsible for anthracnose diseases of various fruits. Journal of Plant Diseases, 82: 596-605.

Gibbs, J. 1969. Inoculum sources for Coffee Berry Disease. Annals of Applied Biology, 64: 515-522.

Hindorf, H. 1970. Colletotrichum spp. isolated from Coffea arabica L. in Kenya. Zeitschrift Pflanzenschutz, 77: 328-331.

Hindorf, H. 1973. Correct identification of the pathogen C. kahawae causing Coffee Berry Disease. Association Scientific International Coffee (ASIC), 17th Colloque, Nairobi, Kenya.

Hindorf, H., Tefestewold, B. and Omondi, C. 1997. Correct identification of the pathogen C. kahawae causing coffee berry disease (CBD). Association Scientific International Coffee (ASIC), 17 (I): 599-603.

Kilimbo, D., Guerra, L., Mabagala, R., Varzea, V., Haddad, F., Loureiro, A. and Teri, J. 2013. Characterization of Colletotrichum kahawae Strains in Tanzania. International Journal of Microbiology Re-search, 5(2): 382-389.

Mulinge, K. 1971. Effect of altitude on the distribution of the fungus causing Coffee Berry Disease in Kenya. Annals Applied Biology, 67: 93-98.

Mulinge, K. 1972. Variation in the level of Colletotrichum coffeanum Noack in the bark of Coffea arabica L. cultivars. Kenyan Coffee, 57, 9-47.

Nguyen, P., Vinnere, O., Olsson, P. and Liljeroth, E. 2010. Identification of Colletotrichum species associated with anthracnose disease of coffee in Vietnam. European Journal Plant Pathology, 127(1): 73 - 87.

Prihastuti, H., Cai, L., Chen, H., McKenzie, E. and Hyde, K. 2009. Characterization of Colletotrichum species associated with coffee berries in northern Thailand. Journal of Plant Pathology, 67: 980 - 995.

Rayner, R. 1970. Commonwealth Mycological Institute, Kew, Surrey, UK.

Sutton, C. 1992. The genus Glomerella and its anamorph Colletotrichum (pp1–26). In: Bailey JA. (Eds.) Colletotrichum: Biology, Pathology and Control. Wallingford, UK: CAB International.

Talhinhas, P., Screenivasaprasad, S., Neves-Martins, J. and Oliveira, H. 2005. Molecular and phenotypic analyses reveal association of diverse Colletotrichum acutatum

groups and a low level of C. gloeosporioides with Olive anthracnose. Applied Environmental microbiology, 71(6): 2987-2998.

Tefestewold Biratu and Mengistu Hulluka. 1989. Colletotrichum species associated with coffee berry disease in Hararghe. Ethiopian J.Agricultural Sciences, 11: 1 – 6.

Tefestewold Biratu. 1995. Studies on Colletotrichum population of Coffea arabica L. in Ethiopia and evaluation of the reactions of coffee germplasms (231 pp). Doctoral Dissertation. Bonn University, German.

Waller, J. 1993. Characterization of the coffee berry disease pathogen Colletotrichum kahawae. Mycological Research, 97(8): 989-994.

Zeru, A, Assefa, F, Adugna, G. and Hindorf, H. 2009. Occurrence of fungal diseases of Coffea arabica L. in montane rainforests of Ethiopia. Journal of Applied Botany and Food Quality, 82: 148 - 151.

Distribution and Status of Coffee Berry Disease in Arsi, Southeastern Ethiopia

Hika Bersisa[1], Mashilla Dejene[2] and Eshetu Derso[3]
[1]Mechara Agricultural Research Center, Mechara, Ethiopia
[2]School of Plant Sciences, Haramaya University, Ethiopia
[3]Ethiopian Agricultural Research Institute, Addis Abeba, Ethiopia
Corresponding Author: hikbersisa@gmail.com

Abstract
Coffee is a non-alcoholic stimulant beverage crop and belongs to the family Rubiaceae, genus Coffea. Arabica coffee (*Coffea arabica L.*) *has been threatened by various coffee fungal diseases. Among this coffee berry disease (CBD) caused by Colletotrichum kahawae is the most economically important pest in East Africa countries including Ethiopia. Field assessment was conducted in three major coffee growing districts of Arsi zone viz, Chole, Gololcha and Shanan Kolu. Assessment was done to examine prevalence, incidence and severity of CBD in the districts. A total of 90samoles were randomly collected from coffee growing farms. The overall mean prevalence, incidence and severity of CBD were 85.52, 49.78 and 19.25%, respectively. The highest incidence (100%) and severity (55.14 %) of CBD were observed in Shanan Kolu, followed by Gololcha, 80 and 54.18% and Chole, 80 and 42.73%. The highest CBD severity and incidence was recorded from the higher altitudes.*

Keywords: Arabica coffee, Coffee berry disease, prevalence, incidence, severity.

Introduction
Arabica coffee (*Coffea arabica* L.) is a non-alcoholic stimulant beverage crop that belongs to the family *Rubiaceae* and genus *Coffea*. Among the hundred species of *Coffea* genus, only Arabica coffee (*Coffea arabica* L.) and Robusta coffee (*Coffea canephora* L.) species are commercially cultivated worldwide (Kimani *et al.*, 2002; Waller *et al.*, 2007). Arabica coffee is indigenous to Ethiopia. Forests in Southwestern Ethiopia are the primary center of origin and genetic diversity of Arabica coffee (Melaku, 1984). Currently it is produced in more than 80 countries of the world highlands, while Robusta coffee is more cultivated in the lowlands than in the highlands of the tropical and subtropical coffee-producing countries in the world. Arabica coffee is more popular worldwide due its bean quality. As a result, Arabica coffee accounts for about 70% of the world coffee trade, while Robusta coffee contributes to about 30% (ICO, 2016).

Coffee crop is the most important agricultural commodity, worth an estimated retail value of USD 70 billion, crucially important in the economy of more than 70 countries and the main income resource for hundreds of millions people worldwide (ICO, 2016). Coffee is Ethiopia's largest export commodity crop and earning foreign currency. However, *Coffea arabica*, is nowadays more threatened by various constraints in all coffee-producing countries of the world. Among these, pathogenic coffee diseases are most economically important in reducing coffee production. Coffee berry disease (CBD) is an anthracnose of green coffee berries caused by the fungus *Colletotrichum kahawae* Waller and Bridge and has been a serious disease to Arabica coffee and poses considerable losses on crop in East Africa, including Ethiopia (Vander, 1981 and Eshetu, 1997).

According to Jima *et al*. (2016) 80% of farmers' livelihood depends on *Arabica coffee* production in coffee growing areas of Arsi. However, study related to coffee berry disease is limited in Arsi coffee growing districts namely Chole, Gololcha and Shanan Kolu. Thus, the present study was conducted to assess coffee berry disease prevalence, incidence and severity.

Materials and methods

Description of the study area: The study was conducted in the three districts of Arsi Zone namely Chole, Gololcha, and Shanan Kolu, Southeastern Ethiopia in 2017. Arsi coffee growing belt is located in southeastern part of Ethiopia between the range of 08°04' to 08°33'N latitude and 039°59' to 040°15'E longitude from the equator. The minimum and maximum altitudes of the surveyed areas were 1537 and 2075 m.a.s.l. respectively.

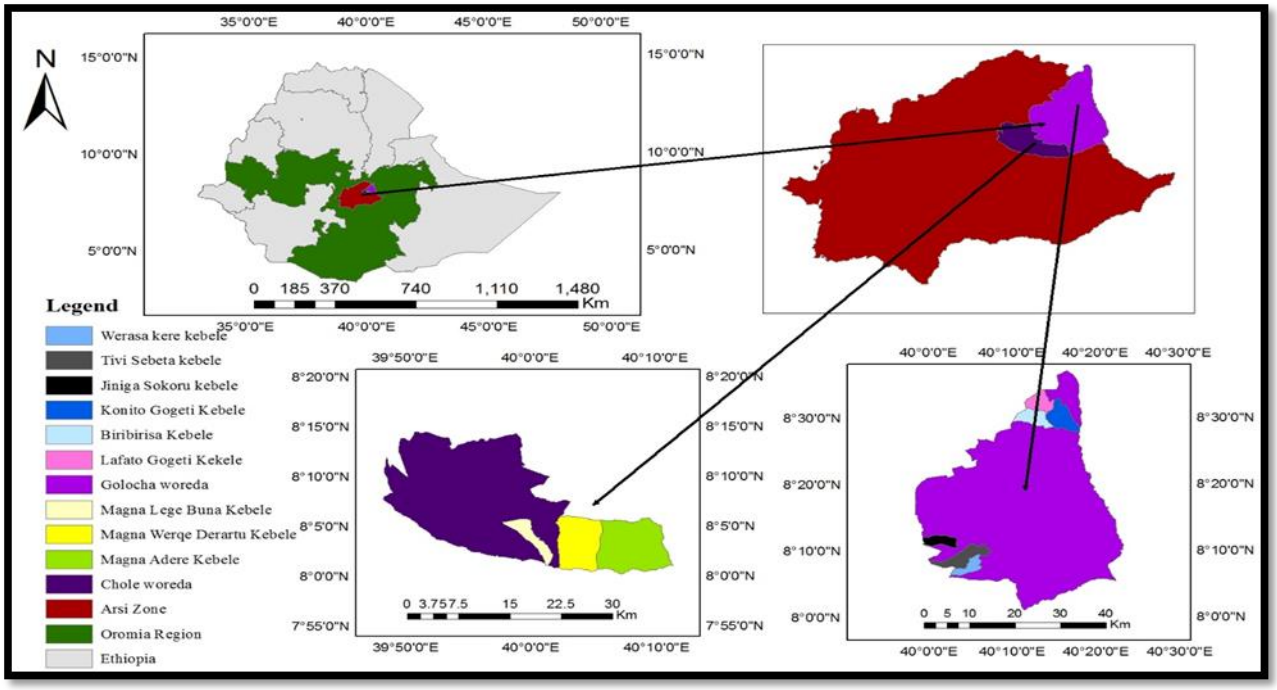


Figure 2. Location of surveyed areas of Arsi Zone.

Assessment of coffee berry disease (CBD)

Incidence assessment: thirty coffee trees per farm were randomly taken and diagnosed visually for presence and absence of CBD on each tree. Percent of CBD incidence was calculated as number of diseased trees/total observed trees x 100.

Severity assessment: ten trees per farm were randomly selected and each tree was divided into three strata of branches (top, middle and bottom). From each stratum, one pairs of branches were selected to compute disease severity. CBD damaged and healthy berries were counted and then percentage of diseased berries over total counted berries was calculated.

Prevalence: the selected farms were visually assessed for presence and absence of CBD. Finally disease distribution was calculated as number of infected farm from the total assessed farms) x 100.

Sampling techniques: Farm samples were taken at an interval of 5 km along the main and accessible rural roads. Three farmers' associations (FAs) were selected per district, while 10 farms were selected per FAs. On the hand, 9 and 90 representative FAs and coffee farms were assessed, respectively, across districts. Accordingly, 30 and 10 representative coffee trees per farm were taken randomly for incidence and severity, respectively. Totally, 900 and 300 coffee trees per district and 2700 and 900 coffee mother trees from overall selected districts were assessed visually for incidence and severity.

Data management and analysis: All data collected from field was feed into computer and managed by using Excel Spread Data Sheet. Then finally the managed data was analyzed using IBM SPSS Statistics 20.

Results and Discussion

Coffee berry disease occurrence and intensity

Coffee berry disease (*C. kahawae*) was observed in all selected coffee growing districts of Arsi. It was recorded with different intensity among and within assessed districts. The frequency and intensity of CBD varied significantly ($p < 0.05$) among and within districts. Other coffee diseases like coffee wilt, coffee leaf rust, brown leaf spot and bacterial blight of coffee were also observed in the districts.

The survey result indicated that there was variation in CBD distribution and status among and within districts. The overall CBD mean and standard deviation of prevalence, incidence and severity across the surveyed areas with values of 85.52, 49.78, 19.25% and 14.05, 21.82, 15.47% (Table 1), respectively. In another way, there was variation among FAs and also coffee farms. Such variation might have occurred due to the presence of diverse environmental conditions, including variation in temperature, rainfall distribution, relative humidity, management and cultural practices undertaken by coffee growers and genetic diversity of Arabica coffee grown in respective areas of the Zone. According to Berhanu (2014) incidence and severity of coffee berry disease varied among and within Hararghe coffee growing districts. Similarly, Abdi and Abu (2015) observed different CBD intensity in districts of Borena and Guji zones. According to Kumlachew *et al.* (2016) there was variation in CBD intensity among and within Jimma, Ilubabor, Kombolcha, and Gedeo.

Table 3. Overall minimum, maximum, mean and standard deviation of incidence, severity and prevalence of CBD

Variables	Min	Max	Mean	Standard Deviation
Incidence	0	100	49.78	21.82
Severity	0	55.14	19.25	15.47
Prevalence	0	98	85.52	14.05

Disease prevalence: Coffee berry disease (*C. kahawae*), which causes anthracnose to green coffee berry, was observed in most surveyed area. The maximum (98%) CBD prevalence was recorded in Gololcha, followed by Shanan Kolu (96%) and Chole (95%). The mean prevalence of CBD was 79.87, 89.57 and 87.13% at Chole, Gololcha and Shanan Kolu, respectively, while the overall average CBD prevalence was 85.52%. The disease prevalence varied from district to district, even from kebele to kebele. More CBD

infected coffee farms were observed in Gololcha than the two remaining districts, followed by Shanan Kolu.

CBD prevalence is 38.8 and 17.2% in Oromia and Southern Nations, Nationalities and Peoples' Region (SNNPR), respectively (IAR, 1997). Berhanu (2014) reported that CBD is prevalent in West and East Hararghe Zones. While a recent study conducted in Borena and Guji Zones indicated that CBD prevalence was 100% in each of the surveyed district with an overall mean of 100% (Abdi and Abu, 2015). In various earlier and recent studies, CBD was prevalent at the higher elevation, which is naturally characterized by optimum relative humidity favoring the pathogen (Bayetta, 2001; Fekadu, 2013; Birhanu, 2014; Abdi and Abu, 2015; Kumlachew *et al.,* 2016). Accordingly, in the present study CBD was prevalent more on coffee farms relatively found at high altitudes of Shanan Kolu and to some extent at Gololcha district.

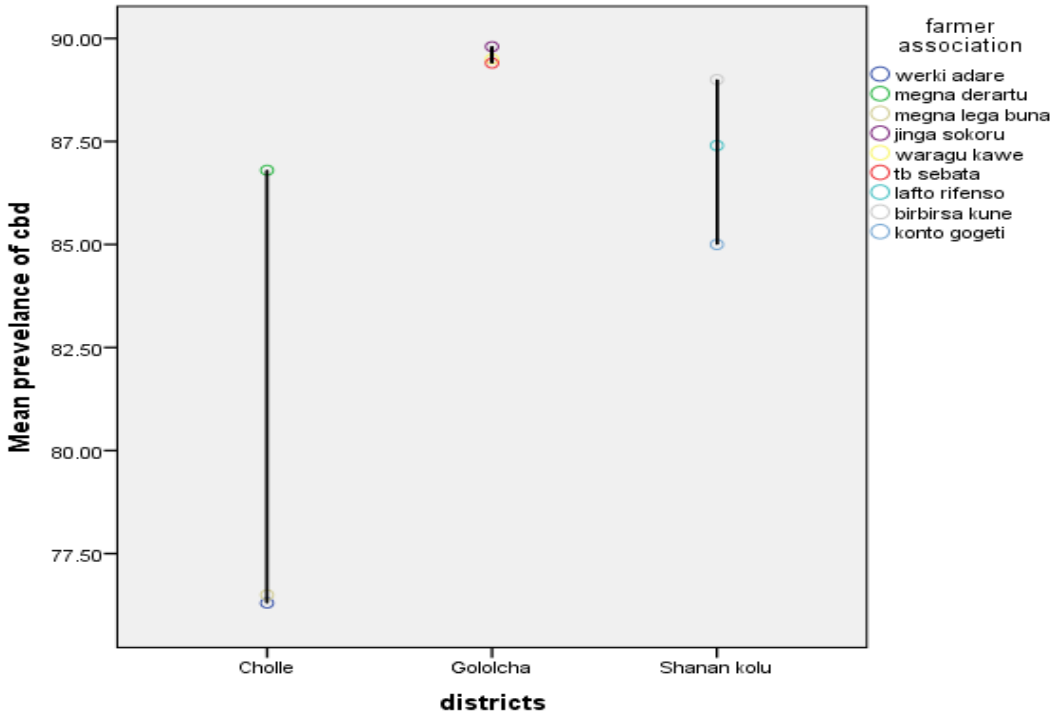


Figure 3. Mean prevalence of CBD per coffee-growing district of Arsi

Disease incidence: The overall mean incidence of CBD recorded across the assessed districts was 49.78%. However, at district level CBD incidence scored up to 100% at Shanan Kolu, followed by both Gololcha and Chole (80%). Accordingly, the CDB mean incidence ranged between 6.67 - 60, 23.33 - 65, and 20 - 80% in Chole, Gololcha and Shanan Kolu, respectively. But, the overall mean incidence per district was 41.89, 54.22 and 56% at Chole, Gololcha and Shanan Kolu, respectively (Figure 2). The finding indicated that CBD incidence varied significantly from district to district, even from kebele to kebele. This variation might be due to host genetic diversity, variations in environmental conditions, cultural practices undertaken by growers and pathogen virulence.

Similar results were reported on CBD incidence at Gedeo, Jimma, Kombolcha and Sidama (Kumlachew *et al.*, 2016). Abdi and Abu (2015) reported 49.3 and 14.8% CBD overall mean incidence and severity in Borena and Guji respectively. According to Kumlachew *et al.* (2016) sixty percent of the surveyed coffee-producing districts had significantly higher

levels of CBD incidence that ranged from 50 to 80%. It indicates markedly increased proportions of CBD infected coffee trees in Bedeno, Kombolcha and Gomma districts with respective incidences of 80, 75.6 and 70.0% (Kumlachew *et al.*, 2016). Berhanu (2014) reported the highest (75%) and lowest (51%) CBD incidence from Bedeno and Daro Lebu, districts of East and West Haraghe Zones, respectively.

The assessment result of the current survey indicates that the highest infection by CBD occurred in the higher elevations (> 1750 m.a.s.l.) as well as medium to low infections were observed in medium to lower elevations (1750 – 1500 m.a.s.l.). This result shows pyramidal disease relationship among CBD, elevation, moisture and temperature. Wayesa *et al*. (2017) explained that high rainfall, high humidity or wetness and relatively low temperatures that persist for long periods favor CBD development and the disease is invariably severe at higher altitudes where these conditions generally exist. Therefore, geographical distribution of CBD varies from place to place.

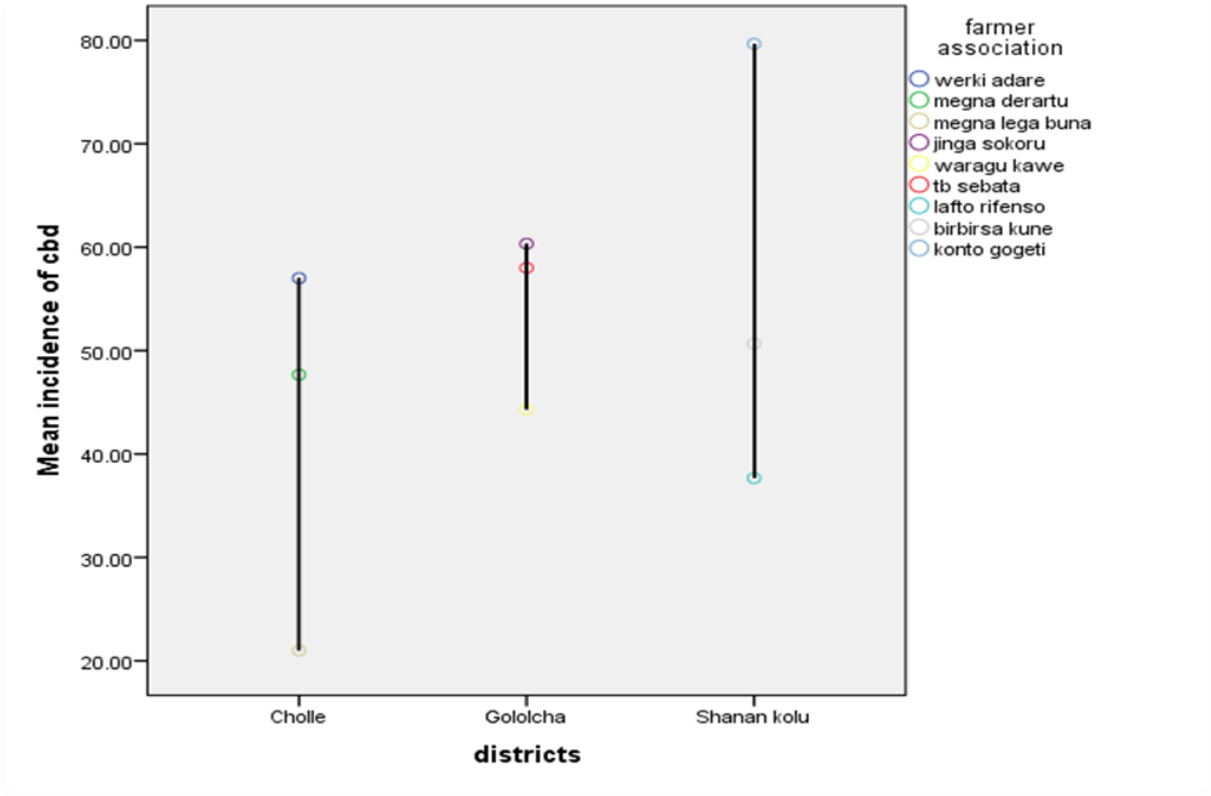


Figure 4. Mean incidence of CBD in coffee-growing districts of Arsi Zone.

Disease severity: Among the overall assessed coffee farms, Shanan Kolu exhibited more CBD severity than surveyed farms. The highest (55.14%) CBD severity was recorded in Shanan Kolu, followed by Gololcha (54.18%) and Chole (42.73%). The overall mean severity per districts was 12.67, 19.56 and 25.52 in Chole, Gololcha and Shanan Kolu, respectively (Figure 4). CBD severity was variable from farm to farm and from one coffee tree to another. This dissimilarity can be due to genetic diversity, diverse environmental conditions, diverse agronomic practices, pathogen virulence and CBD management measures undertaken by growers from place to place. The result is in agreement with the previous works conducted under different agro-ecologies. Arega (2006) reported varied

CBD severity from various coffee forest areas and recorded 17.9, 4.0, 5.4 and 2% severity from Bonga, Yayu, Harena and Sheko, respectively. Berhanu (2014) recorded 26% CBD severity at Boke and 50% at Bedeno. Similarly, Abdi and Abu (2015) reported 14.8% CBD mean severity in Borena and Guji Zones. The recent CBD assessment report showed different severity at different coffee-growing areas (Kumlachew *et al.*, 2016). The highest (46.7%) disease severity was recorded in Gedeo, followed by Hararghe (42.7%) and Jimma (32.0%) (Kumlachew *et al*., 2016).

Berries with well developed CBD symptom showing active lesions (black sunken lesion) and scab lesion wre observed in the farms. The occurrence of these two symptoms indicate the presence of coffee genetic diversity, diverse environmental conditions relative to coffee shade and management variation within and among coffee farms as well as within and among districts. Scab lesion appeared due to presence of unfavorable environmental conditions among and within farm as well as coffee trees, which may be dynamic related to different status of coffee shade trees that change micro climate for disease development. Two types of active lesions were also observed on the berries. The first type is active lesion with enlarged size and more than three black colored dots while the second type leision is a dot or with one black dot alone. The second type of active lesion shows incompatibility of host pathogen interaction, i.e. it indicates expression of hypersensitive reaction, conferred by resistant genes.
The spread and severity of the disease could be due to the use of a limited number of varieties and uniform cultural practices in the entire study areas. The entire coffee cultivated in Chole, Gololcha and Shanan Kolu is local cultivars.

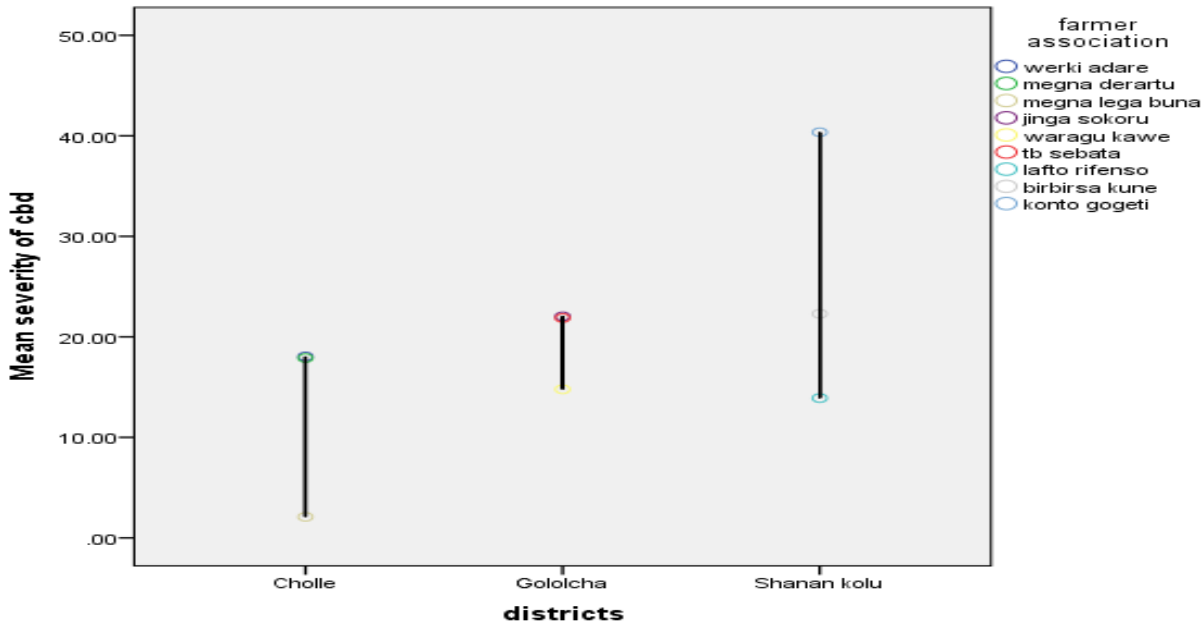


Figure 4. CBD mean severity in coffee-growing districts of Arsi Zone.

Correlation of coffee berry disease occurrence and promoting factors
Correlation between altitude and coffee berry disease: There was a positive correlation between incidence and altitude (r = 0.013), severity (r = 0.012) and prevalence (r = 0.015) of CBD, indicating strong relationship between disease intensity and altitude (Table 2). The CBD incidence and severity increased with altitude. All coffee-growing districts assessed for CBD distribution lied in mid to higher altitude (> 1537 m.a.s.l.). Highest

(100%) and lowest (80%) CBD incidence was recorded from higher altitudes (> 1750 m.a.s.l.) of Shanan Kolu and mid to lowest altitude (≥ 1500 m.a.s.l.) of Chole, respectively. This indicates the presence of conducive environment for epidemiological progression of the pathogen (*C. kahawae*) at these areas.

Berhanu (2014) reported low (51%) and high (75%) CBD incidence from lower altitude of Daro Labu and higher altitude of Bedeno, respectively, while lower (26%) and higher (50%) CBD severity was recorded from lower altitude of Boke and higher altitude of Bedeno, respectively. Abdi and Abu (2015) also demonstrated similar results in Borena and Guji Zones. Kumlachew *et al.* (2016) reported high CBD intensity (that ranged from 35.9 to 51.3%) in the higher altitude of Bedeno, Kombolcha, Wonago, Yirgacheffee, Wonsho, Gimbi, Gomma and Gera. whereas lower disease intensity (< 22%) was recorded at lower altitudes of Abaya, Chora and Yayu, which are found below 1500 m.a.s.l. Similar trend was reported by Zeru *et al.* (2009) in the lower elevation of Harena forest, Bale. However, high CBD intensity is not always the result of increase in altitude unless there is optimum relative humidity and temperature.

Coffee cultural management practices and coffee berry disease: The correlation between cultural practices and the level of CBD infection was highly significant and negatively correlated, incidence (r = -0.234), severity (r = -0.200) and prevalence (r = -0.111) (Table 2). Most coffee farms (74.4%) use cultural practices to reduce CBD incidence, while the remaining (25.6%) farms poorly managed their fields and suffered heavily from the disease. Cultural management practices include removal of unhealthy coffee tree from their farm, planting tolerant local cultivars, pruning of shade trees and clearing mummified berry leftover with coffee mother tree. The highest disease incidence was recorded from farms poorly managed, while moderate to low CBD incidence was observed in moderately managed coffee farms.These cultural practices helped to decline disease incidence by reducing the potential sources of primary inoculum (Bedimo *et al*., 2007; Kumlachew *et al*., 2016). In that fact, cultural practices utilized by growers also reduce the influences of the important disease elements. Particularly pruning and shade regulation could reduce moisture content within coffee canopy via increasing ventilation, which eventually result in reduction of CBD incidence.

Correlation of shade tree and coffee berry disease: There is a negative correlation between shade tree and incidence (r = -0.003), severity (r = -0.091) and prevalence (r = -0.206) of CBD (Table 2). The survey result indicated that low CBD intensity was recorded in fully shaded coffee farms, while moderate and high disease intensity was recorded from semi-shaded and open sun coffee farms, respectively. Most (63.3%) of coffee farms assessed for CBD distribution were fully covered with different recommended leguminous tree species, while the remaining coffee farms were covered with semi-shaded (30%) and open sun (6.7%).

Bedimo *et al*. (2008) reported high and low CBD incidence from open sun and shaded farms, respectively. Accordingly, the infection rate for coffee trees under artificial shade was estimated at 30%, while for the coffee trees without shade was 50%. Shade can also work as a barrier and limit the splash dispersal of the pathogen. The disease severity is higher on coffee trees exposed to sunlight than on those located under the shade (Mouen *et al*., 2008). Kebati *et al*. (2016) reported that CBD infection was higher (57.40%) in non-shaded than shaded coffee (45.08%) in Kenya. They also demonstrated that the total berry loss was higher (75.73%) in none shaded than shaded coffee (63.65%). In fact, shade limit

the rain intensity and consequently the splash dispersal of *C. kahawae* as has been already mentioned in other studies for several pathogens, particularly with *Colletotrichum* spp. (Ntahimpera *et al*., 1998; Ntahimpera *et al*., 1999). Artificial shading was found to reduce the CBD incidence on coffee trees when compared to non-shaded coffee (Kebati *et al*., 2016). Similar reports revealed that shading modifies the micro-climate for disease development (Bedimo *et al*., 2008).

Table 4. Correlation of important promoting factors and CBD intensities

	Alt	FS	CL	Shst	Mgtop	Sev	Inc	Prev
Alt	1	.241*	0.027	-0.097	0.275**	0.012	0.013	0.015
FS		1	0.044	-0.134	0.055	0.051	0.146	0.186
Vocg			1	0.048	-0.052	-0.026	0.012	0.175
Shst				1	0.043	-0.091	-0.003	-0.206
Mgtop					1	-0.2	-0.234*	-0.111
Sev						1		
Inc							1	
Prev								1

Note: *Alt- altitude, FS-farm slope, CL- Coffee landrace grown, Shst- shade status, Mgtop-management option, Sev- Severity, Inc- incidence, and Prev- prevalence * and** Correlation is significant at the 0.05 and 0.01 probability levels, respectively.*

Conclusion

This assessment of CBD in coffee growing areas of Arsi Zone indicated that, the disease is prevalent in most surveyed areas, particularly in mid to high lands (≥ 1500 m.a.s.l.). The overall average of CBD severity and incidence were significant ($p < 0.05$) among and within the districts. The disease limited the production and productivity of Arabica coffee in all assessed areas where local cultivars are more preferred by the growers for their bean weight and typical quality. Therefore, the following measure(s) should be taken in order to improve Arabica coffee production and productivities in coffee growing districts of Arsi. High yielder and disease resistant/tolerant coffee variety (ies) should be generated/introduced by testing coffee landraces with virulent pathogen through artificial inoculation. Cultural practices like pruning, shade regulation, fertilizer application, wider spacing and other disease management options should be utilized by growers in order to reduce disease pressure and yield loss.

References

Abdi Mohammed and Abu Jambo. 2015. Importance and characterization of coffee berry disease (*Colletotrichum kahawae*) in Borena and Guji Zones, Southern Ethiopia. *Journal of Plant Pathology and Microbiology,* 6(9): 1-6 . doi:10.4172/2157-7471.1000302.

Arega Zeru. 2006. Diversity of Arabica coffee populations in afromontane rainforests of Ethiopia in relation to *Colletotrichum kahawae* and *Gibberella xylarioides*. MSc Thesis, Addis Ababa University, Addis Ababa, Ethiopia, 99Pp.

Bayetta Balachew. 2001. Arabica coffee breeding for yield and resistance to coffee berry disease (*Colletotrichum Kahawae*). Doctoral Dissertation. University of London, London, England.

Bedimo, J., Bieysse, D., Njiayouom, I., Deumeni, J., Cilas, C. and Notteghem, J. 2007. Effect of cultural practices on the development of Arabica coffee berry disease caused by *Colletotrichum kahawae*. *European Journal of Plant Pathology*, 119(4): 391-400.

Berhanu Tamiru. 2014. Coffee berry disease (*Colletotrichum kahawae*): status, pathogenic variability and reactions of coffee landraces in Hararghe, Eastern Ethiopia. *International Journal of Plant Breeding and Crop Science*, 2(1): 038-042.

Eshetu Derso. 1997. Coffee disease and their significance in Ethiopia (pp.723-26). *In*: Asic17th Kenya, Nairobi.

Fekadu Alemu. 2013. Assessment of the current status of coffee diseases at Gedeo and Sidama zone, Ethiopia. *International Journal of Advanced Research*, 1(8): 192-202.

IAR (Institute of Agricultural Research). 1997. Jimma national coffee research center progress report for the period 1994 (Part 1 Coffee). Melko.

ICO. 2016. World coffee consumption. http://www.ico.org/prices/new-consumption-table.pdf.

Kebati, R., Nyangeri, J., Omondi, O. and Kubochi, J. 2016. Effect of artificial shading on severity of coffee berry disease in Kiambu County, Kenya. Annual Research and Review in Biology. 9(2): 1-11.

Kimani, M., Little, T. and Vos, J. 2002. Introduction to coffee management through discovery learning. CABI, Nairobi, Kenya.

Kumlachew Alemu, Girma Adugna, Fikre Lemessa and Diriba Muleta. 2016. Current status of coffee berry disease (*Colletotrichum kahawae*, Waller & Bridge) in Ethiopia. *Archives of Phytopathology and Plant Protection*, 49: 421-433.

Melaku Werede. 1984. Coffee genetic resources in Ethiopia conservation and utilization particular reference to CBD resistance (pp 203-211). *In*: Proceedings of the first regional workshop on coffee berry disease. 19-23 July 1982, Addis Ababa, Ethiopia.

Mouen, B., Njiayouom, I., Bieysse, D., Ndoumbe, N., Cilas, C. and Notteghem, J. 2008. Effect of shade on Arabica coffee berry disease development. *Journal of Phytopathology*, 98: 1320 - 1325.

Ntahimpera, N., Ellis, M., Wilson, L. and Madden, L. 1998. Effects of a cover crop on splash dispersal of *Colletotrichum acutatum* conidia. *Phytopathology*, 88: 536-543.

Ntahimpera, N., Ellis, M., Wilson, L. and Madden, L. 1999. Comparison of rain effects on splash dispersal of three *Colletotrichum* species infecting strawberry. *Journal of Phytopathology*, 89: 555-563.

Zeru, A, Assefa, F, Adugna, G. and Hindorf, H. 2009. Occurrence of fungal diseases of *Coffea arabica* L. in montane rainforests of Ethiopia. *Journal of Applied Botany and Food Quality*, 82: 148 - 151.

FOOD SCIENCE

Influence of Containerized Dry Storage Using Diatomaceous Earth) on Major Grains Quality at Dugda and Bako-Tibe Districts

Dubale Befikadu[1*]

[1]*Oromia Agricultural Research Institute, Addis Ababa, Ethiopia*

*Corresponding author's E-mail: dubebefikadu@gmail.com

Abstract

Safe grain storage and prevention of grains quality and quantity losses has become a necessity to overcome shortage of grain and tackle starvation and hunger. Some studies reported that *Dry storage using Diatomaceous earth (DE) enable farmers to store maize and maintain quality. To test the effects of natural DE on stored maize grains quality, trials were conducted between March 2017 and April 2018 at Dugda and Bako Tibe districts of Oromia, Ethiopia. The experiment consisted of six treatments under peasant associations in two agro-ecologies representing midland and lowland. The treatments were mixing DE to grain by weight ratios 0 g, 25 g, 50 g, 75 g, 100 g and 125 g per 50kg of maize grains and were replicated twice per site. Moisture content, insect population, insect damaged kernel in number, grain weight loss, protein and starch content of the grain samples were collected at start of storage, 60, 210, and 360 days after storage and analyzed for physical and chemical grain quality. The quality of DE treated stored maize grains were significantly affected by DE application rate and storage periods. Moisture content of DE treated grain stored in Pics bags at Dugda and Bako Tibe showed statistically significant ($P<0.05$) reductions with storage durations while significant increment ($P<0.05$) was noticed for grains stored in PP bags. Moisture reduction was not however observed in PP bag at Bako Tibe. DE treated grains in Pics bag was observed to have a significantly ($P<0.05$) suppressed insect infestation, minimized grain kernel damage and maintained protein contents during the storage periods at the study sites compared to one stored in PP bag. PP bags allowed rapid increment of insect population, grain damage and weight loss over the storage duration. Number of insects was 81.67 and 108.83 per kg of grain in PP bag compared to 16.25 and 34.5 per kg of grain in Pics bags recorded at Dugda and Bako Tibe respectively after 360 storage days. DE treated grain stored in PP bags had higher insect damage (58.21 % and 92.2%) with a weight loss of 35.66% and 48.53% while the damage was minimal (7.42% and 7.71%) in Pics bags with a weight loss of 18.68% and 15.26% after 360 storage days at Dugda and Bako Tibe respectively. Protein content was significantly affected by DE treatments at Dugda and Bako Tibe sites except at Bako Tibe that showed significant effect with DE while starch content was not affected with DE application rates in both of PP and Pics bags at both districts. PP bags at Dugda showed significant ($P<0.05$) increment of protein contents from 6.01 % at start of grain sampling to 6.07% while it was increased in Pics bag from 5.87% to 6.3% after 360 days. Protein content was not however significantly ($P>0.05$) affected in both PP and Pics bag at Bako Tibe with storage duration. Starch contents in PP bags at Dugda showed significant ($P<0.05$) reduction from 72.04 % at start of grain sampling to 71.21% after 360 days and from 71.99 % at start of grain sampling to 71.48% in Pics bag. The study showed that storing grains either in PP or Pics bags with DE treatments would reduce grain damage and maintain quality compared to untreated ones and that Pics bag had significant effected on DE treated maize grain against the identified insect pest compared to that in PP bag. Better grain quality maintenance and lowest grain damage was observed in samples taken from PP and Pics bags at DE application rates of 50 g per 50 kg grain and greater than in treatments below 50 g per 50 kg grain. It can be suggested to suppress storage insects' infestation, minimize grain damage by treating grains using DE, along with Pics bags. Economic analysis for the results of grain qualitative and quantitative loss obtained upon treating grains with DE should however be conducted for final recommendation of the technology to reduce the use of expensive synthetic chemicals with negative impacts on environment and humans. Study involving effect of DE rate on fungal occurrence effect, aflatoxin level and physiological quality of DE treated grain over storage time is also recommended.*

Key words*:* DE, Grain, Maize, Maintenance, Pics bags, PP bags, Quality, Storage

Introduction

Grains undergo both qualitative and quantitative losses during storage which mainly occur because of improper storage (Ishrat and Shahnaz, 2009). Survey conducted in three major grain producing areas of Ethiopia *viz*. Hetosa, Ada and Bako indicated that the majority of farmers (93.3%) are using traditional grain storage containers that expose their stored grains to be attacked by storage pests and other factors that contribute to deteriorations whereby per house hold grain losses of 12% was estimated from the total grain produced (Abebe and Bekele, 2006). Grain storage under the humid tropical climates are practically impossible without cooling facilities, because grains quality deteriorates rapidly under the prevailing conditions of high temperature and relative humidity (RH) causing high equilibrium grain moisture content (Daniel and Ajala, 2004). Dry storage at high temperature conditions are recommended technologies for grain storage for several grain types in these climates because it is cheaper to reduce storage atmospheric relative humidity around the grain in closed containers than to reduce temperature with cooling facilities (Hong *et al.*, 2005; Asiedu *et al.*, 1999).

Among research outputs on grain storage in tropical environments, the dry containerized storage using desiccants are the major ones to be applied for stored grain quality maintenance under ambient humid tropical conditions (Somado *et al.*, 2006). The containerized diatomaceous earth dry grain storage method is hypothesized to achieve this objective as a desiccant inert dust. Diatomaceous earth (Diatomite) is a chalky sedimentary rock composed of fossilized skeletal remains of single-celled aquatic plant called diatoms. Diatomite deposits in Ethiopia occur mostly in the Main Rift valley. This diatomite is natural one and of fresh water origin among which one is the Gademota deposit out of which composite DE samples was taken for this study. It contributes about 36.5 Million tons (85%) of central main Ethiopian rift valley DE and consists of Sio_2 (86.5%), Al_2O (33.68 %), Fe_2O_3 (2.4%) and CaO (1.11%) (MoM, 2010). The skeletons of fresh water diatomite are made up of amorphous (non-crystalline) silicon dioxide which is non-toxic to mammals and registered as a food additive in Canada, USA and many other countries (Korunic *et al*., 1996; Korunic *et al*., 1998).

Physical properties such as large surface area and low bulking value make diatomite suitable as a delivery medium for insecticides, pesticides and fertilizers. Diatomite is used as an insecticide due to its abrasive and physico-sorptive properties (Fields *et al*., 2002). Diatomaceous earths have long residual effects in food and are effective against insect pests of course visible residues are evident on the grains as an adverse effect (Korunic, 1988; Korunic *et al*., 1998; Korunic, 1999). Research results by (Tadesse and Basedow, 2005; 1997; Marghanita, 1997) also confirmed the effectiveness of DE against insect pest control during storage. However, information is still insufficient on its effect on stored grain quality. This study was therefore to evaluate the potential of natural desiccant diatomaceous earth for maize grain quality maintenance.

Materials and Method

Description of the study sites: Two sites Dugda and Bako Tibe districts were selected from East and West Shoa zones of Oromia, Ethiopia based on difference in climate conditions and maize grain production potential (Fig. 1). Dugda representing midland agro-ecology lies between 8º58´39´´ and 9º18´39´´ N latitude and 36º59´49´´ and 37º14´46´´ longitude and located at an altitude between 1558 and 2514 meters above sea level. Bako Tibe lies between 8º3´6´´ and 8º28´10´´ N latitude and 38º32´25´´ and 39º4´36´´ longitude and altitude between 1568 and 2806 meters above sea level (EROS,

2018). Koto Biliti peasant association of Dugda district lies between 8º3´45.85´´ and 8º9´42.7´´ N latitude and 38º34´16.2´´ and 38º39´29´´ E longitude and located at an altitude between 1797 and 2088 meters above sea level whereas Amerti Gibe peasant association of Bako Tibe district lies between 8º55´25´´ and 9º0´40´´ N latitude and 37º8´40´´ and 37º13´30´´ E longitude and located at an altitude between 1634 and 1789 meters above sea level (EROS, 2018).

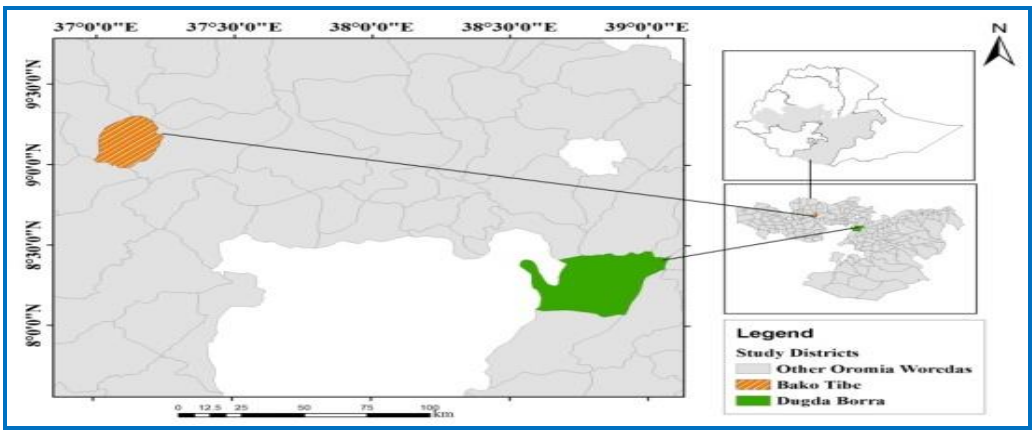


Fig.1 Locations of the Study Districts in Oromia

DE collection, preparation and grain treatment: Composite samples of natural DE was quarried using metallic sampling auger from potentially most abundant natural deposits of Gademota located in the central Ethiopian rift valley about 180 km south of Addis Ababa having 86.5% SiO_2 (MoM, 2010).The collected DE dust was sealed in plastic bags and brought to Food science laboratory of Oromia Agricultural Research Institute for preparation to be used as a desiccant material for dry maize grain storage treatments.

Selection of the sites was done based on potential or abundance and preferred quality of the DE dust. The collected Diatomaceous Earth was oven dried at 130ºC for 4 hrs and sealed in an airtight plastic bag and stored at room temperature to ensure constant moisture content until needed for grain treatment. Maize grains was packed in 50 kg polypropylene Bags and 50 kg Pics bags with different weights of diatomaceous earth at five different diatomaceous earth to grain ratios recommended by weight as 0 g (untreated), 25 g, 50 g, 75 g, 100 g and 125 g per 50kg of grains (Aldryhim, 1990; Daniel *et al.*, 2009). Before DE treatment, grains were cleaned off foreign matters/dockages and thoroughly admixed with different proportion of diatomaceous earth. DE treated maize grains were transported and stored on plastic sheet in farmer's house in selected Agricultural Growth Program (AGP) districts PAs of West Shoa (Amerti Gibe peasant association of Bako Tibe district) and East Shoa (Koto Biliti peasant association of Dugda districts) for the storage periods of 360 days.

Fig. 2 Diatomaceous earth (DE) being quarried using metallic sampling auger

Sampling of the Grain for Evaluation: Different grain treatment level's composite samples (mixed together to make 1 kg) was withdrawn from each storage containers using a slotted, cylindrical lead Trier with pointed metallic end point during the storage periods at the beginning and at an intervals until twelve months of storage period and tested for grains physical and chemical grain quality. For sampling grain from the Bags, procedure described in AOAC (1995) was followed. The bags were laid horizontally and initial composite grains samples were taken from center, sides and top of each bag immediately after the treating grains. The collected samples were then thoroughly mixed manually on a clean plastic sheet and 1 kg of it was kept in a clean airtight plastic bag for laboratory analysis

Temperature and Relative Humidity: Temperature and relative humidity of the storage bags was measured during each grain sampling periods using portable digital Thermo-Hygrometer (Model 20250-11).

Weight Loss: The grain weight loss was determined using the thousand grain mass (TGM) following procedures by (Proctor and Rowley 1983).

$\text{Weight loss (\%)} = \left[\frac{M_1 - M_t}{M_1}\right] \times 100$; Where M_1 is thousand grain mass (TGM) at the beginning of the study and M_t is the TGM of grain at storage time, t.

Insect Damage: Insect damage was determined by count method. Two hundred seeds was randomly taken from each sealed storage treatments and the number of insect damaged and un-damaged was observed visually for the presence of insect hole or burrow. The percentage of insect damaged seed was then calculated out of 200 kernels (Fekadu *et al*., 2000; Wambugu *et al*., 2009).

Insect infestation: Each grain sample was sieved over 2mm mesh sieve (Abraham, 1995). Visible live and dead insects were removed, counted and identified to genus level. The numbers of insects (live and dead) per a kilogram of a sample was recorded (Borror *et al*. 2005; El-Kashlan, *et al*., 1995).

Chemical Analysis of the Grain: Grain moisture, protein and starch contents of the samples were determined using Mininfra Smart Nit grain analyzer.

Experimental Design and Data Analysis: Factorial arrangement using Completely Randomized Design (CRD) was employed for the experiment in two replications at each district. The factors were: DE Rates (0 g or untreated, 25 g, 50 g, 75 g, 100 g and 125 g per 50 kg grain), maize storage containers at two levels (PP bag and Pics bag), agro ecologies at two levels (midland and lowland) and storage periods at four levels (at start of storage, 60, 210 and 360 days after storage). Data were collected at each grain sampling time, including at the start of the study. Statistical analysis was performed on the chemical composition, insect infestation, insect damaged grain and weight loss up on DE dust application over the storage periods using analysis of variance (ANOVA) of SPSS Version 20.0. Means were compared for the significant factors by least significant difference (LSD) test and significance was accepted at 5% level.

Results and discussion

Temperature and Relative humidity:

At Dugda site representing midland ecology, the average temperature range of 22.1 to 25.1 °C and 20.2 to 25.7 °C for PP bags and Pics bag, respectively while the average RH ranges of 29.27 to 61.6% and 35.4 to 66.1% for PP bags and Pics bags, respectively were recorded during subsequent sampling periods (Table 1).

Table 1. Storage temperature and relative humidity profiles of PP Bags and Pics bag at Dugda over the study periods ($\bar{X} \pm SD$).

	PP Bags		Pics bag	
Storage period (days)	Temperature* (ºC)	Relative humidity* (%)	Temperature* (ºC)	Relative humidity* (%)
ID	-	-	-	-
60	24.74 ±1.26	61.62 ±3.02	24.61 ±0.62	66.11 ±4.32
210	22.08 ±4.80	29.27 ±7.52	20.18 ±4.13	35.38 ±5.22
360	25.12 ±0.92	53.88 ±2.22	25.78 ±1.19	58.69 ±2.85

*Means of twelve observations; ID = Initial Duration (sampling day); - Record not taken.

At Amerti Gibe peasant association of Bako Tibe representing lowland land ecology, the average Temperature ranges of 22.5 to 26.01 °C and 22.2 to 27.2 °C for PP bags and Pics bags, respectively while the average relative humidity ranges of 48.5 to 79.2% and 55.2 to 79.9% for PP bags and Pics bags were respectively recorded during storage periods of 360 days (Table 2).

Table 2. Storage temperature and relative humidity profiles of PP bag and Pics bag at Bako Tibe over the study periods ($\bar{X} \pm SD$).

	PP Bags		Pics bag	
Storage period (days)	Temperature* (ºC)	Relative humidity* (%)	Temperature* (ºC)	Relative humidity* (%)
ID	-	-	-	-
60	22.50 ±0.50	79.21 ±2.54	22.22 ±0.46	79.92 ±4.05
210	23.20 ±0.77	76.62 ±1.25	22.28 ±0.54	79.96 ±4.11
360	26.01 ±1.97	48.51 ±3.44	27.28 ±1.70	55.27 ±4.49

*Means of twelve observations; ID = Initial Duration (sampling day); - Record not taken

These average temperature and relative humidity recorded in Dugda and Bako Tibe were optimal for the observed insect pests to flourish and inflict maximum damage. This finding agrees with report of (Dubale *et al*., 2012; Fields and Muir 1996). Storey *et al*., (1979) also reported most storage insects require temperatures higher than 21 ºC to develop to the damaging populations.

Effect of DE application rate on grain physical and chemical quality characteristics at Dugda and Bako Tibe

Effect of DE application on insect damaged kernels (IDK), Insect infestation (Inf); Moisture content (MC), Weight loss (WL), Starch and Protein contents of maize grain during storage periods of 360 days at Dugda and Bako Tibe is presented in graph shown in Fig. 3.

Insect Infestation: Two primary stored grain insect pest species observed during the study period in both Polypropylene and Pics bag were maize weevil (*Sitophilus zeamais*) and Angoumois grain moth (*Sitotroga cerealella*). At Dugda site number of insects (live &

dead) in PP bag was observed to significantly (P< 0.05) fall to 74.75 per kg grains from value of 114.75 per kg grains in untreated bag (*i.e* 0 g per 50 kg grains) at DE application rate of 100 g per 50 kg grains while in Pics bag the mean infestation dropped significantly (P<0.05) to 11.13 number of insects per kg of grain from 13.38 number of insects per kg of grain in untreated bag at DE application rate of 75 g per 50 kg (Table 3.). At Bako Tibe, insect infestation in PP bags was not significantly (p<0.05) affected with DE application rate but minimum infestation mean value of 94.25 number of insects per kg of grain was recorded at application rate of 100 g per 50 kg grains while in Pics bag the value differed significantly (p<0.05) to 17.38 number of insects per kg of grain at application rate of 125g per 50 kg grains (Fig 3). The significant reduction or a very slow increase in the extent of insect infestation in Pics bags at Dugda may be attributed to hermeticity along with sorptive property of DE which in contrary showed significant increment in PP bag over the storage periods. Initial grain samples confirmed the presence of live and dead *Sitophillus zeamais* and *Sitotroga cerealella* in both PP and Pics bag. These two pests could have infested maize while the crop is still in the field (Golob and Hanks, 1990) and infestations could have continued during storage (Hodges *et al*., 1998).

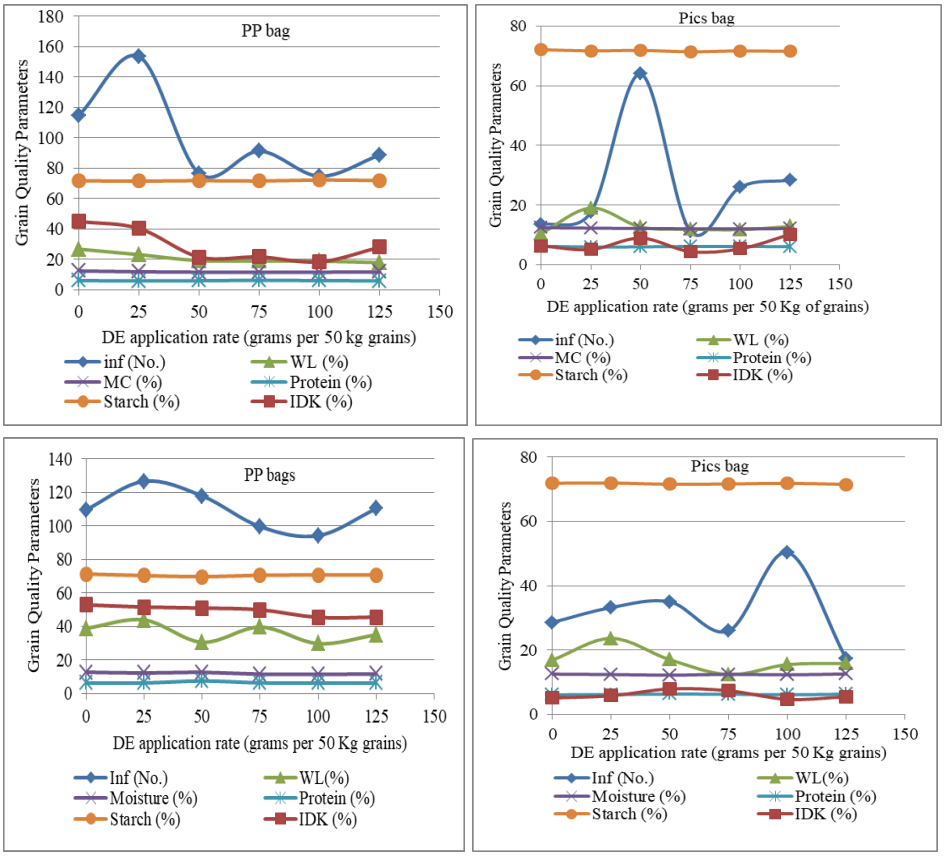


Fig. 3. Effect of DE application rate on grain quality in PP and Pics bag at Dugda and Bako Tibe

Insect Damage: At Dugda site insect damaged kernels in PP bag was observed to significantly (P< 0.05) drop with DE treatment to 18.44% at DE application rate of 100 g per 50 kg grains from initial value of 45% in untreated grain. In Pics bag insect damaged kernels also reduced significantly (P< 0.05) to 4.37% from initial mean value of 6.32% in untreated grain at DE application rate of 75 g per 50 kg (Fig.3). At Bako Tibe, insect damaged kernels in PP bags has not significantly (p>0.05) changed with DE treatment even though minimum percentage of insect damaged kernel recorded was 45.44% at DE application rate of 100 g per 50 kg grain. Insect damage in Pics bag however differed significantly (p<0.05) to minimum mean value of 4.69% at application rate of 100 g per

50 kg grain. Increment in grain damage observed in storage bags had resulted from consumption of grain kernels insect infestation recorded. Grain damage of more than 6% has been reported by Compton *et al*., (1998) to cause economic losses.

Weight loss: Weight loss at Dugda site was not significantly ($p<0.05$) differed with DE treatments both in PP bag and Pics bag.

Table 3. Effects of DE application rate on insect infestation; insect damaged kernels weight loss, moisture, protein and starch contents at Dugda and Bako Tibe districts

Dugda												
DE application rate (g per 50 kg grains)	Infestation (No.)		IDK (%)		WL (%)		MC (%)		Protein (%)		Starch (%)	
	PP bag	Pics bag	PP bag	Pics bag	PP bag	Pics bag	PP bag	Pics bag	PP bag	Pics bag	PP bag	Pics bag
0	114.75^{ab}	13.38^{b}	45^{a}	6.32^{ab}	26.84	10.48	12.44^{a}	12.39^{a}	6.13^{ab}	6.19^{a}	71.77	72.16
25	153.5^{a}	17.63^{b}	40.44^{ab}	5.06^{bc}	23.21	19.02	11.91^{a}	12.26^{ab}	5.88^{bc}	5.92^{ab}	71.53	71.74
50	76.5^{b}	64a^{b}	21.63^{ab}	8.94^{ab}	19.26	12.64	11.66^{a}	12.14^{ab}	6.03^{ab}	5.98^{a}	71.88	71.91
75	91.25^{b}	11.13^{bc}	21.75^{ab}	4.37^{bc}	19.05	11.91	11.59^{b}	12.05^{ab}	6.32^{ab}	6.12^{a}	71.60	71.45
100	74.75^{b}	26^{ab}	18.44^{b}	5.31^{b}	18.91	11.74	11.65^{a}	12.03^{ab}	6.10^{b}	6.14^{a}	72.29	71.75
125	88.75^{b}	28.38^{ab}	28.13^{ab}	10.19^{ab}	17.92	12.86	11.83^{a}	12.1^{a}	5.96^{b}	6.02^{a}	71.93	71.59
LSD (P<0.05)	62.25	62.25	26.57	26.57	NS	NS	0.85	0.85	0.44	0.44	NS	NS
Bako Tibe												
DE application rate (g per 50 kg grains)	Infestation (No.)		IDK (%)		WL (%)		MC (%)		Protein (%)		Starch (%)	
	PP bag	Pics bag	PP bag	Pics bag	PP bag	Pics bag	PP bag	Pics bag	PP bag	Pics bag	PP bag	Pics bag
0	109.75	28.63^{a}	52.94	5.13^{a}	38.90	16.94	12.71	12.53^{a}	6.19^{b}	6.11	71.33	71.90
25	126.75	33.25^{a}	51.63	5.81^{a}	43.93	23.67	12.26	12.41^{a}	6.29^{b}	6.18	70.43	71.98
50	118.00	35^{a}	51.00	7.94^{a}	30.59	17.01	12.62	12.2^{ab}	7.47^{a}	6.33	69.74	71.57
75	99.63	26^{a}	50.00	7.38^{a}	39.68	12.41	11.53	12.49^{a}	6.36^{b}	6.31	70.65	71.67
100	94.25	50.38^{a}	45.44	4.69^{ab}	29.81	15.51	11.41	12.31^{a}	6.18^{b}	6.12	70.78	71.88
125	110.38	17.38^{ab}	45.63	5.50^{a}	35.04	15.82	11.68	12.59^{a}	6.23^{b}	6.32	70.81	71.54
LSD (P<0.05)	NS	33.0	NS	3.25	NS	NS	NS	0.39	1.11	NS	NS	NS

Means with different letters in a column are significantly different (P<0.05) according to Least Significant Difference (LSD) Test. NS=Not significant

However, a decreasing trend in grain weight loss was observed to a minimum value of 17.92 % at DE application rate of 100g per 50 kg grains and 10.48 % at rate of 0 g per 50 kg grains in PP bag and Pics bags respectively (Fig. 3). Similarly, the weight loss was not significantly ($p>0.05$) changed between DE treated and untreated grains both in PP and Pics bag at Bako Tibe site. The lowest mean values of 29.81% and 11.41% were however recorded in PP and Pics bag, respectively (Fig 4). Grain weight loss increment and reductions with DE treatment reflects reduction in insect infestation that could have caused grain weight loss up on grains consumption due to drying effect of DE on insects' cuticle.

Moisture content: At Dugda site moisture content in PP and Pics bag reduced significantly between treatments ($p<0.05$) to 11.59 and 12.03 %, respectively at DE application rate of 100g per 50 kg grains. Moisture content at Bako Tibe in PP bag was not affected significantly ($p>0.05$) with DE application rates. However, in Pics bag it was reduced significantly ($p<0.05$) with application of treatments to result the lowest value of 11.41 % at DE application rate of 100 g per 50 kg grains. Reduction in moisture content observed could be due to sorptive nature of DE dust (Fig. 3). Although grain moisture content recorded was below the maximum recommended (*i.e.* 13.5%) for safe storage of maize grain at both Dugda and Bako Tibe locations (Hayma, 2003), it was high enough to allow development of the identified insect pest species in combination with storage temperatures and relative humidity recorded in the study.

Protein: In PP bags crude protein content at Dugda was significantly ($p<0.05$) higher (6.32 %) at DE application rate of 75g per 50 kg grains than that observed in untreated grains while in Pics bags protein content was significantly ($p<0.05$) higher in all the treatments including the untreated one than that at DE application rate of 25 g per 50 kg grains. In PP bags protein content at Bako Tibe significantly ($p<0.05$) maintained to 7.47 % at DE application rate of 50 g per 50 kg grains while in PP bags protein content was not changed significantly ($p<0.05$) but the value as high as 6.33 % was recorded to be maintained at DE application rate of 50 g per 50 kg grains (Fig. 3).

Starch: Both in PP and Pics bags the starch content at Bako Tibe and Dugda site never significantly ($p>0.05$) differed with DE treatments. The graph in Fig. 3 shows similar linear trend in starch content.

Effect of Storage periods on grain physical and chemical quality characteristics at Dugda and Bako Tibe

Insect Infestation: Two stored grain insect pest species observed during the study period in both PP and Pics bag at both study locations were maize weevil (*Sitophilus zeamais*) and Angoumois grain moth (*Sitotroga cerealella*). The initial insect infestation and observed damage kernels in both PP and Pics bags could be from the infestation of the standing crop at field and at traders store prior to experiments before first sampling. Analysis of variance revealed that insect infestation at Dugda site was significantly ($P < 0.05$) affected with storage time in PP bag but did not significantly ($P>0.05$) differ in Pics bag with storage time. It started to rise to 106.42 per kg of grains in PP bag during period of 210 days and then declined to 81.67 per kg of grains as storage time goes to 360. This faster decline observed in PP bags could be due to grain portions preferred by insect pests reduced at later storage

durations. Insect infestation in PP bag at Bako Tibe increased significantly (P<0.05) from initial mean value of 75.58 to 119.83 per kg of grains during storage period of 60 days. The value then rose to 134.92 per kg of grains after which it declined to 108.83per kg of grains at 360 days. Insect infestation in Pics bag however did not differ significantly (P>0.05) with storage time even though it showed rising trend till 60 days and dropped till end of 360 days of storage (Fig. 4).

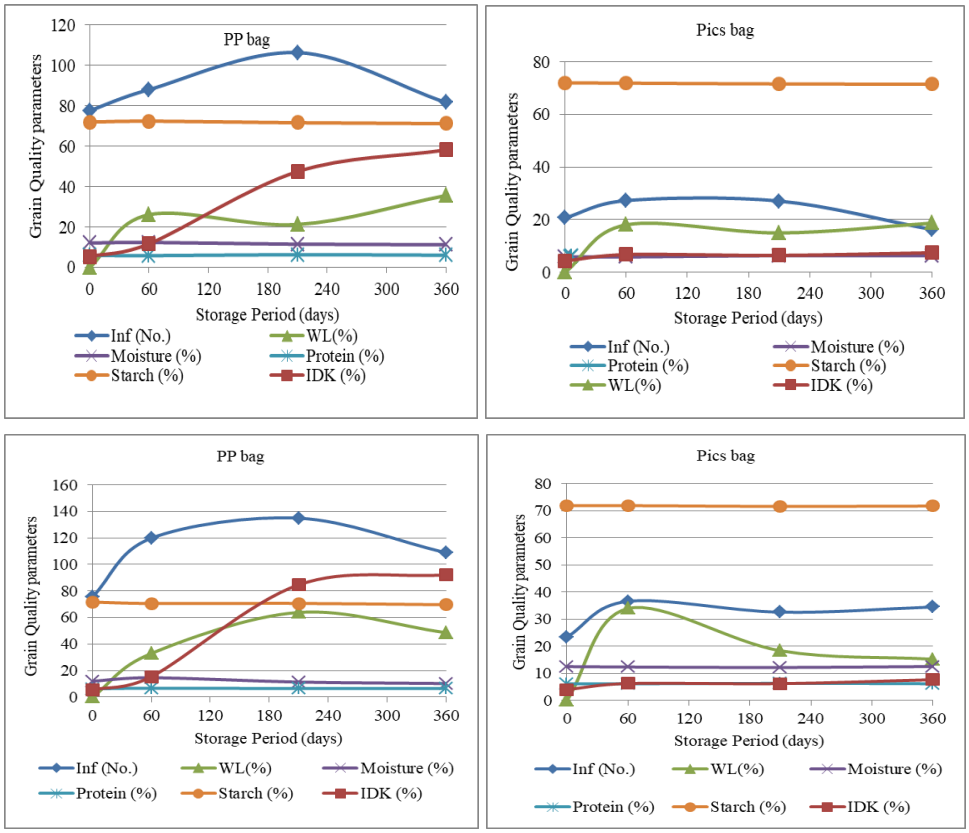


Fig.4 Effect of Storage periods on grain quality in PP and Pics bag at Dugda and Bako Tibe

Insect Damage: Insect damaged kernels at Dugda, began to increase significantly (P<0.05) from initial mean value of 5.46% in PP bag during storage period of 210 days (Fig 5).The value swiftly rose to 58.21% at 360 days. IDK was not significantly (P>0.05) affected with storage time in Pics bag but showed increasing trend from 4.29% to 6.4% during storage period of 210 days and rose to 7.42% assuming linear trend at 360 days of storage. Insect damaged kernels in PP bag at Bako Tibe increased significantly (P>0.05) from initial value of 5.5% to 15.38% during storage period of 60 days.

The value then swiftly rose to 84.67% while it remained in linear trend during 210 days of storage and finally continued to increase in PP bags and attained 92.21% at 360 days of storage. In Pics bag insect damaged kernels increased significantly (P<0.05) from initial mean value of 4.04% to 6.29% during storage period of 60 days while it assumed a linear trend till end of 360 days of storage (Fig. 4).The rise in insect damaged kernel is associated with rise in increased insect infestation and grain consumption with storage time.

Weight loss: At Dugda site, in PP bag the weight loss significantly (P<0.05) rose to 26.15% and 35.88% at 60 and 360 days of storage, respectively compared to reference grain condition

at start of grain sampling. In Pics bag the weight loss significantly ($P< 0.05$) rose to 18.03 % at 60 days of storage which assumed linear trend till 360 days of storage to 18.68 %. Both at Dugda and Bako Tibe in PP and Pics bags, weight loss was observed to unexpectedly reduce at 210 days rather than to increase with respect to that observed at start and at 60 days of storage (Fig. 4). At Bako Tibe, in PP bag the weight loss significantly ($P<0.05$) rose to 63.86% at 210 days of storage from value of 32.91 % at 60 days of storage. It then started to decline till end of 360 days of storage to a mean value of 48.53%. In Pics bag the weight loss significantly ($P< 0.05$) rose to 33.94 % at 60 days of storage from 11% after which it continuously declined to 15.26 % at 360 days of storage. Both at Dugda and Bako Tibe in PP and Pics bags, weight loss was observed to unexpectedly reduce at 210 days rather than to increase with respect to that observed at start and at 60 days of storage (Fig. 4). This could be due to error incurred to raise thousand kernel weight after chemical parameters measurement as moisture adsorption by grain samples could have been occurred when out of sealed plastic bag. Grain weight loss increased with storage duration, reflecting increases in insect population agreeing with report of (Kim and Kossou, 2003) positive correlation between grain weight loss and increase in insect population.

Moisture content: Moisture content in PP bags at Dugda significantly ($P<0.05$)increased from initial mean value of 12.16 to 12.39 % during 60 days and then continuously decreased till 360 days of storage. In Pics bag however it dropped significantly ($P<0.05$)from initial value of 12.41% at the start of grain sampling to 12.28 % at 210 days but finally dropped to 12.13 % at 360 days of storage. Moisture content in PP bags at Bako Tibe significantly increased from initial mean value of 11.98 to 14.58% during 60 days and then continuously decreased till 360 days of storage. In Pics bag however it dropped significantly ($P<0.05$) from initial value of 12.53% at the start of grain sampling to 12.2% at 210 days but finally rose to 12.57% at 360 days of storage (Fig. 4). Reduction in moisture content of grain in PP and Pics bag observed with storage times could be due to sorptive nature of DE dust and the increase in grain moisture content could be due to the cumulative effect of respiration from insects and grain itself that might have added moisture to the grains (Ogendo *et al*., 2004). Increment in grain moisture content observed agrees with report of (Kerstin *et al*., 2010; Chulze, 2010) as changes can be attributed to variations in ambient temperature and relative humidity during storage. Mirna *et al*. (2007) observed similar moisture content variation in PP bags stored grain at a temperature of 20°C and varying relative humidity.

Protein content: Protein content both in PP bag at Dugda increased significantly ($P<0.05$) to mean value of 6.07 % at 360 days from 6.01 % at start of sampling while in Pics bag it rose significantly ($P<0.05$) to 6.3% at 360 days from 5.87% at start of sampling. The increment in crude protein content could be due to decrease in the proportion of total starch content attributed to attack and consumption of the starchy endosperm by insect pests as storage time goes (Watson, 1987). Protein content both in PP and Pics bag at Bako Tibe were not affected significantly ($P>0.05$) with storage time unlike that observed at Dugda in which the protein content was significantly affected with storage time (Fig. 4). Grains stored in Dugda had different climatic condition that can be related to varying temperature and relative humidity since storage peasant associations in Dugda and Bako Tibe was selected in such a way to represent midland and lowland agro-ecologies respectively.

Starch content: Starch content in PP bag at Dugda was significantly reduced from initial mean value of 72.04% to 71.21% at the end of 360 days while it decreased significantly from initial value of 71.99 % to 71.48 % at the end of 360 days (Fig. 4). Reduction in grain starch content at Dugda could be attributed to the increased insect infestation levels and hence attack with storage time by feeding on starchy endosperm of the maize kernel (Watson, 1987). Starch content in PP bag at Bako was significantly reduced from initial mean value of 71.66% to 69.64% at the end of 360 days. Starch content in Pics bag at Bako was however not significantly ($P>0.05$) changed with storage time unlike effect observed in Dugda that could have happened due to difference in agro-ecology (Fig. 4).

Conclusion

The temperature and relative humidity profiles of storage bags were high enough to permit insect development and the observed differences in insect population may be attributed to the effect of the DE treatments and storage durations. This grain moisture in combination with storage temperatures and relative humidity in the current study were high enough to allow development of the identified insect pest species. Two stored grain insect pest species observed during the study period in both PP and Pics bag were *Sitophilus zeamais* and *Sitotroga cerealella*. Varied grain quality was observed due to application of DE, rates of application and storage periods. Initial grain samples confirmed the presence of live and dead *Sitophillus zeamais* and *Sitotroga cerealella* in both PP and Pics bag. Statistically significant reduction or a very slow increase of insect infestation in Pics bags could be attributed to hermeticity along with sorptive property of DE which in contrary showed significant increment in PP bag over the storage periods. DE application to stored maize grain was found to affect population of the identified insect pests and can provide substantial level of control of these insect pests. The increase in weight loss with storage time could be attributed to insect attack shown by the level of infestation. Pics bag protected maize grains against insect damage and had potential to reduce weight loss to less than13% and 17% from 27% and 44% in Dugda and Bako Tibe districts respectively compared to damage and weight loss observed in PP bags. Protein content was significantly affected with DE treatments at Dugda and Bako Tibe sites except at Bako Tibe that showed significant effect with DE while starch contents was not affected with DE application rates in both of PP and Pics bags at both Dugda and Bako Tibe districts.

The study revealed the effect of DE treatment in maintaining stored grain quality, reducing damages and weight losses and thus forwards use of technology and guide farmers on the application of DE and hermetic storage bags like Pics bag used in present study. The use of Pics bag for storage of DE treated stored maize reduced grain storage weight losses, insect damage and infestation in the study area compared to that in PP bags. Therefore, its adoption is suggested to be encouraged at farmer level. To achieve more quality maintenance and reduction of grain damage and weight loss, DE application rates higher than 50 g per 50 kg grain among the treatments was noticed to be effective if used for postharvest loss reduction and hence contribute in attaining food security. Economic analysis for the results of grain qualitative and quantitative loss obtained upon treating grains with DE should however be done for final recommendation of the technology to reduce the use of expensive synthetic chemicals with negative impacts on environment and humans. Further investigation involving effect of DE rate on the occurrence, aflatoxin level and physiological quality of grain over storage time under more controlled environment need to be conducted.

Reference

Abebe, H.G. and Bekele, H. 2006. Farmers' post-harvest grain management choices under liquidity constraints and impending risks: Implications for achieving food security objectives in Ethiopia. Poster Paper Presented at International Association of Agricultural Economists Conference, Gold Coast, Australia, August 12-8.

Abraham, T. (1995). Insects and other arthropods recorded from stored maize in western Ethiopia. *ACSL*, 4(3):339-343.

Aldryhim, Y.N. 1990. Efficacy of the amorphous silica dust, Dryacide, against *Tribolium confusum* Duv. And *Sitophilus granaries* (L.) (Coleoptera: Tenebrionidae and Curculionidae). *Journal of Stored Product Research*, 26(4): 207-210.

AOAC (Association of Official Analytical Chemists). 1995. *Official Methods of Analysis of Association of Official Analytical Chemists*. Association of Official Analytical Chemists, 16th edition, Vol.I, INC, Virginia, USA.

Asiedu E.A., A.J.G., van Gastel, B., Greg, A., Ebert. 1999. Dehumidifying drying: A viable option for long term seed storage in the humid tropics. In: Impact challenges and prospects of maize research and development in West & Central Africa. Proceedings of a regional maize workshop 4th –7th May 1999, IITA Cotonou, Benin Republic pp. 59-69.

Askey, L. 1995. Techniques-Kinder Killers, Virtual Garden [online], available from http://pathfinder. Com/@@MzLKgcAwq7BC4y..ne-Rack/SoLiving/1995/SSGG/killers.htn [accessed 19 June 2018].

Chulze, S.N. 2010. Strategies to reduce mycotoxin levels in maize during storage: a review. *Food Additives and Contaminants*, 27(5): 651–657.

Compton, J.A.F., S. Floyd, P.A. Magrath, S. Addo, S.R. Gbedevi, B. Agbo, G.Bokor, S. Amekupe, Z. Motey, H. Penni, and S. Kumi. 1998. Involving grain traders in determining the effect of postharvest insect damage on the price of maize in African markets. *Crop Protection*, 17: 483–489.

Daniel, I.O, Ajala M.O. 2004. Probit modeling of seed physiological deterioration in humid tropical seed stores. *ASSET A* 4(3): 47-53.

Daniel, I.O., K.O., Oyekale, M. O., Ajala1, L.O., Sanni and M.O.,Okelana. 2009. Physiological quality of hybrid maize seeds during containerized-dry storage with silica gel. *African Journal of Biotechnology*, 8 (2):181-186

Dubale, B., Geremew, B., Solomon, A., Waktole, S. and Sethu, M.R. 2012. Influence of Agro-ecologies, Traditional Storage Containers and Major Insect Pests on Stored Maize (*Zeamays L*.) In Selected Woredas of Jimma Zone. *Asian Journal of Plant Sciences*, 11(5): 226-234

El-Kashlan, I.H., H., Eglal, A., Madeha and M.A., Abdellatif. 1995. Insect pests associated with stored grains in Alexandria Governorate. *Journal of King Saud University of Agricultural Science*, 7(1): 123-127

EROS (Earth Resources Observation and Science). 2018. USGS Earth Resources Observation and Science Center, Sioux Falls, South Dakota. http://lpdaac.usgs.gov, Accessed on July 23, 2018.

Fekadu, L., Geremew, B., and Waktola, W. 2000. Quality of grain sorghum (S*orghum bi color* (L.) Moench) stored in traditional underground pits: Case studies in two agro-climatic zones in Hararghe, Ethiopia. *Journal of Food Science and Technology*, 37(3): 238-244.

Fields, P.G. and W.E., Muir. 1996. Physical Control. In: Integrated Management of Insects In Stored Products, Subramanyam, B. and D.W., Hagstrum (Eds.). Marcel Dekker Inc., New York, pp: 195-221.

Fields, P., Allen, S., Korunic, Z., McLaughlin, A., Stathers, T. 2002. Standardized testing for diatomaceous earth" (PDF). *Proceedings of the Eighth International Working Conference of Stored Product Protection*. York, U.K.: entomological Society of Manitoba.

Golob, P. and C., Hanks. 1990. Protection of farm stored maize against infestation by Prostephanus truncatus (Horn) and Sitophilus species in Tanzania. *Journal of Stored Products Research*, 26, 187-198.

Hayma, J. 2003. The Storage of Tropical Agricultural Products, Agrodok 31, CTA, The Netherlands. 6-25 pp.

Hodges, R. J., D. R. Hall, J. N. Mbugua, and P. W. Likhayo. 1998. The responses of Prostephanus truncatus (Coleoptera: Bostrichidae) and *Sitophilus zeamais* (Coleoptera: Curculionidae) to pheromone and synthetic maize volatiles as lures in crevice or flight traps. *Bull. Entomol. Res.*, 88:131–139.

Hong T.D., R.H., Ellis, D., Astley, A.E., Pinnegar, S.P.C., Groot, H.L., Kraak. 2005. Survival and vigour of ultra-dry seeds after ten years of hermetic storage. *Seed Sci. Technol*. 33: 449-460.

Ishrat, N. and D. Shahnaz. 2009. Detection of seed borne mycoflora in maize (*Zeamays*L.). *Pakistan Journal of Botany*, 41(1): 443-451.

Kerstin, H., K.E., Ognakossan, A.K., Tonou, Y., Lamboni, K.E., Adabe and O., Coulibaly. 2010. Maize Stored Pests Control by PICS-Bags: Technological and Economic Evaluation. 5th World Cowpea Conference in Saly, Senegal, 27 September -1 October 2010.

Kim, S. K. and D. K. Kossou. 2003. Responses and genetics of maize germplasm resistant maize weevil Sitophilus zeamais Motschulsky in West Africa. *Journal of Stored Products Research*, 39: 489–505.

Korunic. Z. 1988. Diatomaceous earths, a group of natural insecticides. *Journal of Stored Products Research*, 34, 87–97.

Korunic, Z., P.G., Fields, M.I.P., Kovacs, J.S., Noll, O.M., Lukov, C., Demianyk and K.J., Shibley. 1996. The effect of diatomaceous earth on grain quality. *Postharvest Biology and Technology*, 9 (1):373–378.

Korunic, Z., S., Cenkowski and P., Fields. 1998. Grain bulk density as affected by diatomaceous earth and application method. *Postharvest Biology and Technology*, 13: 81-89.

Korunic, Z. 1999. Enhaced diatomaceous earth: an alternative to methyl bromide. *Australian Journal of Technology*, 2: 95-104.

Marghanita, J. 1997. Management of spent Diatomaceous earth from the brewing industry: A literature review. Department of Environmental Engineering, the University of Western Australia.

Mirna, V., V., Rozman, I., Kalinovic, A., Liska, D., Kis, and B., Simic, 2007. Influence of Relative Humidity and Temperature on the Changes in Grain Moisture in Stored Soybean and Maize. *Agriculturae Conspectus Scientifi cus*, 72(3): 215-219.

MoM (Ministry of Mines). 2010. Opportunities for diatomite resource development in Ethiopia. Ministry of Mines, Geological Survey of Ethiopia, Geoscience Data Center, Addis Ababa, Ethiopia.

Ogendo, J.O., A.L., Deng, S.R., Belmain, D.J., Walker and A.A.O., Musandu, 2004. Effect of Insecticidal Plant Materials, *Lantana camara* L. and *Tephrosia vogelii* Hook, on the Quality Parameters of Stored Maize Grains. *The Journal of Food Technology in Africa*, 9(1): 29-36.

Somado E.A., M.S., Ines, F., Nwilene, M., Sie, A.A., Ogunbayo, K., Sanni and D.D., Tia. 2006. Comparative studies of drying methods on the seed quality of interspecific NERICA rice varieties (Oryza glaberrima x Oryza sativa) and their parents. *Afr. J. Biotechnol*., 5(18): 1618-1624.

Storey, C. L., R. D. Spiers, and L. S. Henderson. 1979. Insect control in farm stored grain. Farmers Bullettin, No. 2269.

Tadesse, A. and Th., Basedow. 2005. Laboratory and field studies on the effect of natural control measures against insect pests in stored maize in Ethiopia. *Journal of Plant Diseases and Protection*, 112 (2), 156–172.

Wambugu, P.W., P.W., Mathenge, E.O., Auma and R., Havan. 2009. Efficacy of traditional maize (Zea mays l.) seed storage methods in western Kenya. *African Journal of Food Agriculture Nutrition and Development*, 9(4): 1110-1128.

Characterization of Nutritional and Process Quality of Some Faba Bean Varieties and Advanced Lines Grown at Bale, South Eastern Oromia

Shure Soboka[1], TadeleTadesse[2] and AmanuelTekalgn[2]
[1]Oromia Agricultural Research Institute, P.O.Box: 81265, Addis Ababa, Ethiopia.
[2]Sinana Agricultural Research Center, Bale-Robe, Ethiopia.
*Corresponding author: ibsasoboka2020@gmail.com

Abstract
Faba bean is said to be poor man's meat as it is the most important protein source for most of world's population. Field experiment was carrined out at Sinana district of Bale highland to see the effect of faba bean genotypes on some physico-chemical and nutritional qualities as affected by test genotypes. For this experiment fifteen faba bean genotypes including released and promising genotypes were evaluated for thier physico-chemical quality characterisation. From the result it was seen that most quality characters measured have shown significant variation ($p<0.05$) due to faba bean genotypes. Genotypes EH07006-51, EH070015-7 and EH0773-8 have got better quality characters as compared to the released varieties Shallo, Mosisa and the local check. Genotype EH07006-1 is better in percent hydration, Na and K composition as compared to the other test genotypes. From the collected data it is possible to conclude that genotypes EH07006-1, EH07006-51, EH070015-7 and EH0773-8 are better to be selected for the variety verification even-though data on cooking time, antinutritional factor and other agronomic and physiological data are not included. Finally, for final recommendation, multi season and location data including both quality and physiological data should be included.
Key words*: Faba bean, Nutritional quality, protein content*

Introduction

Faba bean (*Viciafabae* L.) is one of the earliest domesticated food legumes in the world, probably in the late Neolithic period (Metayer, 2004). It is believed that the crop was introduced to Ethiopia from the Middle East via Egypt around 5000 B.C., immediately after domestication (Asfaw *et al.*, 1994). Ethiopia is now considered as one of the centers of secondary diversity for faba bean (Torres *et al.*, 2006) where it is mainly used as human food. Faba bean ranks sixth in production among the legumes grown in the world. China has been the main producing country, followed by Ethiopia, Egypt, Italy, and Morocco (FAO, 2014). Even though Ethiopia is the world's second largest producer of faba bean, its share is only 6.96% of world production and 40.5% within Africa (Chopra *et al*., 1989). The average yield of this crop under small-holder farmers ranges from 1.0 to 1.2 t ha^{-1} (Agegnehu *et al*., 2006a), while world average grain yield of faba bean is around 1.8 t ha^{-1} (ICARDA, 2008).

The crop occupies the largest area among the pulses in Ethiopia, it is grown on 370,000 hectares with an annual production of about 450,000 tonnes (ICARDA, 2006) but production is not adequate enough to meet local demand and satisfy lucrative export markets in Sudan, Egypt and elsewhere. Faba bean is extensively grown in the highlands of Ethiopia and is the most important pulse crop cultivated in the country (Tsedeke, 1985).

A major aim for any crop breeding program is the development of good quality lines with an adequate resistance/tolerance to yield-reducing stresses (Gutierrez *et al.,* 2006). Internationally, intensive breeding efforts have been made to reduce the content and range of antinutritional substances which can be divided into many groups depending on their chemical properties, biological activity and potential harmfulness. Those include such non-protein substances as oligosaccharides; lectins and protease inhibitors, tannins, saponins, quinolizidine alkaloids, cyanogenic and pirymidine glycosides, phytates, isoflavones and some other that are less important and do not display a significant antinutritive activity. As well as to improve the nutritional and processing quality of beans where the positive effects of antinutritional constituents are under considerations.

In Ethiopian faba bean breeding program, grain yield, disease resistance and in some cases, protein content is the only quality parameter to be evaluated for the release of improved variety even though the country is the second largest in releasing improved faba bean varieties. As a result nutritional quality reports are available only for a few of faba bean, field pea and lentil cultivars released so far. Scientific justification of food quality of improved faba bean, field pea and lentil released varieties as well as those under pipe lines very important. Therefore, this study was conducted with the objectives to characterize physicochemical and nutritional qualities of released as well as promising faba bean genotypes.

Materials and methods

Experimental Design: Fifteen faba bean genotypes including released and advanced line were collected from Sinana Agricultural Research Center from crop grown under Sinana and Goba districts of Bale highlands in 20016/17 cropping season. The collected samples were cleaned, milled and made to pass through 1mm sieve and made ready for laboratory analysis. Quality assessment was carried out at Oromia Agricultural Research Institute (IQQO) and Melkessa Agricultural Research Center, Food Science Laboratories.

Data on processing quality

Initial weight of solids (IWS) (g): Determined as a loss in moisture by drying 150 grams of bean sample at 60°C for 24 hours in an oven (Ghaderi *et al.,* 1984). Water absorption (WA): A sample of 150 gram (W_1) of raw beans was soaked at room temperature (25°C) in distilled water (1: 5 W/V). After 16 h, the soaked bean was removed from the soaking water, drained, surface dried with lint free filter paper, and reweighed (W_2). From the weight difference, WA was expressed as percentage increase of the seed weight (Martin-Cabrejes *et al.,* 1997). From the result, hydration ratio (HR) was computed as weight of soaked beans (W_2) divided by initial weight (W_1) (Ghaderi *et al*., 1984).

Data on bean chemical composition

Ash content: The ash content was determined gravimetrically in accordance to AACC (2000) method 08-01. About 3g of flour sample was weighed on a pre- ignited and cooled procaine crucible. Ashing of the sample was done in a muffle furnace adjusted to 550°C for three hours. After cooling in desiccators, % ash was calculated from the mass difference on dry matter basis.

Crude protein content: Crude protein content was determined by the micro-Kjeldahl procedure by taking about 0.5g flour samples using a K_2SO_4 - $CuSO_4$ catalyst in according to AACC (2000) method 46-12.

Mineral Content:-The mineral content of faba bean samples was determined by using the method described by AOAC (1998). The ash obtained from the ash analysis earlier was used in the determination of the minerals content. The ash was placed in porcelain crucibles, and dissolved with few drops of distilled water, followed by 5ml of 2N hydrochloric acid and filtered through Whiteman filter paper into 100 ml volumetric flask. The minerals such as calcium (Ca), Sodium (Na) and Potassium (K) was then determined by using Flame photometer while phosphorous (P) content was determined using spectrophotometer.

Statistical Analysis

All data collected was subjected to the (ANOVA) using SAS GLM procedure (SAS Institute, 1998). The significance between mean values (mean separation) was expressed by Least Significant difference (LSD) method.

Results and Discussion

Out of the test physico-chemical quality characters evaluated, phosphorous, moisture content and initial weight of solids are non-significantly varied due to genotypes ($P>0.05$) (Table 1 and 2). Hydration potential varied from the highest 2.12 genotype EH07006-1 to the lowest 2.04 variety Shallo. The higher hydration potential of all the test genotypes mean each grain of faba bean can absorb twice of its initial weight. This indirectly mean high flour yield would be obtained from the test genotypes. According to Hosfield and Uebersax (1980), genotype with higher water absorption would have longer cooking time as more time is needed for the water to be absorbed into the bean. Thousand kernel weight (TKW) of the genotypes varied significantly ($P<0.05$) from the highest 986.07 for the genotype -EH07006-51- to the smallest 633.70 for the local cultivar. TKW is indirectly related to kernel size. According to (Mona - *et.al.* 2011) the TKW of faba bean genotypes grown at Nubaria Research Station, Egypt, varied from 1092 to 1187 gm/1000 grains. - The TKW of faba bean genotypes in the current study fall under small to medium sized grains (Table 1).

Pulse crops are mainly consumed for their protein content. Therefore, irrespective of the form of consumption, protein content and other important nutritional characteristics must be safeguarded and improved (Williams, 1985). In this study, the protein contents of test genotypes varied from 21.93 to 23.90%, which is in similar range with bean germplasm accessions analyzed for protein content, and ranged from 17 to 28%, while the average being around 22.83% (CIAT, 1993). The highest %CP value was recorded for genotype EH06007-2 whiles the lowest for the released variety Mosisa (Table 1). From the result it is seen that even though there is significant variation among the protein contents of the genotypes under this study, there is no large difference in protein composition. It is known that protein content is highly affected by growing environment and crop management. But genetic factor do have higher influence.

The protein contents of test genotypes significantly (P<0.05) varied from 21.93 to 23.90%, which is in similar range with bean germplasm accessions which ranged from 17.1 to 28% CIAT (1993). The highest % CP was recorded for genotype *EH06007-2* while the lowest for the genotype *EH070024-3* and released variety *Mosisa* (Table 1). According to Picard, (1977), the protein content of Vicia faba (V. faba; faba bean) ranges from 26 to 41%.

Table 1. Analysis result on some Faba bean physical quality characters as affected by test genotypes

Genotype	Initial wt/150gm	%MC	Hydration (%)	TKW (gm)	%N at 12.5%	%CP at 12.5%
EH00100-3	137.96±0.49	8.03±0.33	2.10±0.03^{abc}	879.80±11.73^{de}	3.54±0.12^{fg}	22.10±0.75^{fg}
EH06007-2	137.33±0.97	8.45±0.64	2.10±0.04^{abc}	885.53±32.01^{cd}	3.82±0.08^{a}	23.90±0.53^{a}
EH070013-7	137.59±0.05	8.27±0.03	2.08±0.03^{abc}	955.90±40.76^{ab}	3.80±0.03^{ab}	23.74±0.22^{ab}
EH070015-7	137.38±1.03	8.41±0.69	2.05±0.01^{bc}	794.03±59.10^{f}	3.66±0.04^{c-f}	22.88±0.23^{c-f}
EH070023-6	137.38±0.99	8.42±0.66	2.10±0.03^{abc}	718.43±23.09^{g}	3.58±0.08^{efg}	22.39±0.50^{efg}
EH070024-3	137.29±0.46	8.47±0.31	2.07±0.01^{abc}	759.40±20.19^{fg}	3.51±0.14^{g}	21.93±0.90^{g}
EH07003-11	138.07±0.23	7.95±0.16	2.05±0.04^{c}	839.57±14.52^{e}	3.68±0.04^{b-e}	22.97±0.27^{b-e}
EH07006-1	137.66±0.16	8.23±0.11	2.12±0.01^{a}	790.77±12.72^{f}	3.76±0.03^{abc}	23.49±0.17^{abc}
EH07006-51	137.47±1.10	8.35±0.73	2.10±0.06^{abc}	986.07±23.46^{a}	3.67±0.08^{cde}	22.93±0.49^{cde}
EH0773-8	137.91±0.40	8.06±0.27	2.07±0.03^{abc}	918.17±18.48^{bcd}	3.64±0.07^{e-f}	22.76±0.44^{c-f}
EK02017-3	137.63±1.56	8.25±1.04	2.10±0.02^{abc}	926.47±15.43^{bc}	3.62±0.11^{d-g}	22.64±0.69^{d-g}
EK02019-2	136.95±0.73	8.70±0.49	2.11±0.01^{ab}	936.90±4.19^{b}	3.57±0.05^{efg}	22.34±0.28^{efg}
Local Check	137.00±0.36	8.67±0.24	2.05±0.02^{bc}	633.70±21.15^{h}	3.69±0.03^{b-e}	23.08±0.19^{b-e}
Mosisa	137.02±0.76	8.65±0.51	2.06±0.04^{bc}	621.00±5.84^{h}	3.51±0.05^{g}	21.96±0.32^{g}
Shallo	136.59±0.53	8.94±0.35	2.04±0.00^{c}	639.17±24.23^{h}	3.74±0.05^{a-d}	23.37±0.31^{a-d}
Mean	**137.41±0.68**	**8.39±0.46**	**2.08±0.03**	**818.99±121.92**	**3.65±0.11**	**22.83±0.72**
LSD	**Ns**	**ns**	**0.063**	**42.72**	**0.126**	**0.784**
CV<0.5	**0.56**	**5.26**	**1.41**	**3.13**	**2.06**	**2.06**

Values with different letter within a column are significantly different (p < 0.05), TKW = thousand kernel weight (gm.) both at 12.5% moisture bases, MC= Moisture Content (%), CV= Coefficient of variation, LSD= Least Significance difference

The ash which is the direct indication of the mineral content varies from 2.27 to 2.16%. The mineral contents (Na, K and Ca) of the faba bean genotypes also shown significant variation (P<0.05).Genotype EK02017-3 got the highest Na (5.60 ppm) content while the genotype EH070013-7(3.20 ppm) with the lowest one. Potassium also varied from the lowest 143.33 ppm for faba bean genotype EH070024-3 while the highest value 195.67 ppm for genotype EH07006-1. Calcium content also varied from 141.0 mg/100 g for genotype EK02019-2 while the lowest 112.3 for Shallo variety.

Faba beans are a good source of dietary minerals, such as phosphorus, potassium, calcium, sulphur and iron. Results from the study done by Chavan JK, *et al.*, (1989), Calcium content of faba bean varieties ranges from 120 to 260 mg/100 g dry mass bases, which is lower but in similar range with the result of the current study. According to V. Ramakrishna (2006), the mean phosphorous content of faba bean genotypes evaluated for antinutritional compound composition is 430mg/100g, which is close to the result of the current study even-though study should be done to identify the percentage of antinutritional phosphorous and nutritional one as compared to that of total phosphorous.

Table 2. Analysis result of some faba bean chemical quality characters as affected by test genotypes

Genotype	P (mg/100gm)	Ash at 12.5%	Na(ppm)	K(ppm)	Ca(mg/100gm)
EH00100-3	173.62±91.87	2.41±0.04^{cd}	4.67±0.32^{cd}	166.33±4.93^{b-d}	117.3±0.12^{ef}
EH06007-2	246.46±5.57	2.34±0.07^{cde}	3.47±0.38^{g}	155.00±4.36^{fgh}	112.7±0.25^{f}
EH070013-7	195.28±77.95	2.62±0.02^{ab}	3.20±0.26^{g}	157.67±3.06^{e-h}	114.0±0.10^{ef}
EH070015-7	59.45±75.16	2.22±0.08^{ef}	4.10±0.17^{ef}	152.67±4.73^{ghi}	120.0±0.20^{de}
EH070023-6	279.92±64.03	2.59±0.15^{ab}	5.07±0.40^{bc}	148.33±4.73^{hi}	114.7±0.12^{ef}
EH070024-3	203.15±83.52	2.43±0.11^{cd}	4.87±0.21^{bcd}	143.33±3.51^{i}	115.7±0.21^{ef}
EH07003-11	335.04±108.57	2.72±0.09^{a}	5.23±0.15^{ab}	158.33±15.04^{efg}	128.0±0.20^{bc}
EH07006-1	317.32±167.03	2.43±0.06^{cd}	5.13±0.51^{abc}	195.67±4.51^{a}	128.0±0.78^{bc}
EH07006-51	303.54±158.68	2.49±0.18^{bc}	4.57±0.25^{de}	170.00±5.00^{bcd}	134.7±0.47^{ab}
EH0773-8	338.98±19.49	2.36±0.14^{cde}	4.57±0.40^{de}	163.00±9.64^{c-f}	134.7±0.49^{ab}
EK02017-3	264.17±47.33	2.33±0.11^{de}	5.60±0.36^{a}	172.67±3.06^{bc}	126.7±1.10^{cd}
EK02019-2	230.71±83.52	2.31±0.02^{def}	4.00±0.10^{f}	162.67±3.79^{def}	141.0±0.26^{a}
Local Ckeck	262.20±33.41	2.17±0.07^{f}	3.63±0.15^{fg}	175.67±4.51^{b}	128.0±0.26^{bc}
Mosisa	212.99±119.71	2.16±0.01^{f}	4.77±0.15^{bcd}	170.67±2.52^{bcd}	134.0±0.26^{ab}
Shallo	252.36±175.38	2.30±0.06^{def}	5.13±0.15^{abc}	151.67±2.08^{ghi}	112.3±0.21^{f}
Mean	**245.01±101.19**	**2.39±0.18**	**204.00±0.73**	**162.91±13.68**	**124.1±0.99**
LSD	**ns**	**0.156**	**0.487**	**9.903**	**0.716**
CV<0.5	**38.19**	**3.91**	**6.44**	**3.65**	**34.6**

Values with different letter within a column are significantly different (p < 0.05), CV= Coefficient of variation, LSD= Least Significance difference, P = phosphorous content, CP= crude protein content, N= nitrogen content, Na=Sodium, K= Potassium, and Ca=Calcium content

Conclusion and Recommendations

From the result, it was seen that most quality characters measured have shown significant variation due to faba bean genotypes. Genotypes EH07006-51, EH070015-7 and EH0773-8 have better quality characters as compared to the released varieties Shallo, Mosisa and the local check. Genotype EH07006-1 is better in percent hydration, Na and K composition as compared to the other test genotypes. From the collected data it is possible to conclude that genotypes EH07006-1, EH07006-51, EH070015-7 and EH0773-8 are better to be selected for the variety verification even-though data on cooking time, antinutritional factor and other agronomic and physiological data are not included. Finally, for final recommendation, multi season and location data including both quality and physiological data should be included. On the other hand, breeders can use this quality data for merit dependent variety registration.

References

AACC, 2000. Approved Methods of the American Association Cereal Chemists. American Association of Cereal Chemists. Inc., St. Paul, Minnesota.

Agegnehu G., Ghizaw A., Sinebo W. (2006a) Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands, Eur. J. Agron. 25, 202–207.

Asfaw Telaye, Tesfaye Getachew and Beyene Demitsu. 1994. Genetics and breeding of faba bean. Pp .122-137. In: Asfaw Telaye (Eds). Cool-season food Legumes in Ethiopia. Proceedings: First National Cool-season Food legume Review Conference, Addis Ababa, Ethiopia.

Association of Official Analytical chemists (AOAC) 1998. Official methods of Analysis of AOAC international. 16th Edition.4th revision.

Centro Internacional de Agricultura Tropical (CIAT), 1993. Bean Program Annual Report. Working Document No. 161, 1996, Cali, Colombia. Pp. 6-13.

Chavan JK, Kute LS, Kadam SS 1989. Broad bean. In: Handbook of world food legumes: nutritional, processing, technology and utilization, vol I. CRC Press, Boca Raton, Fl, pp 223–245.

Chopra, V. L., R. B. Singh and A. Varma, 1989. Crop productivity and sustainability-shaping the future. 1111p. Proceedings of 2nd international crop science congress. Oxford & IBH publishing. New Delhi.

Food and Agriculture Organization: FAO Statistics Division 2014 /www.faostat.org /

Frehiwot Mulugeta 2009. Lentil Production, Supply, Demand and Marketing issues in Ethiopia, Ethiopia Commodity Exchange Authority, unpublished document, Addis Ababa, Ethiopia

Ghaderi, A.; G. L. Hosfield; M. W. Adams and M. A. Uebersax, 1984. Variability in culinary quality, component interrelationships, and breeding implications in navy and pinto beans. Journal of American Society of Horticultural Sciences. 109 (1): 85-90.

Gutierrez, et. al. 2006. Markers to assist selection for low vicine and convicine contents in faba bean (Vicia faba L.). Theor. Appl. Genet., 114, 59–66.

Hosfield, G. L. and Uebersax, M. A., 1980. Variability in physiochemical properties and nutritional components of tropical and domestic dry bean germ plasm. Journal of American Society of Horticultural Sciences. 105: 246.

ICARDA (International Center of Agricultural Research in Dry areas) 2006. Technology Generations and Dissemination for Sustainable Production of Cereals and Cool Season Legumes. International Center for Agricultural Research in the Dry Areas, Aleppo, Syria. 256 p.

ICARDA (International Center of Agricultural Research in Dry areas), 2008. Drought and Broomrape-A threat to Faba Bean. http://www.icarda.org/ Aleppo, Syria.

Juana Frias, Concepción Diaz-Pollan, and Gloria Urbano 1998. Nutrients and antinutritional factors in faba beans as affected by processing, Z Lebensm Unters Forsch A (1998) 207:140–14.

Martin-Cabrejes, M. A.; R. M Esteban; P. Perez; G. Maina and K. W. Waldron, 1997. Changes in physicochemical properties of dry beans (Phaseolus vulgaris L.) during longterm storage. Journal of Agricultural and Food Chemistry. 45: 3223−3227.

Metayer 2004. Vicia faba breeding for sustainable agriculture in Europe. Gie feverole.

Ramakrishna, V., Jhansi Rani P. and Ramakrishna Rao P., 2006. Anti-Nutritional Factors During Germination in Indian Bean (Dolichos lablab L.) Seeds, World Journal of Dairy & Food Sciences 1 (1): 06-11.

SAS, 1998. Statistical analysis system (SAS) institute inc., Cary, NC, USA.

Torres, *et al*., 2006. Faba bean breeding for resistance against biotic stresses: Towards application of marker technology. Euphytica, pp. 147, 67–80.

Tsedeke Abate, Ferede Negassi, and Kemal Ali, 1985. A review of grain legume pest management research in Ethiopia. In: A. Tsedeke (Ed.) proceedings of the first Ethiopian crop protection symposium, 7 February 1985, Addis Ababa, Ethiopia. 327p

Williams, W., 1985. Genetic Improvement of Grain Protein Crops- Achievements and Prospects. Pp. 63- 84. In: G. E. Russel (ed.). Progress in Plant Breeding-1. Buttermworth & Co. (Publishers) Ltd, London, Boston, Durban, Singapore, Sydney, Toronto, Wellington

Picard, J. 1977; Some results dealing with breeding protein content in Vicia faba L. Protein quality from leguminous crops; EVR 5686 EN, Commission of European Communities, Coordination of Agricultural Research: p 339.

LIVESTOCK RESEARCH

Registration of Bate "*ILRI 5453*" Oat *(Avena sative L.)* variety

Mekonnen Diribsa*, Abuye Tulu, Waqgari Keba, Gutu Fekeda and Warku Temesgen
Oromia Agricultural Research Institute, Bako Agricultural Research Center, PO Box 03, Bako, Oromia, Ethiopia
Corresponding author* e-mail: mokedisa2000@gmail.com and Mobile: 09 13 92 31 56

Abstract
Eight Oat (Avena sativa L.) genotypes including standard check were essentially evaluated for their herbage dry matter yields, grain yields and nutritional quality characters at two environments (Bako and Boneya Boshe) of Western Oromia, during 2014, 2015 and 2016 main cropping season with the objective of selecting the top performing oat (Avena sativa L.) genotypes for variety release. The tested genotypes were ILRI 6710, ILRI 5453, ILRI 5518, ILRI 6207, ILRI 712, ILRI 8237, Jasari (local check) and Bonsa (standard check). The genotypes were arranged in randomized complete block design with three replications. Data on herbage DM yield, grain yield and other agronomic traits were collected and analyzed using GenStat software. The combined analysis for herbage dry matter yield indicated that a significant differences ($p \leq 0.01$) were observed among genotypes, which ranged from 7.36-9.03 ton ha^{-1}. Bate variety had produced mean herbage DM yield of 8.56 ton ha^{-1} with 12.93 % ton ha^{-1} yield advantage over the standard check (Bonsa) which produced 7.58 ton ha^{-1}. Similarly, grain yields differed significantly ($p \leq 0.01$) among the genotypes, which ranged from 28.79 to 31.99 Qt ha^{-1} with a mean of 30.49 Qt ha^{-1}. Accession ILRI 5518 gave the highest mean grain yields (33.67 Qt ha^{-1}) followed by Bate variety (31.99 Qt ha^{-1}) while Jasari variety gave the lowest (28.79 Qt ha^{-1}) over locations. Besides, significant results ($p \leq 0.01$) were *observed in nutritive values for DM, IVOMD and OM among the tested genotypes while non-significant ($p > 0.05$) results were observed in crude protein and fiber quality parameters (NDF, ADF and lignin). Genotype and genotype by environment interaction biplot analysis (GGE) also confirmed that Bate variety showed better stability and thus ideal variety recommended for production in the tested environments and other areas with similar agro-ecologies.*
Keywords: *Avena sativa* L., Bate, Genotype, Herbage yield, Quality parameters

Introduction

The success and prosperity of livestock farming is determined by adequate and timely availability of feed. The green forages are major and the most economical source to fulfill the dietary needs of livestock. The insufficient fodder supply is characterized as major constrain of low animal performance for milk and meat production (Rana *et al*., 2014, Ahmad *et al*., 2014). On the other hand, the continuous and long term feeding with poor quality forage results in malnutrition in animals. Livestock feed resources in Ethiopia are mainly obtained from natural and improved pastures, crop residues, forage crops, agro-industrial by-products and non-conventional feeds (CSA 2012). The contribution of these feed resources, however, depends up on the agro-ecology, the type of crop produced, accessibility and production system (Ahmed *et al.,* 2010). Though, natural pasture is the major source of livestock feed in Ethiopia, its importance is gradually declining because of the expansion of crop production into grazing lands, redistribution of common lands to the landless and land degradation (Berhanu *et al.,* 2009). This and other feed resources related problems became initiating forces for the need of improved forage germplasm introduction and evaluation (like *Avana sativa*).

Oat (*Avena sativa* L.) is a cereal forage crop which belongs to poaceae family. It is used mostly for animal feeding and to some extent as human food. The use of oat as animal feed has declined steadily owing to emerging use and interest in oats as human health food (Ahmad *et al*., 2010). It is favorite feed of animals and its straw is soft and superior to wheat and barley. Oat grain is valuable feed for almost all categories of animals (Zaman *et al.,* 2006). Oat is a fast growing crop and produces a significant amount of fresh fodder within short period (60 to 70 days) with adequate nutritional facts. It contains large amount of digestible crude protein, total digestible nutrients (TDN), vitamin B1, minerals and fat. Thus far, one hundred three (103) *Avena sativa* genotypes were introduced and evaluated at Bako Agricultural Research Center resulting in a release of one oat variety with high performance against standard check across tested environments. Therefore, the objective of the study was to select the top performing oat varieties for variety release.

Materials and Methods

Eight genotypes of oats (*Avena sativa* L.) including two standard checks (Bonsa and Jasari) and one adopted variety (Jasari) were tested across locations (Bako and Billo) for three cropping season (2014-2016 G.C). The objective of the experiment was to evaluate the performance of *Avena sativa* genotypes for herbage DM yield and other agronomic parameters and their stability across environments. The tested accessions were ILRI 6710; ILRI 5453, ILRI 5518, ILRI 6207, ILRI 712, ILRI 8237, Jasari and Bonsa as standard check. The genotypes were arranged in randomized complete block design with three replications in which each plot comprises of six rows having 1.8 x 2.0 m length. Seeds were planted in rows spaced 30 cm apart. A 100 kg ha^{-1} DAP and 100 kg of urea fertilizer were applied in which split application urea was followed for urea. Recommended agronomic package of practices were followed to raise a healthy crop. Data from herbage yield, seed yield and other important agronomic parameters and forage quality parameters were measured as dependent variables. For forage quality analysis 200 g fresh biomass were taken and dried in an oven at 65^{o}c for 72 hours to a constant weight. Partially dried feed samples were ground to pass through a 1mm sieve screen using Wiley mill and stored in airtight plastic bags for chemical analysis. Data on herbage DM yield, grain yield and other agronomic traits were collected and analyzed using GenStat software.

Results and discussion

Varietal Origin/Pedigree and Evaluation

Bate is the name given by the breeder to a released Oat (*Avena sativa L.*) variety with the pedigree of *ILRI 5453*. *Bate* and the other Oat genotypes were originated from International Livestock research Institute (ILRI) and evaluated against the standard checks (Jasari and Bonsa) at two environments (Bako and Billo) in 2014, 2015 and 2016 main cropping seasons.

Herbage dry matter and Grain yield performances

Based on the analysis of results, two genotypes ILRI 6710 and Bate (*ILRI 5453*) beat other accessions in both quantitative and qualitative traits evaluated. Significant differences ($p \leq 0.01$) were observed among genotypes in mean herbage DM and grain yields. *Bate* variety has produced mean herbage DM yields of 8.56 ton ha^{-1} with 12.93 % ton ha^{-1} yield advantage over the standard check (Bonsa) which was produced 7.58 ton ha^{-1}. On top of that, as can be seen from the result, *Bate (ILRI 5453)* showed high herbage yield (DM ton^{-1}) advantage over the standard check (Bonsa) by 12.93 %. Besides, grain yields differed significantly ($p \leq 0.01$), which ranged from 28.79 to 31.99 Qt ha^{-1} with a mean of 30.49 Qt ha^{-1}. Bate variety gave the highest mean grain yield (31.99 Qt ha^{-1}) next to accession 5518 (33.67 Qt ha^{-1}) while Jasari variety gave the lowest (28.79 qt ha^{-1}) Table 1.

Table 1**:** Pooled mean value of herbage yields (DM ton ha^{-1}) and other agronomic parameters of Oat (*Avena sativa L.*) genotypes across environments (Bako and Billo) from the year 2014-2016 G.C.

Genotypes	PL	PH	GY	DMY	DMY Yield advantage %
ILRI 6710	27.38	131.17^{ab}	31.01^{ab}	9.03^{a}	19.13
Bate (ILRI 5453)	28.13	135.03^{a}	31.99^{ab}	8.56^{ab}	12.93
Bonsa (standard check)	26.12	126.33^{bc}	29.66^{bc}	7.58^{bc}	-
Jasari (local check)	28.13	130.78^{ab}	28.79^{c}	7.69^{bc}	1.45
ILRI 5518	27.39	132.97^{ab}	33.67^{a}	7.36^{c}	-2.90
ILRI 6207	27.16	131.47^{ab}	29.06^{bc}	7.74^{bc}	2.11
ILRI 712	28.20	129.58^{b}	30.07^{abc}	8.10^{abc}	6.86
ILRI 8237	26.97	132.50^{ab}	29.64^{bc}	8.21^{abc}	8.31
Mean	27.44	131.23	30.49	8.03	
CV %	9.9	6.1	18.8	20.6	
LSD (0.05)	1.81	5.37	3.77	1.1	
LS	NS	*	**	**	

Key: ns =none significant, **= highly significant, *=significant, PH=plant height, DMY=dry matter yield, PL=panicle length, GY=grain yield**,** CV=coefficient of variation, LS=Level of significance.

Nutritional Quality Analysis

The mean values of nutritional composition of oat (*Avena sativa*) genotypes tested were presented in table 2. **S**ignificant results ($p \leq 0.01$) were observed in nutritive values for DM, IVOMD and OM among the tested genotypes. The highest DM was recorded for genotype ILRI 6710 (61.22 %) which was closely followed by Bate variety (59.54 %) while ILRI 6207 showed the lowest DM content (52.22 %).

Table 2: Nutritive value of different accessions of Oat (*Avena sativa*)

Genotypes	DM%	% DM						
		Ash	CP	NDF	ADF	ADL	IVOMD	OM
ILRI 6710	61.22	8.26	6.81	67.19	47.42	3.65	66.03	52.96
Bate (ILRI 5453)	59.54	7.80	6.43	70.03	52.78	3.37	65.00	51.74
Bonsa (standard check)	57.86	8.25	5.92	71.61	54.31	3.84	61.24	46.35
Jasari (local check)	52.89	9.19	5.41	72.32	59.16	5.12	60.39	43.70
ILRI 5518	53.87	9.13	5.93	70.47	61.92	5.91	61.32	44.74
ILRI 6207	52.22	8.49	3.87	71.62	62.32	4.32	60.46	43.73
ILRI 712	54.38	9.01	5.82	72.00	60.55	6.18	59.77	45.37
ILRI 8237	52.43	8.93	4.06	71.46	56.88	5.56	60.43	43.51
Mean	55.55	8.63	5.53	70.84	56.92	4.74	61.83	46.51
CV	3.0	5.4	23.8	2.9	7.6	28.8	2.0	3.4
LSD (0.05)	3.93	1.11	3.09	4.88	10.23	3.31	2.93	3.79
Significance level	**	NS	NS	NS	NS	NS	**	**

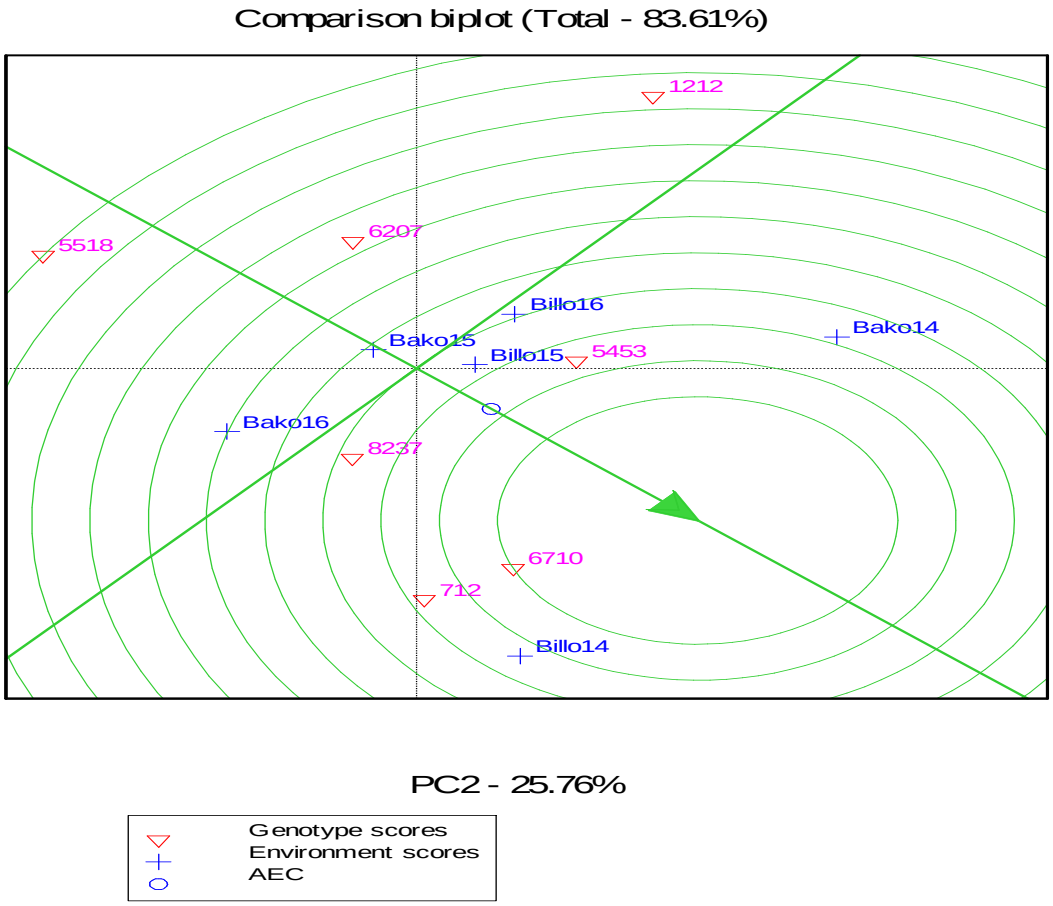
Note**:** NS, non-significant; **, significant at $p<0.01$; DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; IVOMD, *in vitro* organic matter digestibility; OM, organic matter; ADL= Acid detergent lignin CV, coefficient of variation.

Among the tested genotypes, the highest IVOMD was observed for genotype ILRI 6710 (66.03 %) followed by Bate variety (65.00 %). Similarly, Bate variety showed the highest OM content (51.74 %) next to genotype ILRI 6710 (52.96 %) while Jasari variety showed the lowest IVOMD and OM contents (60.39 and 43.70 % respectively). Whereas, non-significant results ($p>0.05$) were observed among the treatments in Ash, CP, NDF, ADF and LDF contents.

Stability of Performance/Adaptation

Yield stability parameters for tested oat genotypes for the three years at the two locations were studied based on the methods of Eberhart and Russel (1966). Analysis using the GGE biplot confirmed that genotype ILRI 6710 and Bate variety are the most stable and desired genotype as compared to the other genotypes since the regression coefficients approximating to unity and had one of the lowest deviations from regression and also have above average mean herbage DM yield. This implies that it has good general adaptability compared to the remaining tested genotypes in the test environments and similar agro-ecologies (fig.1).

Figure1. Stability and adaptability of pigeon pea genotypes across years and locations.



Besides, the *Bate* variety (ILRI 5453) showed herbage yield advantage of about 12.93 over the corresponding check.

Reaction to Major Diseases

Leaf and steam rust are economically importance diseases for cereal production (like fodder oat). In the present study some genotypes (ILRI 5518, Jasari, ILRI 8237 and ILRI 6710) were slightly infected by these diseases at few sites. But the rest oat genotypes including Bate variety were free of the stated diseases.

Table 3. Agronomic and morphological characteristics of Bate and Jasari varieties.

Characteristics	*Bate*	Jasari (check)
Adaptation area:		
Altitude (masl)	1500 – 3000	1500–3000
Rainfall (mm)	800 – 1200	800–1200
Seeding rate (kg/ha):	70-80 kg	70-80 kg
Spacing b/n rows (cm)	25 and drilling	25 and drilling
Planting time:	Mid July	Mid July
Fertilizer rate: (kg/ha):	P_2O_5: 46; N: 18	P_2O_5: 46; N: 18
Days to 50% flowering:	89	82
Days to seed maturity:	120	115
Height at biomass harvest (cm):	135.03	130.78
Life span	Annual	Annual
Flowering color	White	white
Seed color:	White	White
Seed size:	Oval	Oval
Thousand seed weight (g):	213	188
Yield		
Grain yield(qt ha^{-1})	32.99	27.79
Biomass yield (DM/t ha^{-1}:	8.56	7.69
Crop pest reaction (1-9 scale)		
B blight	1	2
Yellow rest	1	3
DM (%):	59.54	52.89
CP (%):	6.43	5.41
OM (%):	51.74	43.70
IVOMD (%):	65.00	60.39
Ash (%):	7.80	9.19
NDF (%):	70.03	72.32
ADF (%):	52.78	59.16
ADL (%)	3.37	5.12
Special merits:	High biomass and gain	
Year of release:	2018	
Breeder/maintainer:	(OARI/ BARC)	

Note: DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; IVOMD, *in vitro* organic matter digestibility; OM, organic matter,ADL= Acid detergent lignin.

Conclusion and Recommendation

In the present study, though, the genotype ILRI 6710 was found to be top in both quantitative and qualitative traits, it was rejected to be released due to oat rust infection which was observed during field evaluation. The released variety, Bate '*ILRI 5453'* has better herbage dry matter yield performance, grain yield, good general adaptability and resistant to oat rust as compared to the rest genotypes. The released variety also has better in nutritional quality, especially dry matter, organic matter and *invtro* digestibility. Therefore, smallholder farmers and other stockholders who are engaged in animal production can utilize the Bate variety as energy supplements for low quality feed resources.

References

Ahmad, M.A. Jabar, A. Khalique, Saima, F. Shahzad, N. Ahmad, M. Fiaz, U. Younas (2014). Effect of different levels of ndf on voluntary feed intake, dry matter digestibility and nutrients utilization in dry Nili Ravi buffaloes, J. Anim. Pl. Sci., 24 (6) (2014), pp. 1602-1605

Ahmed H, Abule E, Mohammed K, Tredate AC (2010) Livestock feed resources utilization and management as influenced by altitude in central high-lands of Ethiopia. Livest Res Rural Dev 2(12):125–132.

Berhanu G, Adane H, Kahsay B (2009) Feed marketing in Ethiopia: results of rapid market appraisal. Improving productivity and market success (IPMS) of Ethiopian farmers project working paper 15. ILRI (International Livestock Research Institute), Nairobi, Kenya, 64 pp.

CSA (2012) Federal democratic Republic of Ethiopia. Central Statistical Agency. Statistical Abstract (CSA), Addis Ababa, Ethiopia

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

Rana A.S, Ahmad A.U.H., Saleem N, Nawaz A., Hussian T., Saad M. (2014) Differential response of sorghum cultivars for fodder yield and quality J. Glob. Innov. Agric. Soc. Sci., 2 (1) (2014), pp. 6-10

Zaman, Q., Hussain, M.N., Aziz, A. and Hayat, K. (2006) Performance of High Yielding Oat Cultivars under Agro-Ecological Conditions of D. I. Khan. *Journal of Agricultural Research*, 44, 29-35.

Evaluation of Napier Grass (Pennisetum purpureum) Genotypes for Forage Yield, Agronomic and Quality Traits under Different Locations in Western Oromia

Mekonnen Diribsa*, Abuye Tulu, Waqgari Keba, Gutu Fekeda, Warku Temesgen
Oromia Agricultural Research Institute, Bako Agricultural Research Center, PO Box 03, Bako, Oromia, Ethiopia
Corresponding author* e-mail: mokedisa2000@gmail.com and Mobile: 09 13 92 31 56

Abstract

*The experimental materials comprised of ten Napier grass (Pennisetum purpureum) genotypes including standard check were evaluated for herbage dry matter (DM,) yield potential and quality across three environments (Bako, Billo and Gute) in western Oromia, Ethiopia during 2016 and 2017 main cropping season. The tested genotypes were ILRI 16804, ILRI 16801, ILRI 16787, ILRI 16785, ILRI 16798, ILRI 16800, ILRI 15743, ILRI 14389, ILRI 16840 and ILCA-16984 (standard check). The genotypes were planted in randomized complete block design with three replications. A blanket basal NPS and urea fertilizer was used at the rate of 100 kg ha^{-1} each and split application was used for urea. All recommended agronomic managements were applied uniformly. Pooled analysis of variance for herbage DM yield showed significant ($p \leq 0.001$) differences among the genotypes (G), environments (E), ($p \leq 0.05$) and genotype by environment interaction. Similarly, survival rate showed significant ($p \leq 0.001$) differences among the genotypes and environments, ($p \leq 0.01$) genotype by environment interaction. However, the G*E interaction effect for other quantitative traits measured were showed non-significant results. Significant differences ($p \leq 0.001$) were observed in herbage DM yields among the tested accessions across environments and years. The overall mean value of herbage DM yield (ton ha^{-1}) was 33.79 with lower value of 27.59 for accession ILRI 16798 and upper value of 45.43 for accession ILRI 16804. Genotypes including ILRI 16804, ILRI 16801 and ILRI 16800 had higher ($p \leq 0.001$) herbage yields of 45.4, 39.5 and 38.3 t ha^{-1} with 49.71 %, 30.07 % and 26.19 % yield advantages, respectively over the check (30.35 ton ha^{-1}). In quality parameters the averaged DM was 56.57 %, with values ranging from 53.34 % for accession ILRI 16840 to 61.18 % for accession ILRI 16801. The highest CP, DOMD and OM contents were recorded for ILRI 16804 followed by ILRI 16801 and ILRI 16800. The lowest NDF, ADF and Lignin were observed for ILRI 16804 followed by ILRI 16801 and ILRI 16800. Genotype and genotype by environment interaction biplot analysis (GGE) also confirmed that ILRI 16804, ILRI 16801 and ILRI 16800 showed better stability and thus ideal varieties recommended for verification in the tested environments and other areas with similar agro-ecologies.*

Key words: Genotype, Herbage yield, Leaf to stem ratio, Napier grass, Quality parameters,

Introduction

Despite high livestock population and existing favorable environmental conditions, the current livestock contribution is below its potential due to various factors, of which lack of improved breed, scarcity of quality feed and poor health management are the major constraints (Berhanu *et al.*, 2009; Dawit *et al*., 2013; Getahun, 2012; Selamawit *et al*., 2017). This resulted in low growth rates, poor fertility and high mortality rates of ruminant animals in the country. Increased livestock production can be achieved through the cultivation of high-quality forages with high yielding ability that are adapted to biotic and abiotic environmental stresses in Ethiopia (Tesema *et al.,* 2010). Amongst the recommended improved forage crops

in Ethiopia, Napier grass could play an important role in providing a significant amount of biomass yield of 20-30 t DM/ha/year with good agronomic management practices (Farrell *et al.,* 2002). Napier grass cultivars have been reported to yield around 60 tonnes dry matter/ha/year, with some studies indicating significantly higher yields (Rengsirikul K. *et al*., 2013; Oliveira M.L.F. *et al.,* 2014). The yield of Napier grass mainly depends on the type of cultivar used which in turn is influenced by both the environment and management practices employed.

Napier grass is the forage of choice worldwide due to its desirable traits such as tolerance to drought and adaptability to a wide range of soil conditions and high photosynthetic and water-use efficiency (Anderson *et al.,* 2008). It is a pioneer species and performs well in low, mid and highland areas of Ethiopia and propagated vegetative by using stem cuttings, root splits which usually vary across agro-ecologies (Tessema, 2008; Getnet *et al*, 2012). The grass can provide a continual supply of green forage throughout the year and mainly used in cut-and carry feeding systems and best fits to all intensive small scale farming systems (Alemayehu, 1997; FAO, 2015). Genotypic variation in growth and morphological characteristics of Napier grass are correlated with DM yield and nutritional quality. Based on chemical composition and *in-vitro* dry matter digestibility (IVDMD), it could be categorized as high quality forage and extremely palatable when young and leafy (Tessema, 2002, Cook *et al.,* 2005). Testing the adaptability and yield potential of Napier grass is very important to identify the best bet varieties for research and development works. Accordingly, the evaluation of Napier grass accessions for basic quantitative and qualitative traits was conducted to address the feed demand of mixed farming systems in the country. Therefore, the objective of this study was to evaluate and identify the best performing Napier grass varieties for wide production in the tested environments and other areas with similar agro-ecologies.

Materials and methods

Experimental design and layout

The present study comprised of 10 diverse genotypes of Napier grass (*Pennisetum purpureum*): ILRI 16804, ILRI 16801, ILRI 16787, ILRI 16785, ILRI 16798, ILRI 16800, ILRI 15743, ILRI 14389, ILRI 16840 and ILCA-16984 (standard check). The genotypes were collected from International Livestock Research Institute (ILRI) and screening activities (nursery evaluation and preliminary variety trial) were conducted at Bako Agricultural Research Center and resulted in selection of the current genotypes. The experiment was evaluated for herbage dry matter (DM) yield potential and quality across three environments (Bako, Billo and Gute) in western Oromia, Ethiopia during 2016 and 2017 main cropping season. The genotypes were planted in a randomized complete block design with three replications. Stem cuttings with three nodes were planted on an area of 4 m x 3 m plot size to a depth of 15-20 cm at an angle of 45^{o}. The intra and inter row spacing of 0.5 m and 0.6 m respectively with 2 m width between blocks and 1 m width between plots were used. A blanket basal NPS fertilizer was used at the rate of 100 kg ha^{-1} and 100 kg of urea fertilizer were applied in which split application was followed for urea. All recommended agronomic managements were applied uniformly. For determination of biomass yield, genotypes were harvested at forage harvesting stage (at about 120 cm heights) from the two middle rows of 5

cm above the ground level. Weight of the total fresh biomass yield was recorded from each plot and 200 g sample was taken to the laboratory. The sample taken from each plot was dried in an oven for 72 hours at a temperature of 65^0c to a constant weight. Partially dried feed samples were ground to pass through a 1mm sieve screen using Wiley mill and stored in airtight plastic bags and pending for farther chemical analysis at Holota National Nutrition Laboratory. Survival rate data was measured in simple calculation by dividing the number of alive crops to the number of planted crops and multiplying by 100. This was conducted at the final stage of the experiment (during the second season of the experimental period).

Statistical Analysis:

Differences among accessions were subjected to analysis of variance (ANOVA) following general linear model (GLM) procedure of SAS (SAS, 2002). Least significance difference (LSD) at 5% significance level was used for comparison of means. The model for data analysis was:

$Yijk = \mu + Gi + Ej + (GE)ij + Bk(j) + e\ ijk$; Where, Yijk = measured response of genotype i in block k of environment j; μ = grand mean; Ti = effect of genotype i; Ej = effect of environment j; GE= genotype and environment interaction; Bk (j) = effect of block k in environment j; e ijk = random error effect of genotype i in block k of environment j

Results and Discussion

Combined analysis of variance

The combined Analysis of variance showed significant differences ($p \leq 0.001$) among genotypes and environments for herbage DM yield and survival rate (Table 1)**.** The result indicated that significant ($p \leq 0.01$) location effects were observed for both leaf to steam ration and plant height. On the other hand, the genotypes displayed significant ($p \leq 0.05$) variations for leaf to steam ration but showed non-significant results for plant height. Similarly, highly significant variations between Napier grass accessions for herbage DM yield were reported in previous studies (Gezahagn *et al.,* 2016). Genotype by environment interaction was found to be significant ($p \leq 0.05$) for herbage DM yields and ($p \leq 0.01$) for survival rate. However, the G*E interaction effect for other quantitative traits measured were showed non-significant results, which indicated that the accessions responded uniformly across environments for those traits.

Table 1: Mean squares for 4 basic quantitative traits of Napier grass accessions evaluated across three locations; Bako, Billo and Gute

Source of variation	DF	DMY	L/S	PH	SR
Genotype	9	591***	0.3448*	3433	924.99***
Environment	2	3535.92***	1.745**	15836**	2057.51***
G*E	18	14.21*	0.3405	2455	191.91**
Error	147	14.08	0.3624	2457	96.82
CV (%)		9.0	25.7	23.3	13.9
LSD (0.05)		4.9	0.26	77.24	13.91
Mean		33.8	1.1	110.3	61.7

*= p<0.05; ** = p<0.01; *** = p<0.001; G x E= Genotype by environment interaction DF: Degree of freedom, DMY: herbage yield in dry mater bases, L/S: Leaf to steam ratio, PH: Plant height, SR: Survival rate.

Yield performances of quantitative traits

Pooled analysis of variance for herbage DM yield and other quantitative traits of different Napier grass accessions evaluated across six environments is indicated in Table 2. Significant results ($p \leq 0.001$) were observed among Napier grass genotypes for herbage dry matter yields, number of tiller, survival rates and number of nodes ($p \leq 0.05$) while the rest parameters were showed non-significant results (Table 2). Herbage DM yield (ton ha^{-1}) ranged from 27.6 for accession 16798 to 45.4 for accession 16804. Such great variation among the tested accessions across testing environments indicated that effective selection and sustainable improvement of the accessions by combining the desirable traits. Similarly, number for tiller ranged from 13 for accession 16840 to 19 for accession 16804 and the average survival rate across environments and years ranged from the lowest of 53.1 % for accession 16785 to the highest of 74.1 % for accession 16804 were recorded. Accessions 16800, 16801 and 16804 showed higher survival rate of 68.9, 70.7 and 74.1 %, respectively than the other accessions. Likewise, accessions 16800, 16801 and 16804 gave the maximum leaf to steam ration of 1.2, 1.3 and 1.2 across locations, respectively. Steam dry matter yield and Leaf dry matter yield also showed significant ($p \leq 0.05$) results among the tested Napier grass accession. The mean values of number of nodes significantly ($p \leq 0.01$) affects the Napier grass accessions in this study.

Table 2. Pooled mean herbage yield (DM t/ha) and other agronomic yield parameters across locations (Bako, Billo and Gute) from the year 2016 and 2017

Genotypes	HDMY	LDMY	SDMY	L/S	NoT	NoN	LIN	PH	SR %
ILRI 16804	45.4^{a}	1.2	0.9	1.2	18.5^{a}	6.7^{ab}	10.7	109.0	74.1^{a}
ILRI 16801	39.5^{b}	1.3	1.0	1.3	15.2^{bcd}	7.0^{ab}	11.4	107.6	70.7^{a}
ILRI 16800	38.3^{b}	1.3	1.1	1.2	14.8^{cde}	7.1^{a}	11.0	114.5	68.9^{a}
ILCA-16984 (check)	30.4^{d}	1.1	1.1	1.1	14.1^{de}	7.2^{a}	11.3	104.6	56.9^{bcd}
ILRI 16798	27.6^{e}	1.0	1.0	1.0	15.9^{bcd}	6.6^{abc}	10.7	106.8	53.7^{cd}
ILRI 16840	30.4^{d}	1.1	1.1	1.0	13.0^{e}	7.1^{a}	10.8	146.5	59.2^{bc}
ILRI 15743	30.7^{d}	1.2	1.1	1.1	13.1^{e}	6.8^{ab}	11.2	110.6	60.4^{b}
ILRI 16787	29.8^{d}	1.1	1.0	1.0	16.3^{bc}	5.9^{c}	11.1	105.7	59.2^{bc}
ILRI 14389	36.0^{c}	1.1	1.0	1.2	18.7^{a}	6.4^{bc}	11.6	103.2	61.1^{b}
ILRI 16785	29.9^{d}	1.0	1.1	1.0	17.1^{ab}	6.3^{bc}	10. 6	94.0	53.1^{d}
Over mean	33.8	1.1	1.0	1.1	15.7	6.7	11.01	110.3	61.7
CV	9.0	14.5	18.9	25. 7	20.1	15.7	15.7	43.3	13.9
LSD (0.05)	4.9	0.25	0.32	0.2 6	5.105	1.71	2.79	77.24	13.91
LS	***	ns	ns	ns	***	**	ns	ns	***

*HDMY=herbage dry matter yield, LDMY=Leaf dry matter yield, SDMY=Steam dry matter yield, L/S= Leaf to steam ratio, NoT=Number of tiller, NoN= Number of nodes, LIN= Length of internodes, PH= Plant height and SR= Survival rate in percentage

Herbage DM yield performances

Table 3 shows the mean herbage DM yield for Napier grass accessions across environments and years. Results from the analysis of variance for herbage DM yield revealed significant effect ($p \leq 0.001$) among the tested accessions across environments and years. The herbage DM yields (ton ha^{-1}) ranged for 18.11 to 31.47 at Bako, 24.72 to 41.22 at Billo and 30.44 to 41.65 at Gute during the 2016 cropping season. Similarly during the year of 2017 similar trends were observed with mean values ranged from 24.62 to 38.81 at Bako, 38.28 to 60.17 at Billo and 43.29 to 59.29 at Gute.

The combined mean values of herbage DM yield (ton ha^{-1}) averaged 33.79 with lower value of 27.59 for accession ILRI 16798 to upper value of 45.43 for accession ILRI 16804 found in the current study is greater than the results reported by Gezahang *et al*. (2016) which ranged from 7.97 to 12.57 with an average value of 11.04 ton ha^{-1}. The three accessions ILRI 16804, ILRI 16801 and ILRI 16800 had higher ($p \leq 0.001$) herbage yields of 45.4, 39.5 and 38.3 t ha^{-1} with 49.71 %, 30.07 % and 26.19 % yield advantage, respectively over the check (30.35 ton ha^{-1}). A maximum mean herbage DM yield (ton ha^{-1}) was recorded during the 2^{nd} year (2017) across locations as compared to 1^{st} year (2016). The considerable variations observed between years in DM yields among the Napier grass accessions in this study is closer to what was reported earlier (variation in DM yields between years among Napier grass accessions) and this observation agreed with reports of Seyoum *et al.*, (1998) and Tessema, (2005). This might be due to the perennial nature of Napier grass, which produces many tillers and dense vegetative growth as the pasture consolidates (Tesema *et al.*, 2010). Harvesting stage, plot cover and plant height at harvesting stage can be affected by Napier grass herbage DM yields. Previous findings reported that increasing foliage height increased biomass yield (Boonman, 1993 and Tessema *et al*., 2003). According to Tesema Z. (2005) and Ishii *et al.* (2005), the taller varieties showed higher dry matter yields than the shorter varieties.

Herbage Quality Parameters

The chemical composition of the feed samples is presented in Table 4. The analysis of variance indicated that statistically significant ($p \leq 0.01$) differences were observed among the Napier grass accessions in percentages of CP and DOMD. Significant ($p \leq 0.05$) differences were also perceived for ash and OM. However, no statistically significant differences were observed among the ten Napier grass accessions for DM, NDF, ADF and lignin.

Table 3. Mean Herbage Dry matter yields (ton ha^{-1}**)** of different Napier grass genotypes across environments and years

	2016			2017				
Accession	Bako	Billo	Gute	Bako	Billo	Gute	Meam	Yield Adv %
ILRI 16804	31.47^{a}	41.22^{a}	41.65^{a}	38.81^{a}	60.17^{a}	59.29^{a}	45.43	49.71
ILRI 16801	26.13^{b}	40.02^{a}	32.35^{bcd}	34.19^{b}	49.14^{b}	55.02^{ab}	39.47	30.07
ILRI 16800	24.72^{b}	38.15^{ab}	32.66^{bc}	33.15^{b}	48.12^{bc}	52.97^{b}	38.29	26.19
ILCA-16984 (check)	19.73^{cd}	30.08^{c}	26.82^{ef}	27.60^{cd}	36.92^{e}	40.93^{cde}	30.35	-
ILRI 16798	16.22^{f}	27.00^{cd}	23.84^{f}	22.18^{e}	39.10^{de}	37.18^{e}	27.59	-9.10
ILRI 16840	20.09^{cd}	27.50^{cd}	28.59^{de}	25.12^{de}	41.11^{d}	40.00^{de}	30.40	0.18
ILRI 15743	18.87^{cde}	28.22^{cd}	28.69^{cde}	23.85^{de}	39.51^{de}	45.16^{c}	30.72	1.22
ILRI 16787	16.52^{ef}	25.80^{d}	26.60^{ef}	26.27^{d}	38.48^{de}	44.87^{c}	29.76	-1.95
ILRI 14389	20.83^{c}	36.08^{b}	33.20^{b}	30.37^{bc}	44.72^{c}	50.54^{b}	35.96	18.48
ILRI 16785	18.11^{def}	24.72^{d}	30.44^{b-e}	24.62^{de}	38.28^{de}	43.29^{cd}	29.91	-1.44
Mean	21.27	31.88	30.48	28.62	43.56	46.93	33.79	
CV %	7.2	6.7	7.7	7.9	4.7	5.9		
LSD (0.05)	2.644	3.687	4.038	3.887	3.482	4.712		
F-value	***	***	***	***	***	***		

Table 4: Mean nutritive value of different accessions of *Napier grass* regional variety trial of three locations.

Genotypes	DM %	% DM						
		Ash	CP	NDF	ADF	Lignin	DOMD	OM
16804	90.68	6.61^{c}	8.32^{a}	63.11	43.20	7.25	60.74^{ab}	84.07^{ab}
16801	90.99	7.12^{c}	7.36^{ab}	63.51	43.26	7.49	59.59^{ab}	83.87^{ab}
16800	91.35	6.83^{c}	7.05^{bcd}	64.38	43.26	7.94	52.1^{cd}	84.52^{a}
ILCA-16984 (check)	90.11	7.80^{bc}	5.42^{e}	65.50	43.29	8.04	52.73^{cd}	82.32^{abc}
16798	89.26	8.77^{ab}	6.12^{cde}	64.60	44.34	7.58	51.49^{cd}	80.49^{c}
16840	89.74	7.84^{bc}	5.92^{de}	65.52	43.24	7.85	47.95^{de}	81.90^{abc}
15743	89.44	9.37^{a}	5.99^{de}	64.68	43.65	7.27	51.83^{cd}	80.07^{c}
16787	89.12	7.90^{abc}	6.90^{bcd}	63.96	43.59	7.77	54.54^{bc}	81.22^{bc}
14389	87.67	8.01^{abc}	7.17^{abc}	64.03	39.78	7.58	52.49^{cd}	79.66^{c}
16785	89.79	8.66^{ab}	5.89^{de}	65.61	43.24	7.85	44.31^{e}	81.13bc
Grand Mean	89.81	7.89	6.61	64.39	43.09	7.66	52.78	81.92
CV %	1.8	10.9	10.3	4.9	6.0	4.6	6.0	2.2
LSD (0.05)	2.717	1.478	1.168	5.430	4.438	0.602	5.413	3.038
F-value	Ns	*	**	ns	ns	ns	**	*

Key: DM%= Dry matter percentage, CP= Crude protein, NDF= Natural detergent fiber, Acid detergent fiber, DOMD= Digestible organic matter in dry matter

The mean DM content of the Napier grass accessions was 89.81 %, with values ranging from 87.67 % for accession ILRI 16798 to 91.35 % for accession ILRI 16800. The mean ash content was 7.89 %, with values ranging from 6.61 % for accession ILRI 16804 to 8. 77 % for ILRI 16798. This indicated that as ash value increased the quality of the forage material decreased and vice versa. The CP content averaged 6.61 % ranging from 5.42 % for accession ILCA-16984 to 8.32 % for accession ILRI 16804. The OM content was significantly ($p \leq 0.05$) higher for accessions ILRI 16800 with mean values of 84.52 % followed by ILRI 16801 (84.07 %) and ILRI 16801 (83.87 %). Similarly, the DOMD was significantly ($p \leq 0.01$) higher for ILRI 16804 and 16801 with mean values of 60.74% and 59.59 %, in that order. As regards to fiber quality, the lowest ADF and NDF were displayed by ILRI 16804 (43.2 and 63.11%, respectively).

Genotype and Genotype by Environment Interaction (GGE) Biplot Analysis

Yield stability parameters for the ten Napier grass genotypes for two years at the three locations were studied based on the methods of Eberhart and Russel (1966). Analysis using the GGE biplot, IPCA-1 and IPCA-2 explained 63.34 and 22.39 %, respectively, of Napier grass accessions by environment interaction and made a total of 95.60 %. (Fig 1).

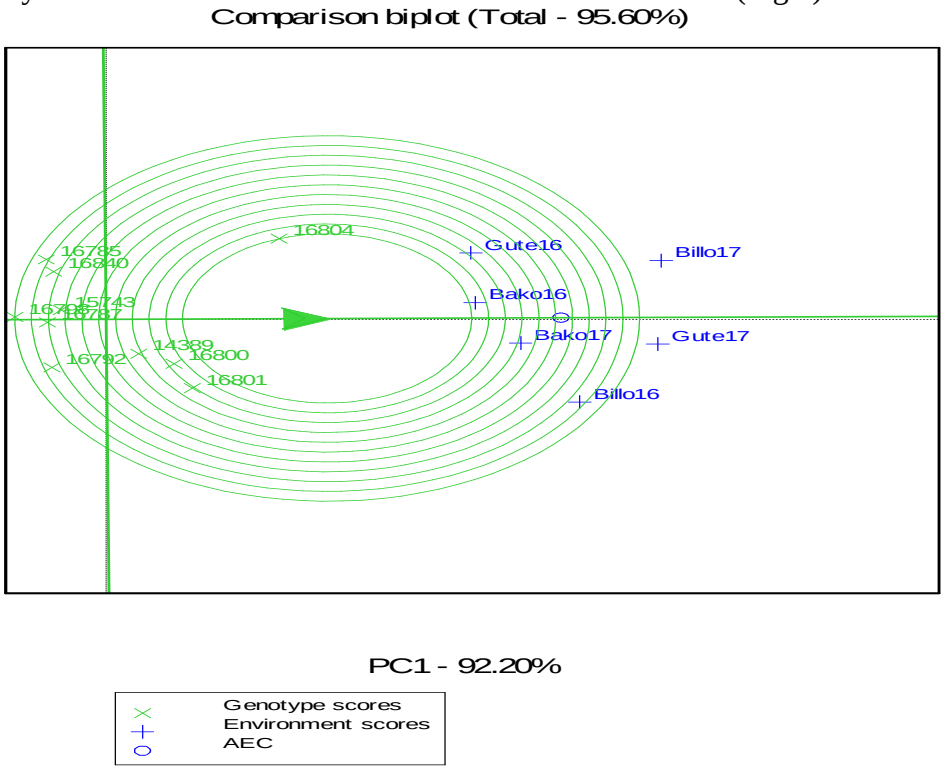


Fig1. GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability.

Environments and genotypes that fall in the central (concentric) circle are considered as ideal environments and stable genotypes, respectively (Yan W.*et al*., 2001). Therefore, accession 16804 fell into the center of concentric circles and thus ideal genotype in terms of higher yielding ability and stability, as compared to other accessions. Likewise, accessions 16801 and 16800 located on the next concentric circle and also considered as desirable genotypes.

Conclusions and Recommendation

Based on the results obtained it can be concluded that better herbage DM yield was recorded for three of the accessions evaluated: ILRI 16804, ILRI 16801 and ILRI 16800. The environments, genotypes and their interaction significantly affected the Napier grass accessions in herbage DM yields and survival rates. Considerable variations were observed between years in DM yields among the Napier grass accessions. The study also indicated that, the accession ILRI 16804, ILRI 16801 and ILRI 16800 had a better nutritional quality due to their higher content of DM, CP, OM and ODMD and lower fiber contents. Analysis using the GGE biplot confirmed that accession 16804 was ideal genotype in terms of higher yielding ability and stability followed by accession 16801 and 16800 as compared to other accessions. Therefore, these accessions are recommended to be verified for variety release.

References

Alemayehu Mengistu, 1997. Conservation based forage development for Ethiopia. Self Help Development International and Institute for Sustainable Development. Berhanena Selam Printing Press, Addis Ababa, Ethiopia. Pp 197.

Anderson, W.F., Dien, B.S., Brandon, S. K., Peterson, J. D. 2008. Assessment of Bermuda grass and bunch grasses as feed stocks for conversion to ethanol. *Applied Biochemistry and Biotechnology,* 145:13–21. DOI: 1007/s12010-007- 8041-y AOAC, 1990. Official Methods

Berhanu G, Adane H, Kahsay B (2009). Feed marketing in Ethiopia: Results of rapid market appraisal. Improving Productivity and Market Success (IPMS) of Ethiopian farmers project Working Paper 15. ILRI (International Livestock Research Institute), Nairobi, Kenya. p 64.

Boonman JG. (1993): East Africa's grasses and fodders: Their ecology and husbandry. Kluwer Academic Publishers, Dortrecht, Netherlands, p. 341.

Cook, B. G., Pengelly, B. C., Brown, S. D., Donnelly, J. L., Eagles, D. A., Franco, M. A., Hanson, J., Mullen, B. F., Partridge, I. J., Peters, M., Schultze-Kraft, R. 2005. Tropical forages. CSIRO, DPI&F(Qld), CIAT and ILRI, Brisbane, Australia.

Dawit A, Ajebu N, Sandip B (2013). Assessment of feed resource availability and livestock production constraints in selected Kebeles of Adami Tullu Jiddo Kombolcha District, Ethiopia. Afr. J. Agric. Res. 8(29):4067-4073

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

Farrell, G., Simons, S. A. and Hillocks, R. J. 2002. Pests, diseases and weeds of Napier grass, Pennisetum purpureum: a review. *Journal of pest management,* 2002, 48 (1) 39-48.

Food and Agricultural Organization (FAO), 2015. Grassland Index. A searchable catalogue of grass and forage legumes. FAO, Rome, Italy.

Getahun D (2012). Assessment of the Livestock Extension Service in Ethiopia: The Case of Southern Region. Int. J. Sci. Technol. Res. 1(10):24-30.

Getnet Assefa and Gezahagn Kebede, 2012. Seed Research and Development of Perennial Forage Crops in the Central Highlands. In: Getnet Assefa, Mesfin Dejene, Jean Hanson, Getachew Anemut, Solomon Mengistu & Alemayehu Mengistu (eds.). Forage Seed Research and Development in Ethiopia. Proceedings of workshop held on

12- 14 May, 2011 at EIAR, Addis Ababa, Ethiopia. ISBN: 978-99944- 53-84-9. Hagerman, A.

Gezahagn K., Fekede F.,, Getnet., Mengistu A., Alemayehu M., Aemiro K., Kassahun M., Solomon M.1, Estifanos T., Shewangizaw W., & Mergia, 2016) Evaluation of Napier Grass (*Pennisetum purpureum* (L.) Schumach) Accessions for Agronomic Traits under Different Environmental Conditions of Ethiopia**.** .*International Journal of Advanced Research (2016), Volume 4, Issue 4, 1029-1035*

Ishii, Y., Yamaguchi, N. and Idota, S. (2005): Dry matter production and in vitro dry matter digestibility of tillers among Napier grass (*Pennisetum purpureum Schumach*) varieties. Grassland Science 51: 153-163.

Oliveira M.L.F., Daher, R.F., Gravina, G.D.A.., da Silva V.B., Viana A.P., Rodrigues E.V., Shimoya A., Junior A.T.D.A., Menezes B.R.D.S., Rocha A.D.S. (2014). Pre-breeding of Elephant grass for energy purposes and biomass analysis in Campos dos Goytacazes-RJ, Brazil. Afr. J. Agric. Res. 2014, 9, 2743–2758.

Rengsirikul K., Ishii Y., Kangvansaichol K., Sripichitt P., Punsuvon V., Vaithanomsat P., Nakamanee, G., Tudsri S.(2013). Biomass yield, chemical composition and potential ethanol yields of eight cultivars of Napier grass (*Pennisetum purpureum* Schumach.) harvested 3-monthly in central Thailand. J. Sustain. Bioenergy Syst. 2013, 3, 107.

Selamawit D, Yeshambel M., Bimrew A (2017). Assessment of livestock production system and feed balance in watersheds of North Achefer District, Ethiopia. J. Agric. Environ. Int. Dev. 111(1):159-174.

Seyoum, B. and Zinashi, S., Tadesse, T.T. and Liyusew, A. 1998. Evaluation of Napier (*Pennisetum purpureum*) and Pennisetum hybrids (*Pennisetum purpureum* x *pennisetum typhoides*) in the central highlands of Ethiopia. Proceedings of the 5th National Conference of the Ethiopian Society of Animal Production (ESAP), May 14-17, 1997. Addis Ababa, Ethiopia, pp. 194-202.

Tesema Z.K., Alemayehu Mengistu (2010). Management of Napier Grass (*Pennisetum Purpureum* (L.) Schumach) for High Yield and Nutritional Quality in Ethiopia: A Review, *Eth. J. Anim. Prod. 10(1) - 2010: 73-94*

Tessema Zewdu, Baars R, Alemu Yami, Dawit N. (2003): Effect of plant height at cutting and fertilizer on growth of Napier grass (*Pennisetum purpureum* (L.) Schumach.). Tropical science 43: 57-61.

Tessema Zewdu, Baars R, Alemu Yami, Dawit N. 2002. In sacco dry matter and nitrogen degradability and their relationship with *in- vitro* dry matter digestibility of Napier grass (Pennisetum purpureum (L.) Schumach.) as influenced by plant height at cutting. *Australian J. Agric. Research*, 53: 7-12.

Tessema Zewdu. (2005): Variation in growth, yield, chemical composition and in vitro dry matter digestibility of Napier grass varieties (*Pennisetum purpureum*). Trop. Sci. 45: 67-73.

Tessema, Z. 1999. Napier Grass Adapts Well in North Western Ethiopia. *AgriTopia*. EARO, Vol.14 No. 1 1999.

Tessema, Z. 2008. Effect of plant density on morphological characteristics, yield and chemical composition of Napier grass (Pennisetum purpureum (L.) Schumach). East *African Journal of Sciences* 2:55–61. DOI: 10.4314/ eajsci.v2i1.40365

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.

Fish diversity assessment and Fishing Gear Evaluation of Muger River

Mathewos Hailu * and Alemu Lema
Oromia Agricultural Research Institute (OARI), Batu Fishery and other Aquatic Life Research Center, PO Box 229, Ziway
*Corresponding Author: Mathewos Hailu, mathewos_hailu@iqqo.org

Abstract
Assessment on fish diversity and fishing gear was carried out in Muger River, a sub basin of Nile river, during dry and wet season between December 2017 and June 2018, to assess the diversity, condition and evaluate fishing gears. The length-weight relationships were fitted using power equation for the identified fish species. A total of 64 fish specimens were collected using gillnets and beachside. Family Cyprinidae was the most dominant with three species and one cihilid was identified. The identified species were *Varicorhinus beso. Labeobarbus intermidus*, *Raiamas senegalensis* and *Oreochromis niloticus. Varicorhinus beso* was dominant with percent Index of relative importance (IRI) of 44.75 followed by *Varicorhinus beso* and *Oreochromis niloticus* with percent IRI of 24.12 and 21.66, respectively.
Key Words: Fish diversity, Nile basin, Relative index

Introduction

Ethiopia has 12 river basins with a mean annual flow estimated as 122 billion m^3 (Awulachew et al., 2007) and a total length of all rivers estimated as 8065 km. All the rivers are international but no perennial flow crosses into the Ethiopian river drainage system (NWDR, 2004). Ethiopia is rich in inland water bodies with diversified fish species composed of Nilo-Sudanic, East African, and endemic form. A study by Golubstov and Darkov (2008) provided a basin-wide summary of the nation's ichthyofaunal diversity. According to this work, the nation's major basins, namely, Baro-Akobo (White Nile within Ethiopia), Abay (Blue Nile within Ethiopia), OmoTurkana, Tekeze-Atbara, Shebelle-Genale, and Rif Valley basins, , have 113, 77, 76–79, 34, 33, and 31 fish species, respectively.

Although the total number of fish species found in the country has not been known, the fish species that have so far been described can be categorized as Nilo Sudanic, highland East African and endemic forms (Roberts, 1975). There are also about 10 exotic fish species introduced from abroad into Ethiopian fresh waters (Shibru Tedla & Fisseha H/Mesqel, 1981). The number of endemic fish species of the country is estimated to range from 37 to 57 (Golubtsov and Mina, 2003).

Having diverse fish fauna in rivers provides the basis for a fishery, which are pursued with a great variety of gear whether for subsistence, income or recreation. Unfortunately, there is little information on total landings and consumption of riverine fish (Tesfaye and Wolf, 2014). Little attention was given to the riverine capture fisheries in Ethiopia. The nature of the inland fishery varies according to the target species and character of the river basin in which it is undertaken. Most fishing activity is concentrated in the vicinity of lakes near cites. The

seasonality of rainfall produces a gradual change in the volume of rivers, generating an annual flood pulse closely associated with fish migrations. In the rainy season, many species make extensive longitudinal migrations upriver to reproduce. These seasonal movements generate substantial shifts in fish density and assemblage composition throughout the year (Saint-Paul et al., 2000).

The study on the diversity of the Ethiopian fish fauna still remains far from complete largely owing to the large expanse of its geography and limited surveys. Many of the drainage basins, especially the rivers, are not exhaustively explored (Getahun, 2007). Muger river is among such rivers that lack studies on the diversity and associated biological characters of the fish fauna. The central aims of this study were to test if fish assemblage composition in Muger river varies between rainy and dry seasons and to evaluate the selectivity of gears on fish size and fish assemblages. Specifically, we tested for differences in the number of species detected, total fish abundance and assemblage composition between dry and rainy seasons, and whether there exist changes in fish assemblages with respect to fishing gear selectivity.

Materials and Methods

Study area

The study was conducted in Muger river, one of the sub basins of Nile river located at Yaya Gulale District of North Shewa Zone, Oromia Regional State in central Ethiopia. The district is located at 170 km from the capital Addis Ababa. Two sampling sites were selected from Muger river based on flow nature and accessibility. The sampling sites are located relatively at higher altitude (>1500 m above sea level). The channel diameter of the sampling sites ranged from 40 to 100 meter. The sampling sites had clear water with sandy, gravel, and rocky bottom.

Fish Sampling and Identification.

Fish samples were collected during one wet season and one dry season between December 2017 and June 2018. Fish specimens were collected using gillnets of various mesh sizes (six, eight, ten and twelve cm stretched mesh) and beach seins. Gillnets were set late in the afternoon and collected early in the morning the next day. The same extent of fishing effort was used across the seasons and sites. Identification of the fish specimens was made to species level using relevant taxonomic literature (Habteselassie, 2012; Froese & Pauly, 2018). Both total length (TL) and total weight (TW) measurements were taken, to the nearest 0.1 cm and 0.1 g, respectively. Ultimately, voucher specimens from each species were preserved in 10% formalin solution and transported to Batu fish and Other Aquatic Life Research Center where they were deposited. Length (L, cm) and weight (W, g) relationships were developed by regression of log W against log L for each species, producing values for the parameters a and b in the length–weight equation $W= aL^b$. The statistical significance of r^2 was estimated and the b value was tested using the t-test to verify if it were significantly different to the isometric (b =3). Estimation of the relative abundance of fishes in the study river was made by comparing the relative catch in number and weight in the total sampling. An index of relative importance (IRI), which is a measure of the relative abundance or commonness of the species based on number and weight of individuals in catches, as well as their frequency of occurrence (Kolding, 1998), was computed as:

$$IRI = \frac{(\%\, W_i + \%\, N_i) * \%\, F_i)}{\sum_{j=1}^{S}(\%\, W_j + \%\, N_j) * \%\, F_j} * 100$$

Where, $\%W_i$ and $\%N_i$ are percentages weight and number of each species of total catch, respectively; $\%F_i$ is a percentage frequency occurrence of each species in total number of settings; $\%W_j$ and N_j are percentage weight and number of total species in total catch. F_j is percentage frequency of occurrence of total species in total number of settings.

All analyses were performed with the R statistical software (R Core Team, 2017) and the respective libraries. To test for differences in fish assemblage attributes between seasons, analyses of variance (ANOVA) on the total number of fish caught and the total number of species as dependent variables was conducted. As the number of species detected can be a function of the number of individuals caught (Gotelli and Colwell, 2001).

Results and Discussion

A total of 64 specimens belonging to four species were identified in Muger River. In Muger river, the family Cyprinidae consisting three species was dominant. The species were *Varicorhinus beso. Labeobarbus intermidus*, *Raiamas senegalensis* and *Oreochromis niloticus* (Figure 1.). Table 1 shows the sample size, length range, parameters a and b, and coefficient of determination (r^2) and their statistical significance.

Figure 1. Fish species composition of Muger River at Yaya Gulale; A. Oreochromis niloticus B. Raiamas senegalensis C. Raiamas senegalensis D. Varicorhinus beso

Table 5. Length range, parameters a and b, and coefficient of Fishes in Muger River

Species	Length range (cm)	**A**	**B**	**r^2**	**%IRI**
Oreochromis niloticus	13-26	0.0101	3.02	0.97	21.66
Labeobarbus intermidus	4.5-20.5	0.0269	3.18	0.9754	24.12
Raiamas senegalensis	21-24.5	0.0057	2.74	0.9399	9.47
Varicorhinus beso	13.5-25	0.013	2.96	0.8867	44.75

Varicorhinus beso was dominant with % IRI of 44.75 followed by *Varicorhinus beso* and *Oreochromis niloticus* with IRI of 24.12 and 21.66, respectively. Among the fishing gears

evaluated monofilament gillnet (10 cm mesh) was found to be effective in dry season while, there is no significance difference between gillnet with 6 cm mesh size and beach seine with similar mesh size. The number of species and total number of fish caught did not differ between seasons (r^2 = 0.02, P = 0.453). The absence of seasonality differences in the number of species captured per site, is rarefied the number of species taken or removed the most abundant species. This indicates that the common fish species caught more consistently in surveys confer predictability in fish assemblages along environmental gradients, such as in the physical characteristics of streams and water quality (Mendonca et al., 2005).

The considerable differences in the number of species inhabiting the various river systems are largely attributable to the size of the river as represented by its basin area or some correlate of it such as length of main channel or stream order (Saint-Paul et al., 2000). Inland capture fisheries extract fish and other living organisms from surface waters inland and deliver nutritional security and income to hundreds of rural households (Welcomme et al. 2010). Inland fish resources also provide a wide range of other ecosystem services.

Management of inland fisheries varies according to the objectives, which are related to the types of use as well as socioeconomic factors connected with the associated stakeholders. The means by which this is done include the management of exploitation (e.g. fishing effort or size limits), the management of fish habitat and the use of fisheries enhancements (Welcomme et al. 2010; Arlinghaus et al. 2016).
Riverine fishery in Ethiopia is practiced using a variety of gear, most of which are passive in nature. Common fishing gear includes the cast net, long lines, pole and lines and fish traps. The use of poisons i.e. *Milletia ferruginia*, is banned in Ethiopia but pit is practiced during fish migration in many areas (Asmare, 2016).

Conclusion and Recommendation

The use of Beach seine with mesh size of six centimeter and greater can provide for sustainable use of artisanal fisheries in Muger river. The catch per unit effort was low in Muger river suggesting that the fish in the river can be used for local consumption than market value. Awareness creation on promoting aquaculture to supplement riverine fisheries could insure the sustainability of fisheries in the area. Prohibiting the use of poisoning plant materials like *Milletia ferrugunia* should be considered while implementing regional fisheries proclamation.

References

Arlinghaus R, Lorenzen K, Johnson BM, Cooke, SJ and Cowx, IG. 2016. Management of freshwater fisheries: addressing habitat, people and fishes. In: Craig JF (ed) Freshwater fisheries ecology. Wiley, Chichester, pp 557–579

Asmare E, Demissie S and Tewabe D. 2016. Fisheries of Jemma and Wonchit Rivers: As a Means of Livelihood Diversification and its Challenges in North Shewa Zone, Ethiopia. Fish Aqua J 7: 182.

Awulachew SB, Yilma AD, Loulseged, M., Loiskandl, W, Ayana M and Alamirew T. 2007. Water resources and irrigation development in Ethiopia. Working Paper No. 123. InternationalWater ManagementInstitute, Colombo, Sri Lanka 78 pp.

Froese R. and Pauly D. (eds). 2011. Fish Base. World Wide Web electronic publication. http://www.fishbase.org, (accessed on 22 May 2011).

Getahun A. 2007. An overview of diversity and conservation status of the Ethiopian freshwater fish fauna. Journal of Afrotropical Zoology, 87–96.

Golubstov A and Darkov, A. 2008. A review of Fish Diversity in the main Drainage systems of Ethiopia, in Ecological and Faunistic Studies in Ethiopia, S. Dmitry, Pavlov, Y. Dgebuadge, A. Andrey,and M. Mina, Eds., JERBE 20 Years Scientifc Cooperation, Addis Ababa, Ethiopia.

Golubtsov and Mina, M.V. 2002. Fishes of the Ethiopian Rift Valley. Pp., 167-258. In: C. Tudorancea and W.D.Taylor (eds.) Ethiopian Rift Valley Lakes. Backhuys Publishers, Leiden, Holland.

Gotelli NJ. and Colwell RK. 2001. Quantifying biodiversity: procedures and pitfalls in the measurement and comparison of species richness. Ecology Letters, 4, 379–391.

Habteselassie R. 2012.Fishes of Ethiopia. Annotated Checklist with Pictorial Identification Guide, Ethiopian Fisheries and Aquatic Science Association, Addis Ababa, Ethiopia. P. 250.

Mendonca FP, Magnusson W.E. and Zuanon J. 2005. Relationships between habitat characteristics and fish assemblages in small streams of Central Amazonia. Copeia, 4, 750–763.

NWDR. 2004. National Water Development Report for Ethiopia. UN-WATER/WWAP/2006/7 Addis Ababa, Ethiopia, 284 pp

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Roberts TR. 1975. Geographical distribution of African freshwaterfishes. Zool. J. Linn. Soc. 57: 249 – 319

Saint-Paul U, Zuanon J, Correa MAV, Garcia M, Fabre NN, Berger U and Junk WJ. 2000. Fish communities in central Amazonia white and black water flood plains. Environmental Biology of Fishes, 57, 235–250

Shibru T and Fisseha H. 1981. Introduction and transplantation of Freshwater fish species in Ethiopia. SINET: Ethiop. J. Sci., 4: 69 – 72

Tesfaye, G and Wolff, M. 2014. The state of inland fisheries in Ethiopia: a synopsis with updated estimates of potential yield. Ecohydrology & Hydrobiology 14: 200–219

Welcomme RL, Cowx IG, Coates D, Bene C, Funge-Smith S, Halls AS and Lorenzen K .2010. Inland capture fisheries. Philos Trans R Soc B 365:2881–2896

NATURAL RESOURCE RESEARCH

Validation of Phosphorus Requirement Map for Teff (*(Eragrostis teff (Zucc.*) in Lume District of East Shewa Zone, Oromia, Ethiopia

Reta Worku[1], *Tilahun Abera[1], Kefyalew Asefa[2], Tilahun Firomsa[1], Tadesse Hunduma[1], Bekele Abebe[1]
[1]Batu Soil Research Center, P.O.Box: 59, Batu, Ethiopia
[2]Oromia Agricultural Research Institute, Addis Ababa, Ethiopia
Corresponding Author: Batu Soil Research Center, e-mail: tileabera3@gmail.com,

Abstract
Teff productivity and production have been far below the potential as compared to other small cereals grown in Ethiopia because of many yield limiting factors, primarily blanket fertilizer recommendation. To shift from blanket fertilizer recommendation to soil test crop response based recommendation, Batu Soil Research Center has undertaken soil test crop response based fertilizer P calibration study on teff for Lume District. Further for easy use of this recommendation the center produced nutrient requirement map that to be validated. Accordingly field trial was carried out on nine sites in the district for two seasons, 2015/16 and 2016/17 to validate the quality of nutrient requirement map on grain yield and yield component of teff. The treatments consisted of control (unfertilized plot), blanket (100/100 NPS/urea kg/ha), P-map (phosphorus applied from nutrient requirement map) and P-required (Pc-P0)P_f) that were arranged in simple adjacent plots and replicated over nine sites. The analysis of variance indicated that teff grain yield of P-map and P-requirement treatments were significantly different ($P<0.05$) compared to other treatments, while biomass yield was significantly different from no fertilizer application (control); and harvest index was significantly ($P<0.05$) influenced by different rates of phosphorus fertilizer application as compared to control. P-map (phosphorus applied from nutrient requirement map) gave the highest grain yield (2178 kg ha^{-1}) and biomass yield (6639 kg ha^{-1}) with harvest index of 34.11%. Moreover, the economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of P-map (phosphorus applied from nutrient requirement map) for teff production was recommended in Lume District.*

Key words: Blanket recommendation, P-map, P-required, teff, validation of nutrient requirement map

Introduction
Teff (*Eragrostis tef* (Zucc.) Trotter) is the major cereal crop in Ethiopia as well as in Oromia. The crop has both its origin and diversity in Ethiopia and plays a vital role in the country overall food security. Teff performs well in Ethiopia at the most suitable altitude of 1800-2200masl, annual rainfall of 900-1400mm and mean annual temperature of 9-29°C (Tan *et al*., 2016).It has been grown for long years and currently produced on 0.1 and 0.03 million hectares annually in the country and Oromia, respectively (CSA, 2016), with production of 1.1 and 0.3 million quintals in Ethiopia and Oromia, respectively. Teff plays appreciable role

in supplying the society of the country with protein, carbohydrates, and minerals. The most preferred staple food Injera, traditionally made out of teff flour, is a national dish which is unique to Ethiopia and Eritrea (Girma and Ababa, 2010). It contains 11% total carbohydrates, 24% dietary fiber, 10% thiamine, 2% riboflavin, 4% niacin, 8% calcium and 20% iron and is free from saturated fat, sugar and cholesterol (Purcell Mountain Farms, 2008).

In recent years, teff has been receiving global attention as healthy food because of its gluten-free nature that renders it suitable for people suffering from gluten allergy known as celiac disease. In addition, the straw is important cattle feed source and the high market prices of both its grains and the straw make it a highly valued cash crop for teff-growing smallholder farmers. Doris (2002) reported that teff contains 11% protein and is an excellent source of essential amino acids, especially lysine, the amino acid that is most often deficient in grain foods. It contains more lysine than barley, millet, and wheat and slightly less than rice or oats. He further mentioned that teff is excellent source of fiber and iron, and has many times the amount of calcium, potassium and other essential minerals found in an equal amount of other grains.

However, its productivity is hampered by low and declining soil fertility resulting in deficiency of essential plant nutrients such as phosphorus which is one of the most limiting nutrients; it is supplemented in crop production with blanket recommendation without considering agro-ecology, environmental effects, spatial and temporal soil fertility variations; hence this method is inefficient economically by increasing production costs and environmental hazards. So soil test crop response based P fertilizer application is important to improve the trend and increase crop yield, dependable and important method to identify the rates required in attaining needed level of plant growth and yield.

Despite the large-scale production and various merits, teff productivity and production have been far below the potential. Currently the average national productivity is 0.92 t ha^{-1}, which is very low as compared to other small cereals grown in Ethiopia. This is because of many yield-limiting factors of which low soil fertility being among the most important (Mwangi, 1995). To feed the ever increasing population and generate income, continuous cultivation of land became a common practice in major teff producing areas, which eventually led to soil fertility decline and subsequent reduction of crop yields. Thus, as noted by Mwangi (1995) the use of inorganic fertilizer is critical to increase crop yield.

Gruhn *et al.* (1995) suggested that the levels of the fertilizer being used are very low and this must be increased to meet the demand for food with population growth. In many cases farmers are being forced to either not use or use low rates of fertilizer due to high fertilizer costs. Use of blanket recommendation rate irrespective of soil variations, however, was found to be one of the discouraging factors to farmers producing teff on relatively fertile soils. Thus, cost effective use of fertilizers on teff, which is low yielder and at the same time the most expensive grain crop in Ethiopia, is very crucial. Fertilizer recommendations are site, crop and soil specific; hence fertilizer rates should also be established for each site or crop and soil separately.

A fundamental assumption of site specific soil fertility management is that economically optimum application rates of fertilizers are used. However, application of P-required is not easily applicable to farmers, it needs soil sampling, laboratory analysis which is cost, time taking and may not accessible for resource poor farmers. To solve this critical problem developed nutrient requirement map for teff using geo-statistical interpolations mainly Ordinary kriging to predict for non-sampled locations based on laboratory results of available P (Singh *et al*, 2010) and Pc (phosphorous critical level) and Pf (phosphorous requirement factor which rise soil P by one ppm) that were developed by calibration studies conducted for teff (Kefyalew *et al*., 2017); because farmers and development agents can easily get nutrient needed for their farm by reading from nutrient requirement map equally instead of P-required.

But the maps created with commonly used sampling and interpolations procedures may be found marginally to poor-quality in some cases. Therefore planners and users should evaluate map quality at test sites before adoption of maps for the whole recommendation (Mueller *et al*, 2001). Soil nutrient requirement map quality can be evaluated by comparing yield and yield component response of fertilizer rate of P-map and fertilizer rate calculated from P requirement (PR) from P-initial, P-critical and P-requirement factor. Hence validation of these maps is very important to demonstrate outputs by supporting with field trials. Therefore, the objectives this study were to validate the previously developed nutrient requirement map of Lume District and promote soil test teff response based phosphorus fertilizer recommendation, and to introduce soil fertility and nutrient requirement map in Lume District.

Materials and Methods

Description of the study area

The trial was conducted on 9 farmers' fields in 9 Peasant Associations (PAs) in Lume District of East Shewa Zone of Oromia in Central Ethiopia, 73 km far from Finfinne (Addis Ababa) to the East. Geographically the district is located between 8^0 27'00" to 80 49'00" North and 39^0 5'00" to 39^0 16'00" East with total area coverage 67514.73ha; altitude ranges from 1590-512masl, and average elevation is 1909masl. Location map with different soil types of the district is showed in Figure 1.

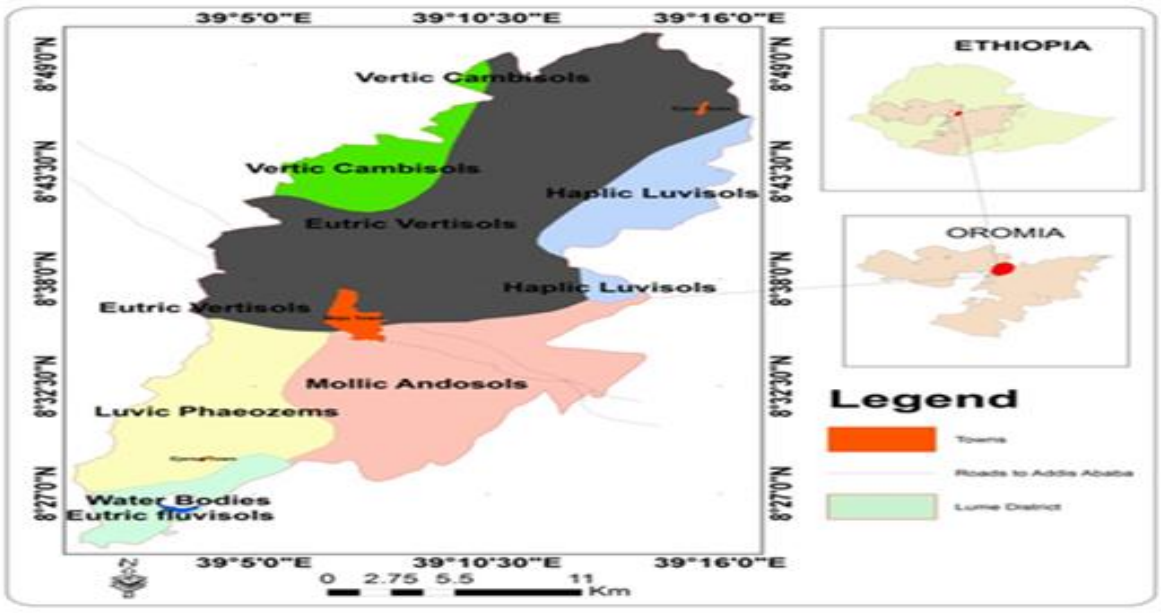
Materials

Boset teff variety was used for the trial as planting material, compound fertilizer in the form of NPS (19% N, 38% P_2O_5 and 7% S) used as a source of N:P:S and recommended optimum nitrogen (46kg N/ha) as urea for additional application, and GPS for field coordinate data recording (geo-referenced) and ArcGIS software for map development.

Methodology

Soil nutrient requirement map quality can be evaluated by comparing predicted and observed soil properties. Predicted and measured values can be determined either within validation or cross validation analysis. The maps were developed through soil sample collected from each mapping units developed at stage of base map preparation. These samples were analyzed for each parameter like NPK, pH, CEC, EC and texture at Batu Soil Research Center laboratory.

These outputs were initially geo-referenced and by using ArcGIS10.1 their maps were developed by geo-statistical interpolation mainly Ordinary Kriging.



.
Figure 1. Location map of Lume District

Farmers research extension group (FREG) establishment

The study was conducted on farmers' fields across the district for two consecutive years. First, nine different PAs were selected for two years systematically based on their accessibility and potential for teff production. From these selected PAs, nine FREGs, each consisted of 10-15 members for each PAs were organized considering gender and youth (40% women) with full participation of development agents (DAs). Then after training was given for these FREGs, one model farmer who can provide farm land for teff production and coordinate the group was selected from each FREG, based on their willingness, with active participation of local DAs. Finally, one composite soil sample at 0-20cm depth was collected from each farm land in zigzag sampling method. After labeling the sample, it was taken to Batu Soil laboratory and analyzed for available P in order to identify the level of P in the soil to calculate amount of P nutrient to be applied for teff field trial.

Land preparation was managed using local ox plow by farmers with close supervision of researchers and DAs; because all field management activities were accomplished by farmer, and hence the approach was cost-sharing mechanism (farmers provided farm land and handled all aspects of field management while center provided all agricultural inputs, technical support, training and guidance). Generally, with continuous field management, there were data collections across the sites with full participation of DAs and farmers, and regular group discussion with farmers and DAs to assess change in level of knowledge and skill of them to identify training need based on observed gaps in each crop growing stages. Besides, to popularize or for advocacy purpose, mini-field day was organized at maturity stage of the crop.

Soil sampling and analysis

Validation of nutrient requirement map involves independent sample collection and compares measured and estimated values for every validation points. Accordingly, based on nutrient requirement map (Figure 3), from teff growing potential PAs, farmers having different rates of fertilizer application and land unit with large area coverage were identified; and 20-25 composite soil samples were collected from each field at 0-20cm depth from willingly selected 9 farmers' of 9 FREGs established. Collected composite soil samples were tagged and taken to center soil laboratory for analysis. The soil samples were air dried, ground, and sieved using 2 mm sieve, and analyzed for soil texture, soil pH, EC and available phosphorus, using standard laboratory procedures at Batu Soil Research Center.

Available phosphorus was determined by the Olsen's method using spectrophotometer (Olsen *et al.*, 1954). Soil pH was measured in water at soil to water ratio of 1:2.5 (Reeuwijk, 1992). EC was also measured in water at soil to water ratio of 1:2.5 by using Electrical conductivity meter. Soil texture was analyzed by Bouyoucous hydrometer method (Bouyoucous, 1951). After the samples were analyzed in laboratory based on their coordinate points and related soil phosphorous values and crop phosphorous critical level, i.e., teff phosphorous requirement was determined as the following equation.

PR= (PC- PO)* Pf Whereas PR = Phosphorus requirement; PC = Phosphorus critical; and Pf = Phosphorus requirement factor

Treatments

There were four treatments used for validation trail in 2015/16 and 2016/17 for two years that included teff phosphorus nutrient requirement (PR), P-map that developed for teff using fertility map, blanket recommendation (100kg/ha NPS and 100kg/ha urea) and control (without fertilizer application), while value of PR for teff was calculated from already determined phosphorous critical and requirement factor of teff for the district (Kefyalew et al., 2017). Where Pc = 13ppm and Pf = 3.65ppm and applied P = (Critical P - Po)* Pf. Validated nutrient requirement map of teff in Lume District is showed in Figure 1. The treatments were arranged in simple adjacent plots with nine replications over sites. The gross plot size was 10mx10m ($100m^2$). Spacing of 1.0m and 0.5m was maintained in between adjacent blocks and plots, respectively for road and harvested plot was 2mx2m ($4m^2$). The details of the treatments are showed in Table 1. Nitrogen fertilizer in the form of urea (46% N) was used according to the recommended rate of 46 kg N ha^{-1} (Kefyalew et al., 2016), and the amount of N found in NPS fertilizer was deducted for additional urea application.

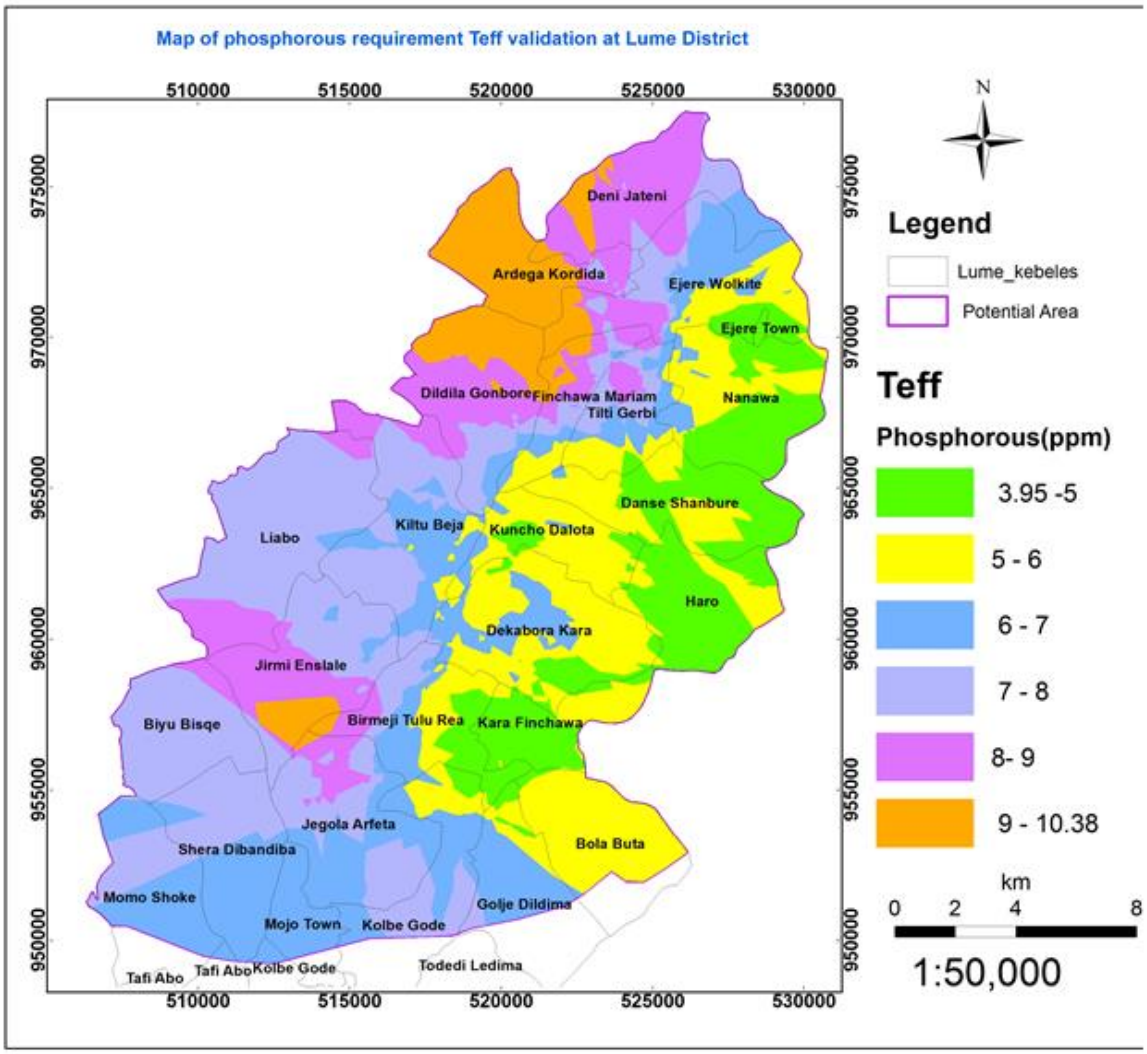


Figure 2. Validated nutrient requirement map of teff in Lume District

Table 1. Rates of fertilizer treatments used for validation of nutrient requirement map for teff (kg/ha)

sites	P-required		P- map		Blanket		Control
	Po (ppm)	P applied *Pc=13,Pf=3.65*	Po (ppm)	P applied *Pc=13,Pf=3.65*	NPS	Urea	No fertilizer
1	6.56	23.51	7.2	21.17	100	100	0
2	10.54	8.98	4.6	30.66	100	100	0
3	9.56	12.56	5.9	25.92	100	100	0
4	8.02	18.18	5.9	25.92	100	100	0
5	15.46	0	5.9	25.92	100	100	0
6	10.26	10.00	7.2	21.17	100	100	0
7	12.1	3.29	4.6	30.66	100	100	0
8	16.7	0	5.9	25.92	100	100	0
9	8.42	16.72	7.2	21.17	100	100	0

Where, Po= initial soil phosphorus, Pc= critical soil phosphorous, Pf= phosphorous requirement factor, biomas, P-map= phosphorus applied from nutrient requirement map, **P**-required = (Pc-P0)*P_f); Blanket= farmer practice

Management of trial field

The trial field was prepared following the conventional tillage practice which included four times plowing before sowing of the crop. As per the specification of the treatments, field layout was prepared; the plot was leveled and made suitable for crop establishment. Sowing was in July 2016 using seed rate of 30 kg ha^{-1}. Full dose of phosphorous as per the treatment and one-half of N alone was applied at sowing. The remaining one-half of N was top dressed at mid-tillering (after 30 days of planting). Other necessary agronomic practices were carried out uniformly for all treatments. The crop was harvested at maturity and was sun dried till constant weight before threshing.

Data collection

Biomass yield: was determined from net plot area harvested plants after sun drying to a constant weight and expressed in kg ha^{-1}.

Grain yield: was taken by harvesting and threshing the grain yield from net plot area. The yield was adjusted to 12.5% moisture content and expressed as yield in kg ha^{-1}.

Harvest index (HI): was calculated as ratio of grain yield per plot to biomass yield per plot expressed as percent.

Statistical analysis

The data were subjected to analysis of variance (ANOVA) as per the experimental design using GenStat (15^{th} edition) software (GenStat, 2012). The Least Significance Difference (LSD) at 5% level of probability was used to determine differences between treatment means.

Partial budget analysis

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 was referred to as dominated and un-dominated 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.

Results and Discussion

Yield and yield component

The analysis of variance indicated that teff grain yield of treatments P-map and P-requirement were significantly different from all other treatments at P<0.05, but biomass yield showed non significant difference among treatments which were significantly different from the control. However, harvest index was insignificantly (P<0.05) influenced by different rates of phosphorus fertilizer application except for control (Table 2).

Table 2. Grain and biomass yield, and harvest index of Boset teff variety as influenced by different rates of phosphorus application

Treatment	GY(kg ha^{-1})	BM (kg ha^{-1})	HI (%)
P-required	2061 ^{a}	6111 ^{ab}	36.11 ^{a}
P-map	2178 ^{a}	6639 ^{a}	34.11 ^{a}
Blanket	1694 ^{b}	5556 ^{b}	30.97 ^{a}
Control	711 ^{c}	3472 ^{c}	22.42 ^{b}
LSD (0.05)	349	852.3	5.514
CV (%)	21.9	16.1	26.3

Means within a column followed by the same letter are not significantly different at 5% significant level according to Fisher protected LSD test; BM = Biomass yield; GY = Grain yield; HI% = Harvest index; Pr = phosphorus required (25 kg P ha^{-1}); P-map = phosphorus predicted (10 kg P ha^{-1}), Blanket (100/100 NPS/urea kg ha^{-1}), control (no fertilizer application)

As indicated in Table 2, the highest grain yield (2178 kg ha^{-1}), and biomass yield (6639 kg ha^{-1}) were obtained by P-map, except harvest index (36.11%), which was resulted from P-required. The lowest grain yield (711 kg ha^{-1}), biomass yield (3472 kg ha^{-1}) and harvest index (22.42%) were resulted from no fertilizer application. P-map increased teff grain yield and biomass yield by 138% and 60% over control treatment, 297% and 20% over blanket fertilizer application, respectively. Therefore, P-requirement and P-map treatments were similar in results and using validated P-map might be useful in P fertilizer application for teff production in Lume District. Moreover, use of P-map minimizes farmers' soil sampling, traveling, and generally, cost of laboratory analysis to determine P-requirement of the crop in the district.

Partial budget analysis

To identify treatments with the optimum return to farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered as worthwhile to farmers, 100% marginal rate of return (MRR) was the minimum acceptable rate of return (CIMMYT, 1988). As indicated in Table 3, the partial budget and dominance analysis showed that the highest net benefit 39545 Birr ha^{-1} with the highest marginal rate of return 1250% was

obtained from treatment P-map (phosphorus applied from nutrient requirement map), while the lowest net benefit 14220 Birr ha^{-1} was obtained from the control treatment. According to this result, a farmer who applies P-map based P fertilizer for Boset teff variety will earn 12.15 Birr per one Birr invested. Moreover, both P-required and P-map based P fertilizer application have been worthwhile to farmers (above the minimum acceptable rate of return, 100% marginal rate of return (MRR) and with almost similar net return.

Table 3. Partial budget and marginal analysis of treatment applied over nine sites for teff

Treatments	P (kg ha^{-1})	N (kg ha^{-1})	Adjusted grain yield down wards by 10% (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR %
Control	0	0	711	14220	0	14220	-
Blanket	16.5	65	1694	33880	2949	31366	D
P-required	25	17.3	2178	43560	2595	40965	331
P-map	10	11.6	2061	41220	1675	39545	1215

Where, NPS cost = 14.54 Birr kg^{-1}, urea cost = 10.60 Birr kg^{-1} of N, NPS, teff grain yield per ha= 20 Birr kg^{-1}, MRR (%) = Marginal rate of return, D= Dominated treatment, Control = unfertilized

Conclusion and Recommendation

Evaluation of the quality of P nutrient requirement map on grain yield and yield component of teff was carried out in Lume District. The highest grain yield (2178 kg ha^{-1}), and biomass yield (6639 kg ha^{-1}) were obtained by P-map, except harvest index (36.11%) was resulted from P-required. The partial budget analysis showed that the highest net benefit 39545 Birr ha^{-1} with the highest marginal rate of return 1250% was obtained from treatment P-map (phosphorus applied from nutrient requirement map), while the lowest net benefit 14220 Birr ha^{-1} was obtained from no fertilizer application (control). According to this result, a farmer who applies P-map based P fertilizer for Boset teff variety will earn 12.15 Birr per one Birr invested. Therefore, P-map based P fertilizer application was useful with almost similar net of return with P-required and recommended for teff production in Lume District. This P-map based P fertilizer application can help farmers not take and transport soil samples to analyze in soil laboratory. In general, the following recommendations will be suggested (1) teff production using P fertilizer rate based on P-map will benefit farmers in Lume District, (2) For easy applicability of this P-map based recommendation of P fertilizer application, user guideline should be developed and provided for farmers with P-map, and (3) validating the P-map at certain interval will be very essential to assess soil fertility change in the district.

References

Central Statistics Authority (CSA), 2016. Agricultural sample survey. Report on area and production of major crops Meher (main rainy) season for private peasant holdings in Ethiopia. Statistical bulletin 578. Addis Ababa, Ethiopia.

CIMMYT Economics Program, International Maize and Wheat Improvement Center, 1988. *From agronomic data to farmer recommendations: an economics training manual* (No. 27). CIMMYT.

Kefyalew Assefa, Tilahun Firomsa and Tadesse Hunduma. 2016. Verification and Demonstration Pc and Pf Determined Through Soil Test Based Crop Response Study for P on Bread WheaTefft at Lume Area of Oromia Region, Ethiopia. International Journal of Research and Innovations in Earth Science Volume 3, Issue 6, ISSN (Online): 2394-1375oris Piccinin (2002), "More about Ethiopian Food: Teff", University of Washington, USA.

Girma A, Ababa A (2010). Teff: The Story of Ethiopia's Biodiversity.

Gruhn, P., Goletti, F. and Yudelman, M.(1995), "Fertilizer, plant nutrient management, and sustainable agriculture: Usage, problems and Challenges", In Gruhn, P., F. Goletti, and R.N. Roy (eds.), Proceedings of the IFPRI/FAO workshop on plant nutrient management, food security, and sustainable agriculture: The future through 2020, International Food Policy Research Institute and United Nations Food and Agriculture organization, May 16-17, 1995, Viterbo, Italy.

Kebebew Assefa, Solomon Chanyalew and Zerihun Tadele (eds.), 2013. Achievements and Prospects of Tef Improvement; Proceedings of the Second International Workshop, November 7-9, 2011, Debre Zeit, Ethiopia. Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia; Institute of Plant Sciences, University of Bern, Switzerland. Printed at Stampfli AG, 3001 Bern, Switzerland. ISBN: 978-3-033-03818-9.

Ketema S (1993) Tef (Eragrosits tef), Breeding, agronomy, genetic resources, utilization and role in Ethiopian agriculture. Institute of Agricultural Research.

Ketema S., 1993. "Phenotypic variations in Tef (*Eragrostis tef*) germplasm-morphological and agronomic traits," A Catalon Technical Manual 6, Institute of Agricultural Research, AddiAbaba, Ethiopia.

Mueller T. G., F. J. Pierce, O. Schabenberger, and D. D. Warncke, 2001. Map Quality for Site-specific Fertility Management. Soil Sci. Soc. Am. J. 65:1547–1558.

Mwangi, W. (1995), "Low use of Fertilizers and Low Productivity in Sub-Saharan Africa", Proceedings of the IFPRI/FAO Workshop on plant nutrient management, food security, and sustainable agriculture: The future through 2020, International Food Policy Research Institute and United Nations Food and Agriculture organization, May 16-17,1995, Viterbo, Italy

Purcell Mountain Farms (2008), "INGREDIENTS: Whole Grain Teff. Nutrition Facts"

Seyfu, K., 1993. Tef (Eragrostis tef). Breeding, genetic resources, utilization and role in Ethiopia agriculture. lAR, Addis Ababa, Ethiopia.

Singh.K.N.Abhishek Rathore,A.K.Tripathi,A.Subba Rao and Salman Khan,2010. Soil Fertility Mapping and its Validation using spatial prediction techniques. Indian Institute of Soil science, Bhopal.

Tan, Z., Yang, Y., Wang, Y., Wang, L. and Sun, G., 2016. The decrease of potential suitable areas and the distribution tendency of staple crops in Ethiopia under future climate conditions. *African Journal of Agricultural Research*, *11*(24), pp.2092-2101.

Validation of Phosphorus Requirement Map for Bread Wheat in Lume District of East Shewa Zone, Oromia, Ethiopia

*Tilahun Abera[1], Reta Worku[1], Tilahun Firomsa[1], Kefyalew Asefa[2], Tadesse Hunduma[1], Bekele Abebe[1]

[1]Batu Soil Research Center, P.O.Box: 59, Batu, Ethiopia
[2]Oromia Agricultural Research Institute, Addis Ababa, Ethiopia
Corresponding Author: tileabera3@gmail.com,

Abstract
Fertilizer recommendations have been blanket type for bread wheat production in Ethiopia. To shift from blanket fertilizer recommendation to soil test crop response based recommendation, Batu Soil Research Center has conducted soil test crop response based P fertilizer calibration study on bread wheat for Lume District. The center has also developed fertility status map for P requirement. For easy use of this recommendation, it has to be validated and nutrient requirement map has to be developed. Consequently, field trial was carried out on nine sites in Lume District in 2015/16 and 2016/17 for two years to validate the quality of nutrient requirement map on grain yield and yield component of bread wheat. The treatments consisted of control (unfertilized plot), blanket application (100/100 kg/ha NPS/urea), P-map (phosphorus applied from nutrient requirement map) and P-required (Pc-P0)P_f) that was managed in simple adjacent plots and replicated over nine sites (Peasant associations, PAs). The analysis of variance indicated that bread wheat grain and biomass yield, and harvest index were significantly ($P<0.05$) influenced by treatments applied. P-required (Pc-P0)*P_f) gave the highest grain yield (4039 kg ha^{-1}) and biomass yield (9964 kg ha^{-1}). While the lowest grain yield (1072 kg ha^{-1}) and biomass yield (3294 kg ha^{-1}) and harvest index (32.03%) were resulted from unfertilized plot. Moreover, economic analysis revealed that for a treatment to be considered as worthwhile to farmers (100% marginal rate of return) application of P-map (phosphorus applied from fertilizer requirement map) was profitable for bread wheat production and recommended for farmers in Lume District.*

Key words: Bread wheat, Blanket recommendation, P-map, P-required, Validation of nutrient requirement map

Introduction

Wheat is among the dominant crops in crop production of Ethiopia; approximately 80% of the wheat area in Ethiopia is planted to bread wheat (Negasa *et al*. 2013). It ranked fourth after tef (*Eragrostis tef*), maize (*Zea mays*) and sorghum (*Sorghum bicolor*) in area and production during 2015-16 cropping season, (CSA, 2016). It is mainly grown in the highlands, which lie between 6 and 16° N latitude and 35 and 42° E longitude, in altitude ranging from 1500-2800masl and with mean minimum temperatures of 6-11°C (MoA, 2012). It covered an area of 1.66 million ha with a total production of 4.21million tons and mean productivity of 2.5t ha^{-1} during 2015-16 cropping season (CSA, 2016).

Fertilizer recommendations are blanket type without consideration of soil and climatic conditions in Ethiopia. Such practice leads to inefficient use of fertilizers by the crop since the

amount to be applied can be more or less than the crop requires. As a result, the farmer may not be able to obtain the maximum benefit that is worthy of the money he has spent in purchasing the inputs. Thus, soil test crop response based fertilizer recommendations are more comprehensive and beneficial since they can help to tailor fertilizer use more efficiently. A fundamental assumption of soil test crop response based soil fertility management is that economically optimum application rates of fertilizers can be used.

However, the applicability of soil test crop response based fertilizer recommendation requires soil sampling and analysis for individual farm land which is very laborious and time consuming for farming communities, because of different reasons (economic, skill, facility, access, etc.). To make practical, technology generated on bread wheat in Lume District, Batu Soil Research Center developed P-nutrient requirement map using soil P-critical and P-requirement factor (Kefyalew, *et.al*. 2018) and soil fertility map of the district. The maps developed with commonly used sampling and interpolation procedures may be found marginally to poor-quality in some cases. Therefore planners and users should evaluate map quality at test sites before adoption of maps for the whole recommendation (Mueller *et al*, 2001). Hence soil nutrient requirement map quality can be evaluated by comparing grain yield and yield component response of fertilizer rate of P-map and fertilizer rate calculated from P requirement (PR) from P-initial, P-critical and P-requirement factor. Hence validation of this map is very important to demonstrate outputs by supporting with field trial. Therefore, this study was initiated to validate the previously developed nutrient requirement map of Lume District and promote soil test crop response based phosphorus fertilizer recommendation for bread wheat and to introduce soil fertility and nutrient requirement maps in Lume District.

Materials and Methods

Description of the study area

The trial was conducted on 9 farmers' fields in 9 PAs in Lume District of East Shewa Zone of Oromia in Central Ethiopia. Geographically Lume District is located between 8^0 27'00" to 80 49'00" North and 39^0 5'00" to 39^0 16'00" East with total area of 67514.73ha. The elevation ranges from 1590-2512masl with average elevation of 1909masl. Location map with different soil types of the district is showed in Figure 1.

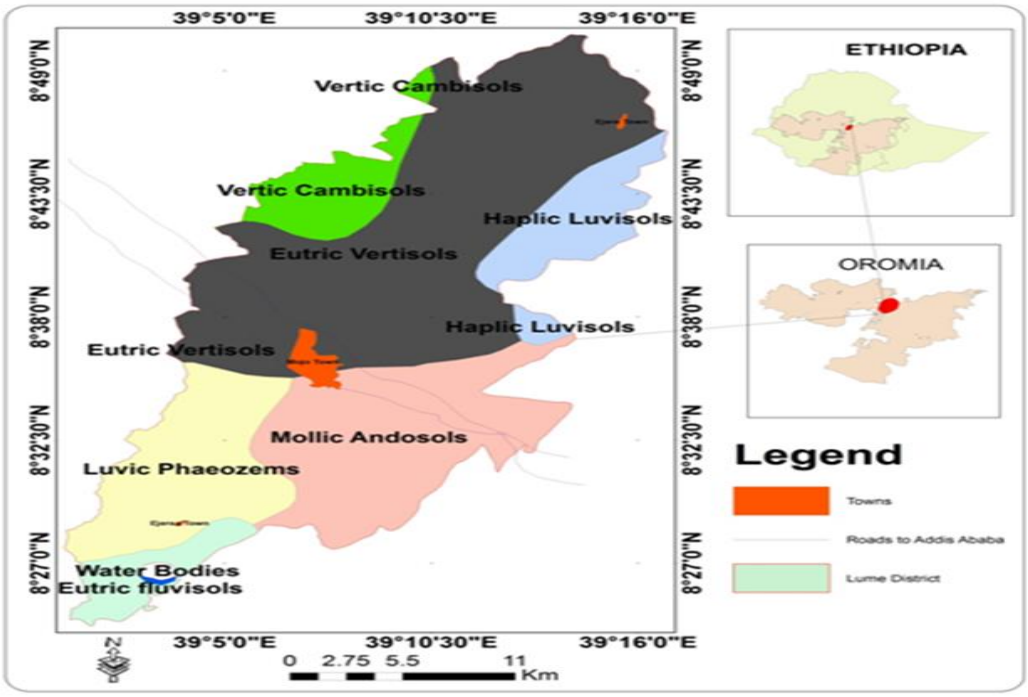


Figure 1. Location map of Lume District

Materials

Kekeba bread wheat variety was used for the trial as planting material, compound fertilizer in the form of NPS (19% N, 38% P_2O_5 and 7% S) used as a source of N:P:S and recommended nitrogen (46kg/ha) as urea for additional application, and GPS for field coordinate data recording (geo-referenced) and ArcGIS software for map development.

Methodology

Soil nutrient requirement map quality can be evaluated by comparing predicted and observed soil properties. Predicted and measured values can be determined either by within validation or cross validation analysis. The maps were developed through soil samples collected from each mapping units developed at stage of base map preparation. These samples were analyzed for each parameter such as N, P, K, pH, CEC, EC and texture at Batu Center soil laboratory. These outputs were initially geo-referenced and by using ArcGIS10.1, their maps were developed by geo-statistical interpolation mainly Ordinary Kriging.

Farmers research extension group (FREG) establishment

The study was conducted on farmers' fields across the district for two consecutive years, 2015/16 and 2016/17. First, nine different PAs were selected for two year trials, systematically based on their accessibility and potential for bread wheat production. From these selected PAs, nine FREGs each consisted of 10-15 members for each PA's organized considering gender and youth (40% women) with full participation of development agent. Then after training was given for these FREGs, and one model farmer who could provide farm land for bread wheat production and coordinate the group was selected from each FREG, based on their willingness. Finally, one composite soil sample at 0-20cm depth was collected

from each farm land in zigzag sampling method. After labeling, the samples were taken to Batu Center soil laboratory and analyzed for available P in order to identify the level of P in the soil to calculate amount of P fertilizer to be applied for bread wheat trial.

Land preparation was made using the local ox plow by farmers with close supervision of researchers and DAs because all field management activities were accomplished by farmer; hence the approach was cost-sharing mechanism (farmers provided farm land and handled all aspects of field management while center provided all agricultural inputs, technical support, training and guidance). Generally, with continuous field management, there were data collections across the location with full participation of DAs and farmers, and regular group discussion with farmers and DAs to assess change in level of knowledge and skill of them to identify training need based on observed gaps in each crop growing stages. Besides, to popularize or for advocacy purpose, mini-field day was organized at maturity stage of the crop.

Soil sampling and analysis

Validation of nutrient requirement map involves independent sample collection and compares measured and estimated values for every validation points. Accordingly, based on nutrient requirement map (Figure 2), from bread wheat growing potential PAs farmers having different rates of fertilizer application and large land unit area coverage were identified. Then one composite soil sample (composited sample from 20-25 sub-samples) and a total of 9 composite soil samples from each provided field for trial by selected model farmers of FREGs' were collected from 0-20cm depth. Collected composite soil samples were tagged and taken to Batu Center soil laboratory for analysis.

The composite soil samples were air dried, ground, and sieved using 2 mm sieve, and analyzed for soil texture, pH, EC and available phosphorus using standard laboratory procedures at Batu Soil Research Center. Available phosphorus was determined by the Olsen's method using spectrophotometer (Olsen *et al.*, 1954). Soil pH was measured in water at soil to water ratio of 1:2.5 (Reeuwijk, 1992). EC also measured in water at soil to water ratio of 1:2.5 by using electrical conductivity meter. Soil texture was analyzed by Bouyoucous hydrometer method (Bouyoucous, 1951). After the samples were analyzed in laboratory based on their coordinate points and related soil phosphorous values and crop phosphorous critical level, i.e., bread wheat phosphorous requirement (PR) was determined using the following equation.

$$PR= (PC- PO)* Pf$$

Where PR = Phosphorus requirement; Pc = Phosphorus critical; and Pf = Phosphorus requirement factor

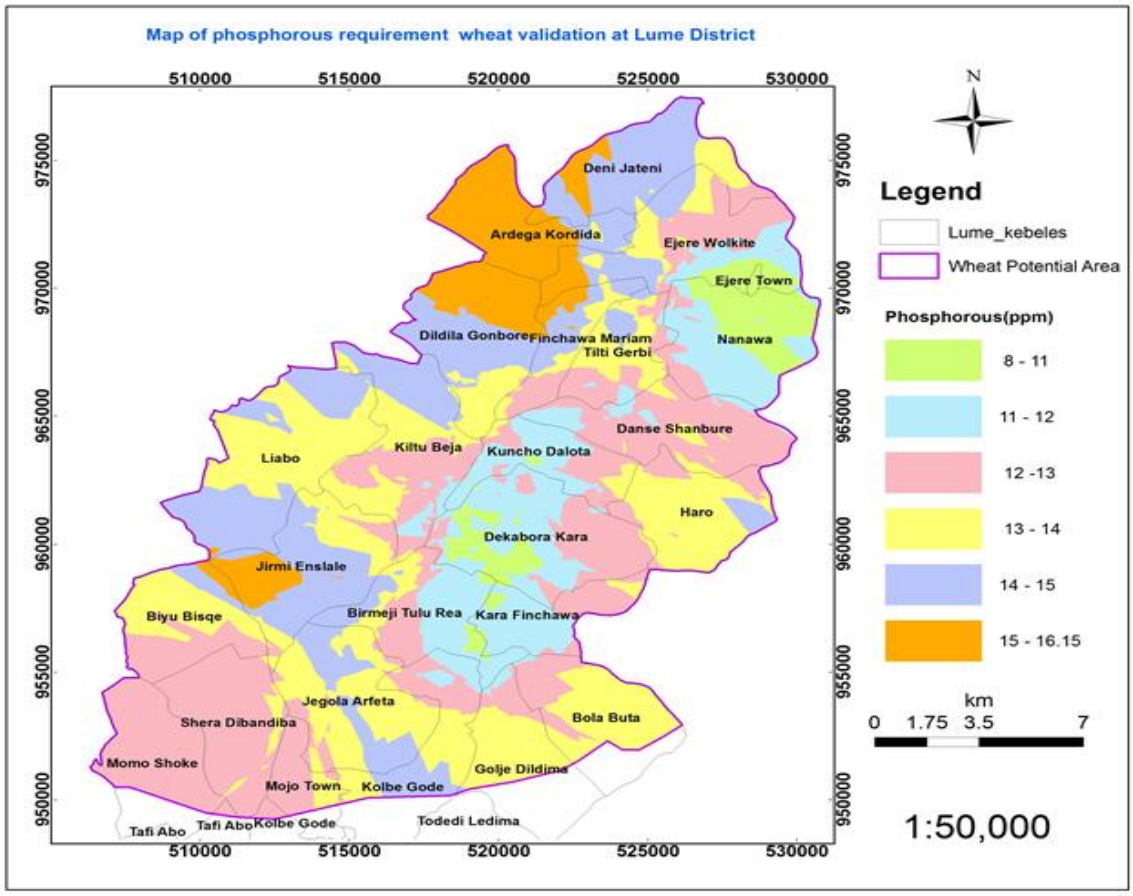


Figure 2. Validated phosphorus requirement map for bread wheat in Lume District

Treatments

There were four treatments used for validation trail that included bread wheat phosphorus fertilizer requirement (PR), P-map that developed using fertility map, blanket recommendation (100 kg NPS and 100kg/ha urea) and control (without fertilizer application), while value of PR for bread wheat was calculated from the already determined phosphorous critical and requirement factor (Kefyalew *et al*., 2018). Where ***Pc = 19ppm, Pf = 4.92ppm*** and ***Applied P = (Critical P - Po)* Pf***. Validated phosphorus requirement map for bread wheat in Lume District is showed in Figure 2.

The treatments were arranged with simple adjacent plots with nine replications over sites. The gross plot size was 10mx10m ($100m^2$). Spacing of 1.0 m and 0.5 m was maintained in between adjacent blocks and plots, respectively. Data for grain and biomass yield were generated for each plot at harvest from 2mx2m ($4m^2$). The details of the treatments are showed in Table 1. Nitrogen fertilizer in the form of urea (46%N) was used according to the recommended rate of 46 kg N ha^{-1} (Kefyalew *et al*., 2018). However, the amount of N found in different levels of NPS fertilizer was deducted.

Table 1. Rates of phosphorus treatments used for validation of nutrient requirement map of bread wheat (kg/ha)

Site	P-required		P-map		Blanket		Control
	Po (ppm)	P applied *Pc=19, pf=4.92*	Po (ppm)	P applied *Pc=19, pf=4.92*	NPS	urea	No fertilizer
1	8.74	50.48	13.03	29.37	100	100	0
2	7.36	57.27	11.77	35.57	100	100	0
3	9.32	47.63	11.77	35.57	100	100	0
4	12.3	32.96	10.51	41.77	100	100	0
5	9.12	48.61	10.51	41.77	100	100	0
6	13.88	25.19	10.51	41.77	100	100	0
7	6.62	60.91	11.77	35.57	100	100	0
8	11.7	35.92	13.03	29.37	100	100	0
9	9.1	48.71	11.77	35.57	100	100	0

Where, Po = initial soil phosphorus, Pc = critical soil phosphorous, Pf = phosphorous requirement factor, Yld = yield, Bm = biomass, P-map = phosphorus applied from fertilizer requirement map, **P**-required = (Pc-P0)*P_f); Blanket = farmer practice

Management of field trial

The field was prepared following conventional tillage practice which included four times plowing before sowing of the crop. As per the specification of the trial, field layout was prepared; the land was leveled and made suitable for crop establishment. Sowing was in July 2016 using seed rate of 150 kg ha^{-1}. Full dose of phosphorous as per the treatment and one-half of N was applied at sowing. The remaining one-half of N was top dressed at mid-tillering stage (after 30 days of planting). Other necessary agronomic practices were carried out uniformly for all treatments. The crop was harvested at maturity and was sun dried till constant weight before threshing.

Data collection

Biomass yield: was determined from net plot area harvested plants after sun drying to a constant weight and expressed in kg ha^{-1}.

Grain yield: was taken by harvesting and threshing the grain yield from net plot area. The yield was adjusted to 12.5% moisture content and expressed in kg ha^{-1}.

Harvest index (HI): was calculated as ratio of grain yield to biomass yield and expressed as percent.

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

Statistical analysis

The data was subjected to analysis of variance (ANOVA) as per the experimental design using GenStat (15^{th} edition) software (GenStat, 2012). The Least Significance Difference (LSD) at 5% level of probability was used to determine differences between treatment means.

Partial budget analysis

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 was referred to as dominated and un-dominated 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.

Results and Discussion

Yield and yield components

Analysis of variance indicated that grain yield of bread wheat with P-required and P-map P fertilizer applications were with similar effects, but significantly different at P<0.05 to blanket and control treatments. Harvest index was significantly different (P<0.05) for all treatments compared to control treatment. Biomass yield showed significant difference (P<0.05) among all treatments; however, thousand kernel weight was not significantly affected by treatments applied (Table 2). The highest grain yield (4039 kg ha^{-1}), biomass yield (9964 kg ha^{-1}) were resulted from P-required application while the lowest grain yield (1072 kg ha^{-1}), biomass yield (3294 kg ha^{-1}) and harvest index (32%) were obtained from without fertilizer application. P-required increased bread wheat grain and biomass yield by 272% and 202% over control, 52% and 46% over blanket fertilizer application, respectively.

Table 2. Grain and biomass yield, harvest index and thousand kernel weight of bread wheat as influenced by different methods of phosphorus rates application

Treatment	GY(kg ha^{-1})	BM (kg ha^{-1})	HI (%)	TKW (g)
P- required	4039 [a]	9964 [a]	40.69[ab]	32.64
P- map	3833 [a]	8744 [b]	43.77 [a]	32.65
Blanket	2656 [b]	6844 [c]	38.99 [b]	32.77
Control	1072 [c]	3294[d]	32.03 [c]	31.55
LSD (0.05)	468.8	1122.6	3.531	NS
CV (%)	16.6	16.0	9.3	8.3

Means within a column followed by the same letter are not significantly different at 5% level of significance according to Fisher protected LSD test; TKW = Thousand kernels weight; BM= Biomass yield; GY = Grain yield; HI% = Harvest index in percent; Pr = phosphorus required (45 kg P ha^{-1}); P- map= phosphorus predicted (36 kg P ha^{-1}), Blanket (100/100 NPS/Urea kg ha^{-1}, control (no fertilizer application)

Partial budget analysis

To identify treatments with the optimum return to the farmer's investment, marginal analysis was performed on non-dominated treatments. For a treatment to be considered as worthwhile to farmers, 100% marginal rate of return (MRR %) was the minimum acceptable rate of return (CIMMYT, 1988). As indicated in Table 3, the partial budget and dominance analysis showed that the highest net benefit 32396 Birr ha^{-1} was obtained P-required (Pc-P0)*P_f), while the lowest net benefit (9648 Birr ha^{-1}) was obtained from control treatment. However, the highest marginal rate of return of 1299% was obtained from P-map (phosphorus applied from fertilizer requirement map). According to this result, farmer's investment of 1 Birr in P-map treatment on Kekeba bread wheat variety (Qaqaba) benefits 12.99 Birr.

Table 3. Partial budget and marginal analysis of treatment applied over nine sites for bread wheat in Lume District

Treatments	**P (kg ha^{-1})**	**N (kg ha^{-1})**	**Adj grain yield down wards by 10% (kg ha^{-1})**	**Gross Benefit (Birr ha^{-1})**	**Total variable cost (Birr ha^{-1})**	**Net return (Birr ha^{-1})**	**MRR %**
Control	0	0	1072	9648	0.00	9648	-
Blanket	16.5	46	2656	23904	2514.00	21390	467
P-required	45	0	4039	36351	3955.00	32396	171
P-map	36	5	3833	34497	3271.00	31226	1299

Where, NPS cost = 14.54 Birr kg^{-1}, UREA cost = 10.60 Birr $kg^{-1}$of N, NPS, Bread wheat grain per ha = 9 Birr kg^{-1}, MRR (%) = Marginal rate of return, D = Dominated treatment, Control = unfertilized

Conclusion and Recommendation

Validation of nutrient requirement map produced to easy use of P fertilizer recommendation for bread wheat production in the district. Highest mean grain yield (4039 kg ha^{-1}) and biomass yield (9964 kg ha^{-1}) were resulted from P-required based P fertilizer application. However, Partial budget analysis revealed that P-map based P fertilizer application resulted in the highest marginal rate of return 1299% with mean grain yield of 3833 kg ha^{-1}. This P-map based P fertilizer application can help farmers not take and transport soil samples to analyze in soil laboratory. Based on these results, the following recommendations will be suggested (1) bread wheat production using P fertilizer rate based on P-map will benefit farmers in Lume District, (2) For easy applicability of this P-map based P fertilizer application, user guideline should be developed and provided for farmers with P-map, and (3) validating the P-map at certain interval will be very essential to assess soil fertility change through time in the district.

References

Bereket Haileselassie, Dawit Habte, Mehretab Haileselassie, and Gebremedhin Gebremeskel. 2014. Effects of Mineral Nitrogen and Phosphorus Fertilizers on Yield and Nutrient Utilization of Bread Wheat (*Tritcum aestivum*) on the Sandy Soils of Hawzen District, Northern Ethiopia. *Agriculture, Forestry and Fisheries,* 3 (3): 189–98.

Bouyoucos GH (1951) A Recalibration of the Hydrometer for Making Mechanical Analysis of Soils. Agronomy Journal (43) : 434-438.

Bray, R.H. 1945. Soil-plant relations: II. Balanced fertilizer use through soil tests for potassium and phosphorus. Soil Sci. 60:463-473

CIMMYT Economics Program, International Maize and Wheat Improvement Center, 1988. *From agronomic data to farmer recommendations: an economics training manual* (No. 27). CIMMYT.

CSA (Central Statistical Agency). 2016. Agricultural sample survey: area and production of major crops, meher season. Vol. I. Addis Ababa, Ethiopia.

Endalkachew K. (2006). Effects of rates and methods of phosphorus placement on residual soil p, yield and p uptake of wheat in nitosols of kulumsa area, arsi zone. MSc. thesis report.

Kefyalew Assefa Gejea[1] and Tilahun Firomsa Erenso[2], 2018. Phosphorus Critical Level and Optimum Nitrogen Rate Determination on Bread Wheat for Sustainable Soil Fertility Management and Economical Production at Lume Area of Oromia Region, Ethiopia. Journal of Biology, Agriculture and Healthcare. www.iiste.org. ISSN 2224-3208 (Paper) ISSN 2225-093X (Online). Vol.8, No.1, 2018

MoA (Ministry of Agriculture). 2012. Ministry of Agriculture, Animal and Plant Health Regulatory Directorate. Crop variety register, Issue No. 15. Addis Ababa, Ethiopia Mueller T. G., F. J. Pierce, O. Schabenberger, and D. D. Warncke,2001. MAP QUALITY FOR SITE-SPECIFIC FERTILITY MANAGEMENT.Soil Sci. Soc. Am. J. 65:1547–1558 (2001).

Negassa, A., Shiferaw, B., Koo, J., Sonder, K., Smale, M., Braun, H.J., Gbegbelegbe, S., Guo, Z., Hodson, D.P., Wood, S. and Payne, T.S., 2013. The potential for wheat production in Africa: analysis of biophysical suitability and economic profitability.

Olsen SR, Cole CW, Watanabe FS, Dean LA (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular, Vol 939 (p. 19). Washington, DC: US Department of Agriculture.

Roger Payne, Darren Murray, Simon Harding, David Baird & Duncan Soutar (2012). Introduction to GenStat for Windows ® TM (15 Edition). VSN International, Hemel Hempstead.

Van Reeuwijk LP (1992). Procedures for soil analysis, 3rd Ed. International Soil Reference and Information Center (ISRIC), Wageningen, the Netherlands. 34p.

Verification of Soil Test Crop Response Based Phosphorous Recommendation for Bread Wheat in Chora District of Buno Bedele Zone, Southwest Oromia, Ethiopia

Dagne Chimdesa and Abdulmalik Mohammed

Bedele Soil Research Center, Bedele, Ethiopia
Corresponding author: dagnechim@gmail.com

Abstract

On-farm verification of soil test crop response based phosphorus critical level for bread wheat was conducted in Chora District during 2017 cropping season. The objects of the study were to verify recommended nitrogen rate (138kg Nha^{-1}), P-critical level determined (3.8ppm) and P-requirement factor (30.28) for phosphorus recommendation using Digalu bread wheat variety. The treatments were soil test crop response based phosphorus recommendation (STCRBPR), farmers' practice (blanket recommendation) and control (without fertilizer). The design was randomized complete block design replicated over farmers' sites. Initial soil reaction pH (H_2O) was strongly acidic ranged from 4.32-4.97, very low available P ranged from 2.21-2.91ppm. The results of the study revealed significant differences ($P \leq 0.05$) among the treatment effects on bread wheat grain yield. The highest mean grain yield (3577kg ha^{-1}) was obtained from the application of STCRBPR, whereas the lowest (794 kg ha^{-1}) was resulted from the control treatment. The study also showed that verification of recommended nitrogen rate (138 kg ha^{-1}), P-critical level (3.8ppm) and P-requirement factor (30.28) for bread wheat had economic benefit of determined N and P rates during the calibration study. Accordingly economic analysis showed that STCRBPR could benefit 2.31birr for every one birr invested. Thus, farmers could be advised to use soil test crop response based phosphorus recommendation to increase productivity and production of bread wheat in the district.

Key words: Bread wheat, Digalu variety, Nitrogen, Phosphorus, P-critical and P-requirement

Introduction

Wheat production covering 1.66 million hectares of cultivated land is one of the most important cereal crops cultivated in Ethiopia, ranking fourth after teff (*Eragrostistef*), maize (*Zea mays*) and sorghum (*Sorghum bicolor*) in area coverage; however, its productivity in Ethiopia is one of the lowest in the world, with the national average grain yield of about 2.54t ha^{-1} in the smallholder farmers' production system (CSA, 2016). Water logging on Vertisols, soil degradation, soil acidity, declining soil fertility and low input production system are some of the most important constraints limiting food production in Ethiopia (Abate *et al.*, 2015).

Providing food for the ever-growing population is one of the critical challenges of today. According to Beets (1982) production can be increased by expanding the area planted to crops, raising the yield per unit area of individual crops or by growing more crops per year. In the future, most of additional food that the world needs must come from larger yields on the lands already under cultivation and/or from lands now considered marginal (Chatterjee and Maiti, 1994). A major share of this increase will likely come from the use of irrigation,

commercial fertilizers, pesticides, improved crops culture, mechanization and improved soil and water management (FAO, 1984).

The demand for fertilization is evident, as growers around the world have already recognized the return, which can be realized from added plant nutrients. Quinenes *et al.* (1992) stated that unless something is done to restore soil fertility first, other efforts to increase crop production could end up with little success. Moreover, using chemical fertilizers that bring more than 100% extra yield is inevitable in most cases (Kelsa *et al*., 1992).

In Ethiopia, low soil fertility is one of the factors limiting the yield of wheat. It may be caused as a result of removal of surface soil by erosion, crop removal of nutrients from the soil, total removal of plant residue from farmland, and lack of proper crop rotation program (Tamirie, 1982). The results of several studies conducted on the status of P in Ethiopian soils (Tekalign and Haque, 1987) indicated that most of the soils studied require addition of P fertilizer for profitable crop growth.

It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question as it is the ultimate measure of fertilization program. An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve high yield of a crop. Sound soil test calibration is essential for successful fertilizer program and crop production (Abaidioo et al., 2000). Having this concept soil test based phosphorus calibration study was conducted in Chora District on bread wheat for three years; and nitrogen rate, phosphorus critical level and phosphorus requirement factor were determined during this calibration study. Then further verification trial was conducted to compare these N rates and determined P critical level with blanket recommendation practiced by farming community in the district.

Materials and Methods

Description of the study area

The verification trial was conducted on-farm in Chora District in Buno Bedele Zone, Southwest Oromia. It is located 536 km southwest of Addis Abeba along the main road from Bedele to Metu at $8^0$20'N latitude and $36^0$15' E longitude. The mean annual rainfall and temperature of the district range from 1000-1500mm, 15-31^{o}C, respectively. Altitude ranges from 1000-2060masl and soil type dominated by Nitisol.

Treatments

The trial was conducted on farmers' fields in the district. Six sites were selected based on initial soil test value from composite soil samples collected and analyzed before planting. Phosphorus recommendation for selected sites was calculated and applied according to the formula, P (kg/ha) = (P critical – P initial)*Prf. This recommendation was compared with farmers' practice (blanket recommendation) and control (without fertilizer). Bread wheat (Digalu variety) was used as test crop with seed rate of 150kg/ha. The treatments were soil test crop response based phosphorus recommendation (STCRBPR), farmers' practices (blanket recommendation, 100 kg/ha DAP and 100kg/ha urea) and control (without fertilizer,

T3) that were laid out in randomized complete block design replicated over farmers' sites. The fields were prepared by using oxen plough in accordance with conventional farming practice of farming community in the area, where the fields were ploughed four times. The gross plot size was 10mx10m with 8.4m x 10m net plot size area. Urea and DAP fertilizers were used as sources of N and P, respectively. Phosphorus fertilizer was applied at planting while urea was applied in split, half at planting and half after 35 days of sowing.

Data management and analysis

Grain yield and soil data were collected; grain yield analysis was done using SAS 9.1 version and LSD for mean separation. Economic analysis was performed to investigate the economic feasibility of treatments, following standard procedure developed by CIMMYT (1988). To estimate economic parameters, products were valued based on market price collected from local markets during January 2018 where bread wheat grain cost was 5Birr kg^{-1} at field price. Fertilizers price of DAP and urea, and seed price of bread wheat were 16.87, 10.87 and 14.5Birr kg-1, respectively at planting time in July, 2018. A wage rate of 50.Birr per work-day and oxen plow rate of 150Birr per work day were used.

Results and Discussion

Soil pH and available phosphorus status before planting

The pH (H_2O) values of the soil samples collected before planting were ranged from 4.32-4.97 (Table 1). Accordingly, the soils were strongly acidic in reaction (FAO, 2008). Continuous cultivation and long-term application of inorganic fertilizers lower soil pH and aggravate the losses of basic cations from highly weathered soils (Mokwunye et al. 1996). Hence, this soil pH affects bread wheat production which is less than its requirement (FAO, 2006). Available phosphorus (Olsen method) of collected composite samples before planting was ranged from 2.21-2.91ppm (Table 1). The available P contents of the soil samples were very low (Olsen *et al.,* 1954). The low contents of available P observed in the soil of the study areas are in agreement with the results reported by Mesfin (1998); Yihenew (2002); and Dagne (2016) stated that as the Ethiopian agricultural soils particularly the Nitisols and other acid soils have low available P content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion.

Table 1.Initial soil pH and available phosphorus status before planting in Chora District in 2017 cropping season

Site	pH(H_2O)	P-avail (Olsen method)
Site 1	4.97	2.918
Site 2	4.45	2.360
Site 3	4.49	2.356
Site 4	4.32	2.213
Site 5	4.39	2.530
Site 6	4.74	2.536

P-avail = available phosphorus

\

Phosphorus critical level

There were significant differences ($P \leq 0.05$) among the treatments in bread wheat grain yield. The highest mean grain yield (3577kg ha^{-1}) was resulted from the application of STCRBPR (soil test crop response based phosphorus recommendation) whereas the lowest (794kg ha^{-1}) was obtained from the control treatment (Table 2).

Table 2. Response of bread wheat to P critical level in Chor District, 2017 cropping season

Treatment	Grain yield (kg/ha)
STCRBPR (soil test crop response based fertilizer recommendation)	3577[a]
Framers Practices (blanket recommendation)	1456[b]
Control (without fertilizer)	794[c]
LSD (5%)	301
CV (%)	12

LSD = Least Significant Difference, CV = Coefficient of Variation

Economic analysis

To estimate economic parameters, products were valued based on market price collected from local markets during January 2018 where wheat grain cost was 5Birr kg^{-1} at field price. Fertilizers price of DAP and urea, and seed price of wheat were 16.87, 10.87 and 14.50 Birr kg^{-1}, respectively in July, 2018. A wage rate of 50Birr per work-day and oxen plow rate of 150Birr per work day were used. The partial budget presented in Table 3 shows the least total variable cost (TVC) was recorded by control treatment (without fertilizer), while the highest net benefit (NB) was obtained from STCRBPR (7482Birr ha^{-1}). The analysis of marginal rate of return (MRR), on the other hand, revealed that the rate of return per unit cost of production was highest from STCRBPR (MRR% = 231). This showed that it would benefit 2.31Birr for 1 Birr invested.

Table 3. Partial budget analysis for verification trail of soil test crop response based phosphorus recommendation foe bread wheat in Chora District, 2017 cropping season

Partial budget with dominance					
Treatment	**Yield (kg ha^{-1})**	**GFB (Birr ha^{-1})**	**VC (Birr ha^{-1})**	**NB (Birr ha^{-1})**	**Dominance**
1. Control (without fertilizer)	794.00	3970 .00	5100.50	-	Dominated
2. Blanket recommendation	1456.00	7280.00	7201.30	8759.79	Un dominated
3. STBCRPR	3577.00	17885.00	10403.00	10899.16	Un dominated

Marginal rate of return (MRR %)

Treatments	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	Incremental		MRR (%)
			Cost	benefit	
1.Control (without fertilizer)	5100.50	-			
2. Blanket recommendation	7201.30	78.70	2100.80	-	
3. STBCRPR	10403.00	7482.00	3201.70	7403.30	231

ETB = Ethiopian Birr; GFB = Gross field benefit; TVC = Total variable cost; NB = Net benefit; MRR = Marginal rate of return; STCRB PR= Soil Test Crop Response Based Phosphorus Recommendation

Conclusion and Recommendation

Soil test crop response based phosphorus verification conducted on farmers' fields in Chora District indicated the economic benefit of recommended P-critical level, P requirement factors and N rate for Digalu bread wheat variety. Soil test crop response based phosphorus recommendation (STCRBPR) was superior to both farmers' practices (blanket recommendation) and control (without fertilizer). Based on these verification results nitrogen rate (138 kg N ha^{-1}), P-critical level 3.8ppm and P-requirement factor 30.28 were recommended for bread wheat production in the district. Farming communities and other stakeholders could use these recommendations in the district. Because of dynamic nature of the soil and varietal improvement of the crop, assessing soil fertility status at certain interval will be recommended. Moreover, to sustain and improve the current soil fertility status of the study area for better production, integrated soil fertility management practices (soil conservation, lime application, crop rotation, and addition of organic fertilizer with integration of chemical fertilizers) should get great emphasis for sustainable crop production in the district.

References

Abaidioo, R.C., Keyser, H.H., Singleton, P.W. and Borthakur, D. 2000. Bradyrhizobium spp. (TGx) isolatesnodulating the new soybean in Africa are diverse and distinct from bradyrhizobia that nodulate North American soybeans. *International journal of Systematic and Evolutionary Microbiology***50**:225-234.

Abate, Gashaw T.; de Brauw, Alan; Minot, Nicholas; and Bernard, Tanguy. 2015. The impact of the use of new technologies on farmers' wheat yield in Ethiopia: Evidence from a randomized controlled trial. REAP Report. Washington, D.C.: International Food Policy Research Institute (IFPRI).

Beets, W.C., 1982. Multiple Cropping and Tropical Farming System. Gower, London, Britain and West Views Press Colorado, USA. 256p.

Chatterjee, B.N. and S. Maiti, 1994. Cropping System; Theory and Practice. Oxford and BBH Publishing Co, New Delhi, Bombay, Calcutta. 323p.

CIMMYT ,1988. From Agronomic Data to Farmer Recommendation: An Economics Training Manual . Completely Revised edition. Mexico , DF .

CSA, 2016. Agricultural sampling survey, report on area production of major crops. Stastical buletin 584

Dagne Chimdessa, 2016. Soils Characteristics in Maize Based Farming System of Western Oromia, Ethiopia. *Journal of Energy and Natural Resources*. 5 ; 37-46.

FAO, 1984. Fertilizer and plant nutrition guide. Food and Agriculture Organization of the United Nations, Rome. pp. 54-67.

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integratednutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16. FAO, Rome.

FAO, 2008.Efficiency of soil and fertilizer phosphorus use Reconciling changing concepts of soil phosphorus behavior with agronomic information. Bulletin 18.

Kelsa Kena, Tadesse Yohannes and Tesfa Bogal, 1992. Influence of fertilizer and its related management practices on maize grain yield in major producing areas of Ethiopia. pp. 15-104.Proceedings of the First National Maize Workshop of Ethiopia 5-7 may, 1992 Addis Ababa, Ethiopia.

Mesfin Abebe, 1998. Nature and management of Ethiopian soils. Alemaya University, Ethiopia. 272p.

Mokwunye, A.U., A. de Jager and E.M..Smailing, 1996. Restoring and maintaining the productivity of West Africa Soils: Key to sustainable development. International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama. 94p.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. *USA Circular J.* 939: 1-19.

Quinenes, M., A. Foster, D. Akibo and N.P. Siclima, 1992. Methodology used by SG 2000 Project in Africa for transfer of improved production technologies to small scale farmer. pp. 149-153. Proceeding of the First National Maize Workshop of Ethiopia, Addis Ababa

Tamirie Hawando, 1982. Problems of soils and its implications on crop improvement program in Ethiopia context. Department of plant science, college of Agriculture, Addis Ababa University. pp 5-12

Tekalign Mamo and I. Haque, 1987. Phosphorous status of some Ethiopia soils. Sorption characteristics. P*lant and Soil*. 102: 261-266.

Yihenew Gebreselssie, 2002. Selected chemical and physical characteristics of soils of Adet Research Center and its testing sites in Northwestern Ethiopian. Society of Soil Science. *Ethiopian J, Natural. Resource* 4: 199-215

Verification of Soil Test Crop Response Based Phosphorous Recommendation for Maize in Chora District of Buno Bedele Zone of Southwest Oromia, Ethiopia

[1]Dagne Chimdessa and Abdulmalik Mohammed

Bedele Soil Research Center, Bedele, Ethiopia
[1]Corresponding Author: dagnechim@gmail.com

Abstract

On-farm verification of soil test crop response based phosphorus recommendation was conducted in Chora District in 2017 cropping season. The objects were to verify recommended nitrogen rate (92 kg ha^{-1}), P-critical level determined (8.5ppm) and P-requirement factor (6.64) for maize variety BH661 in the district. The treatments were soil test crop response based phosphorus recommendation (STCRBPR), farmers' practices (blanket recommendation), and control (without fertilizer). The design was randomized complete block replicated over farmers' sites. Initial soil reaction pH (H_2O) was strongly acidic ranged from 4.75-5.28, very low available P ranged from 1.99-3.11ppm. The verification results revealed that there were significant differences ($P \leq 0.05$) among the treatments in maize grain yield. The highest mean grain yield (7319kg ha^{-1}) was resulted from the application of STCRBPR whereas the lowest (1652 kg ha^{-1}) was obtained from the control; Verification results showed that nitrogen rate 92 kg ha^{-1}, P-critical level (8.5ppm) and P-requirement factor (6.64) determined were recommended for nitrogen and phosphorus fertilizers application in the district. The economic evaluation for validity of P critical level showed that STCRBPR could benefit farmers 2.12 Birr for 1Birr invested. Thus, farmers in Chora District should use soil test crop response based phosphorus recommendation to increase productivity and production of maize.

Key words: Maize variety BH-661, Nitrogen, Phosphorus, P-critical and P-requirement

Introduction

Nowadays, providing food for the ever-growing population is one of the critical challenges. According to Beets (1982) production can be increased by expanding the area planted to crops, raising the yield per unit area of individual crops or by growing more crops per year. In the future, most additional food needed for the world must come from larger yields on the lands already under cultivation and/or from lands now considered marginal (Chatterjee and Maiti, 1994). A major share of this increase will likely come from the use of irrigation, commercial fertilizers, pesticides, improved crops culture, mechanization and improved soil and water management (FAO, 1984).

The demand for fertilization is evident, as growers around the world have already recognized the return, which can be realized from added plant nutrients. Quinenes *et al.* (1992) stated that unless something is done to restore soil fertility first, other efforts to increase crop production could end up with little success. Moreover, using chemical fertilizers that bring more than 100% extra yield is inevitable in most cases (Kelsa *et al*., 1992). In Ethiopia, low soil fertility is one of the factors limiting maize yield. It may be caused as a result of removal of surface

soil by erosion, crop removal of nutrients from the soil, total removal of plant residue from farmland, and lack of proper crop rotation program (Tamirie, 1982). The results of several studies conducted on the status of P in Ethiopian soils (Tekalign and Haque, 1987) indicated that most of the soils studied require addition of P fertilizer for profitable crop growth.

It is essential that the results of soil tests could be calibrated or correlated against crop responses from applications of plant nutrients in question as it is the ultimate measure of fertilization program. An accurate soil test interpretation requires knowledge of the relationship between the amount of a nutrient extracted by a given soil test and the amount of plant nutrients that should be added to achieve optimum yield for each crop. Sound soil test calibration is essential for successful fertilizer program and crop production (Abaidioo et al., 2000). Based on this concept soil test crop response based phosphorus calibration study was conducted in Chora District on maize for three years and N rate, P critical level and P requirement factor were determined. Then further verification trial was required to compare determined N rate, P-critical level and P-requirement with blanket recommendation practiced by farming community and control (without fertilizer) for increasing productivity and production of maize in the district

Materials and Methods

Description of the study area

The trial was conducted on-farm in Chora District of Buno Bedele Zone, Southwest Oromia. It is located 536km southwest of Addis Abeba along the main road from Bedele to Metu at $8^0$20'N latitude and $36^0$15' E longitude. The mean annual rainfall and temperature of the district range from 1000-1500mm, 15-31^{0}C, respectively. Altitude ranges from 1000-2060masl and soil type of the district is dominated by Nitisols.

Treatments

The trial was conducted on farmers' fields in the district. Six sites were selected based on initial soil test value of composite soil samples that were collected during site selection and analyzed before planting, which also serve as initial P-value while calculating P rate. Thus, phosphorus rate was calculated and applied according to the formula, P (kg/ha) = (P critical – P initial)*Prf. This P rate was compared with farmers' practice (blanket recommendation) and control. Maize (variety BH661) was used as test crop. The treatments were soil test crop response based phosphorus recommendation (STCRBPR), farmers' practices (blanket recommendation, 100kh/ha DAP and 100 kg/ha urea)), and control (without fertilizer) were laid out in randomized complete block design replicated over farmers' sites. The fields were prepared by using oxen plough following conventional farming practice of farming community in the district where fields were ploughed four times.

The gross plot size was 10.40mx10m with 7.20mx10m net plot size, with population of 50.000 plants/ha. Urea and DAP were used as fertilizer sources of N and P, respectively. Phosphorus fertilizer was applied at planting, while urea was applied 30 days after planting, grain yield and soil data were collected. Maize grain yield was analyzed using SAS 9.1 version and LSD was used for mean separation. Economic analysis was performed to investigate the economic feasibility of treatments (CIMMYT, 1988). To estimate economic

feasibility, products were valued based on market price collected from local markets in January 2018 where maize grain cost was 4Birr kg^{-1} at field price. Fertilizers price of DAP and urea, and maize seed price were 16.87, 10.87, and 22.13Birr kg^{-1}, in April 2018, respectively. A wage rate of 50Birr per work-day and oxen plow rate of 150Birr per work day were used.

Results and Discussion

Soil pH and available phosphorus status before planting

The pH (H_2O) of the soil samples collected before planting were ranged from 4.75-5.28 (Table 1). Accordingly, the soils were strongly acidic in reaction (FAO, 2008). Continuous cultivation and long-term application of inorganic fertilizers lower soil pH and aggravate the losses of basic cations from highly weathered soils (Mokwunyeet al. 1996). The result showed that soil pH affects maize production which is less than the maize requirement (FAO, 2006). Available phosphorus (Olsen method) collected before planting were ranged from 1.99-3.11ppm (Table 1). The available P contents of the soil were very low (Olsen *et al.*, 1954). The low contents of available P observed in the soil of the study areas are in agreement with the results reported by Mesfin (1998); Yihenew (2002); Dagne (2016) who reported that the Ethiopian agricultural soils particularly the Nitisols and other acid soils have low available P content due to their inherently low P content, high P fixation capacity, crop harvest and soil erosion.

Table 1. Initial soil pH and available phosphorus status before planting in Chora District, 2017 cropping season

Site	pH(H_2O)	P-avail (Olsen method)
Site 1	4.94	2.197
Site 2	5.28	3.117
Site 3	4.75	2.935
Site 4	4.79	1.994
Site 5	4.84	2.195
Site 6	5.10	3.018

P-avail = available phosphorus

Phosphorus critical level

There were significant differences ($P \leq 0.05$) among the treatments in maize grain yield. The highest mean grain yield (7319kg ha^{-1}) was resulted from the application of STCRBPR (soil test crop response based phosphorus recommendation), whereas the lowest (1652kg ha^{-1}) was obtained from the control treatment (Table 2).

Table 2. Response of maize to phosphorus critical level in 2017 cropping season

Treatment	Grain yield (kg /ha)
STCRBPR (soil test crop response based fertilizer recommendation)	7319[a]
Framers practices (blanket recommendation)	3294[b]
Control (without fertilizer)	1652[c]
LSD (5%)	802
CV (%)	15

LSD = Least Significant Difference, CV = Coefficient of Variation

Economic analysis

To estimate economic parameters, products were valued based on market price collected from local markets in January 2018 where maize grain cost was 4Birr kg^{-1} at field price. Fertilizers price of DAP and urea, and maize seed price were 16.87, 10.87 and 22.13Birr kg^{-1}, respectively. A wage rate of 50Birr per work-day and oxen plow rate of 150Birr per work-day were used.

The economic analysis presented in Table 3 shows that the least total variable cost (TVC) was recorded by control treatment (without fertilizer), while the highest net benefit (NB) was obtained from STCRBPR (14414Birr ha^{-1}). The analysis of marginal rate of return (MRR) also revealed that the rate of return per unit cost of production was highest from STBCRPR (MRR % = 212). This showed that for 1 Birr invested 2.12Birr economic benefit is obtained.

Table 3. Partial budget analysis with dominance and marginal rate of return

Partial budget with dominance					
Treatment	**Yield (kg ha^{-1})**	**GFB (Birr ha^{-1})**	**VC (Birr ha^{-1})**	**NB (Birr ha^{-1})**	**Dominance**
Control (without fertilizer)	1652.00	6608 .00	5079.10	1528.90	Dominated
Farmers practices (Blanket recommendation)	3294.00	13176.00	9703.30	3472.70	Un dominated
STCRBPR	7319.00	29276.00	14862.05	14413.95	Un dominated

Marginal rate of return (MRR %)

Treatment	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	Incremental		MRR (%)
			Cost	Benefit	
Control (without fertilizer)	5079.10	1528.90			
Farmers practice (Blanket recommendation)	9703.30	3472.70	4624.20	1943.80	
STBCRPR	14862.05	14413.95	5158.75	10941.25	212.09

Key: GFB = Gross field benefit; TVC = Total variable cost; NB = Net benefit; MRR = Marginal rate of return; STBCR PR= Soil Test Based Crop Response Phosphorus Recommendation

Conclusion and Recommendation

Verification of soil test crop response based phosphorus recommendation in Chora District showed economic benefit of recommended P-critical level, P-requirement factor, and N rate for maize variety, BH661. Soil test crop response based phosphorus recommendation was superior to both farmers' practices and control treatment. Hence recommended nitrogen rate (92 kg ha^{-1}), P-critical level (8.5ppm) and P-requirement factor (6.64) determined in calibration study were recommended for maize variety BH661 in increasing productivity and production in Chora District. Furthermore, to sustain and improve the current soil fertility status of the district for better production, integrated soil fertility management practices (soil conservation, lime application, crop rotation, and addition of organic fertilizer with integration of chemical fertilizers) should be emphasized for sustainable maize production in the district. Generally, soil fertility assessment at certain interval is critical to update these recommended N rate and P-critical level following dynamic changes in soil fertility status through time in the district.

References

Abaidioo, R.C., Keyser, H.H., Singleton, P.W. and Borthakur, D. (2000). Bradyrhizobium spp. (TGx) isolates nodulating the new soybean in Africa are diverse and distinct from bradyrhizobia that nodulate North American soybeans. *Int. j of Systematic and Evol. Microbiology* **50**:225-234.

Beets, W.C., 1982. Multiple Cropping and Tropical Farming System. Gower, London, Britain and West Views Press Colorado, USA. 256p.

Chatterjee, B.N. and S. Maiti, 1994. Cropping System; Theory and Practice. Oxford and BBH Publishing Co, New Delhi, Bombay, Calcutta. 323p.

CIMMYT ,1988. From Agronomic Data to Farmer Recommendation: An Economics Training Manual Completely Revised edition. Mexico , DF .

Dagne Chimdessa, 2016. Soils Characteristics in Maize Based Farming System of Western Oromia, Ethiopia. *Journal of Energy and Natural Resources*. 5 ; 37-46.

FAO, 1984. Fertilizer and plant nutrition guide. Food and Agriculture Organization of the United Nations, Rome. pp. 54-67.

FAO (Food and Agriculture Organization), 2006. Plant nutrition for food security: A guide for integrated nutrient management. FAO, Fertilizer and Plant Nutrition Bulletin 16. FAO, Rome.

FAO, 2008.Efficiency of soil and fertilizer phosphorus use Reconciling changing concepts of soil phosphorus behavior with agronomic information.Bulletin 18

Mesfin Abebe, 1998. Nature and management of Ethiopian soils. Alemaya University, Ethiopia. 272p.

Mokwunye, A.U., A. de Jager and E.M..Smailing, 1996. Restoring and maintaining the productivity of West Africa Soils: Key to sustainable development. International Fertilizer Development Center (IFDC), Muscle Shoals, Alabama. 94p.

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean, 1954. Estimation of available pho sphorous in soils by extraction with sodium bicarbonate. *USA Circular J.* 939: 1-19.

Tamirie Hawando, 1982. Problems of soils and its implications on crop improvement program in Ethiopia context. Department of plant science, college of Agriculture, Addis Ababa University. pp 5-12

Tekalign Mamo and I. Haque, 1987. Phosphorous status of some Ethiopia soils. Sorption characteristics. *Plant and Soil*. 102: 261-266.

Yihenew Gebreselssie, 2002. Selected chemical and physical characteristics of soils of Adet Research Center and its testing sites in Northwestern Ethiopian. Society of Soil Science. *Ethiopian J, Natural. Resource* 4: 199-215

AGRICULTURAL ENGINEERING

Adaptation and Verification of Holetta Model Ware Potato Storage Structure in Horo and Jardega Jarte Districts of Horo-Guduru Wollega Zone

Gutu Birhanu[1], Abdeta Tadese[2] & Gemechisa Yadeta[3]
[1,2,3]Oromia Agricultural Research Institute Bako Agricultural Engineering Research Center, P. O. Box 07,Bako,West Shoa, Oromia Regional State, Ethiopia

Abstract
Agricultural products become important for various purposes. To sustain an adequate supply on the market, handling method, storage and transport technologies of agricultural products are imperative. Especially for perishable commodity, great attention should be given. Horticultural product must be transferred from the field to the table in a state that is acceptable to end users. In Ethiopia as whole, substantial amount of horticultures are believed to go waste before it reaches for users due to lack of proper handling and appropriate storage. Until damage occurred, mostly effect of mishandling and storage is not realized. However, poor handling and storage can easily result in total loss of agricultural produce. Holetta model ware potato storage was developed to prolong shelf life of potato in two Districts of Horro-Gudure Wollega Zone. In order to adapt and verify Holetta model ware potato storage, the study was conducted at Horro and Jardega Jarte districts in Gitilo Dale and Sombo Watu sites. From the result obtained, for Gitilo Dale site ware potato storage prolonged potato tuber for four and half months with 0.85% damage, 1.35% shrinkage and 8.32% sprouted. Average maximum and minimum storage temperatures are 21 and 10 ^{0}C respectively whereas maximum and minimum of relative humidity of storage are 70 and 34% consecutively. Whereas for Sombo Watu site within four and half months, the storage is characterized with 3.32% damage, 8.42% shrinked and 15.65% get sprouted. Average maximum and minimum storage temperatures are 26 and 17 ^{0}C respectively whereas maximum and minimum of relative humidity of storage are 63 and 20% consecutively. As per result observed from result obtained, the storage is recommended for Gitilo Dale site.
Key word: Damage, Humidity, Potato, Storage, Sprout, Temperature and Wilt

Introduction

Potato (*Solanum Tuberosum L.*) is the fourth most important food crop in the world [1, 2] and grown in more than 125 countries and consumed almost daily by more than billion people. Several millions of people living in developing countries depend on potatoes for their survival. Ethiopia has highest potato producing potential than any country in Africa with 70% of 13.5 million hectors of arable land suitable to potato cultivation and production as well [3]. However, the potato is widely regarded as a secondary non-cereal crop in part because it has never reached the potential in supporting food security. In Oromia, root crops covered more than 86 thousand hectares of land and yielded more than 5 million quintals of produce per year. Potatoes, onion and sweet potatoes constituted 62.56%, 13.94%, and 12.57% of the regional area under root crops, respectively. [4].

Potato is one of the most productive food crops in terms of yields of edible energy and good quality protein per unit area and per unit of time fitting into intensive cropping systems [5].

Contribution of potato tubers to the diet and income generation in the country is insignificant due to several factors. The reasons are low production and productivity, lack of adequate pest control, lack improve varieties, market, lack of attention to product quality and prevention of physical damage, as well as the lack of storage and packing facilities [3,6]. To reach the end users, there should be appropriate post-harvest handling mechanism. Methods and technologies of handling are imperative for various agricultural products.

Great attention should be given for ware storage especially for perishable commodities in order to transfer from the field to the table in a state of acceptable to users. Most of them begin deteriorate as soon as they are harvested, and most are particularly prone to handling damage at all times till consumed. Since they are susceptible to any action, proper handling and appropriate storage structure is paramount important to preserve their self-life. During the peak harvest seasons, because of the lack of different post-harvest technologies and market facilities with in their reach small scale farmers are forced to sell their produces at lower prices.

In general speaking, handling damage is greatly underestimated, because usually mishandling do not appears until sometime damage occurred. Mechanical or physical damage of the products can be occurred through all stage of the chain from harvest to consumption with inclusiveness of handling and transportation from rural to urban markets. Lack of proper storage systems are among the main factors contributing to the low yield of potato in the region, which is the case at the country level also [7]. Furthermore, market price of the product and marketing systems are also problematic [8]. Due to lack of an appropriate storage and handling equipment's, substantial amount of horticultural product is believed to go waste before it reaches for consumption or is sold at a thrown away price. According to Mulatu, 2005 [9] unavailability of proper potato seed storage forces the farmer to sell immediately during harvest with low price, whereas availability of proper storage facilities allow farmers to sell their potato tuber as a seed during planting or in the later season with higher price compared to the immediate sell.

Farmers stored potato either for ware or seed using various traditional mechanisms. These traditional storage facilities do not allow the farmer to store potato not more than three and half months without deterioration [8]. However farmer requires good storage either to use tubers of their own harvest as a seed source to postpone sales to get better market price and for household consumption in the later season. Low market demand for potato tuber production cost was among the main factor. According to Fuglie, 2007 [10] farmers in the Jeldu and Degem districts were already distinguished the seed and ware potato and they might look only for seed potato market, whereas according to Ayalew and Hirpa, 2014 [8] study farmers immediately sell the tuber as a ware due to fear of market unavailability for seed potato.

Postharvest losses can also be minimized by storing them at low temperature and high relative humidity environment [11]. The storage employs the cooling power of evaporation. Evaporative cooling occurs when dry warm air blown across a wet surface. Heat in the air is utilized to evaporate the water resulting in air temperature drop and a corresponding increase in relative humidity [12, 13]. According to Rusten 1985[14], Evaporative cooling is generally more efficient where air temperature are high; relative humidity very low, water available and air movement is adequately available.

An evaporative cooling chamber is simple technology, easy to construct and low cost of its construction since it can be made from locally available materials. Low temperature storage

system can effectively extend shelf life of fruit and vegetables in minimizing major postharvest losses by arresting metabolic breakdown and fungal deterioration. An evaporative cooling system having an efficiency of 50% has significant effect on room temperature of non-air conditioned as well as shaded rooms [15].

Material and Method

Site Selection

Potential potato producing districts were identified and selected according to recommendation established by Horo Guduru Zone Natural Resource and Agricultural Development office based on merit and accessibility to road. From Horo district, *Gitilo Dale* site was selected for conducting research. *Gitilo Dale* is located at altitude of 2770m above sea level, latitude $9^0 32^{'}$N, longitude $37^0 04^{'}$and characterized with wind speed of 0.02 to 0.04 m/s.. From Jardega Jarte district, *Sombo Watu* was selected. *Sombo Watu* is characterized with altitude of 2410m above sea level, latitude $9^0 57^{'}$N, longitude $37^0 05^{'}$E and has wind speed range of 0.01 to 0.02m/s.

Material

Important materials for construction of an appropriate evaporative cooling storage were identified and selected. Accordingly different sizes of wooden plank, straw, thatch, timber, mesh wire, mud and nails with different sizes were prepared and employed for construction of required size and shape of storage structure. Five storages were constructed and each potato storage has a capacity to store five quintals of potato tube. However Gudane Jalane and Menagesha potato variety were available at *Gitilo Dale* site but Gudena variety was selected and used as treatment since it is predominately cultivated. Jalane potato variety is used in *Sombu Watu*.

Construction of Storage

So far two meter width and three meter length ware potato storage were constructed for three & two farmers in Horro & Jardega Jarte districts respectively. The constructed potato storage structures were faced wind direction to enhance removal of warmed air due to respiration of potato tubers. The storages were constructed in sites where air is mostly windy for more than four months starting from September. The storage type is an evaporative cooling system and has various important components. Floor is basic component of potato storage structure and should be strong enough to support or carry the required load. Storage load mainly imposed from entire constructed body and loaded potato tubers. The floor carried the bed or maximum height of the piles of potatoes laid on four crates which has1.2m length and 0.6m width where potato tubers get over laid. Each crate has a capacity to store 80 kg of potato tubers. The constructed wall stands up to 1.5m above floor level to support bulk potatoes under normal condition. The wall in a bulk potato store, together with a layer of insulation, must resist all lateral forces. On these walls with preference to windy direction, ventilation window was suited for air entrance and exit for cooling system.

Four ventilation windows /with 35 by 40cm dimension were prepared in our workshop and constructed. Among these, two of them allow cool air in flow from environment in to the storage and the remaining two of them exit hot air from storage to the environment. The roof spans were 3 meter by 1.7meter and to provide a minimum overhang of 0.5m on inlet and out let elevations. The roof must prevent rain penetration and must not allow light to reach the potatoes. The actual opening part of the door requires no special structural attention. However, if it is intended to fully utilize the entire store volume, it is necessary to provide

vertical timber boards across the door opening. Main treatments are amount of damage, sprouted, shrinkage, temperature, humidity and area of storage. In traditional method, potato tubers were stored over floor that is exposed to sun light which is subjective to be decomposed easily.

Evaluation of Storage

Four quintals of potato tubers were get stored in each storage. Prior to harvesting potato tubers, potato stalks were removed in order to make better curing period. Before storing weight of potato, volume of potato, storage and ambient condition were collected starting on loading day. Potato tubers were harvested and screened /before storing them.

Storage parameters include temperature control, relative humidity control and air circulation. Both storage air inlet & outlet ventilation windows were opened during night time at 13:00 to 00:00 and closed at day time 00:00 to 12:00 at local time. Storage losses are mainly caused by the processes like respiration, sprouting and evaporation of water from the tubers. Therefore parameters like damage, wilting & sprouting which determine storage performance were closely observed & data were being collected within five days interval for both sites.

Result and Discussion

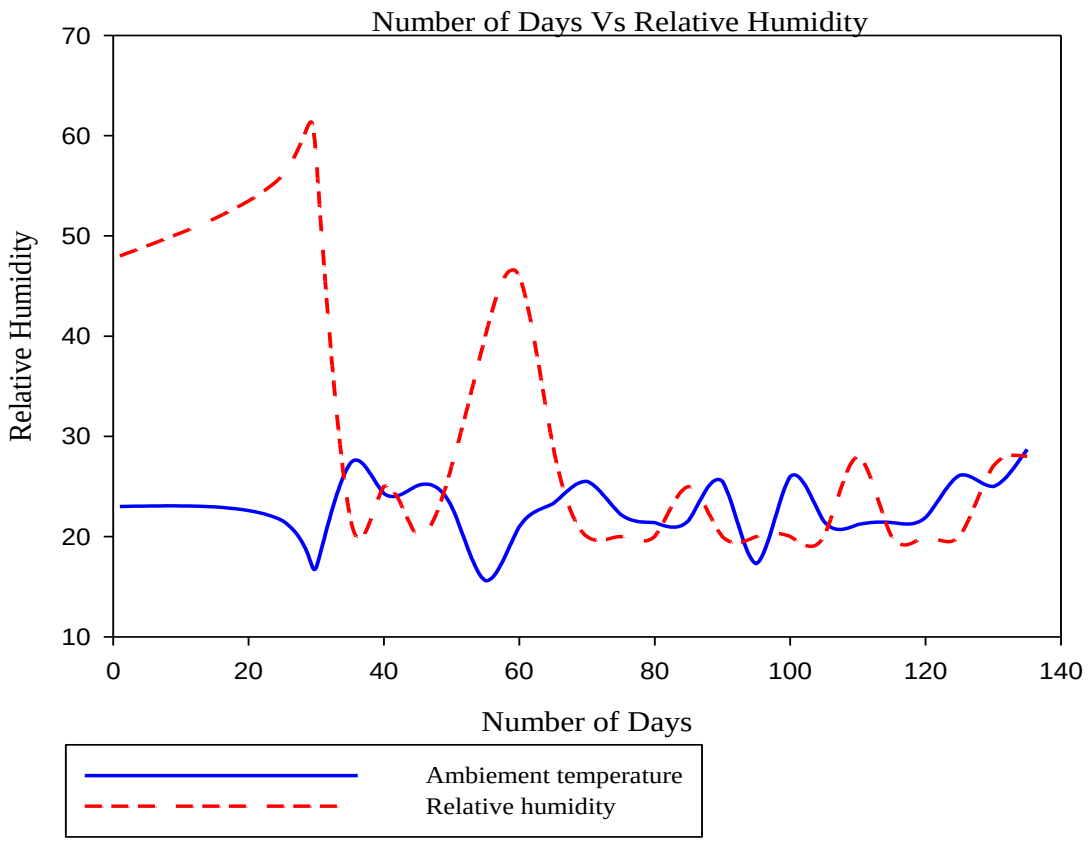
Since all data were collected at the same time with similar air condition, average based ambient condition was taken for all storages. Important data's' were begun to be collected proceeding storing date. Proper data was taken as follow, four quintals of potato tube were kept in each storage for case of *Gitilo Dale* site at the same day and important data's were registered. Whereas for case of *Sombo Watu*, three days later the remaining two storages were loaded and data collections were began.

In overall, proper storage practices include temperature, relative humidity, air circulation and maintenance of space between containers for adequate ventilation, and avoiding incompatible product mixes. Storage losses are mainly caused by the processes like respiration, sprouting, evaporation of water from the tubers, spread of diseases, changes in the chemical composition and physical properties of the tuber and damage by extreme temperatures. Temperature and relative humidity of surrounding environment and storage were collected at day and night of storage and control within five days interval since both are important parameters for determining shelf life of stored commodities. As a whole, ambient temperature and humidity, temperature and humidity of storage, mass of damage, sprouted and shrinkage were among those important treatment collected to determine number day potato get stored without inconsiderable losses occurred.

Gudane variety was collected using modern potato digger at Gitilo Dale site and stored starting from October 08, 2018 in three storages. Meanwhile, Jalane variety was digged and stored later than five days at Sombo Watu site. In both sites, data were collected and interaction of these parameters was anticipated as follows for each district, separately.

Horo District

Ambient temperature and humidity variation during day time at Gitilo Dale

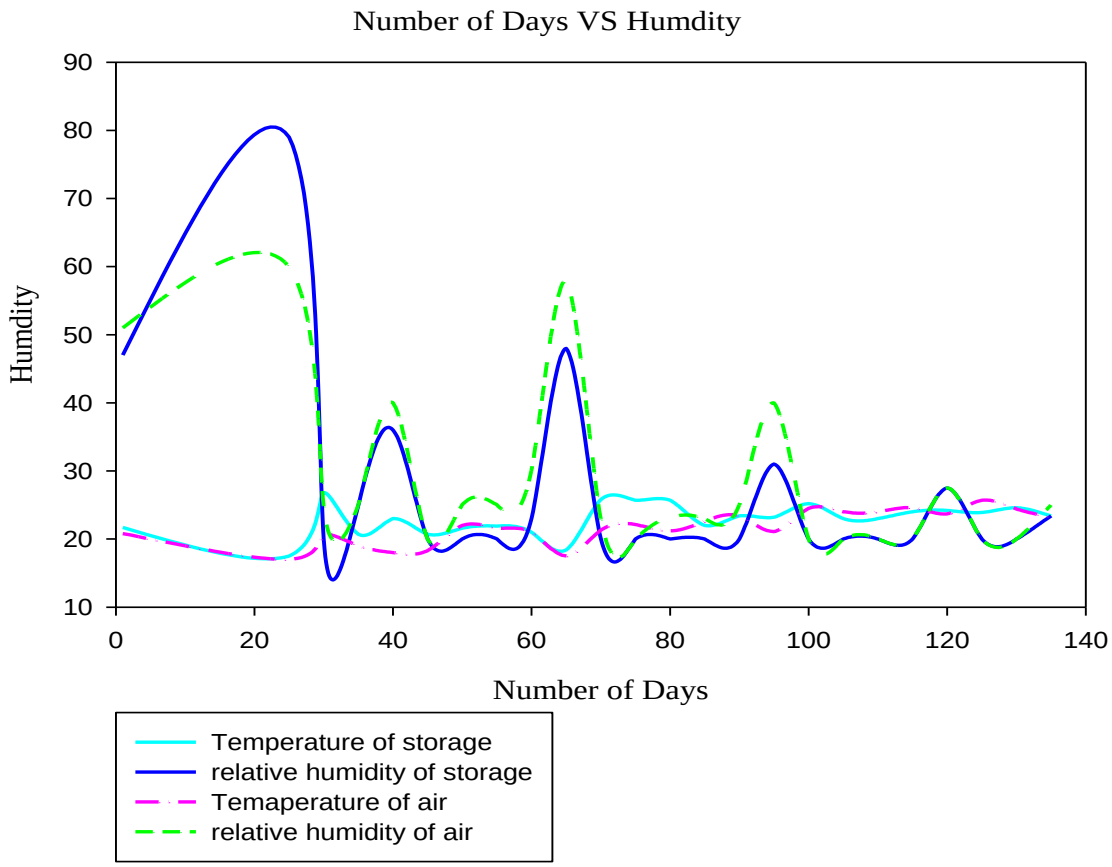


According to Basedya & Samuel, 2013 [16] under ambient temperatures from 25 to 35 °C, respiration rate is higher and storage life is short. Deterioration of fruits and vegetables during storage depends largely on temperature. Temperature control is one of the most important factors in maintaining product quality, throughout the period between harvest and consumption.

Respiration and metabolic rates are directly related to room or air temperatures within a given range. The higher the rate of respiration, the faster the produce deteriorates. However average based maximum and minimum ambient temperature variation of Gitilo Dale at mid-day is 27.3 °C and 15.6 °C respectively which is still less than recommendation.

Relative humidity, air movement and surface area are other important parameters to be considered during handling product stored since they have much contribution to determine shelf life of product stored. Here maximum and minimum relative humidity of potato stored during mid-day was 60 and 20%.

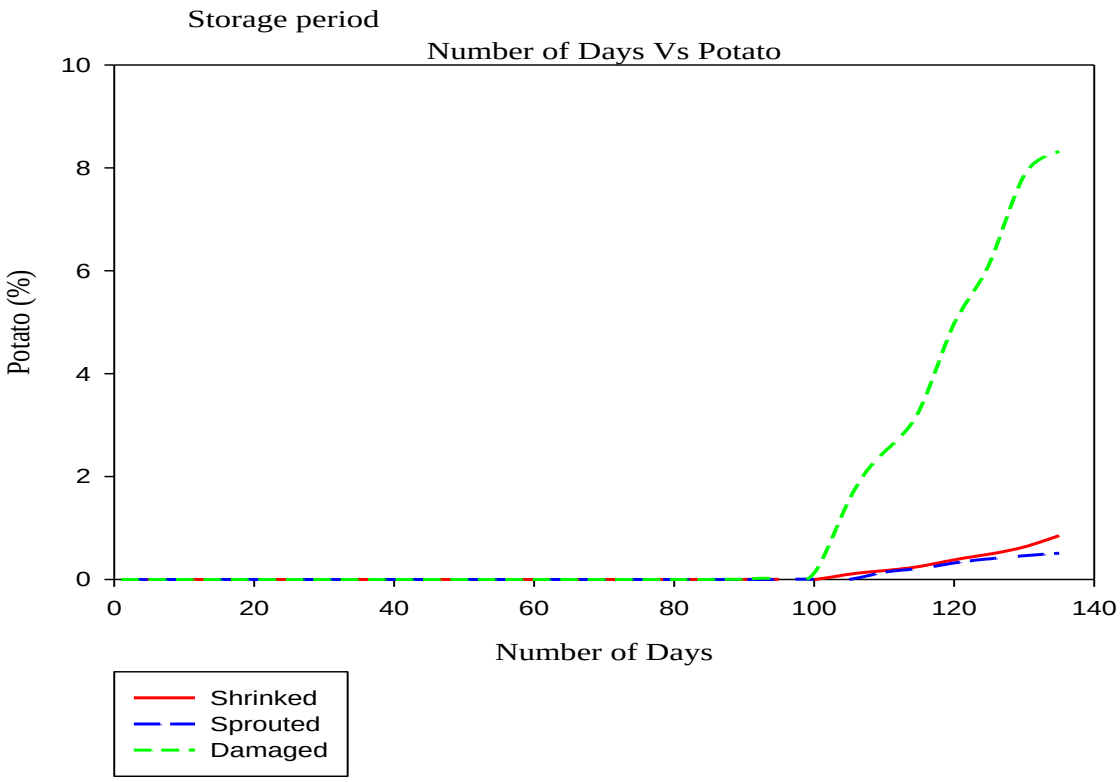
Night time ambient temperature and humidity as well as temperature and humidity of storage at Gitilo Dale Site



According to Odesola & Onyebuchi, 2009 [17] at high relative humidity, agricultural products maintain their weight, wilting and softening are reduced and rate of water evaporation is low and therefore cooling is low. Maintaining high humidity around harvested produce reduces water loss, which would result in decreased returns through poor quality which mean wilting, shriveling and loss of saleable weight [16].

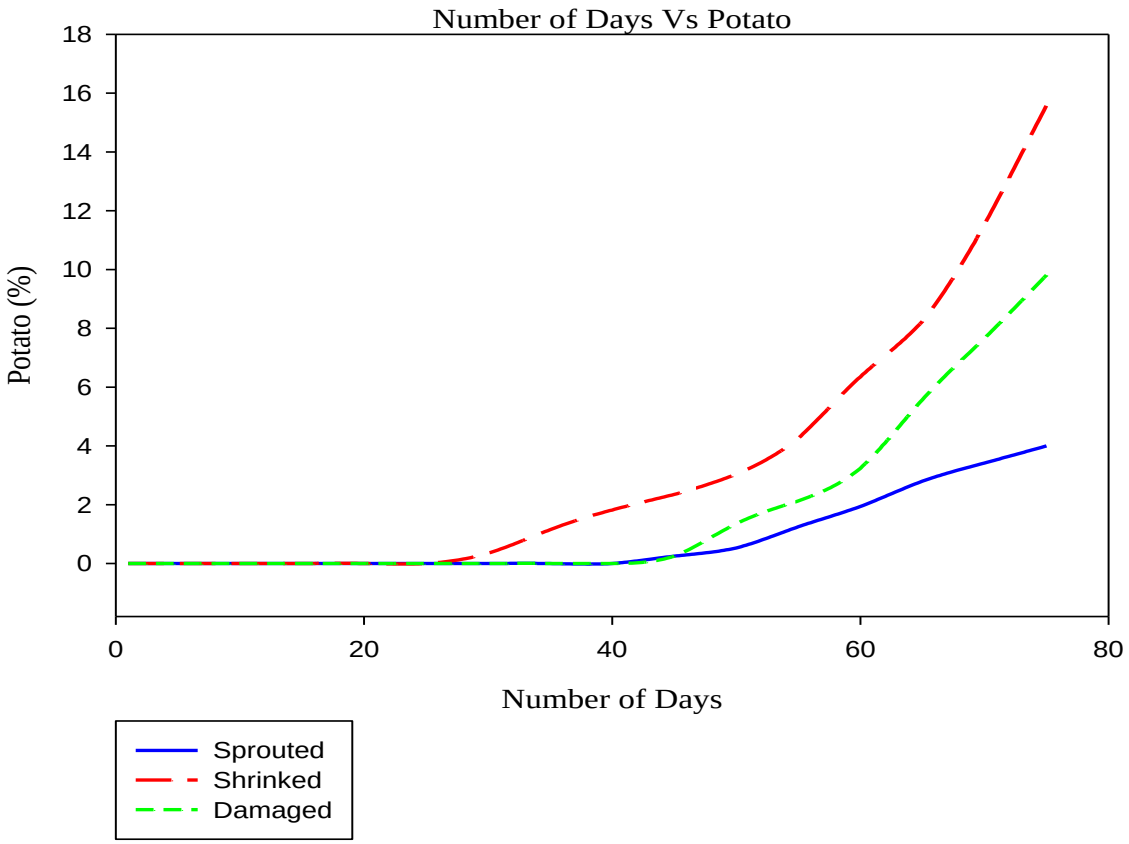
In order to prolong shelf life of tubers, relative humidity and temperature should be maintained properly. According to heat transfer application heat goes from higher temperature to lower temperature. During day time since the storage is tight and no way for light and wind, what products respire concentrated in storage. When ventilation windows which is directed to wind motion get opened during the night, cold wind wiped out the warms from the storage and storage get cooled.

According to Basedya & Samuel, 2013 maximum and minimum temperature of potato storage is 16 and 9 °c whereas maximum & minimum temperature of the storage is during night is 21 & 10 °c respectively. Here maximum & minimum relative humidity of environment around the storage is 70 % & 34% Air movement here is better and dried air blown outside of the ware storage which carried off warmed air from inside of the storage.



Rate of evaporation is mainly dependent on movement of air and surface area over which tubers stored. As water evaporates from a surface tends to raise the humidity of the air that is closest to the water surface. If humid air remains in place, the rate of evaporation will start to slow down as humidity rises. On the other hand, if the humid air and the water surface constantly been moved away and replaced with drier air, the rate of evaporation will either remain constant or increase. The greater the surface area from which water can evaporate, the greater the rate of evaporation [17].

Potato storaged as control employing traditional mechanisum

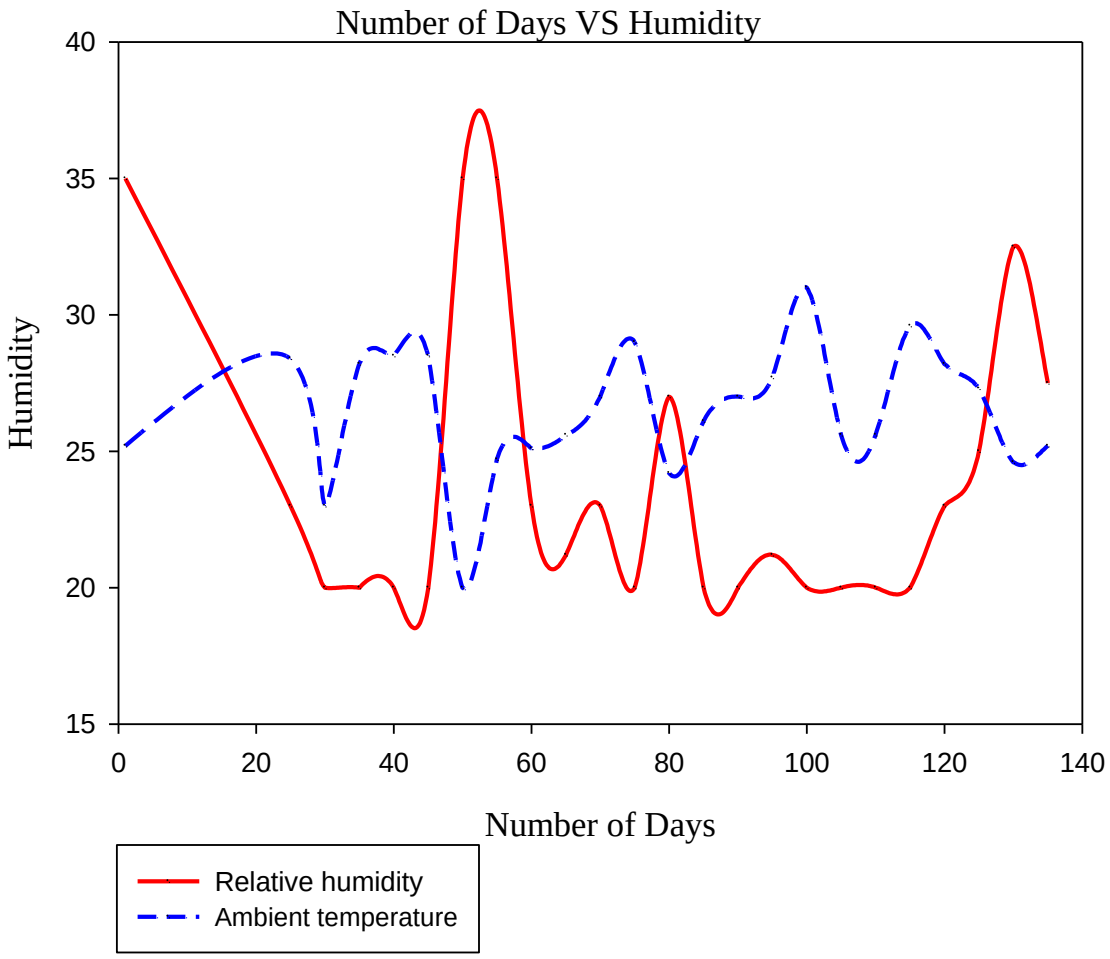


As the period of storage increased, rate of decomposition, shriveliing and sprout increased too. However at hundred thirty five days: 8.32 %, 1.36 % & 0.85% became sprouted, shrinked & damaged respectively. Here all sprouted tubers were directly used for on field plantation for the next season where as some shrinked part were used for dish. The storage was very tight and opaque for light to minimize degree of damage and welting and storage ventilation window should be opened as per programmed.

Since potato tuber respires, water gets losses quickly. Unless water vapor should be blown up with dry air coming outside through vent, wilting, shriveling & weight loss increased. Here there was no vent and means to remove humid air to get cooled environment and pad. Sample of 25kg potato tubers were used as control at seventy five days 54.65% wilted, 14.19% damaged and 30% sprouted.. It is traditional method so that the result becomes too high.

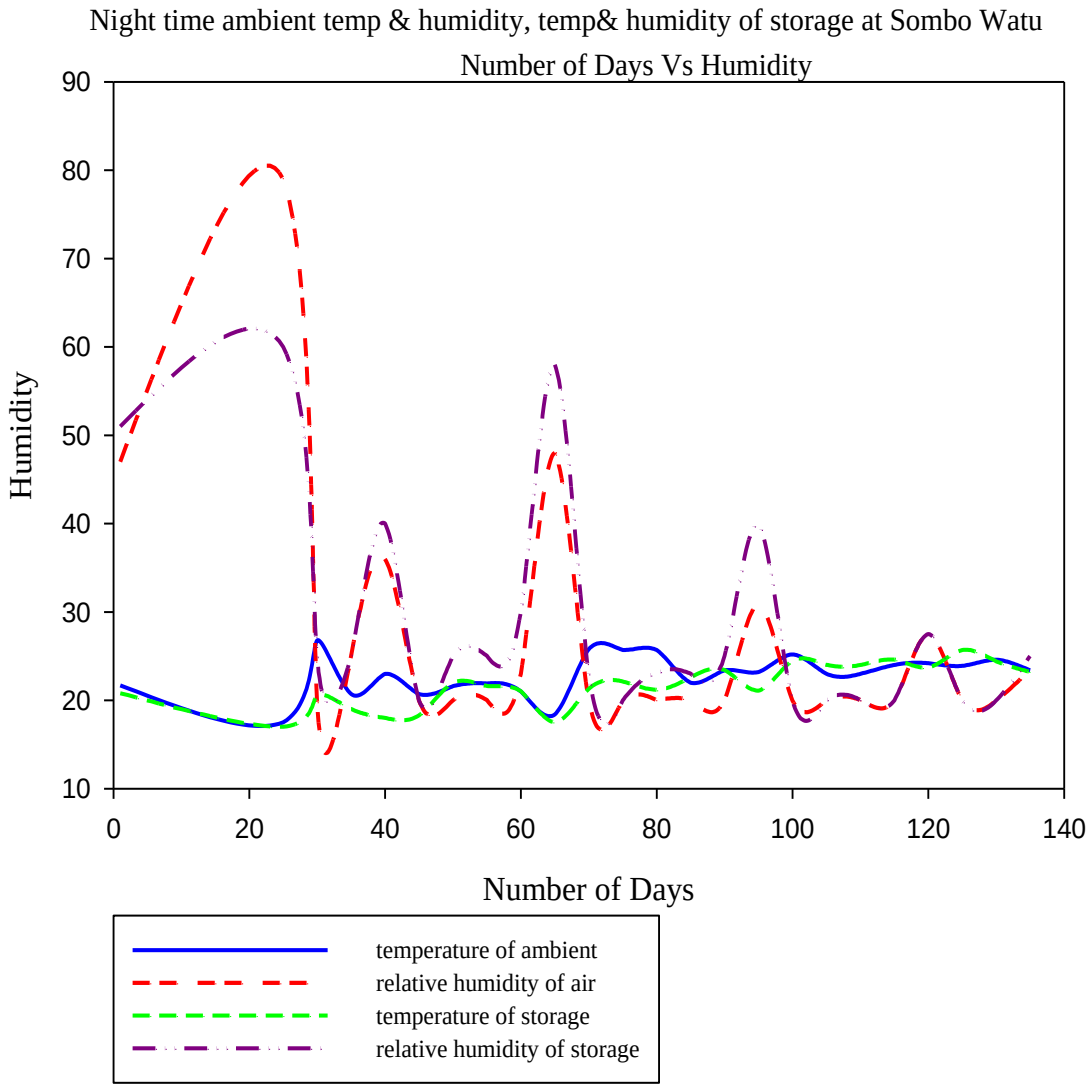
i. Jardega Jarte District

Day time ambient temperature and humidity variation of Jardega Jarte



Under ambient temperatures from 25 to 35°C according to Basediya, 2013 respiration rate is higher and storage life is short. However in case of Sombo Watu site of Jardega Jarte average based maximum and minimum ambient temperature variation at mid-day were 31 & 23°c respectively which is more or less in the specified range.

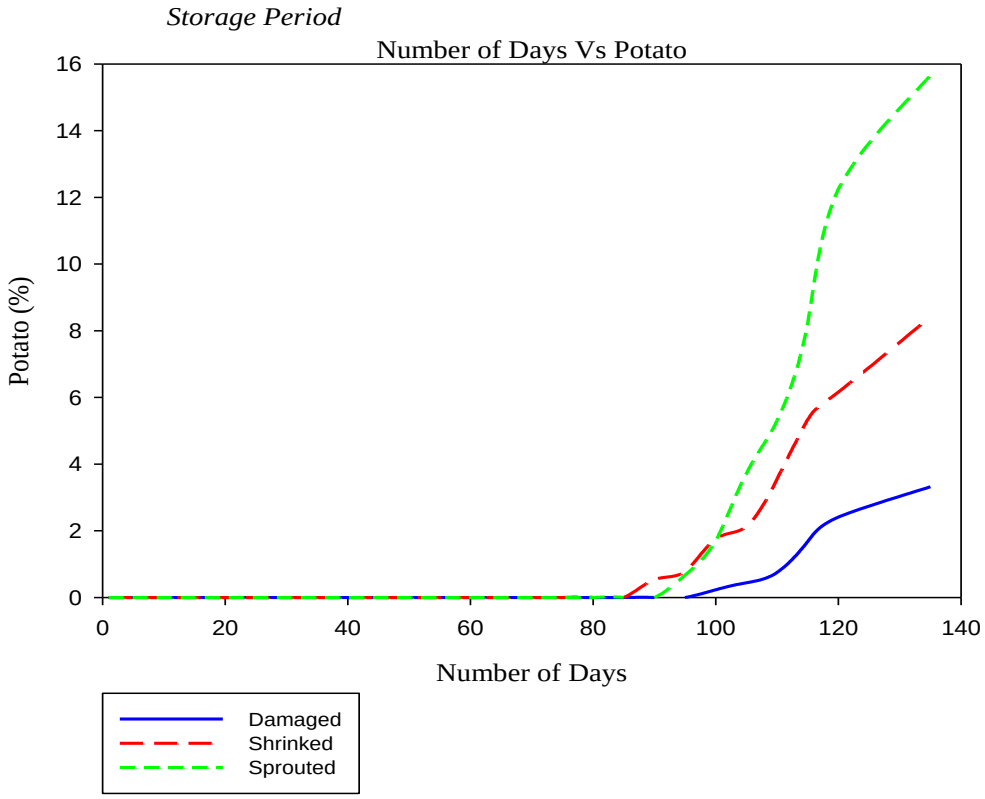
Since they have much contribution to determine shelf life of product stored, relative humidity, air movement and surface area are important parameters to be considered during handling product stored. Here maximum and minimum relative humidity of potato stored during mid-day was 36 and 20%. Both parameters were directly and indirectly influencing storage performance in handling practices.



According to Odesola & Onyebuchi, 2009 [17], when the relative humidity is high the rate of water evaporation is low and therefore cooling is also low. But relative humidity of the storage during night time is still higher than ambient when computed on average, maximum & minimum became 62 and 20% respectively.

However humidity & high temperate in combination favors the growth of fungi and bacteria. At night time higher temperature with warmed air presented in the storage but cold and dried air is blown in environment outside the storage. Since, at every day at 1:00 local time, ventilation window get opened for recirculation of air the chamber. Cold dried drive out warmed air due to creation of bouncy force because ingredient of density difference air. Temperature of storage is higher than temperature of air in environment this implies that water vapor get respired during the day time get accumulated and become removed at night time. This causes temperature difference which bases cool environment for potato tubers.

Since ambient temperature and relative humidity of Sombo Watu is higher than Horro district,



rate deterioration is increasing from time to time. As the period of storage increased, rate of decomposition, shriveling and sprout increased faster than that of Horro District. Since altitude is lower, air becomes warmer & wind speed is lesser. However at hundred thirty five days about 15.65%, 8.42% & 3.32% became sprouted, shrinked & damaged respectively, at equal number of days. Damage or decomposition mainly connected with injure caused during transporting from field in to storage and respiration processes. All damage and some sever shrinkage tubers are not useful. The remaining tubers can be used as food and seed. The sprouted potato totally used as seed for both off season and on season. Most of the time for off season case; it generates high income for farmers than on season.

Cost- Benefit Analysis

The storage is mainly constructed from locally available materials and total cost of construction of single storage is calculated to be 2192.26 Birr. To analysis net income, residual value of the storage was considered as 10% of initial cost of the storage. In addition useful life of storage is assumed to be 10 years. Storage has capacity of storing four quintals of potato tubers. Price of produce at farm level was 275 birr during harvesting time and 500 birr after 4 month storage. After four months, the produce can be used for various cases. The sprouted potato can be used as seed potato for the next season and those who losses their little weight can be used as dish. Here annual depreciation and interest cost can be calculated as formula below:

Annual depreciation = (initial cost- residual value)/useful life

Annual interest = ((initial cost + residual value)/2)*1% (FAO, 1994)

Table below show estimate total storage cost and income per one storage

	Basic Information required	Et. Birr
1	Fixed cost	228.46
1.1	Annual depreciation	215.3
1.2	Annual interest	13.16
2	Variable cost	1100.00
	Input (4qt seed)*275 birr	1100.00
3	Total cost	1328.46
4	Total output after 4 months 3.87qt*500 birr	1935.00
5	Net income in one year	**606.54**

Conclusion

From the experimental result obtained, we observed that various parameters are engaged to determine quality of storage of potato tubers. In addition to the maturity level and variety, damage, shriveling and sprouting have great importance in order to decide shelf life of stored potato and their valuable. Thus, damages and sprout can be minimized by taking care during transportation from field to the storage and harvesting time. Harvesting period and activity also affects the storing time and the stalk of the potato should be removed twelve days before storage to strengthen skin of potato under the soil.

With proper storage practices, holeta model ware storage has prolonged shelf life of potato for five months with little losses. While the remaining factor keeps constant, at Gitilo Dale site, this storage enabled to preserve potato tubers for about four and half months with little damages less than 1%. Since altitude, weather condition and wind speed of Holetta and Horro district is diverse, result obtained at both sites are somewhat different. Meanwhile, at Sombo Watu site within the same months potato get stored with losses of 3.5%.

Proper handling practices and managing time of operation are another important issue which affects storage produce life. Storage ventilation window operation time should be managed in order to have long storage time. Window should be opened at 13:00 and closed before 06:00 in order to block sunlight from entering the storage. If the light gets diffused in it speeds up sprouting faster and losses too. Main advantage of storage is prolonging shelf life of potato thereby sustainable availability of potato over the market and makes gain of additional money for farmers.

Reference

1. Nicolas C.,Visser R., Jacobsen E.,Vleeshouwers V.,de Wit P., Groenen M., Pieterse C., Wulff B.,2010.'Functional genomics of phytophthora infestans effectors and solanum resistance genes, PHD Dissertation, Wageningen University, Wageningen.
2. Visser, R, Bachen C, De Boer J, Bryan G, Chakrabati S, Feingold S,Gromadka R,Van Ham R, Hung S, Sagredo B and Tang X, 2009.'Sequencing the potato genome: outline and first results to come from the elucidation of the sequence of the world's third most important food crop'. A.m. Potato Res.86417-429.
3. Larry O' Loughlin, 2013. 'Potato in development, a model of collaboration for farmers in Africa', Supported by Irish AID and European Union, Ireland.
4. Central Statistical Agency of Ethiopia (CSA), 2007.'Agricultural sample survey: Report on area and production of crops', Addis Ababa, Ethiopia.

5. Emana B., Nigussie M., 2011. 'Potato Value Chain Analysis and Development in Ethiopia in Case of Tigray and SNNP Regions', International Potato Center, Addis Ababa, Ethiopia.
6. Endale, G., W. Gebremedhin, B. Lemaga. 2008.'Potato Seed Management'. In Root and tuber crops: The untapped resources, edition. W. Gebremedhin, G. Endale, and B. Lemaga, 53–78.Addis Ababa: Ethiopian Institute of Agricultural Research.
7. FAO, 2005. 'Food loss prevention in perishable crop'. FAO Agricultural Service Bulletin No.43.FAO, Rome, Italy.
8. Madhin G. Solomon, A, Gebre E, Kassa B, 2000. "Multi Location Testing of Clones In Ethiopia", Ethiopian Agricultural Research Organization, Progress Report.
9. Tewodros Ayalew, Paul C. Struik and Adane Hirpa, 2014.'Characterization of Seed Potato (*Solamum Tuberosum L*.) storage, pre-planting treatment and Marketing Systems in Ethiopia: The case of West Arsi Zone.
10. Mulatu E, Ibrahim E, Bekele E, 2005. 'Improving potato seed tuber quality and producers' livelihoods in Hararghe Eastern Ethiopia. Journal of New Seeds, Volume 7:31-56. http://dx.doi.org/10.1300/J153v07n03_03.
11. Fuglie K, 2007.'Priorities for potato research in developing countries: Result of a survey', American Journal of Potato Research, Volume 84: pp 353-365. http://dx.doi.org/10.1007/BF02987182.
12. Hall, E.G., 1973.'Mixed storage of foodstuff'. Sydney CRSIRO, Food Res. Circular No.9.
13. FAO and SIDA, 1976.'Farm structures of tropical climate'. FAO/SIDA, Rome, Italy.
14. Harper, J.C., 1976. 'Elements of food Engineering', Book, AV Publication Cooperation. Inc. Connection USA.
15. Chouksey RG, 1985.' Design of passive ventilated and evaporative cooled storage structures for potato and other semi perishables'. In Proc. Silver jubilee convention of ISAE held at Bhopal, India, October 29–31, pp 45–51.
16. Lawrence SA, Tiwari GN, 1989. 'Performance study of an evaporative cooling system for a typical house in Port Moresby'. Solar Wind Technology 6(6):717–724.
17. Amrat lal Basediya, D. V. K. Samuel & Vimala Beera, 2013. 'Evaporative cooling system for storage of fruits and vegetables - a review', Journal Food Science Technology: Volume 50(3):429–442, DOI 10.1007/s13197-011-0311-6.
18. Odesola IF, Onyebuchi O, 2009.'A review of porous evaporative cooling for the preservation of fruits and vegetables'. Pacific Journal Science Technology: Volume 10(2):935–941.

Development and Evaluation of Drum type Teff Seed Row planter

[1]Gelgelo Kibi, [1]Mekibab Alemayeh, [2]Kamil Ahimed, [1]Ashebir Hailu, [1]Solomon Lemessa
[1]Bako Agricultural Engineering Research Center, P.O.Box 07, Bako, Ethiopia
[2]Oromia Agricultural Research Institute, Addis Ababa, Ethiopia
Corresponding author: E-mail:- gelgelokibi@gmail.com

Abstract

Teff has the largest value in terms of both production and consumption in Ethiopia and the value of the commercial surplus of teff is second only to coffee. However, despite its importance in Ethiopia, teff yields are low. Recently it has been argued that the traditional sowing technology is a major constraint to increased teff productivity. Additionally, Traditional row planting is tedious, labor intensive and has ergonomically problems. Hence, this study was initiated to develop an effective and low-cost animal drawn teff row planter. Four rows teff planter was developed and evaluated on different soil types. Three sowing methods, hand broadcasting, machine and traditional row, were used. The developed equine animal drawn teff planter reduces human power from four to one Machine row planting only takes 4.12 - 5.41 person-hours, While plastic bottle row planting requires 108 -127.6 person-hours per hectare. Even though, equine animal teff row planter was important in time and labor saving and improves the operational difficulties of traditional row planting, it requires improvement on upgrading planting precision, basically to the metering mechanism of flute roller.

Keywords: Teff, seed row planter, Planting Time, seed rate, distribution uniformity

Introduction

Teff is Ethiopia's most important staple crop. Teff has the largest value in terms of both production and consumption in Ethiopia and the value of the commercial surplus of teff is second only to coffee (Minten *et al.,* 2013). Despite its importance in Ethiopia, teff yields are low. In the production year 2012-2013, yields were 1.4 metric tons (mt) per hectare (ha), significantly lower than other cereals, such as maize (3.1 mt/ha), sorghum and wheat (both 2.1 mt/ha) (CSA 2013). This low teff yield is seemingly explained by the limited knowledge about possible avenues for improving teff productivity, combined with problems inherent to teff botany. Teff research has received limited national and international attention, the latter presumably because of its localized importance in Ethiopia (Berhane *et al.,* 2011, Fufa *et al.,* 2011). Moreover, teff yields are low because of agronomic constraints that include lodging, low modern input use, and high post-harvest losses (Habtegebrial *et al.,* 2007, Berhe *et al.,* 2011, Fufa *et al.,* 2011).

Recently it has been argued that the traditional sowing technology is a major constraint to increased teff productivity (Berhe *et al.,* 2011). Farmers typically plant teff by broadcasting, at a high seed rate. Alternative planting methods, such as row planting seeds or transplanting seedlings, in which the seed rate is reduced and more space between plants is given, are seen as being superior to traditional broadcasting (Berhe *et al.,* 2011, Fufa *et al.,* 2011).

Experiments on these alternative planting methods in controlled settings have shown large and positive impacts on teff yields (Berhe *et al.*, 2011, Fufa *et al.*, 2011). As a consequence, in 2013 the Ethiopian government rolled out a nationwide campaign to promote the use of improved technologies for teff production, including row planting, aiming to scale up their adoption to almost 2.5 million teff farmers.

Traditional row planting is tedious, labor intensive and has ergonomic problems. Subsequently, with a goal of mechanizing teff planting in mechanical row planter technologies, tremendous efforts have been made in the country by various organizations, including; EIAR, ATA, OARI, and others. However, their field evaluations and later assessments showed that, none of the developed planters have been functioned effectively, in terms of applying the teff seeds and fertilizers in uniform rates and rows and reduction of required labor, especially in all soil types as well as weather conditions of the country (ideo.org, 2013, Joachim V. *et al.*, 2013; ESSP II, 2013).

Therefore, the aim of this study is to develop an effective and low-cost, animal drawn drum type teff row planter and evaluating its performances at the farm level.

Material and Method

Description of the Planter

The developed planter consisted of frame, seed and fertilizer hopper, metering mechanism, seed and fertilizer control valve.

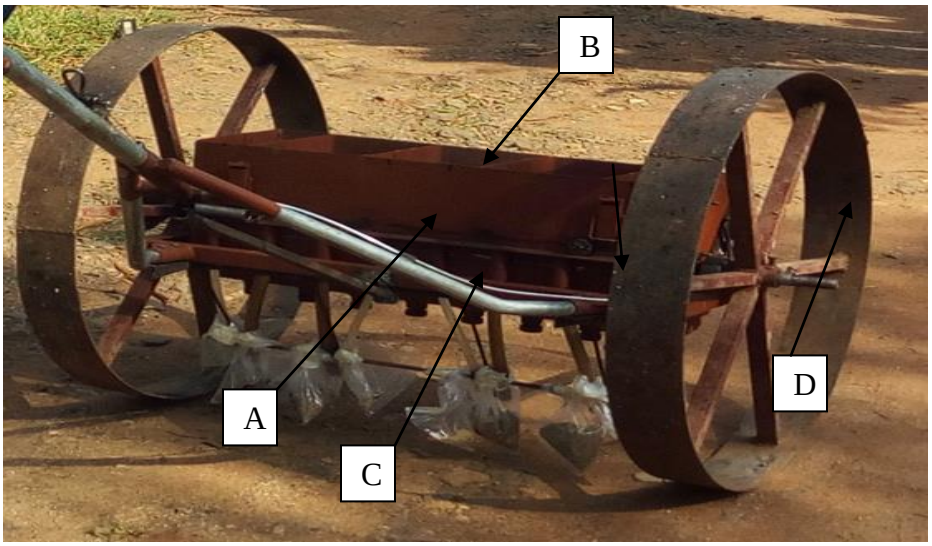


Figure 1. Basic parts of the planter. A - Frame, B - Seed and Fertilizer Hopper, C - Seed and Fertilizer Control Valve, D – Wheel

Figure 2. On farm Evaluation of the teff seed row planter

Treatments and Method of Sowing

The approach and experimental design applied during the experiment were mentioned in table 1 using Kena variety. Animal used for this experiment was horse. Machine row planting was replicated four times for each site.

Table 1. Treatment Approach

Sites	Treat.	Sowing Method	Fertilizer rate (Kg/ha)	Sowing rate Kg/ha	Plot (m^2)
Toke Kutaye, Amboand Diga Wereda	1	Hand broadcasting	100kg NPS and 50kg Urea	25	10 X 20
	2	Hand broadcasting	100kg NPS and 50kg Urea	10	10 X 20
	3	Machine row planting	100kg NPS and 50kg Urea	10	10 X 20
	4	Plastic bottle Planting	100kg NPS and 50kg Urea	29.6	10 X 20

Performance of the Prototype

The evaluation parameters were yield, labor requirement, planting time, labor productivity and distribution uniformity.

The data were collected from the parameters as mentioned below:

Yield: Teff yield is measured in Kg/ha, obtained by dividing output by area

Labor Requirement: it is the number of person required on operation per time (in person per operation)

Planting Time: the time taken for sowing by animal drawn planter and manual (hr/ha)

Economic evaluation: the cost of operation for the machine was worked out by calculating the fabrication, fixed and variable costs.

Distribution Uniformity: Plant uniformity within and across the rows was determined form coefficient of variations

Labor productivity: Labor productivity is measured as total teff output (in kg) divided by total labor input (in person-hours) for row planting teff.

Economic evaluation

The cost of operation for the machine was worked out by calculating the fabrication, fixed and variable costs. Estimation of annual and hourly operational costs of the planter were based on capital cost of the planter, interest on capital, cost of repairs and spare parts, labor cost, and depreciation. The operational cost components of the prototype planter were estimated in Birr (EB) as follows: (Ashebir T, 2015)
Depreciation (Dp), was calculated as follows:

$$Dp = \frac{CC - SVC}{EL}, EB/hr$$

SVC = CC X 10%, Assume, EL = 10years

Interest on capital (IC), was calculated as follows: (I = 8%)

$$IC = \left(\frac{CC + SVC}{2}\right) X \left(\frac{I\%}{NAOHP}\right), EB/hr$$

Labor wages (LW), was calculated as follows: (70 birr/day and 6hr working hour)

$$LW = \frac{DLW}{DWH}, EB/hr$$

Cost of repairs and spares (CRS) was calculated as follows: (AWHP = 180hr or One month)

$$CRS = \frac{CCX\,6\%}{AWHP}, EB/hr$$

Wage of oxen (WO), was calculated as follows: (150 birr/day and 6hr working hour)

$$WO = \frac{DOW}{DWH}, EB/hr$$

Hourly operational costs = (Dp + IC + LW + CRS + WO)

Where:- Dp = Depreciation, CC = Capital cost, SVC = Selvage Cost, CRS = Cost of repairs and spares, EL= Estimate life (h), I = Interest %, DLW = Daily labor wage, DWH = Daily working hours (hr), IC = Interest on capital (EB/hr), WO = Wage of oxen, DOW = Daily oxen wage, LW = Labor wages, NAOHP = Number of the annual operational hours of the planter (EB/h), AWHP = Annual working hours of the planter

Result and Discussion

Teff Yield

Given the general hypothesis in the yield benefit of row planting to estimate the effect of machine and plastic bottle row planting, broadcasting of the equal planting rate with the machine (10kg) and traditional broadcasting on teff yield using production data from the experimental plots were collected accordingly. Teff yield was measured in Kg/ha and yield obtained was shown as follow.

Table 2. Yield results (Kg/ha) of different sowing method across the districts

Sowing methods	Plot	Districts			
		T/kutaye	Ambo	Diga	Mean
Hand broadcasting (25kg/ha)	1	600	730	530	620
Hand broadcasting (10kg/ha)	1	650	740	460	617
Machine row planting (10kg/ha)	1	920	855	630	802
	2	862	905	620	796
	3	880	960	615	818
	4	910	840	635	795
	Mean	893	890	625	803
Plastic bottle Planting (29.6kg/ha)	1	1200	990	650	947

Plastic bottle planting gave better yield over other treatments. This was observed due to planting rate and operational difficulty of drawn animal that reduce number of rows of the plot. Comparing with the same rate broadcasting methods, the machine row planting had 37.4, 20.3 and 35.9% better yield at Toke kutaye, Ambo and Diga weredas, respectively. This was attributed to the fact even distribution of teff seed during sowing and row planting facilitate crop managements.

The mean grain yield obtained from machine row planting method was 48.8, 21.9, and 17.9% greater than hand broadcasting of 25kg/ha planting method at Toke kutaye, Ambo and Diga weredas, respectively. Though plastic bottle planting improved teff productivity more than the machine row planting, it is a labor intensive during implementation on. This is why traditional row planting is not adopted by all farmers. According to Vandercasteelen (2014) implementing row planting tends to have a positive yet moderate yield effect though it requires substantially more than human labor.

Labor Requirement

Using equine animal drawn teff planter requires one person. In case of traditional method of teff row planting totally four persons are required per single operation, one for dropping seed, one for dropping fertilizer and two for adjusting the row spacing. Comparing human man power required for horse drawn teff planter reduces human power from four to one which is significant for specific operation. Additionally, the animal drawn teff planter removes the tediousness of traditional teff row planting.

Planting Time

Using the detailed data collected from the experimental plots, Table 3 shows the labor requirement for machine and plastic bottle row planting farmers in person-hours per hectare. As expected, there is an increase in labor input for plastic bottle planting manner and it is very significant when we compare to machine row planting. Even though, person – hour per

hectare for teff is greater than fertilizer drill all of human power (i.e four) hour per hectare for planting is the same. Because their operations are depends on each other's.

Planting Time (Hr/ha)

Table 3. Lobar intensiveness (hr/ha) of plastic bottle row planting was compared with the machine row planting.

Sowing method	**Seed/fe**	**Plot**	**Districts**			
			T/kutaye	Ambo	Diga	Mean
Machine row planting		1	4.58	5.43	4.12	4.71
		2	4.34	5.56	3.96	4.62
		3	4.02	5.66	4.13	4.60
		4	4.67	4.98	4.28	4.64
		Mean	4.40	5.41	4.12	4.64
Plastic bottle row planting	Teff seed		27	31.9	31	29.97
	Fertilizer		26.5	27.3	28.8	27.53

Machine row planting on average takes 4.40, 5.41 and 4.12 person-hours, While plastic bottle row planting requires 108, 127.6 and 124 person-hours (or about 17, 20 and 19 person-days extra per hectare for six hour working time per a day) for Toke Kutaye, Ambo and Diga wereda, respectively. Labor productivity was measured as yield (in kg) divided by total labor input (in person-hours). This allows us to estimate the effect of machine and plastic bottle row planting on labor productivity after harvest.

Table 4. Labor productivity of machine row planting and plastic bottle row planting

Sowing method	**Districts**		
	T/kutaye	**Ambo**	**Diga**
Machine row planting			
a. Average yield (kg/ha)	893	890	625
b. Labor input (person - hr/ha)	4.40	5.41	4.12
Labor productivity machine (a/b)	202.95	164.51	151.69
Plastic bottle row planting			
a. Average yield (kg/ha)	1200	990	650
b. Labor input (person - hr/ha)	108	127.6	124
Labor productivity plastic bottle (a/b)	11.11	7.76	5.24

Plastic bottle row planting was shown to have a strong and highly significant negative effect on labor productivity. Using the machine row planting` practice, farmers were able to produce between 151.7 – 202.95 kg of teff for each person-hour of labor. While using plastic bottle row planting, it was reduced to between 5.24 and 11.11 kg per person - hour. The plastic bottle row planting therefore decreases labor productivity by between 3.5 and 5.5 percent per hour (This mean, machine row planting increases labor productivity by 18.27 – 28.95 times).

Economic evaluation

The cost of operation for the machine was worked out by calculating the fabrication, fixed and variable costs. Estimation of annual and hourly operational costs of the planter were based on capital cost of the planter, interest on capital, cost of repairs and spare parts, labor cost, and depreciation.

Depreciation (Dp), was calculated as follows:

$$Dp = \frac{CC - SVC}{EL}, EB/hr$$ Assume, EL = 10years

$$= (4902.56 - 490.256)/(10X180) = 2.45EB/hr$$

$$SVC = CC \text{ X } 10\% = 4902.56X.01 = 490.256EB$$

Interest on capital (IC), was calculated as follows: (I = 8%)

$$IC = \left(\frac{CC + SVC}{2}\right) X \left(\frac{I\%}{NAOHP}\right), EB/hr$$

$$= ((4902.56+490.256)/2) \text{ X } (0.08/180) = 1.2EB/hr$$

Fixed cost (ET/hr) = Dp + IC = 2.45 +1.2 = 3.65ET/hr

Labor wages (LW), was calculated as follows: (70 birr/day and 6hr working hour)

$$LW = \frac{DLW}{DWH}, EB/hr$$

$$= 70/6 = 11.67EB/hr$$

Cost of repairs and spares (CRS) was calculated as follows: (AWHP = 180hr or One month)

$$CRS = \frac{CCX\,6\%}{AWHP}, EB/hr$$

$$= (4902.56 \text{ X}0.06)/180 = 1.63EB/hr$$

Wage of oxen (WO), was calculated as follows: (150 birr/day and 6hr working hour)

$$WO = \frac{DOW}{DWH}, EB/hr$$

$$= 150/6 = 25EB/hr$$

Variable cost (EB/hr) = LW + CRS + WO = 11.67 +1.63 +25 = 38.3EB/hr

Hourly operational costs = (Dp + IC + LW + CRS + WO)

For plastic bottle row planting operational cost is only labor wage. It is the same with the labor wage of the planter per a person. But it is four times because of number of labors required per operation.

Table 5. Summary of cost of the prototype

Planter Capital Cost, ET birr	Fixed cost, ET birr/hr	Variable cost, ET birr/hr	Total operational cost (Fc+Vc), ET birr/hr
4902.56	3.65	38.3	41.95

The operational cost of the prototype planter is 184.58, 226.95 and 172.83 ET birr/ha while the plastic bottle row planting takes 1260.36, 1489.09 and 1447.08 ET birr/ha at Toke Kutaye, Ambo and Diga wereda, respectively. This is why traditional row planting is not adopted by all farmers again in addition to labor intensive and ergonomically problem

Distribution Uniformity

According to PAMI (Prairie Agricultural Machinery of Canadian machinery research) the coefficient of variation is categorized as follows for rating distribution of sowing implement.

CV greater than 15% -- unacceptable
CV between 10 - 15% -- acceptable
CV less than 10% -- Very good
CV less than 5% -- Excellent

Plant uniformity with in across the rows was determined form coefficient of variations. The coefficient of variation (CV) of the sites is calculated from average sample and standard deviation of the taken data. . `

	Districts			
	Toke Kutaye	Ambo	Diga	Over all
STDEV	10.39	9.02	7.94	9.79
Average Sample	82	79.67	64.00	75.22
CV (%)	11.81	11.32	12.41	13.02

Based on recommendation planting uniformity of the evaluated prototype is within in the acceptable range for this parameter.

Conclusion and recommendation

From the obtained results, the prototype showed significant advantage over other planting method on some evaluation parameters like yield over traditional hand broadcast of 25 and 10kg/ha rate and labor requirement and planting time over plastic bottle row planting. Though, the test results showed the needs of more improvements, generally, the developed animal drawn teff row planter was seen as it is important in time and labor saving and improves the operational difficulties of traditional row planting. Hence, the developed planter has no many and costly materials in its construction, so it was also seen as it's relatively cost effective in the area, provided that its performances are get improved.

The improvement of the planter is recommended to upgrade its planting precision with regards to its seed and fertilizer dropping and recommended seed rate uniformity on the common soil types of the area. Thus, the metering parts of the machine can also be changed to other metering mechanisms, such as, flute roller, that might be used to maintain distribution and plant uniformity in using for planting / drilling small seeds. In addition, other improvements of the prototype were given, to change its operation mechanism to be manually carried either on the chest or back rather than animal drawn for heave soil. Lastly, increasing the used seed rate, from 10kg/hectr to 12-15kg/hectr were recommended as the average seed rate on different soil type and moisture availabilities.

Reference

Ashebir Tsegaye (2015), Development of Animal Drawn Multicrop Planter. Thesis, Haramaya University, Ethiopia

Berhane, G., Z. Paulos, and K. Tafere. 2011. Foodgrain Consumption and Calorie Intake Patterns in Ethiopia. ESSP II Working Paper 23. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.

Berhe, T., Z. Gebretsadik, S. Edwards, and H. Araya. 2011. "Boosting Tef Productivity Using Improved Agronomic Practices and Appropriate Fertilizer." In Achievements and Prospects of Tef Improvement. Proceedings of the Second International Workshop, November 7-9, 2011, Debre Zeit, Ethiopia, edited by K. Assefa, T. Solomon, and Z. Chanyalew, 133–140.

CSA (Central Statistical Agency). 2013. "Agricultural Sample Survey: Area and Production of Major Crops, Meher Season". Vol. I. Addis Ababa, Ethiopia.

Fufa, B., B. Behute, R. Simons, and T. Berhe. 2011. "Tef Diagnostic Report: Strengthening the Tef Value Chain in Ethiopia". Addis Ababa, Ethiopia.

Habtegebrial, K., B.R. Singh, and M. Haile. 2007. "Impact of Tillage and Nitrogen Fertilization on Yield, Nitrogen Use Efficiency of Tef (Eragrostis Tef (Zucc.) Trotter) and Soil Properties." Soil and Tillage Research 94(1): 55–63.

Minten, B., S. Tamru, E. Engida, and T. Kuma. 2013. Ethiopia's Value Chains on the Move : The Case of Teff. ESSP II Working Paper 52. International Food Policy Research Institute (IFPRI). Addis Ababa, Ethiopia.

Development and Evaluation of Potato Grading Machine

Abdulahi Umar
Oromia Agricultural Research Institute, Fedis Agricultural Research Center, Harar, Ethiopia
Email: umarabdulahi2010@gmail.com

Abstract

This study presents the performance evaluation of a fabricated potato grader that uses an expanding pitch rods or increasing gaps as small, medium and large potato grades. Response variables were the grading system efficiency in percent and capacity in kg hr^{-1}. These were evaluated on the linear speed of conveying elevator in meters per minutes (m/min) and of inclination angles of the grading unit in degrees. Results of the evaluation showed that the grader had its optimum performance when operated at 25m/min linear speed of the conveyor and inclination of 23 degrees giving a system efficiency of 90.6**%**, and capacity of 1146.0 kg/hr. The total cost of the potato grader was Birr 40,000.00 with an estimated life span of 5 years. It had an annual fixed cost of Birr 8,000.00 and variable operating cost of Birr 15.00/hr. The grader had a break-even point of 1000 ton/year. If available quantity of tubers is greater than the break-even quantity, the use of the grader profit. Otherwise, the device is expensive to use when available quantity is less than the break-even quantity.

Keywords: Angles of Inclination, Conveyor, Efficiency, Grading

Introduction

Potato grading is an important factor in the production and marketing process of potato. Grading helps the potato producers and sellers to determine the price. It reduces the cost of marketing and helping the consumers to get standard potato at fair price. It facilitates the scope to widen the avenue for potato export. Grading has a direct influence on utilization point of view, as the small, medium sized and large tubers are prepared for 'seed tubers' and large sized tubers are preferred for processing purpose. The horticultural product has inherent variability in size at harvest that differentiates them in value. For the ease of buyer it is necessary to grade them according to some objective standard. Therefore it is need of the time to provide facilities at the doorstep of the farming community, so that they may be able to market better quality horticultural products. For most types of fruit and vegetable, bruising is the most common type of post-harvest mechanical injury.

In post-harvest handling, conveying and grading were two most important operations responsible for mechanical injury. Fresh crop and damage free post-harvest handling of fruits and vegetables were considered basic requirements to increase the farmer's profit margin. According to a study by many researchers large number of factors was limiting our production and export potential of fruits and vegetables. The most common among them were poor farm management practices, lack of adequate social and physical infrastructure such as skill development, extension, transportation, and storage facilities, absence of marketing intelligence, improper storage of seeds, irregularities in domestic and international markets and lack of grading. The normal practice in *Dire Dawa* and *Harar, Haramaya and Kombolcha,* Eastern Ethiopia were to market the ungraded potato tubers and where it was necessary then it was obligatory to be carried out manually by cullers who consider a number of grading factors and separate potatoes according to their physical quality which was tedious,

labor intensive, time consuming, slow and non-consistent. Nowadays in world trade organization (WTO) scenario, grading of the horticultural products became basic requirement for national and international marketing system. Marketable tubers will command a premium price in the market when properly graded. Bringing ungraded tubers in the market will affect marketing system making a delay on the disposal of other products. This causes significant loss due to physiological degradation of the crops as a result of long queue. a basis on the classification of potato tubers was provided as small, medium and large with minor diameters of 30-3.9 cm, 4.0-7.4 cm and 7.5 cm and above respectivel (Anonymous. 2005). This study was then conducted to evaluate the performance of the design developed and fabricated expanding pitch rod-type potato grader in terms of grading system efficiency and capacity percentage; establishing the optimum operating machine parameters such as speed of the conveyer (rpm) and angles of inclination of the grading unit (degrees); and performing simple cost and economic analysis of the device were made. Therefore, the activity was proposed to design, fabricate and evaluate the performance of a potato grader. Specifically as it was aimed in the study, a machine for grading potato tubers by size was designed and fabricated. The performance evaluation of the grading machine in terms of grading system efficiency and capacity was undertaken.

Materials and Methods

Description *of the Study Site*

The potato grader was designed and manufactured at the Fedis Agricultural Research Center Workshop, Oromia Agricultural Research Institute, Ethiopia. The grading experiment was conducted in the Fedis Agricultural Research Center located in the Harar city, which is located in eastern Ethiopia,

Materials

The materials used were the designed and fabricated potato grader and air-cooled diesel engine specified as:

- Model: KM178F/FS
- Air –cooled Diesel Engine
- Maximum output power is 3.68 kw

Design of Potato Grading Machine

Potato grader: Shown in figure 1 is the Photo of the grader that was initially fabricated having the overall dimension of 563cm long, 130cm width and 130cm height, respectively. The grader comprises of a feeding trough, conveyer, prime mover, grading unit, catchment bag mounted on a frame. Machine parts were designed using standard formula. The hopper serves as guide for the potato tubers into the elevating conveyer that elevates and feed into the grading unit. The grading unit was a expanding pitch type with increasing gap starting from the inlet. The expanding pitch assembly has three regions: the region for small, medium and large-sized tubers. The first region has gaps that allow only small tubers to pass. The gap of the expanding pitch for this region ranges from 3.0 cm to 3.9 cm. the second region has gaps of 4.0 cm up to 5 cm allowing medium sized tubers to pass. The third is the region for the large tubers with gaps greater than 6 cm. below the expanding pitch were catchment bags for

the graded tubers. The bag has three divisions to separate the graded tubers from the regions of the expanding pitch type grading unit.

Figure.1. photo of the potato grade

Key: 1. Hopper, 2. Conveyer 3. Grading Unit 4. Potato Tubers Outlets, 5. Main frame of grading unit, 6. Main frame of conveyer, 7. Pulley, 8. Belt, 9. Engine,

Take-in conveyor

To elevate and convey the potato from feeding trough to the hopper- like space bar and the expanding pitch grading unit, a flight type conveyor was designed. The design of take-in conveyor was made by keeping in view the function to perform, fabrication facilities and skill, simplicity of the design, social acceptability, knowhow of the end users, trend of the local industry, local soil and environmental conditions etc. Raising the incoming product to the grading unit was involved a small drop. Loading capacity, fall height and angle of repose (of the product to be lifted and conveyed) were considered for safe conveying of the produce without any injury to the crop. Take-in conveyor consisted of driving shaft, driving drum, flat belt, frame of the conveyor and power transmission system. The conveyor was powered through a V-belt and pulley arrangement from the main prime mover, the engine. Speed reduction arrangement was also developed to vary the linear speed of the conveyor to change the feed rate.

Capacity of the conveyor

The take-in conveyor was designed to operate at a speed of 20 m/min as suggested by Ragni and Berardinelli (2001). The conveyor of 300 mm width was used with the loading capacity of 10-kg/m length of the conveyor. The capacity of the conveyor was determined by the following formula as suggested by Maghirang et al. (2009).

$$Q = \frac{3600qv}{1000} \qquad (1)$$

Where, Q = capacity, tons per hour,

q = weight of the potato per meter length of conveyor, kg/m,

v = linear speed of the conveyor, m/sec,

The product was loaded on the conveyor at 10 kg per meter length. By the use of three levels of engine speed it was enabled the take-in conveyor to operate at three linear speeds there by changing the feed rates of the potato to be graded.

Power requirement

Power required to conveying the produce from feeding trough surface to the hopper of the grading unit at height of 1.28 meter, with an inclined conveyor having 2.40-meter length, was worked out by encountering the frictional resistance during elevating and transporting the produce, with the following formula as suggested by More and Saxena (2003).

$N_{fric} = (QL\Omega)/362$ (kW) (2)

Where, N_{fric} = Power to encounter the frictional resistance (kW), Q = Capacity of the conveyor (tons /hr), L = Length of conveyor (m), Ω = Friction factor (0.1 for the fruit conveyor). The power required to elevate the crop to the height H meters was worked out by the following formula as Suggested by More and Saxena (2003).

$N_{eff} = (QH)/362$ (kW) (3)

Where,

N_{eff} = Power required to elevate the crop (kW),
H = Lift height (m)
Q = Capacity of the conveyor (tons /hr)

Since this conveyor performed both functions i.e. conveying and elevating, therefore, total power required (N) for operation of take-in conveyor was determined by the following expression.

$N = N_{eff} + N_{fric}$ (4)

Where, N = Total power required to operate the conveyor (kW). To operate the take-in conveyor at 20-m/min and load rate of 10 kg/m length of the conveyor, as was suggested by [2] and total power worked out was 0.05 kW.

Conveyor driving shaft

In order to operate the conveyor, power (0.05 kW) was transmitted through a shaft to its belt through the driving drum. In order to drive the conveyor at recommended linear speed, torque (T) required to rotate the driving drum was worked out by using the following formula as described (Annonymouse, 2005).

$$T = \frac{97303^{*} N}{n} \quad (5)$$

Where, T = Torque required to transmit power kg-cm,
N = Total power required to operate the conveyor, kW,
n = Speed of driving shaft, rpm determined by the following expression.

$$V = r\frac{2 * \pi * n}{60} \quad (6)$$

Where, V is linear speed of the conveyor (m/s)
r is radius of the conveyor drum
n is the rotational speed of the driving shaft (rpm)

Torque (153 kg-cm) was transmitted to the driving drum of the conveyor through shaft at rotational speed of 31.74 rpm to run the conveyor at linear speed of 20 m/min.
The diameter of the shaft was worked out by using the following formula as suggested by Khurmi and Gupta [4]

$$D = \frac{\sqrt[3]{16T}}{Ss\pi} \quad (6)$$

Where, D = Diameter of conveyor driving shaft (cm), T = Torque on shaft kg-cm
Ss = Safe shear stress (Kg/cm2) = U_s/F, Us = 3523 kg/cm^2 (Ultimate stress) (Medium Carbon Steel, 0.15 % to 0.4 % Carbon), F = 8 Factor of safety Stanton, E. and A.B. Wintson [4].

The design diameter of the shaft was12.10 mm and the actual shaft of diameter 25 mm was used to operate the conveyor. Diameter of the shaft used, was larger than the designed diameter of the shaft, hence the design was safe.

Main frame

Mainframe was made with the mild steel square pipe, which was readily available and the most consuming material in farm machinery. To determine the size of mild steel angle bar, dead load and variable loads were considered. There were a weight of dead and variable load was imposed on the machine elements to design its features. For the maximum deflection to be observed, in selected element of the main frame at 4 factor of safety was assumed. This designed load on the square pipe was not enough to produce a mark able deflection in the frame member that may cause any fatigue on the metal of the frame member during operation of the machine.

Grading unit

The grading unit comprises a primary expanding pitch grading unit of the round bars of 10 mm diameter. The conveyor collects the product/potato tubers from the hopper/feeding trough and delivers to the grading unit. Steel bars were cushioned with rubber pipes to cover the exposed hard surface so that the surface may not damage the crop during conveying and grading, Weight of crop on a single bar was worked out as 1 kg. The bending moment 55.3 N-m was determined and thickness of the bar was worked out with the ultimate stress of the material of the bar (4.227× 10^8 N/m^2) and factor of safety (Spinvakovsky and Dyachkov. 1972). The following formula was used to determine the bending moments:

$$M = S.Z \quad (7)$$

Where, S = Safe shear stress,
Z = Section modulus
The bar under load was of round cross section with 10 mm dia., hence the thickness of circular cross section was determined by using following formula:

$$Z = \pi \frac{d^3}{6} \quad (8)$$

Where,
Z is Section Modulus
d is diameter of the bar, mm (known)

Potato Tubers

Size and shape of potato tubers

The common commercial variety of Eastern Hararghe potato tubers was planned to be studied in this experiment. One popular variety was sampled with a total of 50 observations. The mass of each potato was measured to 0.01 g on a digital balance. Its volume was measured by the volume of water displaced. A potato was submerged into the known water volume and the volume of water displaced was measured. Water temperature was kept at 25°C. Specific gravity of each potato was calculated from the potato mass in air times one divided by the mass of water displaced. Three mutually perpendicular axes; *a* (the longest intercept), *b* (the longest intercept normal to *a*), and *c* (the longest intercept normal to *a, b*), of potato was measured to accuracy of 0.1 mm by a micrometer (caliper); known by laying on its flat surface and reaching its natural resting position. Primary grading unit was used to separate the product having size less than 39 mm and the remaining crop was transferred by sliding or rolling to next rang of grade size 40 mm to 50 mm, which are categorized as medium sized potato grade next size range from 51 to 65 mm diameter as large and greater than 65 and over are considered extra-large sized potato tubers. The grading unit was designed to divide the product into four sizes. The grading unit was operated at three inclinations and three speed designated as S_1, S_2 and S_3 of the engine which accommodated the different feed rates during operation.

Power transmission system

A pulley and belt arrangement was designed to transfer power at in parallel with velocity ratio 1:7. Because both the shafts input & output were in the same plane having pulleys diameters of 7cm and 48 cm.

Performance evaluation of Potato Grading Machine

The machine has the following components that directly comes in contact with the crop to be graded, the potato tubers

Crop and Machine Parameters

Crop Parameters,

Potato tubers were graded according to size with specified ranges of minor diameter as, 3.0-3.9 cm for small, and 4 - 4.9 cm for medium and greater 5 cm for large sizes. The response variables were the grading system efficiency, GSE (Eq. 9) and capacity, C (Eq. 10).

Machine parameters

The *machine parameters* were the two independent variables:

- the speeds of the conveyer shaft S_1, S_2 and S_3 in rpm,
- inclination of the grading unit (A_1, A_2 and A_3 degrees)

Two machine parameters were used during the evaluation. These were the linear speed of the conveyer (15 20 and 25 m/min) and the angles of inclination of the grading unit (23, 26 and 29 degrees). The influence of these machine parameters to the performance of the machine during the evaluation was observed. Machine performance, response variables, was indicated by the grading system efficiency (GSE) in percent and capacity (C) in kg/hr. The grading system efficiency was determined by taking the products of the efficiencies of small, medium and large regions as shown in Eq. 9, 10, 11, and 12. Where eff_s is the

efficiency, in decimal, of the small region of the grader to classify the small tubers, eff_m was the efficiency of the medium region and eff_l was the efficiency of the large region.

$$GSE = (eff_S * eff_M * eff_L) * 100;\ \% \quad (9)$$

Samples preparation

A 135 kg of fresh potato tubers were procured from the known farmer's family in Haramaya district at vegetable producing area on the 5th November, 2017. Tubers with initial damages such as scratches, abrasion, decay and greening were not considered in the sample. Thus, there was no initial damage during the testing of the device. The samples were divided into 27 groups with 5 kg each containing small, medium and large. On the average, each group had 28% small, 52% medium and 20% large-sized tubers. Each tuber was manually measured with digital Vernier caliper to determine the size and was given a label to easily distinguish after grading.

Operation

The principle of operation of the device began with the linear motion of the elevating conveyer through the prime mover, the diesel engine. Tubers with minor diameters pass through the gaps during rolling or sliding down over the expanding pitch dropping into collection bag hung to the outlets provided below the grading unit.

Test run

A test runs of 27 were used in the study with 9 treatment combination and 3 replications. Each replication used 5 kg of potato tubers as it was initially prepared. Evaluation procedures: As it was initially prepared, each 5kg of potato tubers were loaded into the feeding trough while the conveyer dropping on the expanding pitch grading unit was inclining down. After the grading operation, tubers that dropped on the appropriate region were counted and recorded. This was used to determine the grading efficiency of each region as shown in Eq. 10, 11 and 12. The time, in seconds, it took to grade the samples were also recorded.

$$eff_S = \frac{GradedSmallTubers}{TotalSmallTubersInSample_s} \quad (10)$$

$$eff_m = \frac{GradedMediumTubers}{TotalMediumTubersInSample} \quad (11)$$

$$eff_l = \frac{GradedLargeTubers}{TotalLargeTubersInSample} \quad (12)$$

The capacity of the grader was determined by considering the time it takes to grade the given quantity of tubers. In this study 5 kg of tubers were used. The capacity was expressed in kg/hr as shown in [Eq.13], where W is the weight in kg and t is time in seconds.

$$C = \frac{W}{t};\ kg/hr \quad (13)$$

Test Procedures

The grader was tested using the following procedures:

1. Samples were procured from the known potato producing family farmers. Each sample has a weight of 5 kg which was selected at random having small, medium, large and extra large sizes;
2. Tubers with initial damaged were discarded.
3. Each class in the samples was noted;
4. When the device was ready the samples was fed into the hopper of the conveyor;
5. The time of grading the given sample was recorded;
6. Graded tubers in the catchment bag were individually inspected and those that were correctly graded were recorded (weight, minor, intermediate and major diameters); finally damaged tubers were also observed.

Instrumentation and Measurements
Measuring instruments used were:
Digital balance ACS-30

Max. Weight {30kg), Min. weight (20g), Graduation (5g) and Best Accuracy + or – 0.1g

Digital tachometer

Model: UNI- T UT371, Technical specification, Measurement 10 to 99, 999 RPM,
Best Accuracy 0.04% + or – 2dgt

Data Analysis
The data was analyzed using factorial experimental design in strip plot design with three levels of speeds for elevating conveyer (rpm) and three levels of inclination (degrees) as machine parameters. Least significant difference test (LSD) at 5% level of significance was used to conduct treatment means comparisons.

Economics of the potato grader:
Break-even point of the device was considered in this study which is expressed in terms of the amount of tubers needed to be grade per year. The analysis included the actual cost of the device, custom rate, annual cost, depreciation, insurance and tax and repair and maintenance or the fixed and variable cost. Break even cost of the device is given by [Eq. 14] where CR is the custom rate, AFC is the annual fixed cost and VC is the variable cost.

$$BEP = \frac{AFC}{CR - VC} \quad (14)$$

Results and Discussion

The physical properties such as major, minor, intermediate diameter, mass, volume measured of *bubu* variety was shown in Table 1.

Table1: Physical properties of potato variety

Item no.	Physical attributes	Mean
1	Major diameter (mm)	65.01
2	Intermediate diameter (mm)	55.3
3	Minor diameter (mm)	45.5
4	Mass (g)	110.6
5	Measured volume (cc)	98.0

The physical properties of the ungraded potatoes tubers shown in tab.1 the average major, intermediate and minor diameters were 65.01, 55.3 and 45.5mm respectively. The average weight (g) and measured volume (cc) were also 110.6 and 98.0, respectively. Whereas the averages of small, medium and large sized grades with their sizes and weights, collected catchment bag individually inspected and those that were correctly graded and recorded data (weight, minor, intermediate and major diameters) were shown in table 2 below. As shown in the table 2 physical properties for the small sized grade potatoes the averages of major, intermediate and minor diameters were 61.41, 45.57and 35.19 mm respectively, having an average weight of 57.53 grams. The physical properties of medium sized grade potatoes the averages of major, intermediate and minor diameters were 66.9350.33 and 41.35mm respectively, having an average weight of 86.68grams. The average physical properties of large sized potato tubers having major, intermediate and minor diameters were 71.32, 54.58 and 46.0 mm, respectively, with an average weight of 112.25grams.

Table 2: The averages of collected catchment bag individually inspected and those that were correctly graded and recorded data

No.	Size (grade) categories	Major Diameter (mm)	Intermediate Diameter (mm)	Minor Diameter (mm)	Weight (g)
1	Small sized grade (G1)	57.40	40.39	31.76	57.53
2	Medium sized grade (G2)	66.93	50.33	41.35	86.68
3	Large Sized grade (G3)	71.32	54.58	45.21	112.25

Table 3: Shows the influence of speed and inclination on the performance of the grader in terms of capacity (kg/hr) and grading system efficiency (GSE %)

Speed (m/min)	Slope of grading sieve Angle A , (degrees)	capacity (kg/hr)	GES (%)
$S_{1\,(15)}$	A1 (20°)	779.8	75.1
	A2 (23°)	1037.0	77.2
	A3 (26°)	1106.8	73.2
$S_{2\,(20)}$	A1	763.4	84.8
	A2	891.5	84.2
	A3	961.6	75.8
$S_{3\,(25)}$	A1	1031.4	87.1
	A2	1070.5	90.6
	A3	1146.0	77.4

Table 4: Analysis of variance (ANOVA) table for the capacity (kg/hr)

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
Model	458282.1	8	57285.27	10.63	< 0.0001
A-speed	199402.9	2	99701.43	18.49	< 0.0001
B-Inclination	190801.7	2	95400.87	17.70	< 0.0001
AB Interaction	68077.52	4	17019.38	3.16	0.0394
Error	97045.24	18	5391.402		
Total	555327.4	26			
Std. Dev.					73.4
Mean					976.5
C.V. %					7.5
LSD					125.955

Influence of speeds and angles of inclination combination on grading capacity and grading system efficiency

Grading capacity

Means separation for the treatment combination of the linear speeds (15, 20 and 25m/min) of the conveyer at three levels and angles of inclination of grading unit at (A_1 = 23, A_2 =26 and A_3= 29) this can be shown in the two way table of means of the speeds and angles of inclinations combined in table 3 below.

Table 5: shows the means of capacities (kg/hr) resulted from the combination of speeds and angles of inclination

Speeds (m/min)	**Inclination (degree)**		
	A_1	A_2	A_3
S_1	779.8	1037.0	1106.8
S_2	763.4	891.5	961.6
S_3	1031.4	1070.5	1146.0

The capacity of the grader increases with the increasing of the angles of inclination. In table 3 it is shown that the grading capacity increased from 779.8 kg/hr to 1106.8 kg/hr as the angles of inclination increased from 23° to 29° whereas the speed of the conveyer kept constant at the minimum speed S_1which is 15m/min. Similarly, it was shown the grading capacities continued increasing starting from 763.4 kg/hr to 961.6 kg/hr when operated at the fixed conveyer speed 20m/min. In the same way it can be shown that the grading capacity increases as the angles of inclinations.

Means Separation and Comparison

In table 6 the mean difference of S_1A_3 and S_1A_2 is less than the least significant different obtained which is 125.955, so that the two means of potato grading machine capacities of S_1A_3 and S_1A_2 treatment combinations are not significantly different. Whereas the differences of the means values of the speed of the engine S_1 at A_3 and A_1 the angles of

inclination of the grading unit is 327 which is greater than the least significant difference, LSD is 125.955 indicating that there is significant different between the two means.

Table 6. The means of the capacity in the descending order when the inclination is combined with the lowest speed of the conveyer.

	Angle of Inclination		
Speeds (m/min)	A_3	A_2	A_1
S_1	1106.8^a	$1037.0a^a$	779.8^b

Similarly, there is a mean difference value between means of capacities of the means S_1 at A_2 and A3 which is 257.2 also greater values than the **LSD** value of 125.955. Therefore in these treatment combinations S1A3 is the best.

Table 7. Comparisons between the means of S2 at A1, A2 and A3 angles of inclinations of grading unit of the machine.

		Inclination (degrees)		
		A_1	A_2	A_3
Speed (m/min)	S_2	961.6^a	891.5^a	763.4^b

The means differences in table 7 above between: S_2A_3 and S_2A_2 is 70.1 this value is less than the LSD value obtained 125.955 indicating the treatment combination is not significantly different. Whereas the means differences between S_2A_3 and S_2A_1 and S_2A_2 and S_2A_1 are, 198.2 and 128.1, respectively. These means difference values of the speed and angles of inclination of the grading unit of the grader machine are greater than the LSD (0.05) value obtained 125.955. Therefore these later mean values are significantly different.

Table 8. Means comparisons between the means of S_3 at A_2, A_3 and A_1 angles of inclinations of grading unit of the machine.

		Inclination (degrees)		
Speed (m/min)	S_3	A_3	A_2	A_1
		1146.0^a	1070.5^a	1031.4^a

The difference between means values of the (S_3A_2, S_3A_3), (S_3A_2, S_3A_1) and (S_3A_3, S_3A_1) are 75.5, 114.6 and 39.1, respectively. These difference values between means are less than the LSD $_{\alpha(0.05)}$ value obtained. Therefore the differences between these means are not significantly different.

Table 9: Analysis of variance ANOVA table (GSE %) for selected factorial model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F
A-speed	443.6	2	221.8	31.80	< 0.0001
B-Inclination	327.7	2	163.8	23.49	< 0.0001
AB	94.5	4	23.6	3.39	0.0312
Pure Error	125.5	18	7.0		
Cor Total	991.3	26			
Std. Dev.					2.640919
Mean					80.37574
C.V. %					3.285716
LSD					4.53

Means separation of grading system efficiency, GSE (%) of the potato grading machine
Table 10: shows the means of **GSE (%)** resulted from the combination of speeds and angles of inclination

Speeds (m\min)	Inclination (degrees)		
	A1	A2	A3
S_1	75.1	77.2	73.2
S_2	84.8	84.2	75.8
S_3	87.1	90.6	77.4

a) Mean Comparisons
The Means Comparisons of the responses grader system efficiency of the obtained by the treatment combination of the angles of inclination of the grading unit and the speeds (rpm) of the conveyor was made during the data analysis and result interpretation. The means Comparisons were undertaken by taking one at a time and combining against the three angles of inclination as shown in table 11 below.

Table11. The means of the grading system efficiency in the descending order when the inclination is combined with the lowest speed of the conveyer.

Treatment combination	Angles of Inclination (degrees)		
	A2	A1	A3
Speed (rpm) S_1	77.2^a	75.1^a	73.2^a

In table 11 the mean difference of S1A2 and S1A1 is less than the least significant different obtained which is 4.53, so that the two means of potato grading machine efficiencies of S1A2 and S1A1 treatment combinations are not significantly different. The means difference values between S1A2 and S1A3 are 4 which is less than the $LSD_{(0.05)}$ value obtained which is 4.53, indicated that the treatments combination was not significant. Similarly, the means difference value between S_1 (A_2, A_1), S1 (S2, A3) and S_1 (A1, A3) are 2.1,4 and 1.9 respectively. These all the three values are less than the obtained $LSD_{(0.05)}$ equals 4.53. Therefore, all of the above treatment combinations are not significantly different. The means of the grading system efficiency was put in the descending order when the inclination is combined with the lowest speed of the conveyer as shown in table 12 below.
Table 12 shows the results of the treatment combination of the speed (rpm) the angles of inclination of grading unit

Treatment combination	Angles of Inclination (degrees)		
	A_1	A_3	A_2
S_2 Speed (m/min)	84.8^a	84.2^a	75.8^b

The means difference values between S_2 (A_1, A_3), S_2 (A_1, A_2) and S_2 (A_3, A_2) are 0.6, 9 and 8.4respectively. The value of the $LSD_{(0.05)}$ obtained is 4.53. Therefore, the S_2 (A_1, A_3), S_2 (A_1, A_2) treatment combinations are not significantly different. Whereas, treatment combination between S_2A_1 and S_2A_2 are significantly different. In the same way the treatment combinations S_2 (A_3, A_2), is significantly different.

Table 13. Shows the results of the treatment combination of the speed (rpm) the angles of inclination of grading unit

Treatment combination	Angles of Inclination (degrees)		
	A_2	A_1	A_3
S_3 Speed (m/min)	90.6[a]	87.1[a]	77.4[b]

The means difference values between S_3 (A_2, A_1), S_3 (A_1, A_3) and S_3 (A_1, A_3) are 3.5, 13.2 and 9.7, respectively. The treatment combination between S_3 (A_2, A_1) is not significantly. The means value differences between S_3 (A_2, A_3) and S_3 (A_1, A_3) are 13.2 and 9.7, respectively. Therefore, these treatment combinations are significantly different. Comparison among mean values of the grading system efficiency and capacity as influenced by the speed of the take-in conveyor. The GSE of the grader showed that 20 and 25m/min are significant from (15m/min). Lowest speed, 15m/min graded the tubers at a lower rate causing accumulation in the grading unit. While fastest speed 25m/min caused aggressive re-orientation of the tubers affecting the efficiency. Due to high velocity of tubers in the grading unit, some tubers were observed jumping and/or flying over longer distances of the round bars. As the speed increases the GSE tends to be decreased. Meanwhile, analysis of variance on the influence of machine parameters to grading system efficiency showed significant effect.

The capacity of the grader using speed of 20 and 25min is significantly higher than using a speed of 15m/min. Highest speed (25m/min) induces more velocity to the tubers causing them to travel along the unit at a faster rate. However, there velocity resulted to insufficient resident time for the tubers to interact with the diverging round bars or expanding pitch. This explains why efficiency is lower at high speed. Conversely, lowest speed (15m/min) resulted to slow material flow in the grading unit resulting to longer time of operation which caused lower capacity. No damaged tubers were found at all speeds.

Table 14: Shows the influence of conveying speed grading efficiency and capacity

Machine parameter	Speed (m/min)		
	S_1	S_2	S_3
Grading System Efficiency (GSE), %	75.17[a]	81.6[b]	85.03[b]
Capacity, kg/hr	974.53[a]	872.17[a]	1082.63[b]

The capacity of the grader at S_1 was significantly higher than at S_2 and S_3 to longer time of operation that caused lower capacity. The slow movement of tubers along the gaps of the caused accumulation of tubers which formed multi-layering. In this situation, some tubers were carried over by the layer to the region of next classification without gradually passing the gaps of the spiral. This explains why efficiency was lower at extremely high and low speeds.

Table 15. Comparison among mean values of the grading system efficiency, capacity, as influenced by the inclination of the grading unit.

Machine parameters	Inclination (degrees)		
	A_1	A_2	A_3
Grading System Efficiency (GSE), %	82.33	84	75.47
Capacity, kg/hr	858.20	1024.83	1046.30

Break even analysis and Economics of the potato grader

The total cost of the potato grader was Birr 40,000.00 with an estimated life span of 5 years. It had an annual fixed cost of Birr 8,000.00 and variable operating cost of Birr 15.00/hr. Assumptions include: interest, 10%, tax, insurance and shelter, 3%, repair and maintenance, 15%, operation per day, 8hr, annual use, 2500 hrs and custom rate Birr 0.5/kg. The grader had a break-even point of 50 ton/year. If available quantity of tubers is greater than the break-even quantity, the use of the grader will result to profit. Otherwise, the device is expensive to use when available quantity is less than the break-even quantity (Stanton and Wintson, 1977).

Conclusion and Recommendations

The optimum operating parameters for the machine was established at a speed of 20m/min and inclination of 23 degrees with an efficiency of 90.6 %. The capacity of 1146.0 kg/hr and no damaged tubers were observed. A mechanical potato grader, powered by diesel engine, was designed, fabricated and evaluated. The device operates with the principle of expanding pitch as grading unit. The grading unit was formed by shaping round bars in pitch pattern with increasing spaces thereby promoting size differentiation of potato tubers being conveyed along the length, on the rods. The grader was made to vary the speed of the conveyor by varying the speed of the engine accelerator, degree of inclination of the grading unit. The speed imparts velocity on the tubers causing them to move along the gaps of the grading unit round bars. Inclination of the grading unit facilitates the flow of tubers on the grading unit. The performance of the fabricated grader was evaluated on one variety of potato tubers. Grading system efficiency and capacity were observed. The optimum operating parameters for the machine was established at a speed of 25m/min, inclination of 23 degrees and giving a system efficiency of 90.6%, capacity of 1146.0 kg/hr, no damaged tubers of the potato was observed. The initial cost of the grader was 40, 000.00 and was expected to last for 5 years.

The designed, fabricated and evaluated potato grader is recommended to be used by the local farmers at Harari, Dire Dawa to immediately address prevailing problems on long queues due to slow manual grading in the market area. The prototype design can also be adapted for modification and improvement taking note, however, on the following recommendations based on the observations were noted during the evaluation: 1). Consider the use of longer length for the expanding pitch and incorporating oscillation/vibration and spirally rotating mechanisms to increase the capacity and grading efficiencies; 2). Constructing the device with higher vertical clearance from the ground for convenience in the collection of graded product; 3). Designing the hopper which can accommodate larger volume so it will not require constant attention of the operator; 4). Lengthening the regions for small-and medium-sized classifications since multi layering and crowding of potato tubers were observe at that region; 5. Redesigning the grading unit to have shorter overall length to make the device more portable, accessible and easy to store.

References

Anonymous. 2005. Pakistan Economic Survey, 2004-05. Government of Pakistan, Finance Division, Economic Advisor's Wing, Islamabad.

Maghirang, R. G., G. S. Rodulfo and B. Kebasen. Potato Production Guide. Info. Bull. No. 272/2009. College of Agriculture, University of the Philippines, Los Baños (UPLB) College 4031. Laguna 2009.

More, P.K. and R.P. Saxena. 2003. Design and development of multi-fruit grader. J. Agricultural Mechanization in Asia, Africa and Latin America. 34 (3): 39 -52.

Spinvakovsky, A. and V. Dyachkov. 1972. Conveyors and related equipment. Peace Publishers,Moscow.

Stanton, E. and A.B. Wintson. 1977. Machine Design. D.B. Faraporevala Sons & Co. Private Ltd. 210, Dr. D. Naoroji Road, Bombay-1

Improvement of Engine Driven Sorghum Thresher by Incorporating Grain Cleaning System

Tekalign Bedada
Oromia Agricultural Research Institute, Fedis Agricultural Research Center, Harar, Ethiopia
E-mail: **bedada.tekalign@yahoo.com**, P.o.box 904

Abstract

The improved engine driven sorghum threshing machine was designed and produced at Fedis agricultural research center with the objectives of solving the critical threshing and cleaning problems of sorghum produce farmers' and subsequently, to reduce the drudgery of the farmers', grain loss and cost of threshing, in comparison with traditional methods of manual threshing by using wood log. The experimental design was split-split plot design with three replications. The developed machine was tested in east Hararghe Zone, Haramaya district, Horo Kebele. The variables considered includes two sorghum varieties (*muria* and *fandisha*), three levels of cylinder speed (500,700 and 900 rpm), three position of cylinder-concave clearances (13, 18 and 23 mm) and three feed rates of the un-threshed sorghum head (10 kg/min, 15 kg/min and 20 kg/min). The result obtained indicated 87.28-95.30% threshing efficiency, 7-10 qt/ha output capacity and 74%-88% cleaning efficiency at constant grain moisture contents of 15-17% for both varieties.

Keywords: Sorghum thresher, threshing, Cleaning system, Improvement, Sorghum thresher

Introduction

For millions of people in the semi-arid tropics of Asia and Africa sorghum is the most important staple food. This crop sustains the lives of the poorest rural people and will continue to do so in the foreseeable future. Sorghum grows in harsh environments where other crops do not grow well (FAO, 1990). The traditional method sorghum threshing is laborious, time consuming and uneconomical. This method of threshing consumes more time, compared to other mechanical threshing method. Using this method a farmer can obtain 15 - 40 kg of grain per hour (FAO, 1990. Traditional threshing method also causes grain loss, to the extent of 6% (Miah, 1990).Threshing operations of agricultural crop produce leave all kinds of trash mixed with grain; they comprise both plant materials (e.g. foreign seeds or kernels, chaff, stalk, empty grains, etc.) and mineral materials (e.g. earth, stones, sand, metal particles, etc.), which can adversely affect subsequent storage and processing conditions of the food grain. Totally, a traditional method of threshing and subsequent cleaning of grains is physically demanding and energy consuming (Ali, 1986). The cleaning operation aims at removing as much trash as possible from the threshed grain (FAO, 1990). Cleanliness is an important quality characteristic for market acceptance of food products. One of the most important valuable additions is reduction of the contaminant to the minimum. Rooney (2003) reported that a major limitation in producing excellent food products from sorghum is a lack of consistent supply of good quality grain for processing. Contaminants affect the quality of grains and make grains less attractive in appearance therefore they constitute easy habitants for pests, increase handling cost, and ultimately cause low market value (HurburghJr, 1995).

The cleaning process is a mass transfer process involving segregation of particles on a pan before coming to the air stream, motion in the air stream and motion after coming out of the air stream (Kashayap and Pandya, 1965). Knowledge of the dynamics of grain air interaction is essential to adequately understand the cleaning process and to design appropriate cleaning equipment (Freltag, 1968). Modeling the cleaning process in a stationary thresher would help to save energy consumption, thereby reducing the time and cost of winnowing when the knowledge gained is put to use. Thus, the objective of this study is to incorporate the cleaning system to the sorghum threshing machine for increasing cleaning efficiency of the machine and to evaluate the performance of the machine.

Material and Method

Experimental Design

The mathematical expression for cleaning efficiency (η) between the dependent and independent variables given by Simonyan (2006) is:

$$\eta = f_e\left(\theta_g, \theta_s, \beta_g, \beta_s, f_r, \alpha, V_t, D, V_a, P_p\right) = 74 - 88\ \% \qquad (1)$$

Where, η = cleaning efficiency (%), θ_g = grain moisture content (%) w b, θ_s = straw moisture content (%) w b, β_g = grain bulk density (kg/m^3), β_s = straw bulk density (kg/m^3), f_r = feed rate (kg/s), α = sieve oscillating frequency (1/s), V_t = cylinder speed (m/s), D = diameter of sieve hole (m), V_a = air velocity (m/s) and P_p = particle density (kg/m^3).

The diameter of sorghum grain was calculated tri-axially (along its three axis) and geometric mean diameter d_e by Mohsenin, (1980).

$$d_s = (abc)^{1/3} = 3.1\ mm^3 \qquad (2)$$

Where, a, b, c = diameters along three axes.

The bulk density of the sorghum grain and straw were determined using the following formula (Mohsenin, 1980).

$$\beta = \frac{m}{v} \qquad (3)$$

$\beta_g = 424\ kg/m^3$ for the grain and $\beta_s =$ 25.48 kg/m^3 for the straw

Where: m = mass of grain, chaff or straw (kg), v = volume of container (m^3)

Moisture content of samples was determined using Dole 400'moister tester ($= 15 - 17\%$) and can also be determined the method by Henderson et al (1997).

$$MC_{wb} = \frac{W_i - W_d}{W_i} \times 100 \qquad (4)$$

Where: MC_{wb} = Moisture content, wet basis, %, W_i = Initial weight of sample, kg and W_d = dried weight of sample, kg

Cleaning efficiency (Purity) was obtained by the following formula

$$\eta = \frac{G_o}{G_o + C_{cg}} \times 100 \quad = 74 - 88\% \qquad (5)$$

Where: η = cleaning efficiency, %, G_o = weight of pure grain at the outlet, kg and C_{cg} = weight of contaminant, kg.

Linear Velocity for a rotating shaft with speed n and pulley of radius r was calculated by

$$V = \frac{2\pi rn}{60} = 6.13\ m/sec \quad (6)$$

Where: V = velocity, m/s, n= speed in revolutions per minute, rpm
The sieve oscillation frequency, α, was calculated by formula

$$\alpha = \frac{N}{t} = 10.4/sec \quad (7)$$

Where**:** N = number of reciprocations, t = time in seconds

Experimental Material

The experimental materials are the developed sorghum thresher (Figure.1), sorghum panicles of the locally available varieties, 8 hp Kama engine, 'Dole 400'moister tester and a stopwatch The variety of sorghum that was tested at the time of experiment were *Muira* and *Fendisha*.

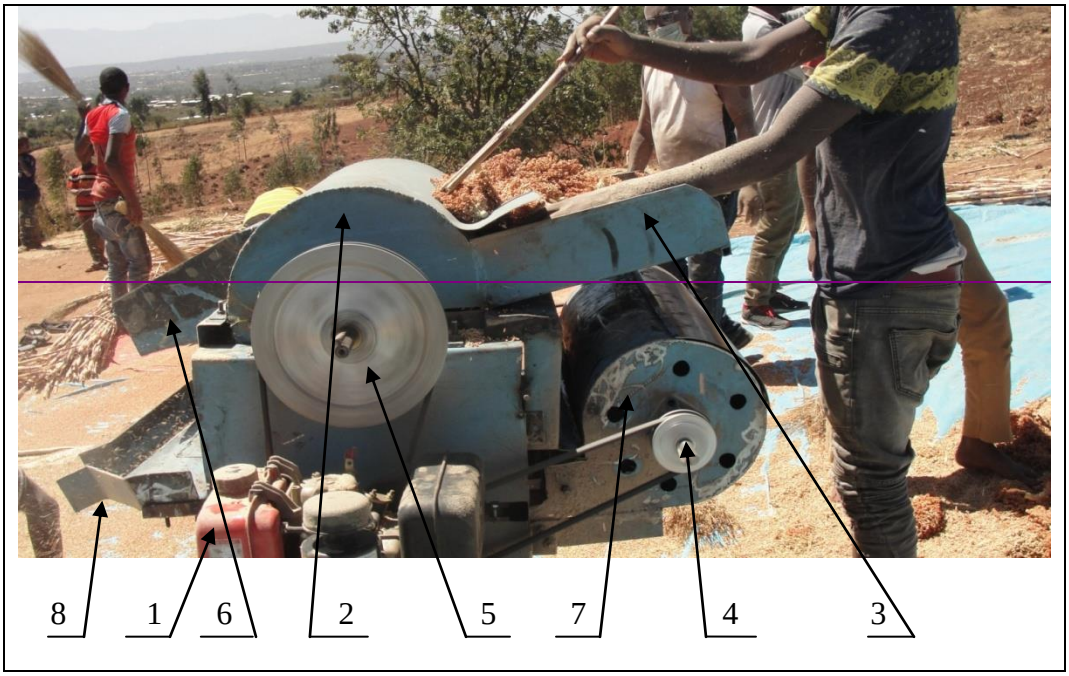


Figure.1 Engine driven sorghum thresher

1. Engine
2. Drum upper cover
3. Feeding chute
4. Fun pulley
5. Drum pulley
6. Straw outlet
7. Funsystem
8. Grain outlet

The improvement work done

The improvement of the machine was to incorporate the cleaning system since the machine doesn't have cleaning part. Therefore according to its design made the fun, the eccentric shaft

air deflector and the sieve components were made in the work shop then assembled and fixed on the machine. The cleaning system which was attached on the machine can get power from drum pulley and perform the cleaning activity. Due to the cleaning system the machine performance was changed, see table1 below.

Table1: The performance of the machine before and after improvement.

Threshing efficiency (%)	Cleaning efficiency (%)	Threshing Capacity Kg/hr	Threshing efficiency (%)	Cleaning efficiency (%)	Threshing Capacity Kg/hr
88.97to 97.08	-	600 to 836	87.28 to 95.30%	74% to 88%	700 to1000

Experimental Site

The performance test of the machine was done in east Hararghe zone, Haramaya district at the place known as *Ganda Horo*, which is nearest to Awaday town. The site is the major sorghum growing area in the zone. The experiment was done by using the farmer's harvest.

Experimental Method

The thresher is derived with 8 hp kama engine and moisture content of the sorghum grain was in a range of 15-17%. Two sorghum varieties; *Muria* and *Fandisha*, three different cylinder (an axial-flow spike tooth type) concave clearance of 13 mm, 18mm and 23 mm, three levels of cylinder rpm 500, 700, and 900 and three levels of sorghum panicles feed rates;10kg/min, 15 kg/.min and 20 kg/.min were used for the testing of the machine. The selected experimental design for this study was split-split plot design with three replications.

During the test operations, the selected weight of sorghum panicles were fed through the inlet part of the machine by an operator and the threshed outputs were collected from the outlets. Three samples were taken from each test of main and straw out let. From each sample pure, with glum, un-threshed and broken grain were separated, weighed and then, the result was recorded. The above procedure was repeated thrice for all combinations of sorghum variety with cylinder-concave clearance, rpm and feed rate. The selected design was used to analyze the obtained data during the experiment. Accordingly, the two sorghum varieties were taken as the main plot treatment factors, three cylinder-concave clearances as sub-plot treatment factors, three rpm as sub-plot-plot and three feed rates as sub-plot-plot-plot treatment factors with three replications as block. To analyze the treatment factors by split plot design laid down (2x3x3x3) x3 factorial combinations with three replications, which result 162 numbers of trials.

Results and Discussions

The statistical aalysisis indicated that the coefficient of variation (CV) was 1.72% for pure grain, 30.28% for grain with glum and 25.42% for un-threshed grain. Least Sigificat difference (0.05) values for pure, with glum and un-threshed grain were 0.386, 0.389 and 0.058 respectively. During the test it was observed that the threshing efficiency of the machine was varied in a range of 87.28% to 95.30%. Maximum threshing efficiency of 95.30% was obtained for *fandisha* variety at speed of cylinder 900 rpm, 13 mm cylinder-

concave clearance and feed rate of 10 kg/min. The 87.28 % or minimum threshing efficiency of the machine was observed at feed rate of 20 kg/ min, 500 rpm and concave clearance of 23 mm.

Highest un-threshed grain of 1.32% was noticed at feed rate of 20 kg/min, 500 rpm speed of the cylinder and cylinder-concave clearance of 18 mm. However, the lowest un-threshed grain percentage (0.43%) which was obtained at the feed rate of 10 kg/min, 900 rpm speed of the cylinder and cylinder-concave clearance of 13 mm. From this result it can be generalized that threshing efficiency increases with increasing cylinder speed in a given range. Increasing feed rate raises threshing efficiency to certain limit and then decreases. Increasing cylinder-concave clearance decreases threshing efficiency and also, results in more un-threshed grain on the sorghum head.

For *muiraa* variety maximum threshing efficiency (95%) was recorded at feed rate of 10 kg/min and 900 rpm speed of cylinder and cylinder-concave clearance of 13 mm, While, the minimum threshing efficiency (87.28%) was recorded at a feed rate of 15 kg/min , 500 rpm speed of cylinder and 23 mm cylinder-concave clearance. Grain with glum and un-threshed grain were in contrary with threshing efficiency in such a way that, their values were decreased by increasing cylinder speed. The output capacity of the machine was varied from 7-10 qt/h for *muira* and *fendisha*. Due to the nature of its head, *muira* showed the utmost output capacity of the machine than *fendisha*. Cleaning efficiency of the machine was obtained between 74%-88%. Broken grain was 1.5% and average fuel consumption of the diesel engine was 0.12 lit/qt.

Conclusion and Recommendation

The improved sorghum thresher with cleaning system was found better in threshing capacity of 7-10 qt/hr as compared to threshing done by hand. The recommended threshing efficiency is at 90 to 95.3%. Cleaning efficiency of the machine was between 74-88%. It needs farther improvements to attain the permissible percentage 95%. The optimum conditions for thresher evaluation were set for threshing efficiency and cleaning efficiency being 95% (Singhal and Thierstein, 1987). Broken grain was 1.5 % which is below the standard of 2% maximum (Sharma *et al*., 1984). To get maximum efficiency and output capacity users should adjust the cylinder speed on 900 rpm, concave-clearance on 13 mm and feed rate at 10 kg/min for both *muira* and fendisha and considering recommended moister content of the grain. Since the obtained machine's performances were found to be in the acceptable ranges and taken as good results, so it is recommended that, the machine should be multiplied and promoted (disseminated) for farmers, to reduce the drudgery of sorghum threshing and grain losses.

References

Ali, M. A. (1986) Comparative Ergonomics Studies of Male and Female Operations on Selected Farm Task. Unpublished M.Sc. Thesis.Ahmadu Bello University, Zaria, Nigeria.

FAO (Food and Agricultural Organization).1990. Food and Agriculture Organization of the United Nations, Agricultural Engineering in Development: selection of mechanization inputs, Agricultural Services Bulletin No. 84.

Henderson, S. M., R. L. Perry and J. H. Young (1997). Principles of Process Engineering. 4th Edition .ASAE Michigan USA

Hurburgh,Jr,C. R. (1995). An economic model of corn cleaning. Applied Engineering in Agriculture 11(4): 539-647

Rooney L. W. (2003). Overview: Sorghum and millet food research failures and successes. Food science faculty, cereal quality laboratory, soil and crop science department. Texas A &M University USA.

Sharma,V.K., et al, 1984. Design, Development and Evaluation of a Tractor-Operated Multi-crop Thresher : *AMA,* vol. 15(42), pp.26-30.

Simonyan, K., Yiljep, Y. and Mudiare, O. 2006.Modeling the Cleaning Process of a Stationary Sorghum Thresher. Agricultural Engineering International: the *CIGR Ejournal.* Manuscript P M 06 012. Vol. VIII.

Singhal, O.P. and Thierstein, G.E. 1987. Development of an Axial-Flow Thresher with Multi-Crop Potential: *AMA,* vol. 18(3), pp.57-65.