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Editors**:** Tesfaye Letta, Teshome Bogale, Kedir Wako, Dagnachew Lule, Chemeda Daba, Zerihun Abebe and Tadesse Birhanu

Designer: Natnael Yisak

IQQO
Oromia Agricultural Research Institute

Oromia Agricultural Research Institute
P.O. Box 81265, Addis Ababa, Ethiopia   FAX 0114, 70, 71, 29   tel. 0114707021
E mail oari.info@gmail.com

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BREEDING AND GENETICS

AMMI Model for Yield Stability Analysis of Linseed Genotypes for the Highlands of Bale, Ethiopia

Tadele Tadesse[1]*, Amanuel Tekalign[1], Gashaw Sefera[1] and Behailu Muligeta[1]

Oromia Agriculture Research Institute, Sinana Agriculture Research Center, Bale-Robe, Ethiopia

* Corresponding author: tadyeko20@gmail.com / tadeleta20@yahoo.com

Abstract

Field experiment was conducted at on station of Sinana Agricultural Research Center, Agrfa and Adeba on- farms in the high lands of Bale zone during the year 2014 and 2015.Eleven linseed genotypes were evaluated against two standard checks and a local check. The objective of this study was to identify high yielding and stable linseed variety for the study area. The field experiment was laid out in randomized complete design with four replications. The combined analysis of variance showed highly significant effects of genotypes, environment, and genotype by environment interaction. The partitioning of the total sum of square exhibited that the effect of environment was a predominant source of variation followed by genotypes and GE interaction effect. Genotype G6 and G9 were identified as the best high yielding and stable varieties by all stability parameters used in this study. Hence, these two genotypes are recommended for product in the study area and similar agroecologies.

Key Words: AMMI, ASV, GSI, Linseed, Stability Parameter

Introduction

Ethiopia is considered to be the center of diversity for linseed (Vavilov, 1926). Linseed is a major oilseed and rotation crop for barley in higher elevations of Arsi, Bale, Gojam, Gonder, Wello, Shewa and Welega parts of Ethiopia. High yields of wheat, barley and tef can be obtained following linseed (Getinet and Negusei 1997). Though the crop has so many important merits, its production per unit areas is very low due to the lack of stable and high yielding cultivars. Therefore, improving yield and yield stability is the main objectives of linseed breeding program in the country. Yield is a complex character where it is highly influenced by both genes as well as environment.

Adaptation is the result of genotypes x environment interaction and generally falls in to two classes: 1) the ability to perform at an acceptable level in a range of environment, general adaptability 2) the ability to perform well in desirable environments, specific adaptability (Farshadfar and Sutka, 2006; Solomon *et al*., 2008). The genotype-environment interaction reduces association between phenotypic and genotypic values leads to bias in the estimates of gene effect combining ability for various characters sensitive to environmental fluctuations. Such traits are less preferable to selection (Farshadfar and Sutka, 2000). The existence of genotype-environment interaction (GEI) complicates the identification of superior genotypes for a range of environments and calls for the evaluation genotypes in many environments to determine their true genetic potential (Yaghotipoor and Farshadfar, 2007).The importance of G x E interactions in cultivar evaluation and breeding programs has been demonstrated almost in all crops. Various statistical methods (parametric and non-parametric) have been proposed to study genotype –environment interaction (Hussein *et al.,* 2000; Lin and Binns , 1994; Hussein *et al.*,2000; Mohammad *et al.,* 2010). To identify linseed genotypes with wider or specific adaptation to different environments, multi-location yield trial are grown each year. These have lead to empirical identification of superior cultivars, sum of which have been released in several countries. Multi-location yield trials facilitate quantification of the environment and the GEI effects. However, a fact not generally recognized is that, in addition, every yield trial by analyzing processes that determine yield can inexpensively quantify the genetic, physiological and environmental controls that results in yield differences among cultivars, seasons and locations (Tarakanovas and Rusgas, 2006). Various methods of GE interaction analysis exist, including parametric and non-parametric approaches. The most widely used parametric methods is the joint regression including regression coefficient (bi) variance of deviation from regression (S^2di) (Farshadfar and Sutka ,2006; Pourdad and Mohammadi , 2008).

The ordinary form of ANOVA is an additive model and therefore describes only the main effect. Principal component analysis is a multiplicative model and has the opposite problem of not describing the additive main effects. Linear regression models combine the additive and multiplicative components and thus analyze both main effects and interaction, but in general they confound the interaction with the main effects reducing its power for general significance testing (Farshadfar and Sutka , 2006).

The additive main effects and multiplicative interaction (AMMI) model is a powerful multivariate method to multi-environmental trial. This technique, incorporates both additive and multiplicative components into an integrated, powerful least square analysis (Farshadfar and Sutka , 2003; Mohamaddi and Haghparast, 2007; Pourdad and Mohammadi, 2008]. Therefore, the objective of the present study was to identify stable and high yielding genotypes.

Materials and Methods

The experiment was carried out at on station of Sinana Agricultural Research Center and on fields of two farmers (Agarfa and Adaba). Sinana Research Center (7^o N latitude and 40^oE longitude; and 2400m a.s.l.) is located 463 km south east of Addis Ababa and East of Robe, the capital of Bale zone. The other two locations are located (Agarfa) 45-km and (Adaba) 70km from Sinana in the Southwest direction. This experiment was conducted on soil with vertisol clay loam texture during the main season of 2014/15 and 2015/16.

Fourteen linseed genotypes were tested for two years across the three test locations. The experiment was laid out in complete randomized block design with four replications on a plot size of 4.8m^2 (six rows at 20cm apart and 4m long). Yield data was collected from the central four rows. Combined analysis of variance using balanced ANOVA was computed using CROPSTAT program.

The additive main effect and multiplicative interaction (AMMI)

AMMI analysis was performed using the model suggested by (Crossa *et al*,.1991) as:

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

Y_{ij} is the yieldof the i^{th} genotype in the j^{th} environment, μ is the grand mean, g_i is the mean of the i^{th} genotype minus the grand mean e_j is the mean of j^{th} environment minus the grand mean, λ_n is the square root of the eigen value of the principal component. Analysis (PCA) axis, α_{ni} and Y_{nj} are the principal are the principal component scores for the PCA axis n of the i^{th} genotype and j^{th} environment, respectively and R_{ij} is the residual. The GE biplot was projected for the 14 genotypes tested at six environments. The regression of yield for each variety on yield means for each environment was computed and parameters MS-REG, the contribution of each variety to the regression component of the treatment x location interaction and MS-TL the contribution of each variety to interaction MS, were estimated with the CropStat program.

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

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

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

Genotype Selection Index (GSI) : Based on the rank of mean grain yield of genotypes (RY_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

$GSI_i = RY_i + RASV_i$

Table 1. Genotype code and the name of 14 linseed genotypes

No.	Genotype code	Name
1	G1	CDC 1747 X CI-1652/SPS2
2	G2	CDC 1747 X CI-1652/SPS1
3	G3	CHILALO X R12-D33C/SPS3
4	G4	CHILALO X R12-D33C/SPS8
5	G5	CI-1652 X CDC 1747/SPS1
6	G6	CHILALO X R12-N27G/SPS6
7	G7	CHILALO X R12-N27G/SPS11
8	G8	CI-1652 X R12 -D33C/SPS6
9	G9	R12-N100 X CI-1525/SPS4
10	G10	R12-N100 X CI1525/SPS7
11	G11	R12-N100 X CI1525/SPS10
12	G12	Dibanne (standard check)
13	G13	Jitu (standard check)
14	G14	Local

Result and Discussion

The result of combined analysis of variance (Table 2) showed high significant differences for genotypes, environment and GE interaction indicating the effect of environment in the GE interaction, genetic variability and possibility of selection for stable genotypes. As it is indicated by different scientists, (Farshadfar and Sutka, 2003; Farshadfar and Sutka, 2006) when GE interaction was significant, it is possible to proceed and calculate the stability for the tested genotypes. Mean comparison for the tested genotypes indicated that maximum grain yield was obtained from G6 (1.85t/ha) followed by G9 (1.69t/ha) and G11 (1.64t/ha) whereas the least mean grain yield was obtained from G3 (1.42t/ha).

Table 2. Combined analysis of variance for grain yield of linseed at three locations over two years

Source of Variation	Degree of freedom	Mean Square
Year (Y)	1	3.55262**
Location(L)	2	8.929441**
Replication	3	0.509109**
Genotype (G)	13	0.281792**
Y x L	2	3.07369**
Y x G	13	0.103805**
L x G	26	0.099389**
Y x L x G	26	0.055773**
Residual	249	0.061127**
CV%		15.7

The result of regression analysis (Table 3) revealed that the main effects of genotypes and GE interaction were relatively small and accounted 10.01% and 14.71% of the total sum of square (TSS), respectively. Liner GE interaction was not significant and accounted for 18.72% of the variability in the GE interaction. As a general rule the effectiveness of regression analysis is when 50% of the total sum squares is accounted for by liner GE interaction (Hayward *et al*.,1993), hence regression analysis is not useful for stability analysis of genotypes .

Table 3. Regression analysis of stability for linseed genotypes

Source of variation	D.F.	S.S.	M.S.	TSS(%)
Genotypes (G)	13	0.915823	0.070448**	10.01
Location (L)	5	6.88972	1.37794**	75.29
G X L	65	1.34592	0.020706**	14.71
G X Site Reg	13	0.251952	0.019381	18.72
Deviation	52	1.09396	0.021038**	81.28
TOTAL	83	9.15146		

AMMI model analysis: In AMMI model, principal component analysis is based on the matrix of deviation from additivity or residual will be analyzed. In this respect both the results of AMMI analysis, the genotypes and environment will be grouped based on their similar responses (Gauch,1992; Pourdad and Mohammadi, 2008; Wade *et al.*, 1995). Using ANOVA yield sum of square was partitioned into genotype, environment, and GE interaction. GE interaction was further portioned by principal component analysis (Table 4). The result if AMMI analysis indicated that 10.01% of the total variability was justified by genotypes, 75.29% by environments and 14.71% by GE interaction. A large contribution of the environment indicated that environments were diverse, with large difference among environmental means causing most of the variation in grain yield. The same result was reported by (Farshadfar, 2008). The result of AMMI analysis also showed that the first principal component axis (IPCA1) accounted for 63.42% over the interaction SS, IPCA2 and IPCA3 explained 25.16% and 6.69% of the GE interaction SS, respectively. The first two IPCA scores were significant at (P<0.01%) and cumulatively accounted for

88.58% of the total GE interaction. This indicates that the use of AMMI model fit the data well and justifies the use of AMMI2.

Table 4. Analysis of Variance for grain yield of Linseed for the AMMI model

Source of variation	D.F.	Sum of Square	%SS	M.S.
Genotype (G)	13	0.915823	10.01[a]	0.0704479**
Location (L)	5	6.88972	75.29[a]	1.37794**
G X L	65	1.34592	14.71[a]	0.0207064**
IPCA 1	17	0.853613	63.42[b]	0.0502125**
IPCA 2	15	0.338712	25.16[b]	0.0225808**
IPCA 3	13	0.090051	6.69[b]	0.006927**
IPCA 4	11	0.0549334	4.08[b]	0.00499394**
Residual	9	0.00860686		
TOTAL	83	9.15146		

a: from total sum of square percent, b: from GE sum of square percent, ** significant at 1% probability level

AMMI Stability Value (ASV) : ASV is the distance from zero in a two dimensional scattergram of IPCA1 scores against IPCA2 scores. Since the IPCA1 score contributes more to the GE sum of square, it has to be weighted by the proportional difference between IPCA1 and IPCA2 scores to compensate for the relative contribution of IPCA1 and IPCA2 total GE interaction sum squares. The distance from zero is then determined using the theorem of Pythagoras (Purchase *et al.*, 2000). In general the importance of AMMI model is in reduction of noise even if principal components don't cover much of the GESS (Gauch, 1992; Gauch and Zobel, 1996).

In ASV method, the genotype with least ASV score is the most stable. AMMI Stability Value (ASV) discriminated genotypes G9, G6, G13, G5 and G11 as the stable genotypes respectively.

Table 5. Regression coefficient, deviation from regression, IPCA scores, ASV and GSI of genotypes

Genotype	Mean Yield (t/ha)	Slope (bi)	MS-DEV	IPCA1	IPCA2	IPCA3	IPCA4	ASV	GSI
G1	1.51	1.72	0.06	-0.56	0.01	0.17	0.01	1.41	25
G2	1.53	1.19	0.02	0.11	-0.41	-0.11	0.19	0.50	15
G3	1.42	0.54	0.03	0.14	0.32	-0.02	0.13	0.49	20
G4	1.59	0.93	0.04	0.21	-0.19	0.06	-0.04	0.57	14
G5	1.53	1.11	0.05	-0.08	-0.09	-0.23	0.09	0.21	14
G6	1.85	0.99	0.04	-0.37	-0.04	0.07	-0.11	0.12	3
G7	1.55	1.25	0.01	-0.30	0.04	-0.28	-0.22	0.76	20
G8	1.60	0.71	0.02	0.36	-0.14	0.11	-0.16	0.92	17
G9	1.69	1.00	0.9	0.03	-0.03	0.07	0.06	0.09	3
G10	1.51	0.60	0.01	0.23	0.16	0.09	-0.15	0.60	22
G11	1.64	1.07	0.01	-0.14	0.10	-0.05	0.20	0.37	8
G12	1.57	0.83	0.02	0.20	-0.12	-0.12	-0.09	0.52	15
G13	1.59	1.20	0.01	-0.05	-0.07	0.27	0.07	0.14	8
G14	1.44	0.36	0.04	0.20	0.44	-0.05	0.05	0.67	24

N.B. MS-DEV= deviation from regression, IPCA= Interaction Principle Component Analysis axis, ASV= AMMI Stability Value, GSI= Genotype Selection Index

Genotype Selection Index (GSI): As stability per se is not a desirable selection criterion, because the most stable genotypes would not necessarily give the best yield performance (Mohamaddi and Haghparast, 2007), hence, simultaneous consideration of grain yield and ASV in single non-parametric index is needed. Therefore, the rank of ASV and mean grain yield (RY_i) are incorporated in single selection index namely Genotype Selection Index (GSI). The least GSI is considered as the most stable with high grain yield. Thus GSI indicates (Table 5), G6 and G9 have the most stability with high grain yield.

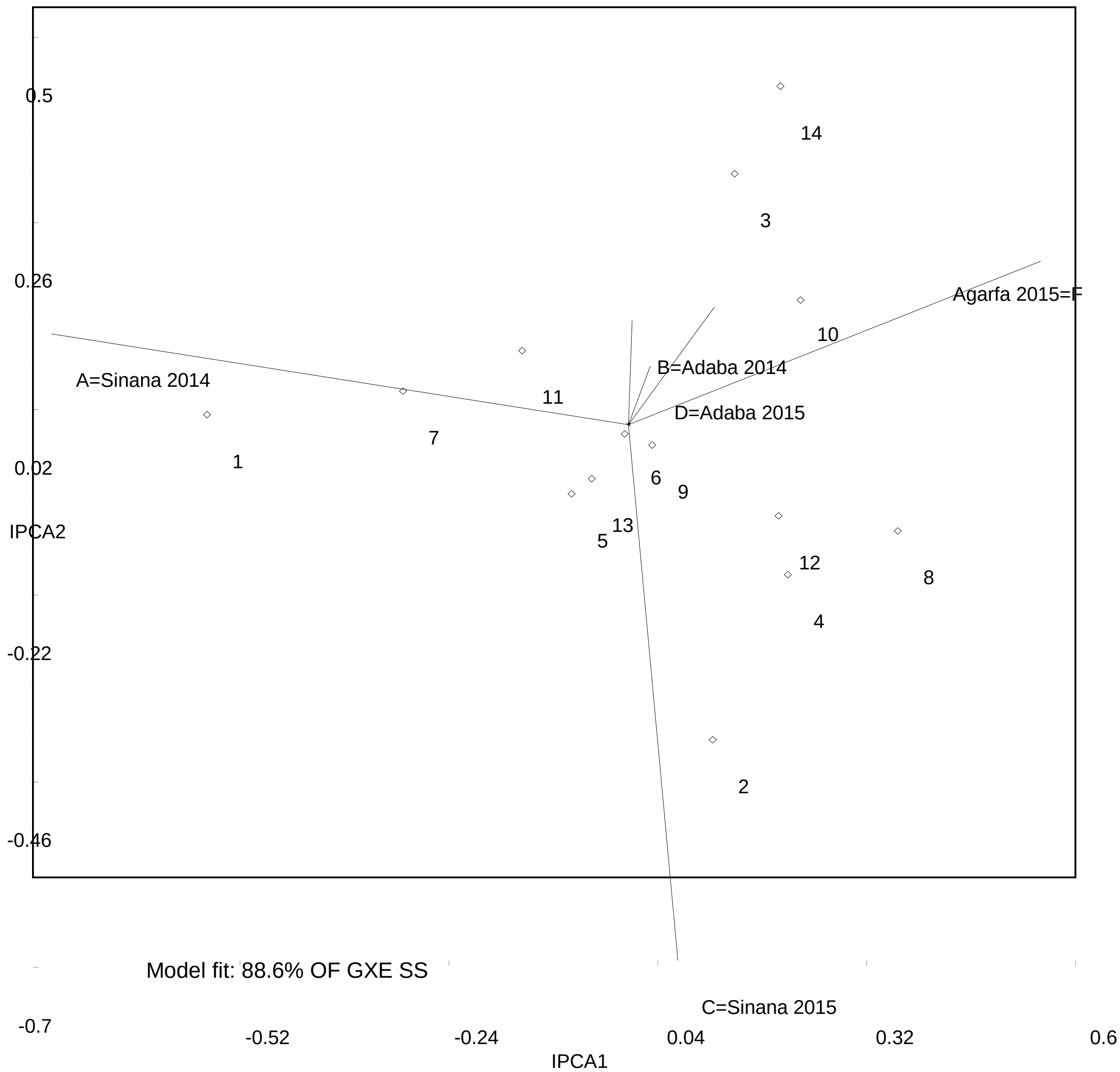

Figure 1. Biplot analysis of GE interaction based on AMM2 model for the first two interactions principal component scores.

The AMMI2 biplot (Figure 1) explained 88.6% of the GE interaction, making it a useful test for interaction. It was observed that most of the genotypes and environments were dispersed around the biplot. Genotypes farther from the center of biplot show specific adaptation. Mohammadi and Amri (2008) in their study revealed that those genotypes which are far from the center of the biplot, have high GE interaction and those genotypes that nearest to the center of biplot, have high stability.

Biplot analysis (Figure 1) displayed that genotypes G1, G2 and G14 and environment A, F and C have greatest effect in the GE interaction. G1 has specific adaptation with environment A, while G2 has specific adaptation with environment C. genotypes towards the center of biplot have zero interaction, therefore, have general adaptation with different mean grain yield. Genotypes G6, G9, G11, G13 and G5 are located in this category and as the entries G6, G9, G11 and G13 have mean grain yield over the grand mean, therefore they can be considered as stable with high performance. The genotype G1 has specific adaptation with environment A because their angle is less than 90 degree and their GE interaction is positive. Genotypes G2, G4, G8 and G12 have positive interaction with environment C, but the length of vector for G2 is more on the environment C, hence it has specific adaptability with environment C. The G3, G10 and G14 have positive interaction with environment F, but G10 is more adapted to it.

Conclusion and recommendation

Based on the stability parameters viz. regression coefficient, deviation from regression, the AMMI Stability Value (ASV) and mean grain yield, G6 and G9 were selected as the best two varieties. The result of Genotypes Selection Index (GSI) analysis also showed that the most stable varieties with high grain yield were G6 and G9.Hence, these two genotypes were identified as the best and are recommended for production in the study area and similar agro ecologies.

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Adaptation Study of Improved Food Barley (*Hordeum vulgare* L.) Varieties at Kelem and West Wollega Zones of Western Oromia

Dereje Abera [1*] Wakgari Raga[1] Gelata Negash[1] Abay Guta[1]

Haro Sabu Agricultural Research Center, P.0.Box 10, Kellem Wollega, Dambi Dollo

*Corresponding author: E-mail: dereaber@gmail.com

Abstract

The study was conducted on six improved food barley varieties against local check for their adaptability at Badesso and Mata sub-sites of Haro Sabu Agricultural Research Center (HSARC) for three consecutive (2014-2016) main cropping seasons with the objectives of identifying and recommending high yielding, insect pest resistant/tolerant varieties for Kelem and West Wollega areas of Western Oromia. The seed were sown in randomized complete block design with three replications in the net plot size of 1.6 m^2 using four harvestable rows at the spacing of 0.2m between rows. Agronomic traits viz. number of effective tiller per plant (ETP), number of spikelet per panicle (SPP), plant height (PH), *panicle height (PNH), number of grain per spike (GPS), days to 50% heading (DH), days to maturity (DM), thousand seed weight (TSW) and grain yield (GY)were collected. Combined analysis of variance detected significant difference among varieties for all studied traits.GGE biplot analysis was done and ranking based on varieties-focused scaling was used. Two varieties, Dinsho and Abdane were identified as ideal varieties in terms of yielding ability and stability. Hence, these varieties are recommended for production in the study area and similar agroecology in western Oromia.*

Key words: Adaptability, Hordeum vulgare, Barley Varieties

Introduction

Barley *(Hordeum vulgare* L.) is the fifth most cultivated cereal crop of the world (Eshghi and Akhundova, 2010) as cited in Girma (2012). In Ethiopia, it is also the fifth important cereal crop next to tef, maize, sorghum and wheat in total area coverage and total annual production in main season (CSA, 2015). In Ethiopia, barley is the third cereal crop based on yield per unit area (Bayeh and Grando, 2011). Barley can be cultivated at altitudes ranging between 1500 and 3500 above sea level. The ideal production of barley in Ethiopia is between altitudes of 2000 to 3000m above sea level (Tamene *et al*., 2016). It is a hardy crop grown in wide range of agro-climatic regions under several production systems.

In Ethiopia, barley is mainly produced for different purposes including human consumption, malt and animal feed (Bekele *et al.,* 2005; Horseley and Hochhalter, 2004).The average yield obtained in Oromia was 1.23-ton ha^{-1} (CSA, 2015) but this is by far less than the potential of the crop. The most important biotic and abiotic factors that reduce yield of barley in Ethiopia are use of poor yielding varieties, insect, disease, poor soil fertility, water logging, and soil acidity and weed competition (Bekele, 2005). Among these, the lack of improved (high yielding, logging and insect and disease resistant) variety/ies have been mentioned as an important barley production constraints in West and Kelem Wollega Zones of Western Oromia. The improvement of food barley is important in these target area thereby to ensure food security of the farmers. Hence, this experiment was carried to test released barley varieties and recommend the best one for the study area.

Materials and Methods

This experiment was conducted at Badesso and Mata, sub sites of Haro-Sabu Agricultural Research Center for three consecutive years (2014-2016). The elevation of testing sites were 2016 and 2054 m.a.s.l for Mata and Badeso, respectively. The study 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, at Mata and Badesso, respectively. The six improved food barley varieties introduced from Sinana (Abdane, Biftu, Dafo, Dinsho and Harbu) and one from Holeta (HB-1307) Agricultural Research Centers were evaluated against one local check. The experiment was laid out in randomized complete block design with three replications. The net plot size of 1.6 m^2 with four harvestable rows was used at the spacing of 0.2m between rows. The seed was sown by drilling method and 46 $Kgha^{-1}$ DAP was applied at sowing and then 41 $Kgha^{-1}$ of Urea was used in split form (50% at sowing and the remaining 50% at 40 days after emergency).

Data on number of effective tillers per plant (ETP), number of spikelets per panicle (SPP), PH Plant height in cm (PH), Panicle height in cm (PNH) and number of grain per spike (GPS) were collected. Plot based data were also collected for phonological trait such as days to 50% heading (DH) and days to 50% maturity (DM) and yield components such as thousand seed weight in gram (TSW) and grain yield (YLD) in ton ha^{-1} .Plant based data were recorded from randomly selected and tagged plants from harvestable rows. The collected data were organized and analyzed using SAS (version 9.01) computer software according to the methods developed by Gomez and Gomez (1980). Similarly, GGE biplot analysis was done using Genstat computer soft ware (2012).

Results and Discussions

Combined analysis of variance revealed significant difference among varieties and across years for all observed traits. Locations had significantly affected all observed traits with the exception of grain per spikelet (GPS) in present study (Table 1). In line with this, Badessa (2014) reported significant ($p<0.05$) difference among evaluated food barley genotypes for all agronomic traits in other study. The interaction of varieties by years significantly affected all observed agronomic traits with the exception of panicle height. Varieties*location significantly affected all recorded traits excluding panicle height and plant height while varieties*year*location exhibited significant difference for all observation except plant height.

Table 1. Combined analysis of variance for grain yield and yield related traits in barley varieties tested at Mata and Badeso for three years (2014-2016)

SV	df	DH	DM	ETP	SPP	PH	PNH	GPS	TSW	GY
Var	6	179.56**	622.44**	3.44**	30.55**	759.08**	5.54**	268.89**	162.61**	2.28**
Rep	2	2.39	21.94**	0.35	1.89	130.61*	3.04*	4.22	2.54	0.06
Year	2	210.58**	44.91**	14.37**	133.14**	3414.90**	21.25**	2496.096**	137.25**	4.48**
Location	1	208.29**	23.14**	2.43*	12.89*	135.78*	3.70*	1.65	516.88**	2.01*
Var*Year	12	8.86**	18.15**	1.32**	28.34**	64.21*	0.40	123.96**	72.70**	1.29**
Var*Loc	6	3.92*	62.92**	1.52*	10.81**	27.84	0.60	173.16**	98.24**	0.5*
Var*Year *Loc	14	12.99**	17.31**	1.23**	10.11**	29.87	1.02*	120.95**	200.66**	2.31*

df =degree of freedom, DH=days to heading, DM=days to maturity, ETP= effective tiller per plant, SPP=number of spikelet per panicle, PH= plant height (cm), PNH=Panicle height (cm), GPS= grains per spikelet, TSW= thousand seed weight (g),GY=grain yield (tonha^{-1})

Mean performance of tested barley varieties tested for different traits is shown in Table 2. Overall mean value of days to heading varied from 48.94 for Dafo to 59.06 days for Dinsho with the mean value of 53.78. Dinsho and Abdane had the longest days to heading while Biftu and Harbu were the earlier varieties. The mean value of days to maturity ranged from 87.39 for Harbu to 105 days for HB-1307 with the mean value of 92.65.

Abdane (92.89) and local check (92.94) had the longest mean value of days to maturity after Dinsho. On the contrary, Dafo (87.83) and Harbu (87.39) had earlier days to maturity (Table 2). The minimum mean value of thousand seed weight was observed for Biftu (30.38) while the maximum value recorded from local check (39.90) with the mean value of 34.40 gm. The higher mean value of thousand seed weight was obtained from Dafo (35.42 gm) and Dinsho (35.38gm) after local check. On the other hands, the mean value of grain yield (GY) varied from 2.28 (HB-1307) to 3.30 (Dinsho) with the mean value of 2.94. Besides, Abdane (3.26), Biftu (3.19) and Dinsho (3.3) showed larger mean grain yield over the other varieties while the least mean grain yield was obtained from HB-1307 (Table 2). Therefore, Abdane, Biftu and Dinsho were identified for better mean performance of grain yield and some yield contributing traits presently. On the contrary, the largest mean value of grain yield was reported previously (Kemelew and Alemayehu, 2011 and Girma, 2012) for HB-1307.

Table 2: The mean performance of barley varieties for phonological traits, thousand seed weight and grain yield across two locations for three years (2014-2016)

Varieties	days to heading	days to maturity	thousand seed weight	grain yield ton ha^{-1}
Abdane	55.44b	92.9bc	34.4bc	3.26a
Biftu	52.5cd	91.20d	30.38c	3.2ab
Dafo	48.94e	87.83e	35.4ab	2.83c
Dinsho	59.06a	91.3cd	35.4ab	3.30a
Harbu	52.00d	87.39e	33.8bc	2.82c
HB-1307	54.4bc	105.0a	31.3bc	2.28d
Local	54.2bc	92.9b	39.90a	2.8bc
Mean	53.79	92.66	34.4	2.94
CV (%)	5.46	2.58	21.3	15.8
R-sq	0.75	0.92	0.89	0.88
LSD	1.95	1.58	4.86	0.31

The result of GGE bi-plot analysis is shown in figure 1. The environments and genotypes obtained in the concentric (central circle) are considered as ideal environments and stable genotypes respectively (Yan and Rajcan,2002). A variety is more desirable if it is located closer to the ideal variety. Using the ideal genotypes/variety as the center, concentric circles were drawn to help visualize the distance between each varieties and the ideal variety. Therefore, ranking based on the genotypes-focused scaling, assumes that stability and mean yield are equally important (Ezatollah *et al.,* 2011). Varieties Dinsho, Abdane which fell into the center of concentric circles were ideal varieties in terms of yielding ability and stability when compared to the other varieties. Biftu was located on the next concentric circle and was desirable variety (Figure 1).

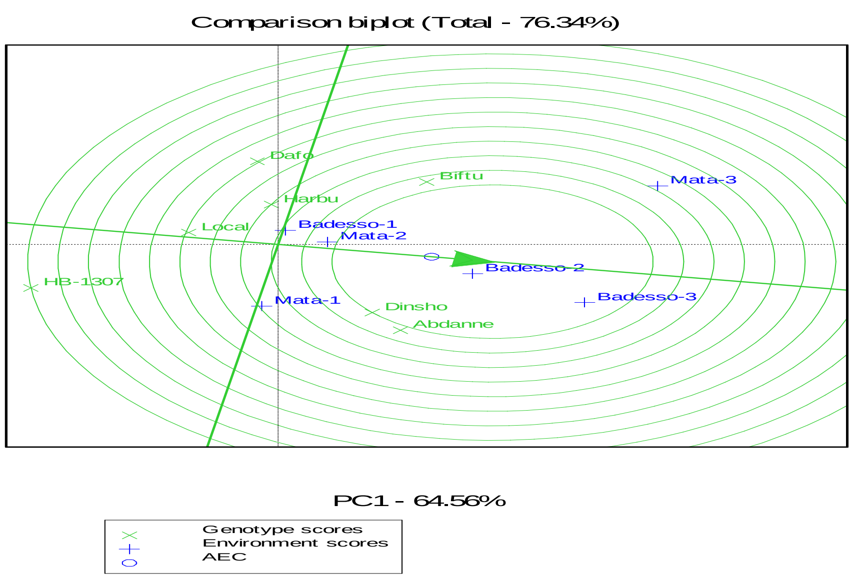

Figure1. GGE bi-plot based on varieties-focused scaling for comparison of varieties for grain yield potential and stability

Conclusion and recommendation

Abdane, Biftu and Dinsho had shown higher mean values of grain yield across the two sites and also exhibited better mean values of grain yield over the three years. GGE bi-plot analysis showed that Dinsho, Abdane were identified as ideal varieties in terms of yielding ability and stability and followed by Biftu. Hence, these varieties are recommended for the study areas and with similar agro-ecologies.

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Participatory Selection of Lentil (*Lens culinaris* Medik) Varieties for High lands of Guji, Southern Ethiopia

Tekalign Afeta[*1], Demissie Alemayehu[1], BelachewDabalo[1]
[1]Bore Agricultural Research Center (BOARC), P. O. Box 21, Bore, Ethiopia
Corresponding e-mail: dameadugna@gmail.com/dameadugna@yahoo.com

Abstract

Participatory variety selection was carried out in highland of Guji Zone at three selected farmers' fields during 2016 main cropping season. The objective of this study was to evaluate the performance of released lentil varieties and select the best one for the target production area. Four released lentil varieties were evaluated at on station of Bore Agricultural Research Center and on fields of three selected farmers. Randomized complete block design with three replications was used. Each farmer was considered as a replicate. Significant differences ($p<0.05$) were observed among varieties in days to flowering, days to maturity, plant height, number of pods per plant, and grain yield per hectare. Grain yield ranged from 1093 to 1944 kgha^{-1} with grand mean of 1556 kgha^{-1}. Alemaya and Ada'a were the two better performing varieties with seed yield of 1944 kgha^{-1} and 1861 kgha^{-1}, respectively. Based on their own selection criteria farmers also selected these two varieties. The result of this study showed that varieties Alemaya and Derash were adapted varieties to Bore high land and similar agroecologies in Guji zone.

Keyword: *Lentil, Participatory Variety Selection, Seed yield.*

Introduction

Lentil (*Lens culinaris* Medik) is one of the most ancient annual food crops that have been grown as an important food source (Fikru *et al*., 2014). It is cultivated for its seed and mostly eaten as split (Cokkizgin and Shytaya, 2013). The primary product of lentil is its seed, which has relatively higher contents of protein, carbohydrate and calories compared to other legumes (Fikru *et al*., 2014). It is the most desired crop because of its high average protein content and fast cooking characteristic in many lentil-producing regions. It can be used as a main dish, side dish, or in salads. Seeds can be fried and seasoned for consumption but sometimes difficult to cook because of the hard seed coat those results from excessive drying. Its flour is used to make soups, stews, purees, and mixed with cereals to make bread and cake; and as a food for infants (Abraham, 2015).

It also plays a significant role in maintenance and improvement of soil fertility. Its cultivation enriches soil nutrient status by adding nitrogen, carbon and organic matter which promotes sustainable cereal-based systems of crop production (Abraham, 2015). Both red and green lentils are produced in the region with variable proportion. It is an important crop in food**,** feed and farming systems of West Asia and North and East Africa. It has been established in a wide range of agro-ecology but production is limited to tropical areas. The spread of lentil from the center of origin has been accompanied by the selection of traits important for adaptation to environments that can be climate, soil and their impact on season length, abiotic and biotic stresses (Fikru *et al*., 2014).

In the highlands of Guji, farmers as well as Seed Producer Cooperatives (SPCs) are highly demanding better yielding varieties of lentil to maximize their product, and improve the livelihood of their families. Participatory Varietal Selection (PVS) has been proposed as an option to the problem of fitting the crop to a multitude of both target environments and users preferences (Ceccarelli *et al*. 1996). It is worth mentioning that although farmer participation is often advocated on the basis of equity, there are sound scientific and practical reasons for farmer involvement to increase the efficiency and the effectiveness of a breeding program (Ceccarelli and Grando, 2002). The present study was conducted with the objectives to evaluate and select lentil varieties for high yield and other agronomic traits through farmer's participation in decision making during the selection process.

Materials and Methods

The experiment was carried out during 2016 main cropping season at Bore Agricultural Research Center, Guji Zone southern Oromia. The experimental site is situated at the latitude of 06°23'55" N – 06°24'15" N and longitude of 38°34'45" E – 38°35'5"E at an altitude of 2728 m above sea level. The area represents highlands of Guji Zone, receiving high rainfall and characterized by a bimodal rainfall distribution. The first rainy season is from April up to October and the second season starts in late November and ends at the beginning of March. The major soil types are *Nitosols* (red basaltic soils) and *Orthic Aerosols* (Yazachew and Kasahun, 2011; Wakene*et al*., 2014). The soil is clayey loam in texture and strongly acidic with pH value of around 5.13.

Four released lentil genotypes were obtained from Debre Zeit Agricultural Research Center (DZARC) were used for the study. The trial was laid down in randomized complete block design (RCBD) with all three replication on Bore Agricultural Research Center main station as for mother Trial. The three farmer fields were planted with one replication each considered as baby trial. Each genotype was planted in 8 rows of 3 m row length with 20 cm spacing between rows. Diammonium phosphate (DAP) was applied at rate of 100 kg/ha. The whole DAP was applied at sowing. Sowing was done by hand drilling at seed rate of 60-120 kg/ha seeds per row.

Agronomic and phenological data were collected on plot and plant basis from the mother trial. Plant height (cm), number of branches per plant, number of pods per plant, and number of seeds per pod, were collected from ten randomly taken plants from the middle six rows in each plot. Grain yield (kg) of the middle six rows in each plot was measured and converted to kilogram per hectare for analysis. The recorded agronomic data were subjected to the analysis of variance (Gomez and Gomez, 1984) using Statistical Analysis Software GenStat discovery 15thedition.

Farmers' selection process was carried out at physiological maturity of the plant. Every farmer's group, comprising women and men, made discussion during selection. The selection criteria set by farmers were frost tolerant (FT), seed color (marketability) (Sc), stem strength (St), maturity (early) (M), shattering ability (Sh), number of pods plant^{-1} (PPP) and number of branches plant^{-1} (BPP).Farmers' evaluation and selection data were collected on plot basis from the three trials i.e., farmers were grouped around each host farmer of the trials.

Farmers' selection data were analyzed using simple ranking method in accordance with the given value (De Boef and Thijssen, 2007). Simple ranking is a tool often used to identify promising varieties based on farmers' preferences. The ranking procedure was explained for farmer participants and then each selection criterion was ranked from 1 to 5 (5 = very good, 4 = good, 3 = average, 2 = poor and 1 = very poor) for each variety. Ranking was done on consensus where differences are resolved through discussion (De Boef and Thijssen, 2007).

Results

Agronomic traits viz., days to flowering, days to maturity, plant height, number of branches per plant, number of pods per plant, number of seeds per pod and grain yield were analyzed (Table 1). The varieties significantly ($P < 0.05$) varied for days to flowering and maturity. The difference in days to flowering among the varieties range from 76 days to 80 days. Derash (76 days) was early flowering variety whereas Ada'a, Teshale and Alemaya were late flowering varieties. Similarly, the differences in days to maturity among the genotypes were varied from 136 to 141 days. Derash (136 days) early maturing variety complete their life cycle in relatively shortest period whereas Ada'a and Alemaya varieties were matured relatively late. Thus early maturing genotypes have the advantage over late maturing types in environments where frost occurrs late in the season. Significant differences (P < 0.05) were also observed among varieties for plant height. Relatively variety, Ada'a was the tallest variety (39.6 cm) followed by Alemaya (33.6 cm) and Derash (32. 1 cm) whereas the shortest variety was Teshale (31.5 cm).

Table 1. Mean values of grain yield and different agronomic traits

Genotypes	DF	DM	PH (cm)	BPP	PPP	SPP	YLD (kg ha^{-1})
Derash	76^{b}	136.0^{c}	32.08^{b}	2.7^{a}	62.3^{a}	1.4^{a}	1324^{b}
Ada'a	80^{a}	141.3^{a}	39.6^{a}	3.3^{a}	39.1^{b}	1.6^{a}	1861^{a}
Alemaya	80^{a}	140.0^{ab}	33.6^{b}	2.8^{a}	40.5^{b}	1.5^{a}	1944^{a}
Teshale	79.7^{a}	138.3^{bc}	31.5^{b}	2.9^{a}	36.1^{b}	1.4^{a}	1093^{b}
Mean	79.9	138.9	34.2	2.9	44.5	1.5	1556
LSD (5%)	1.0	2.6	3.3	NS	17.2	NS	533.9
CV (%)	0.6	0.9	4.8	15.6	19.4	16.1	17.2

Where DF= Days to flowering, DM= Days to maturity, PH= Plant height, BPP= Number of branches plant-1, PPP= Number of pods plant-1, SPP= Number of Seeds pod-1, LSD= Least significant difference, CV= Coefficient of variation.

Significant variation (P < 0.05) was observed among varieties for pod number per plant. The highest pod number per plant was recorded for Derash (62.3) and the lowest was for Teshale (36.1cm). There significant difference among the tested varieties (P<0.05%) in grain yield performance. Grain yield ranged from to 1093 to 1944 kgha^{-1} with grand mean of 1556 kgha^{-1}. Alemaya (1944 kgha^{-1}) and Ada'a (1861 kgha^{-1}) were top yielding varieties whereas Derash (1304 kgha^{-1}) and Teshale (1093 kgha^{-1}) took the least ranks.

Farmers Variety Evaluation

The results obtained from farmers' evaluation in three trials are presented in Table 2. The evaluations mean score value for each genotype ranged from 7.75 to 10.75 (Table 2). Alemaya scored as the best whereas Ada'a was the last. Farmers' ranked Teshale and Derash second and third best varieties, respectively.

Table 2. Sum of scores at three farmer sites for each trait, overall means value of each selection criteria and ranking of genotypes

Variety	Farmer's Criteria								Mean	Rank
	FT	Sc	St	M	Sh	PPP	BPP	Total		
Derash	9	11	15	12	9	11	9	76	9.50	3
Ada'a	13	9	8	4	14	7	7	62	7.75	4
Alemaya	14	15	10	8	10	14	15	86	10.75	1
Teshale	9	10	13	14	10	12	13	81	10.13	2

Where, FT= Frost tolerant, Sc= Seed color (Marketability), St= stem strength (lodging), M= Maturity (early), Sh= shattering ability, PPP= Number of Pods plant-1 and BPP= Number of Branches plant-1 rating of the performance of variety for a given criteria: 5= very good, 4= good, 3= average, 2= poor and 1 = very poor by adopting from De Boef and Thijssen, 2007

Different varieties were selected by different farmers at different farmers' field due to their performance in the field at selection time. However, including yielding ability criteria, best varieties namely Alemaya, Teshale and Derash were selected as top ranking in the selection /adapted varieties. Except Ada'a and Teshale the same varieties had better performance and found to be promising from the analysis of researchers' collected data of some agronomic trait. Due to its late maturing and lodging character Ada'a variety, got the lowest rank whereas variety Teshale was with the lowest yield. The study showed that participatory approach of variety played a significance role as it confirmed by conventional plant breeding.

Farmers and the researcher used different parameters and methods to evaluate the tested genotypes. It is obvious that farmers have demonstrated the ability to select well-adapted and preferred varieties under their circumstances using their own criteria. A range of improved varieties should be available for selection under their participation. In this study researchers consider farmers selection traits in their varietal development such as seed yield, seed size and overall field performance. Generally, the selected varieties have high yield and tolerance to both biotic and abiotic stresses with farmers' preferences.

Conclusions and recommendation

Alemaya and Derash gave the higher grain yield and showed better performance in other agronomic traits than the other varieties indicating that they are adapted to the study area. Hence ,Alemaya and Derash are recommended for lentil growing areas of Gugi.

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Adaptation Study of Improved Chickpea (*Cicer arietinum* L.) Varieties in Guji zone of Southern Ethiopia

*Deresa Shumi[1], Demissie Alemayehu1[2], Tekalign Afeta [2]
Bore Agricultural Research Center (BOARC), P. O. Box 21, Bore, Ethiopia
[2]Haramaya University, Department of Plant Science, Post Graduate Studies, Dire Dawa
E-mail Address: **dameadugna@gmail.com/dameadugna@yahoo.com**

Abstract

A field experiment was conducted at Bore on station, Ana Sora on farm and Adola sub-site using six improved chickpea varieties (Arerti, Dalota, Ejere, Habru, Natoli and Teketaye) during 2015/16 Bona cropping season. The objective of the study was to assess the adaptability of these varieties in Guji Zone. The field experiment was laid out in randomized complete block design with three replications. The result revealed that significant ($P < 0.05$) differences among varieties for number of pods plant^{-1}, hundred seed weight and grain yield (kg ha^{-1}) at all the three locations. At Bore on station and Adola sub site, variety Dalota was the best followed by Habru while variety Teketay was the best at Ana Sora on farm. The overall mean indicated that Dalota and Habru were the two best varieties with seed yield of 2411 kg ha^{-1} and 1822 kg ha^{-1}, respectively. Hence, Dalota and Habru were recommended for production in Guji Zone of Southern Oromia and similar agro-ecologies.

Keyword: Adaptation, Chickpea, Cicer arietinum, Grain yield.

Introduction

Chickpea (*Cicer arietinum L*.) is an ancient crop that belongs to the legume family. It has been grown in Africa, the Middle East, and India for centuries and eaten as dry pulse or green vegetable (Corp *et al*., 2004). A cool season annual pulse crop is grown in tropical, subtropical, and temperate regions of the world. Most production and consumption of chickpea (95%) takes place in developing countries (Muehlbauer and Tulu, 1997).

Chickpea is an important source of protein for millions of people in the developing countries, particularly in South Asia and Africa, who are largely vegetarian either by choice or because of economic reasons. In addition to having high protein content (20-22%), complex carbohydrates, fiber, minerals (phosphorus, calcium, magnesium, iron and zinc) and β-carotene while low in fat and cholesterol (Corp *et al*., 2004).

Chickpea is Ethiopia's most important pulse crop widely grown in highland and semi-highland regions of the country mainly on clay soil. It ranked second next to faba bean, which occupies about 239,747.51 hectares of land annually with estimated production of 4,586, 822.55 quintals (CSA, 2014/15). It is also an excellent source of animal feed and plays an important role in the maintenance of soil fertility, particularly in the dry rain fed areas (Katerji *etal*, 2001) and it fixes *Rhizobium* bacteria on roots(Akcin,1988). The chickpea plant and its straw are used as forage, hay and silage in the v*ertisol* soils of Ethiopian highlands. Besides, similar to other pulse crops it is a good rotational crop and thus improves soil fertility (Yasin and Mathewos, 2016).

Guji zone has conducive environment for production of the chickpea. However, this crop has not been yet in production in this zone. Therefore, this activity was carried out to evaluate and select the best performing chickpea variety for the target areas.

Materials and Methods

The study were conducted at Bore on-station, Ana Sora on farm and Adola sub-site of Bore Agricultural Research Center ,Guji Zone Southern Oromia during the 'Bona' cropping season of 2015. The areas located within the altitude range of 1725-2754 m.a.s.l. Six (6) improved Chickpea varieties namely *Arerti, Dalota, Ejere, Habru, Natoli and Teketaye* were introduced from Debre Zeit Agricultural Research

Center/EIAR. The treatments were arranged in randomized complete block design (RCBD) with three replications. The plot size was $7.2m^2$ (6 rows of three meter length with 40cm spacing between rows) and 10cm between plants while the net harvesting area was $4.48m^2$ (the four central rows). At the time of planting, all plots received a basal application of NPS at the rate of $50kgha^{-1}$. The experimental fields were managed as per the recommended practices for chickpea.

Days to emergence, days to flower initiation, days to physiological maturity, plant height, number of pods, seeds per pod and hundred seed weight were recorded. To determine grain yield per plot the four central rows and were threshed. The grain yield was adjusted to the moisture content of 10% as follows: Adjusted Grain Yield = $\frac{(100-\mathrm{MC})\ \mathrm{X\ Undjusted\ grain\ yield}}{100-10}$, where MC- is the moisture content of chickpea seeds at the time of measurement and 10 is the standard moisture content of chickpea in percent.

Finally, yield per plot was converted to per hectare basis and the average yield was reported in kg ha^{-1}.The recorded data were subjected to analysis of variance using GenStat discovery 15^{th} edition software following the standard procedures outlined by Gomez and Gomez (1984). Comparisons among the treatment means were done using Fishers protected least significant difference (LSD) test at 5% Level of significant.

Results and Discussion

Analysis of variance of the three location show that phenological and growth parameters; namely days to 50% emergency at Bore on station and Adola sub-site, days to 50% flowering at Bore on station and Ana sora on farm, days to physiological maturity at Bore on station and Ana Sora on farm and plant height at Adola sub-site were significant ($P < 0.05$) for the varieties (Table 1). Days to flowering ranged from 71 to 75 days for Bore on station and 71 to 76 days for Ana sora on farm. Days to maturity ranged from 144.3 to 153.7 days for Bore on station and 144.3 to 154.3 days for Ana sora on farm. Similarly, plant height ranged from 46.77 to 62.33 cm for Adola sub site. Yasin and Mathewos (2016) and Yasin*et al*., 2017also reported that significant difference among the varieties for plant height for this crop in other study.

Analysis of variance of at three locations revealed that number of pods per plant and hundred seed weight were significant ($P < 0.05$) difference among the varieties (Table 2). Variety Teketaye had the highest average number of pod per plant with 87 pods while Arerti and Ejere showed the lowest average of pod per plant with mean of 61.67 and 64.33 pods, respectively at Bore on station. At Ana sora on farm and Adola sub-site the highest average number of pods per plant was recorded from variety Dalota were 67.33 and 68.80, respectively. The lowest number of pods per plant was recorded from variety Natoli (41.33 and 42.37 pods) at Ana sora on farm and Adola sub-site, respectively. The varietal effect on the hundred seed weight was significant ($P <0.05$) at three locations and the results (Table 2) indicated that the maximum hundred seed weight (37.78 g, 36.67 g and 40 g) were recorded in variety Dalota, followed by varieties Habru and Natoli with (35.56 g; 35 g), Ejere and Habru (35 g; 33.33 g) and Habru, Natoli and Ejere with (35 g) at Bore on station, Ana sora on farm and Adola sub-site, respectively (Table 2).

Variety Dalota had the highest hundred seed weight followed by Habru and Natoli over three locations whereas the variety Arerti had the lowest. This indicates that all the varieties respond differently to the tested locations. According to Yasin and Mathewos (2016) there was significant difference among the varieties for number of pod per plant and hundred seed weight. In other study also Chickpea varieties showed significant difference on number of pods per plant (Yasin *et al*., 2017).

Table 1. Mean days to 50% emergency, days to 50% flowering, days to physiological maturity and plant height of chickpea varieties at Bore on station, Ana Sora on farm and Adola sub-site during 2015/16 cropping season

Varieties	Phenology and Growth Parameters											
	Bore On-station				Ana Sora on farm				Adola sub-site			
	DE	DF	DM	PH	DE	DF	DM	PH	DE	DF	DM	PH
Dalota	9.00b	75.00a	153.70a	59.77a	9.33a	75.67a	154.3a	67.10a	9.0a	52.67a	82.00a	52.2bc
Habru	9.67a	72.33b	144.30c	56.77a	9.33a	72.33c	144.3b	63.46a	8.0b	52.67a	84.67a	62.33a
Arerti	10.0a	71.00b	145.0bc	58.20a	10.0a	71.00c	145.0b	68.27a	8.0b	52.67a	85.00a	46.77c
Natoli	10.0a	75.00a	146.3bc	56.17a	9.67a	75.0ab	146.3b	62.40a	9.0a	54.00a	84.00a	50.03c
Teketaye	10.0a	72.33b	147.70b	61.10a	10.0a	73.0bc	147.7b	75.60a	7.3c	52.67a	83.00a	50.27c
Ejere	9.0b	71.00b	144.3c	57.13a	9.33a	71.00c	144.3b	66.63a	9.0a	52.00a	82.00a	57.0ab
Mean	9.6	72.78	146.89	58.20	9.61	73.00	147.00	67.20	8.40	52.78	83.44	53.10
LSD (5%)	0.4	2.37	3.22	NS	NS	2.37	3.53	NS	0.42	NS	NS	6.05
CV (%)	2.5	1.80	1.20	7.7	4.9	1.8	1.4	9.3	2.8	1.8	1.6	6.40

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; DE=Days to emergency, DF=Days to flower, DM = days to maturity, PH = Plant height (cm), LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

Table 2. Mean number of pods plant^{-1}, number of seeds pod^{-1} and hundred seed weight (g) of chickpea varieties at Bore on station and Ana Sora on farm and Adola sub-site during 2015/16 cropping season

Varieties	Yield Component Parameters								
	Bore On-station			Ana Sora on farm			Adola sub-site		
	NPPP	NSPP	HSW	NPPP	NSPP	HSW	NPPP	NSPP	HSW
Dalota	74.33^{ab}	1.33^{a}	37.78^{a}	67.33^{a}	1.00^{a}	36.67^{a}	69.80^{a}	1.33^{a}	40.00^{a}
Habru	67.33^{b}	1.00^{a}	35.56^{ab}	29.00^{b}	1.00^{a}	33.33^{abc}	45.93^{b}	1.00^{a}	35.00^{b}
Arerti	61.67^{c}	1.00^{a}	28.89^{c}	44.00^{b}	1.00^{a}	28.33^{d}	50.53^{b}	1.67^{a}	26.67^{c}
Natoli	77.33^{ab}	1.00^{a}	35.00^{ab}	41.33^{b}	1.00^{a}	30.00^{cd}	42.37^{b}	1.00^{a}	35.00^{b}
Teketaye	87.00^{a}	1.00^{a}	32.78^{b}	42.67^{b}	1.33^{a}	31.67^{bcd}	57.47^{ab}	1.00^{a}	31.67^{b}
Ejere	64.33^{bc}	1.00^{a}	34.44^{b}	43.33^{b}	1.00^{a}	35.00^{ab}	42.50^{b}	1.00^{a}	35.00^{b}
Mean	72.0	1.06	34.07	44.60	1.06	32.50	51.40	1.17	33.89
LSD(5%)	2.66	NS	3.19	18.87	NS	4.19	16.68	NS	4.69
CV (%)	23.50	22.30	9.90	23.80	22.30	7.30	18.20	28.60	7.80

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; NPPP = Number of pods plant-1, NSPP=Number of Seeds pod-1, HSW=Hundred Seed Weight (g), LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

The study revealed that chickpea varieties showed significant ($P < 0.05$) difference for grain yield (kg ha^{-1}) at three locations (Table 3). Variety Dalota had the highest grain yield (3038 kg ha^{-1}); while Teketaye had the lowest grain yield (1139 kg ha^{-1}) at Bore on station. At Ana sora on farm the highest grain yield was recorded from variety Teketaye (2274 kg ha^{-1}) followed by Dalota (1892 kg ha^{-1}) and the lowest grain yield was recorded from Ejere (910 kg ha^{-1}) variety. At Adola sub-site the highest average of grain yield was recorded from variety Dalota (2303 kg ha^{-1}) followed by Habru (1986 kg ha^{-1}), whereas the lowest was recorded from Ejere (1226 kg ha^{-1}) variety. From the overall mean grain yield the highest yield was recorded from variety Dalota (2411 kg ha^{-1}) followed by Habru (1822kg ha^{-1}) while, the lowest from variety Ejere (1264 kg ha^{-1}). This indicates that all the varieties respond differently to the tested locations. This result are in line with those of Biru *et al*. (2014) who tested different improved Chickpea varieties and reported the average grain yield over environments varies from 520 to 2010 kg ha^{-1}. Similarly Yasin and Mathewos (2016) and Yasin *et al*.(2017) also reported that there was significant difference for grain yield among the varieties across locations.

Table 3.Mean grain yield in (kg ha^{-1}) of chickpea varieties adaptation trial over three locations during cropping season of 2015/16

Varieties	Grain yield (kg ha^{-1})			overall means
	Bore On-station	Ana Sora on farm	Adola sub-site	
Dalota	3038^{a}	1892^{ab}	2303^{a}	2411
Habru	2160^{ab}	1319^{bc}	1986^{ab}	1822
Arerti	1729^{bc}	1813^{ab}	1247^{bc}	1596
Natoli	1912^{bc}	1431^{bc}	1455^{bc}	1599
Teketaye	1139^{c}	2274^{a}	1444^{bc}	1619
Ejere	1656^{bc}	910^{c}	1226^{c}	1264
Mean	1939	1606	1610	
LSD 5%)	942.6	798.4	747.5	
CV (%)	27.3	27.9	26.10	

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance, LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

Conclusion and Recommendation

The present study showed the presence of differences among the varieties for grain yield and yield related traits. Chickpea varieties Dalota and Habru were selected for their high grain and other agronomic traits. Therefore, from this study, it could be concluded that Dalota and Habru are the two varieties best adapted to Guj zone.

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Adaptation of Fenugreek (*Trigonella foenum-graecum* L.)Varieties at Midlands of Guji Zone, Southern Oromia

Solomon Teshome[1], Arega Amdie[2], Tekile Bobo[3] and Bariso Wako[4]

Oromia Agricultural Research Institute, Bore Agricultural Research Center, Ethiopia

Abs*tract*

Introduction of improved fenugreek varieties can boost the yield level in the study area .The experiment was conducted at mid lands of Guji during main season of 2016 cropping season with objective to select adaptable, high yielder and disease resistant fenugreek varieties with good agronomic traits. The trial consists of of local check and three improved varieties namely Hunda'ol, Ebbisa and Chala. The experiment was laid out in a completely randomized block design with three replications. Days to 50% emergence, flowering, maturity, plant height, number of pods per plant, 1000 seed weight and total seed yield per hectare were recorded. Analysis of variance showed that significant difference among studied varieties for plant height, thousand seed weight and total seed yield. Local check was the best followed by one improved variety (Chala) with grain yield of 1750.1 kg ha^{-1} and 1570.2 kg ha^{-1}, respectively. The result of this study indicated that there is a need of collecting fenugreek landraces from the study area for future breeding activity.

Key words: Adaptation trial, Fenugreek, Improved varieties

Introduction

Fenugreek (*Trigonella foenum greecum* L.) is an important self-pollinated seed spice crop belonging to subfamily Papilionaceae of the family Fabaceae (Suleiman *et al*., 2008). It is native of south Eastern Europe and West Asia and has been part of North African Countries, Argentina, France, Morocco, and Lebanon. Plants are used medicinally in different countries and are a source of many potent and powerful drugs. Fenugreek seed contains protein (9.5%), fat (10%), crude fiber (18.5%), carbohydrate (42.3%) and many other minor nutrients and vitamins. This plant decrease body fats and effective on obesity. The yields can be significant increase in quantity and quality through the suitable management of cultivation, irrigation and harvesting. In this context, fenugreek (*Trigonella foenum graecum* L.), an annual legume, is extensively cultivated in most regions of the world for its medicinal value (Petropoulos, 2002).

Fenugreek can be a very useful legume crop for incorporation into short-term rotation and for hay and silage for livestock feed, for fixation of nitrogen in soil and its fertility, and etc (Sadeghzadeh-Ahari *et al*., 2009). Fenugreek seeds have been known and valued as medicinal material from very early times. Fenugreek as a chemurgic crop has a wide use for industrial purposes. Its seeds are considered to be of commercial interest as a source of a steroid diosgenin, which is of importance to the pharmaceutical industry (Mehrafarin *et al*., 2010).

The yield potential of fenugreek can be defined as the total biomass produced or agricultural important part of the crop. The total biomass is a result of the integration of metabolic reactions in the plant. Consequently, any factor influencing the metabolic activity of the plant at any period of its growth can affect the yield (Ahmed *et al*., 2010). Metabolic processes of fenugreek plants are greatly governed by both internal, i.e. genetic makeup of the plant and external conditions, which involve two main factors namely climatic and edaphic environmental factors. The yield potential of fenugreek could be regulated through alternation of genetic makeup and reconstitution of genetic structure through breeding programs and/or by modifications of environment through cultural treatments (Ahmed *et al*., 2010; Basu *et al*., 2009).

Introduction of high yielding varieties can boost the yield levels in the adopted areas. Improved fenugreek cultivars are not yet sufficiently put under production and most of the areas in the Guji zone.To overcome absence of improved variety and management practices introduction and adaptation studies of high yielding varieties with all agronomic management practices are very critical. This experiment was conducted with the objective of selecting and recommending the best high yielding variety for the study area.

Material and Methods

The study was conducted at mid lands of Guji zone during 2016 cropping season at Adola district on three sites. The experimental area is situated averagely at an altitude of 1768 meters above sea level and is located 469 km south of Addis Ababa along the Hawassa road. The area is averagely characterized by a mean annual rainfall of 978 mm. The main rainy season is from May to October. The average annual maximum and minimum temperature is 22.2 C^o and 10.26 C^o, respectively.

The trial consists of local check and three improved varieties (Hunda ol, Ebbisa and Chala). The seed source is from Sinana Agricultural Research Center (Hunda'ol and Ebisa) and Debre Zeiyt Agricultural Research Center (Chala). The experiment was laid out in a completely randomized block design with three replications. Gross plot size was 2.2m^2 accommodating a minimum of 5 harvestable rows. Days to 50% emergence, flowering, maturity, plant height (cm), number of pods per plant, thousand seed weight and total seed yield per hectare was recorded.Data were subjected to analysis of variance (ANOVA) using the General Linear Model of the SAS statistical package (SAS, 2003) Version 9.1.3. All significant pairs of treatment means were compared using the LSD at 5% level of significance.

Result

Analysis of variance showed that plant height, thousand seed yield and total seed yield was highly significantly (P<0.01) among tested genotypes (Table 1). The highest plant height (49.92 cm) was recorded in variety Chala followed by local check (48.74 cm). On the other hand, the shortest plant height (41.71cm) was recorded by Ebisa variety. The highest thousand seed weight (17.57 g) was documentated in variety Chala whereas and the lowest (13.84 gm) seed weight was observed in variety Ebisa. High grain yield was (1750.1 kg ha^{-1}) was recorded in local check followed by variety Chala (1570.2 kg ha^{-1}) and Hundaol (1355.4 kg ha^{-1}). The lowest (1213.82 kg ha^{-1}) total seed yield was witnessed in variety Ebisa.

Table 1. Combined analysis of fenugreek varieties to different parameters across location

Trt	DE	DF	DM	PH	NPP	TSW	YPP	Yield
Chala	5.888	57.666	120.667	49.92^{a}	14.600	17.57^{a}	725.4^{ab}	1570.2^{ab}
Ebisa	5.555	57.555	120.667	41.711^{b}	12.288	13.84^{b}	560.78^{b}	1213.82^{b}
Hundaol	5.888	57.888	120.667	43.261^{ab}	13.177	14.35^{b}	626.19^{ab}	1355.4^{ab}
Local	5.888	57.111	120.667	48.74^{a}	16.161	14.22^{b}	808.50^{a}	1750.10^{a}
LSD(0.05)	ns	ns	ns	6.69	ns	1.30	680.21	1465
CV	6.97	3.19	15.98	15.19	35.54	9.04	6.46	6.46

Where Trt=treatment, LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; DE= days to emergency, DF= days to flowering, DM=days to maturity, PH=plant height (cm), NPP=number of pods per plant, TSW=thousand seed weight (g) and YPP=yield per plot (kg ha^{-1}). Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance

Conclusion and recommendation

The maximum mean seed yield (1750 kg ha^{-1}) was recorded in local check. The lowest grain yield (1213.82 kg ha^{-1}) was recorded in variety Ebisa. The grain yield performance of local was superior to the introduced unproved fenugreek varieties. The result of this study showed that there is a possibility of collecting fenugreek landraces and select for the area.

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Advanced Screening of Bread Wheat Genotypes against Major Wheat Diseases in Bale

Tamene Mideksa[1]* and Wubishet Alemu[1]

*[1]Oromia Agricultural Research Institute, Sinana Agricultural Research Center, P.O.BOX, 208, Bale-Robe, Ethiopia

Corresponding author: gutamesa@gmail.com

Abstract

Wheat rust diseases caused by Puccinia spp are important diseases of wheat worldwide. One hundred seventy three (173) bread wheat genotypes were screened against stripe and stem rusts caused by Puccinia striiformis f.sp. *tritici and Puccinia graminis* f.sp. *tritici respectively under natural condition. The experiment was conducted during 2016 main cropping season at Sinana Agricultural Research Center. Each genotype was sown in two row of 20 cm spacing, 1m long and 20 cm distance between plots in augmented design. One genotype was found immune against stripe rust namely ETBW8900 whereas sixty-six bread wheat genotypes were found immune against stem rust. One genotype was found resistant to stripe rust namely ETBW8715 while one genotype was found resistant against stem rust namely ETBW8885. Forty-five genotypes were found moderately resistant against stripe rust whereas twenty-four genotypes were found moderately resistant to stem rust. Sixteen genotypes were found moderately susceptible to stripe rust while thirty-two genotypes were found moderately susceptible against stem rust. One hundred ten genotypes were rated as susceptible against stripe rust whereas fifty genotypes were found susceptible against stem rust. Thirty-eight best performed bread wheat genotypes were selected based on their disease reaction and promoted to the next breeding program for further evaluation.*

Keywords: Wheat, Yellow rust, Stem rust, resistant genotype

Introduction

Wheat is one of the most important widely cultivated cereal crops in Ethiopia. It is cultivated both in bi-modal and uni-modal rain fall areas although it occupies large hectares of cultivated land in the latter rain fall agro ecology.It ranks fourth in area coverage next to teff, maize and sorghum, respectively (CSA, 2014). Several multifaceted biotic diseases fungal, viruses, bacteria, nematodes pathogens were recorded on wheat in Ethiopia. Among wheat diseases recorded in wheat in Ethiopia, yellow rust, stem rust, leaf rust, septoria leaf blotch and fusarium head blight are significantly threatening wheat production in most of wheat producing agro ecologies (Bekele, 2003). Leaf rust is widely distributed in Ethiopia but is most important in some wheat belt areas such Gololcha, Ginnir, and Madda walabu districts in Bale where bread wheat is a dominant crop. Studies conducted on these diseases revealed that the yield losses due to yellow rust, stem rust, leaf rust and septoria are as high as 20-71%, 42-52%, 75 and 82%, respectively, depending on resistance backgrounds of varieties (Bekele, 2003, Dereje, 2003, Eshetu, 1985; Ayele and Wondimu, 1992).

The major management method of these diseases is the use of resistant varieties. Efforts made towards resistant variety development to major wheat disease were successful. However, because of rusts pathogens evolution and challenges from new races evolved, resistance screening program become a routine work in wheat improving program in Ethiopia. Breeding for resistance or tolerance to wheat diseases pathogens is one of the most effective ways to reduce crop losses in Ethiopia. However, wheat pathogens can move to a new region and adapt to the resistance traits deployed in modern wheat varieties due to new races evolution .This results in the emergence of pathogens, which can result in significant losses of wheat production. For example, wheat yellow rust and stem rusts are constantly changing and adapting to the Yr and Sr genes present in the commonly grown varieties that were once resistant to prevalent races in Ethiopia. Wheat diseases are usually best managed by combining the multiple diseases resistance sources staked into one variety rather than single resistance in one variety. To understand how germplasm will react to one or multiple wheat diseases in Ethiopia and stake resistance genes in one variety, it will be necessary to evaluate the available germplasm for their resistance to diseases in regular basis. The present study was initiated with the following objectives:

- To screen bread wheat genotypes for their resistance to major diseases of wheat
- To broaden the genetic base of bread genotypes and advance the selected materials for further test

Materials and Methods

The experiment was conducted at experimental station of Sinana Agricultural Research Center during 2016 main cropping season. 173 CIMMYT materials were obtained from Kulumsa Agricultural Research Center. Each genotypes/lines was sown in two row of 20 cm spacing, 1m long and 20 cm distance between plots in augmented design. Check cultivars; Digalu, Alidoro, Enkoy, K6295-4A, KBG-01, Kubsa, Madda walabu, Meraro, Millennium, Morocco and PBW-343 were planted at 10 entries interval for comparison. To enhance natural epidemics Morocco and PBW-343 was planted between blocks perpendicular within genotypes. Recommended seed rate 150 kg ha^{-1} and fertilizer rate 41/46 N/P_2O_5 was used at planting. Land preparation and weeding was done manually as recommended for wheat. Disease severity was recorded by estimating the approximate percentage of leaf area affected (modified Cobb scale) (Peterson *et al*., 1948) on plot bases.

Results and Discussion

The use of resistant variety is considered to be the best options for the management of diseases. Screening available genotypes is better for the search of source of resistant in wheat against wheat rust diseases caused by *Puccinia spp*. As indicated in table 1 out of 173 genotypes, one genotype was found immune against stripe rust, namely ETBW 8900. Sixty-six genotypes were found immune against stem rust. Genotype (ETBW8715) was found resistant to stripe rust while genotype (ETBW8885) was found resistant against stem rust. Forty-five genotypes were found moderately resistant against stripe rust whereas twenty-four genotypes were also moderately resistant to stem rust. Some of these were ETBW8557, ETBW8734, ETBW8556, ETBW8558, ETBW8559, ETBW8572, ETBW8818 and ETBW8827. Sixteen genotypes were found moderately susceptible against stripe rust while thirty-two genotypes were found moderately susceptible against stem rust. One hundred ten genotypes were found susceptible against stripe rust whereas fifty genotypes were found susceptible to stem rust. This study revealed that 173 genotypes of wheat have shown different level of susceptibility and resistance to stripe rust and stem rust. Concurrent with the present findings, it has been reported by Peterson *et al* (1948) less than 10% (10 MS) stripe rust infection has been reported as the highest resistance and less than 5% (5 MS) is the effective resistance of the wheat variety/line/germplasm.So, this study helps in selecting genotypes to avoid the crops from getting affected by pathogen.

Conclusion and Recommended

Screening available bread wheat genotypes is the better for the search of source of resistant against wheat rusts. Out of 173 bread wheat genotypes screened against stripe rust and stem rust, 38 best performed bread wheat genotypes were selected based on their disease reaction and other some agronomic parameters. The selected genotypes will be promoted to the next breeding program for further evaluation.

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Genotype x Environment Interaction and Yield Stability of Improved Rice Varieties(*Oryza sativa L.)* Tested Over Locations at Western Oromia

[1]*Girma Chemeda, [1]Gudeta Bedada and [2]Girma Mengistu

[1]Bako Agricultural Research Center, P.O.Box 3, Bako, Ethiopia

[2]Oromia Agricultural Research Institute, Finfine

Corresponding authore: girmachemeda@yahoo.com

Abstract

Eleven rice genotypes were evaluated at 6 environments in Western Ethiopia during 2015 and 2016 main cropping season. The objective of the study was to determine the magnitude of genotype x environment interaction and performance stability of rice genotypes. The study was conducted using a randomized complete design with 3 replications. Genotype x environment interaction and yield stability were estimated using the additive main effects and multiplicative interaction and site regression genotype plus genotype x environment. Interaction bi plot pooled analysis of variance for grain yield showed significant (P<0.01 and P<0.05) differences among genotypes, environment, genotype x environment interaction effects. This indicates that genotypes differentially respond to the change in test environments or the test environments differentially discriminated the genotypes or both. Environment accounted for 69.39%, of the total yield variation, genotype for 8.50% and genotype x environment for 3.90%, indicating the need for spatial and temporal replication of the trials. Regression and AMMI analysis were employed in order to determine the stability of genotypes. The two models regression analysis and AMMI revealed similar result in that variety Adet and Hidassie were stable and widely adapted genotypes. Adet and Hidassie varieties were the most stable and high yielding variety and were therefore recommended for commercial production in the western Ethiopia upland rice growing areas.

Keywords*:* Rice, genotype x environment interaction, stability parameters, yield

Introduction

More than half of the world's population depends on rice for its major daily source of food energy and protein and thus the importance of rice in relation to food security and socio-economic stability is self-evident (FAO, 2003). Rice is the fastest growing source of food in Africa. During the past three decades rice grain has seen a steady increase in consumption and demand given its important place in the strategic food security planning policies of many African countries (Norman and Otoo, 2003; Africa Rice Center, 2007; Forum for Agricultural Research in Africa, 2009). Rice is proven to be one of the potential strategic commodity crops that can assure food security and poverty reduction in Ethiopia (Seyum and Gebrekidan, 2005; Gebrekidan and Seyoum, 2006; Zenna *et al*., 2008). Moreover, rice could also be considered as one of the best and cheapest alternative technology available to small-scale farmers for improving productivity of grain yields in flooded and swampy environments through efficient utilization of land and water (Gebrekidan and Seyoum, 2006).

The recent surge in demand triggered by soaring import price, consumer preference in urban areas, population growth and rapid urbanization forced the country to expand small-scale and commercial rice production in various agro-ecologies (Zenna *et al*., 2008). As a result of which, rice production is escalating rapidly from year to year (Gebrekidan and Seyoum, 2006; Aredo *et al*., 2008; Zenna *et al*., 2008). Nevertheless, the challenges facing the successful development of the rice sector are huge and includes: lack of adequate rice milling facilities, lack of improved varieties and recommended crop management practices for different rice ecosystems, and biotic and a biotic stresses; low agricultural inputs (fertilizer, improved rice varieties seed, agro-chemicals…etc), poor mechanization and lack of adequate human resource in the value chain (MoARD, 2010).

Western Oromia is one of the potential areas where rice is recently introduced and being produced mainly in rain fed upland ecology. However, improved rice varieties and development out puts are very limited in the area to satisfy the growing demand of large and small-scale farmers for improved rice varieties. Grain yield depends on genotype, environment and management practices and their interaction with each other (Messina *et al*., 2009). Under the same management conditions, variation in grain yield is principally explained by the effects of genotype and environment (Dingkuhn *et al*., 2006). Information of genotype × environment interaction leads to successful evaluation of stable genotype, which could be used for general cultivation.

The level of performance of any character is a result of the genotype (G) of the cultivar, the environment in which it is grown (E), and the interaction between G and E (GEI). Interaction between these two explanatory variables gives insight for identifying genotype suitable for specific environments. The environmental effect is typically a large contributor to total variation (Blanche *et al*., 2009). Moreover, G x E interactions greatly affect the phenotype of a variety, so the stability analysis is required to characterize the performance of varieties in different environments, to help plant breeders in selecting desirable varieties. Mosavi (2013) observed significant yield differences among rice genotypes, environment and genotype by environment interaction. Therefore, the major objective of present study was to evaluate and select high yielding improved rice varieties for upland ecology of western Oromia.

Materials and methods

Eleven rice varieties including standard check (*Chewaka)* were tested at three locations, Bako, Chewaka, Uke and Guttin for two cropping seasons (2015-2016). Genotypes were planted in a completely randomized block design with three replications in which each plot comprises of six rows having 5 m length. The spacing between rows was 20 cm and the seeds were drilled in rows. Recommended fertilizer rate at 100 kg P_2O_5 100 and UREA per hectare ha^{-1} was used. UREA was applied at split half at planting and half at panicale initiation.

Management practices were done according to the recommendations for the particular crop and/or location. The middle 4 rows were harvested and the grain yield was adjusted to 14% seed moisture content before data processing for analysis. Grain yield analysis was carried out using regression

(Eberhart and Russell, 1966) and AMMI models in Agrobase software (Agrobase, 2000). The linear model proposed by Eberhart and Russell (1966) is:

$$Y_{ij} = \mu_i + b_i I_j + S^2 d_{ij}$$

where Yij is the mean performance of the ith variety (I = 1, 2, 3…, n) in the jth environment; is the $S^2 d_{ij}$ mean of the i^th variety over all the environments; bi is the regression coefficient which measures the response of i^th variety to varying environments; S2dij is the deviation from regression of ith variety in the j^th environment and Ij is the environmental index of the j^th environment. Similarly, the AMMI model (Gauch and Zobel, 1996) is:

$$Y_{ge} = \mu + \alpha_g + \beta_e + \sum_{n=1}^{N} \lambda n \gamma_{gn} \delta_{en} + \rho_{ge}$$

where Y_{ger} is the observed yield of genotype g in environment e for replication r; Additive parameters:μ is the grand mean; α_g the deviation of genotype g from the grand mean and β_e is the deviation of environment e; the multiplicative parameters:λ_n is the singular value for interaction principal component axis (IPCA) n,Y_{gn} is the genotype eigenvector for axis n, and δ_{en} is the environment eigenvector; ρ_{ge} PCA residuals (noise portion) and ε_{ger} is error term.

Table 1.Discription of tested rice varieties

No	Variety name	Year of Release	Rain fall (mm)	Ecosystem	Days to maturity	Yield (ton ha^{-1})	
						On-farm	On-station
1	Adet	2014	800-1400	Upland	112-120	2.4	4.2
2	NERICA 13	2014	650-800	Upland	104	3.3	3.8
3	Getachew	2007	800-1400	Upland	97-125	2.1	3.0
4	Andassa	2007	800-1400	Upland	111-135	2.5	3.8
5	Chewaqa	2013	800-1200	Upland	160	3.3	4.2
6	Hidassie	2012	800-1400	Upland	100-130	2.2-3.2	3.0-4.2
7	Tana	2007	800-1400	Upland	109-135	2.4	4.4
8	NERICA-2	2007	Intermittent Irrigation	Irrigated upland	80-90	3.5	5.5
9	NERICA-4	2006	800-1400	Upland	110	3.0	4.8
10	Tana	2007	800-1400	Upland	109-135	2.4	4.4
11	SUPERICA-1	2006	800-1400	Upland	115	2.3	5.1

Results and Discussion

Combined analysis of variance: Genotype (G), environment (E) and genotype × environment interaction (GEI) were highly significant (P<0.01) for grain yield (Table 1). The factors explained rice grain yield was affected by genotype (69.39%), environment (8.50%) and their interaction (3.90%). In general, a wide genetic diversity for maximum traits existed in the rice materials used in this study and this may be due to their diverse origins. The effects of G and E showed highly significant mean square (MS) for maximum traits reflected genotypic differences towards adaptation to different environments.

Thus the highly significant G × E effects suggest that the genotypes may be selected for adaptation to specific environments. This is in harmony with the findings of Aina *et al*., (2009) and Xufei-fei *et al.*, (2014) in G × E interaction effects of cassava genotypes. The significant genotype × environment interaction effects demonstrated that genotypes responded differently to the variation in environmental conditions of locations. This is indicative of the necessity of testing rice varieties at multiple locations. This also attests to the difficulties encountered by breeders in selecting new varieties for release. The large sum of squares for genotypes indicated that the genotypes were diverse, with large differences among genotypic means causing most of the variation in grain yield, which is congruence with the findings of Misra *et al.* (2009) and Fentie *et al.*, (2013) in rice production.

Regression analysis based on Eberhart and Russell Model: Mean square due to genotypes and interaction of genotype x environment (linear) were found to be highly significant (P < 0.01 (Table 2). Significant interaction effect of genotypes x environments was found in yield performance among the genotypes under different environments. This is in line with the findings of Chaudhary *et al.* (1994) who reported highly significant difference for genotypes and Genotype x Environment in field pea.

The mean performance, regression coefficient (b_i) and squared deviation (s^2d_i) from the regression values was presented in Table 3. According to Ebrehart and Russell (1996) genotypes with high mean yield and regression coefficient (b_i) equal to unity and deviation from regression (s^2d_i) approach to zero. The commercial variety *Adet and Hidassiei* have mean yields higher than the average, (b_i) but did not differ significantly from unity and (s^2d_i) approaching zero. This implied that these genotypes were stable and widely adapted.

Table 2. ANOVA of rice varieties tested by Eberhart-Russell Regression Model

Source of variance	Df	SS	MS
Varieties	10	28.34	2.83**
Env.+ in Var.x Env.	55	180.69	3.28
Env. in linear	1	115.66	
Var. x Env. (linear)	10	33.27	3.32**
Pooled deviation	44	31.76	0.72
Residual	132	24.54	0.186

Grand mean = 4.055 R-squared = 0.8242 C.V. = 18.42%

Table 3. Stability analysis of rice verities rice tested in different at three location for three years in western Ethiopia during 2015-2016

Varieties	Regression coefficient (b_i)	Squared deviation from Regression (s^2d_i)	Grain yield (tons ha^{-1})
Adet	1.156**	0.5429	6.04
Kokit	0.1270	0.1786	3.59
Hidassies	1.654**	0.7949	4.58
Nerica 13	1.382**	0.4985	3.62
Superica 1	1.4781	0.2417	4.52
Nerica 2	1.234*	0.3501	4.10
Getechew	0.9989	0.1523	3.88
Andassa	1.1494	0.0452	3.28
Nerica 4	0.8610	0.2812	3.72
Tana	1.183*	0.4536	3.33
Chewaqa	0.032*	2.3569	4.37
	Mean		4.09

Stability analysis by AMMI model: The mean grain yield value of 11 rice varieties averaged over six environments presented in Table 4 showed varieties *Adet* and *Hidassie* had the highest grain yield of 8.2 ton ha^{-1} and 8.1 ton ha-^{1} and lowest 4.58 ton ha^{-1} and 3.37 ton ha^{-1} respectively. Different genotypes showed inconsistent performance across all the environments. The variety Adet (6.04 ton ha $^{-1}$) was the top performers, while variety Andassa 3.28 ton ha^{-1}, and Tana 3.33 t ha^{-1}, were the poorest yielders.

Table 4: Grain yield of rice varieties over location and year at western Oromia

		2015/16			2016/17				
	Varieties	Uke	Chewaqa	Bako	Bako	Uke	Guttin	Meam	Rank
1	Adet	6.89	8.23	4.96	6.07	5.52	4.58	6.04	1
2	Kokit	3.50	3.22	4.00	4.31	3.85	2.66	3.59	8
3	Hidassies	6.61	8.10	3.37	1.14	4.55	3.69	4.58	2
4	Nerica 13	4.29	7.32	3.82	2.37	2.36	1.58	3.62	9
5	Superica 1	6.21	7.73	3.50	1.62	4.48	3.58	4.52	3
6	Nerica 2	5.30	7.31	3.63	2.04	3.61	2.74	4.10	5
7	Getechew	4.98	6.35	3.40	2.09	3.70	2.75	3.88	6
8	Andassa	4.67	5.57	2.68	1.18	3.24	2.31	3.28	11
9	Nerica 4	4.18	6.35	3.61	2.76	3.20	2.23	3.72	7
10	Tana	4.75	5.67	2.48	1.05	3.52	2.54	3.33	10
11	Chewaqa	3.59	4.98	5.69	6.07	3.45	2.42	4.37	4
	Mean	5.00	6.44	3.74	2.79	3.77	2.82	4.09	

Table 5: Partitioning of the explained mean square (MS) from AMMI analysis for seed yield tested rice variety

Source	Df	MS	Genotype x Environment interaction
Total	197		
Environments	5	69.393**	
Reps within Env.	12	1.146	
Genotype	10	8.503*	
Genotype x Env.	50	3.902**	
IPCA 1	14	10.245**	73.52
IPCA 2	12	1.901**	11.69
Residual	120	0.499	

AMMI biplot display:Among the varieties Adet and Hidassie were generally exhibited high yield with high main (additive) effects showing positive IPCA1 score, but variety Adet being the overall best. Hence, variety Adet was identified as specially adapted to the environments of Uke and Chewaka and these two environments were considered as the wide range suitable environments for this variety.

Conclusions

The present study revealed that rice variety yield were liable to a significant fluctuation with changes in the growing environments, G x E interaction effect being almost eight times higher than that of genotype effect. This study clearly demonstrated that the regression and AMMI analyses models were found to be effective for determining the magnitude and pattern of G x E interaction effect in the rice genotypes. From the regression and AMMI analyses, therefore, *Adet* and *Hidassie* varieties were the most stable and high yielding genotype and as a result, these were recommended for commercial use for the western Ethiopia upland rice growing areas.

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Yield Stability and Genotype × Environment Interaction of Large Seed Speckled Common Bean (*Phaseolus vulgaris*L.) Genotypes at Western Low lands of Oromia

Meseret Tola*, Adane Arega, Chala Debela, Solomon Bekele, Alemayehu Dhabessa and Zerihun Abebe

Bako Agricultural Research Center P.O.box 03, Bako,Oromia, Ethiopia

Corresponding author: meserettola342@yahoo.com

Abstract

Stable yield performance of genotypes is very important in countries like Ethiopia where means to modify environments are limited. However, happening of significant genotype X environment interaction (GEI) complicates selection of stable genotypes. In western Ethiopia, the yield potential of common bean is underutilized due to inadequate addressing of all potential areas and mismatch between selection and production environments. Thus, 17 large speckled common bean genotypes were evaluated at three locations (Bako, Billo and Gute) for two consecutive years to estimate the magnitude of GEI effects and to identify broadly or specifically adapted genotypes during 2015 and 2016 main cropping seasons. The genotypes were arranged in Randomized Complete block Design with three replications.Combined ANOVA, AMMI and GGE bi plot models were used to analyze the data. Both main and interaction effects were highly significant ($P<0.01$) and environment, genotype, and GEI explained 49.8%, 25.1% and 20.0% variations, respectively, indicating greater influence of test environments and importance of simultaneous consideration of mean performance and stability. IPCA1 and IPCA2 were highly significant ($p < 0.01$) and together contributed more than 89.5% variation in the GEI sum of squares. AMMI 1 bi plot enabled identification of broadly adapted genotypes, G_3 (DAB-443) and G_{10} (DAB-364). GGE biplot analysis suggested presence of one mega-environment and enabled identification of high seed yielding and broadly adapted genotypes (DAB-449 (G4).

Introduction

Common bean (*Phaseolus vulgaris* L.) is the most important grain legume in nearly all lowland and mid-altitude areas of Ethiopia. It is produced primarily by smallholder farmers both for cash and consumption. According to CSA (2016), red common bean was cultivated on 244,049.94 hectare of land and 38049.95 ton was produced with the productivity of 1.5ton ha^{-1}.In the study zone, the area covered by the crop during 2016 cropping season was 39,469.11 ha and 59788.954 tons was produced with the productivity of 1.51 tons ha^{-1}. Its fastest ripening at the critical food deficit period earlier than othercrops made it an ideal food deficit filler crop. It's suitability for double or triple production per year enabled its production on off season free lands and relatively cheaper labor force. Its reasonable protein content (22%) made it the poor man's meat securing more than 16.7 million rural people against hidden hunger (Zeleke*et al*., 2016).

In Ethiopia, it is grown suitably in areas with an altitude ranging between 1200 – 2200m above sea level with optimum temperature range of 16 – 28^{o}C and a rainfall of 350-500 mm well distributed over the growing season (Mekbib, 2003). It performs best on deep, friable and well aerated soil with good drainage, reasonably high nutrient content and pH range of 5.8 to 6.5 (Liebenberg, 2002). Particularly, in western Ethiopia common bean is one of the most important cash crops and source of protein for farmers in many lowlands and mid-altitude zones. Apart from being food and a source of income, common bean is also replenishes of soil fertility through biological nitrogen fixation.

When genotypes are introduced into new environments, genotype x environment interaction (GEI) is expected and in its presence, selection of superior genotypes based on means averaged over locations is misleading (Ebdon and Gauch, 2002b; Gauch and Zobel, 1997). GEI reflects differences in adaptation and can be exploited by selecting for specific adaptation or minimized by selecting for broad adaptation (Adjei *et al*., 2010). These objectives can be achieved by grouping environments into mega-environments and then selecting specifically adapted genotypes for each mega-environment or broadly adapted genotypes for wider environments (Zeleke *et al*, 2016). Multi-location evaluation of genotypes and stability analysis provides useful information for mega-environment classification and identification of broadly or specifically adapted genotypes (Crossa, 1990). Several statistical analysis have been used for interpretation of GEI. But currently, AMMI and GGE models are preferred tools for multi-location trials data analysis and which genotype outsmart where pattern discovery (Samonte *et al.*, 2005; Yan *et al.*, 2007;Asfaw *et al.*, 2009; Namaratu *et al.*, 2009).

In western Oromia, there is no or little information on Genotype x Environment interaction and adaptability for large speckeled common bean genotypes. As a result, this study was done to estimate the magnitude of genotype by environment interaction effects and to analyse the stability of genotypes for seed yield performance in western low lands of Oromia.

Materials and Methods

Seventeen large speckled common bean genotypes including one standard check were evaluated under rain-fed conditions for two consecutive years (2015-2016) at Bako, Gute and Bilo-boshe. The experimental land was ploughed, disked and harrowed by tractor.The planting was done in mid-June across all locations and randomized complete bock design with three replications was used. Each plot consists six rows of four meter length with spacing of 40cm between rows and 10cm between plants.In organic fertilizer in the form of DAP (18% N and 46% P_2O_5) was applied at the rate of 100 kg DAP ha^{-1} during planting time.All other management practices were done as per the recommendations.

Multivariate method, Additive Main Effects and Multiplicative Interaction (AMMI) model was used to assess genotype by environment interaction (GEI) pattern. AMMI model is expressed as:

$$Y_{ij} = \mu + Gi + Ej + (\sum \lambda_k \alpha_{ik} \gamma_{jk}) + P_{ij} + e_{ij}$$

Where Y_{ijl} is the yield of genotype (G) in environment (E) for replicate (r), μ is the total yield mean, G_i is the main effect of genotype or the genotype (G) mean deviation (genotype mean minus total yield mean), E_j is the main effect of environment or the environment (E) mean deviation, λ_k is the singular value for IPCA axis N (N is the number of remain PCA axis in AMMI model: $\alpha_{ik}$is the genotype (G) eigenvector value for IPCA axis N, γ_{jk} environment (E) eigenvector value for IPCA axis, P_{ij} is the is the residual or noise and$+$ e_{ijl} is the error (Gauch, 1992; M. Umma Kulsum et al, 2014).

AMMI stability value of the i^{th} genotype (ASV) was calculated for each genotype and each environment according to the relative contribution of $IPCA_1$ to $IPCA_2$ to the interaction SS as follows (Purchase *et al*., 2000):

$$ASV_i = \sqrt{\left[\frac{SS_{IPCA1}}{SS_{IPCA2}}[IPCA1_{score}]\right]^2 + [IPCA2_{score}]^2}$$

Where, SS_{IPCA1}/SS_{IPCA2} is the weight given to the $IPCA_1$ value by dividing the $IPCA_1$ sum of squares by the $IPCA_2$ sum of squares.

Based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value (RASVi) a selection index called Genotype Selection Index (GSI) was calculated for each genotype, which incorporates both mean grain yield (RYi) and stability index in single criteria (GSIi) as (Purchase, 2000).

$$GSIi = RASVi + RYi$$

Environmental index (Ii) was obtained by the difference among the mean of each environment and the general mean. Genotype plus genotype by environment variation (GGE) was used to assess the performance of genotypes in different environments. The environmental effects were removed from the data and results obtained from the data were used to calculate environment and variety scores and these scores were used to plot the standard principal component bi-plots (Yan and Kang, 2003).

Analysis of variance was carried out with a statistical analysis system (SAS) version 9.3 software (SAS Institute Inc., 2002). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi- plots were performed using Gen Stat 18th edition statistical package (GenStat, 2016).

Results and Discussion

Combined Analysis of Variance for Individual Environments

Analysis of variance showed statistically significant differences (P<0.01) among genotypes, environments and their interaction for seed yield (Table 1). This indicated the presence of genetic variation among the common bean genotypes and possibility to select high yielding and stable genotypes (s), the environments are variable and the differential response of common bean genotypes across environments. Similar result was reported for common beanand groundnut varieties by Zeleke*et al*. (2016) and Alemayehu *et al*. (2016).

Table 1. Combined Analysis of variance for seed yield of common bean genotypes evaluated across six environments during 2015 and 2016 main croppingseason.

Source of variation	Degree freedom	Mean square
Environments	5	12668370**
Genotypes	16	1993864**
Block within environments	2	125429^{ns}
Interaction	80	317996**
Error	202	30966.00
LSD (0.05)	283.30	
CV (%)	19.90	

LSD=Least Significant differences, CV=coefficient of variation, **= significant at P = 0.01, ns = non-significant

The mean seed yield of large speckled common bean genotypes across environment (year x location) ranged from 253.7 to 1303.3 kg ha^{-1}. From all genotypes DAB-358 was the lowest yielding (Table 3). The highest grain yield was obtained from genotype DAB-361 followed by DAB-414. The average seed yield across environments ranged from the lowest of 253.7 kg ha^{-1} for DAB-358 genotype to the highest of 1303.3 kg ha^{-1} for DAB-361 genotype (Table 1). This difference could be due to their genetic potential. DAB-472 genotype was the top ranking genotype at two environments (Bako-2015 and Gute-2015), DAB-367 ranked first at Boshe-2015, DAB-361 at Bako-2016 and Gute-2016 (Table 2). The difference in yield rank of varieties across the environments revealed the high crossover type of GxE interaction.

Table 2. Mean seed yield and economically important diseases of ofLarge Speckled common bean genotypes grown across six environments in western Oromia

	Seed yield (kg ha^{-1})							*CBB (1-9) Scale			Anthracnose (1-9) Scale		
	2015			2016				2015/16			2015/16		
Genotype	Bako	Boshe	Gute	Bako	Boshe	Gute	Mean	Bako	Boshe	Gute	Bako	Boshe	Gute
DAB-446	1565	851	591.3	1180	941	535	943.9	3	3	5	3	3	5
DAB-286	1279	1171	78.0	736.3	509	379	692.1	3	2	4	4	4	5
DAB-443	1516	618	429.3	468.3	327	303	610.3	3	2	4	5	4	4
DAB-361	2650	693	573.0	1426.0	918	1560	1303.3	3	2	4	2	4	4
DAB-414	2481	818	789.0	1167.3	1112	953	1220.1	3	2	4	2	1	3
DAB-344	2286	914	122.3	941.7	779	479	920.3	3	2	4	3	2	2
DAB-341	2274	838	295.3	1092.3	961	898	1059.8	3	2	4	2	2	2
DAB-367	2575	1157	537.3	1254.7	728	560	1135.3	3	2	4	3	3	3
DAB-358	438	312	172.3	334.0	116	150	253.7	3	3	4	7	6	6
DAB-364	1782	573	732.0	1138.0	684	670	929.8	3	2	4	2	2	3
DAB-410	1944	991	89.7	844.0	497	481	807.8	3	2	4	3	3	5
DAB-337	1320	475	170.0	717.3	490	522	615.7	3	2	4	2	4	5
DAB-366	2869	800	604.0	1023.3	1031	918	1207.6	2	1	4	2	2	3
DAB-449	2876	914	822.0	961.7	810	798	1197.0	3	2	4	3	2	4
DAB-472	2931	891	1127.0	1034.0	755	594	1222.0	2	2	4	2	2	2
DAB-360	508	793	42.0	533.7	423	308	434.6	3	2	5	5	3	4
St. check	711	692	276.3	425.3	479	147	455.1	3	2	4	6	3	5
LSD (0.05)	450.7	286.9	361.4	259.4	280.9	199.1	113.3						
CV(%)	14.3	21.2	39.0	17.3	24.8	19.8	22.5						

**CBB=common bacterial Blight score on leaf*

AMMI model analysis: The AMMI model analysis of variance for seed yield is presented in Table 4. This analysis also showed presence of highly significant ($p < 0.01$) differences among common bean genotypes for seed yield performance. From the total treatment sum of squares, the largest portion was due to environmental main effect (49.8%) followed by genotypes main effect (25.1%) and the effect of GEI was 20%. The largest portion of environments sum of squares indicated greater influence of the environments on seed yield performance of common bean genotypes and contributed greater to GLI when compared to that of genotypes as main effects.Similar results were reported by Yayis, *et al.* (2014) and Akande, *et al.* (2009). Substantial percentage of G x E interaction was explained by IPCA-1 (13.7%) followed by IPCA-2 (2.9%) and therefore used to plot a two dimensional GGE biplot. Amare and Tamado (2014) suggested the most accurate model for AMMI can be predicted by using the first two IPCA.

Table 3: Partitioning of the explained sum of square (SS) and mean square (MS) from AMMI analysis for seed yield of seventeen common bean genotypes

Source o variation	DF	Sum of square.	Explained SS (%)	Mean square
Total	305	127189405	100	417014
Treatments	101	120683338	94.9	1194885**
Genotypes	16	31901822	25.1	1993864**
Environments	5	63341850	49.8	12668370**
Block	12	1255369	0.98	104614**
Interactions	80	25439666	20.0	317996**
IPCA 1	20	17461216	13.7	873061**
IPCA 2	18	3709783	2.9	206099**
Residuals	42	4268667		101635
Pooled error	192	5250698		27347

Key: ns= non- significant, **= significant at 1% and *= significant at 5% probability level. SS= sum of square, DF= degree of freedom.

AMMI biplots analysis: AMMI1 biplot showed G_3 (DAB-443) and G_{10} (DAB-364) as broadly adapted and high seed yielding.The variation of yield for each genotype was significant at different environments. Genotypes DAB-361, DAB-414, DAB-446, DAB-366, and DAB-449 were specifically adapted to high yielding environments (Fig 1). Considering the IPCA-1 score, DAB-360 was the most unstable genotype and also adapted to lower yielding environments. DAB-443 and DAB-364 were more stable in comparison to other genotypes. Genotype DAB-443 was adapted to low yielding environments and also relatively stable (Fig 1).G_2 (DAB-286), G_9 (DAB-358), G_{12} (DAB-337), G_{16} (DAB-360), G_{17} (standard check) were adapted to low yielding environments but not stable. Genotypes DAB-443 (G_3) and DAB-364 (G_{10}) have IPCA-1 value nearest to zeroby which they were shown to have a higher stability for seed yield than other genotypes (Fig 1). DAB-361 (G_4) had highest seed yield followed byDAB-472 (G_{15}),DAB-414 (G_5) and DAB-366 (G_{13}) (Fig 1).

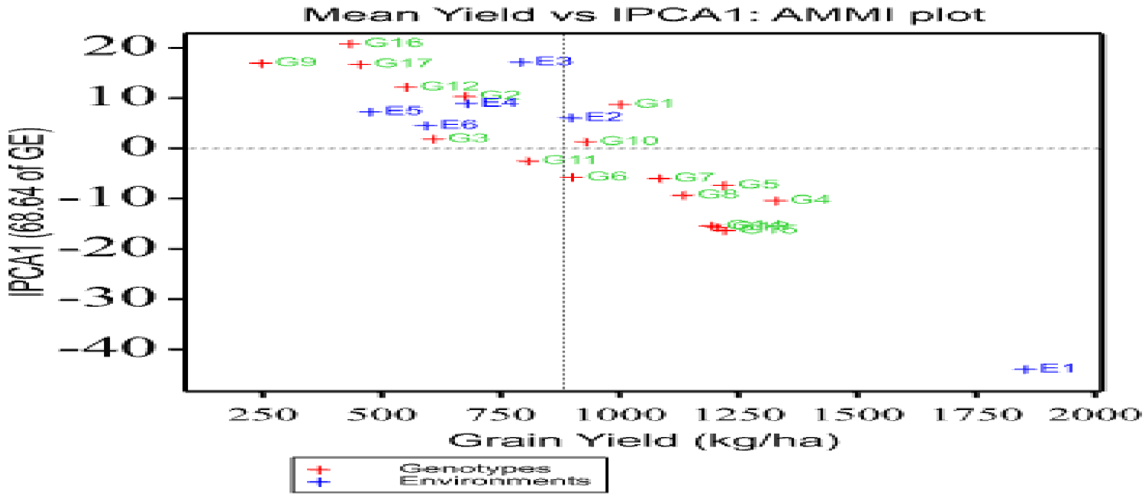

Figure- 1. Biplot of interaction principal component axis (IPCA1) against mean seed yield of 17 common bean genotypes evaluated across sixenvironments.

AMMI stability value and genotype selection index analysis : According to AMMI stability value (ASV), genotypes, DAB-443 and DAB-364 were found to be broadly adapted. According to GSI, genotypes, DAB-414, DAB-364 and DAB-361 with relatively lower values were found high seed yielding and broadly adapted genotypes (Table 5).

Table5. AMMI stability value, genotype selection index and ranks based on them for seed yield of 17 common bean genotypes evaluated at six locations during 2015 and 2016 cropping seasons.

Genotypes	Seed yield (kg ha^{-1})	ASV	RY	RASV	GSI
DAB-446	1003.0	41.6	8	7	15
DAB-286	676.6	51.0	12	9	21
DAB-443	610.2	8.7	13	1	14
DAB-361	1330.1	51.1	1	10	11
DAB-414	1220.1	35.0	3	6	9
DAB-344	901.5	29.1	10	5	15
DAB-341	1085.7	28.2	7	4	11
DAB-367	1135.3	45.3	6	8	14
DAB-358	247.3	80.2	17	16	33
DAB-364	929.9	12.0	9	2	11
DAB-410	808.8	16.8	11	3	14
DAB-337	552.4	57.6	14	11	25
DAB-366	1206.7	74.0	4	13	17
DAB-449	1194.6	72.6	5	12	17
DAB-472	1222.2	76.9	2	14	16
DAB-360	434.7	97.9	16	17	33
Standard check	455.1	78.7	15	15	30

Keys: ASV: AMMI stability value, RY: Rank of yield, RASV: Rank of AMMI stability value and GSI: Genotype selection index

GGE bi plot analysis

In GGE biplot (Fig 2), IPCA-1 and IPCA-2 explained 82.28 and 7.23%, respectively, of genotypes by environment interaction and made a total of 89.5%. The other study conducted on groundnut crop explained an interaction of 85.9% extracted from IPCA-1 and IPCA-2 (Alemayehu *et al*., 2016). The polygon view of the GGE-biplot analysis helps one detect cross-over and non-crossover genotype-by-environment interaction and possible mega environments in multi-location yield trials (Yan *et al*. 2007). DAB-361 (G4), DAB-449 (G4) and DAB-358 (G9) were vertex genotypes (Fig 2). They are best in the environment lying within their respective sector in the polygon view of GGE biplot (Yan and Tinker, 2006).

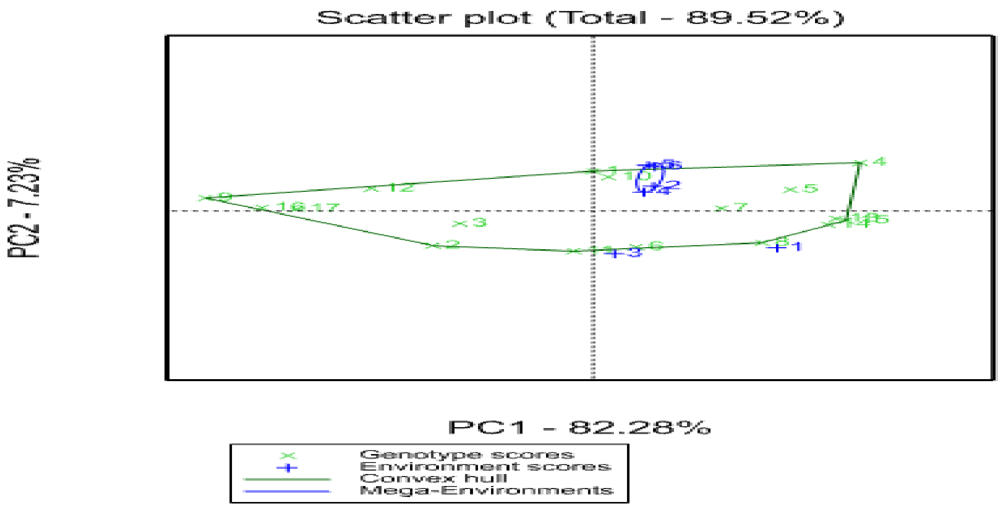

Fig-2. GGE biplot showing mega-locations and their respective higher seed yielding genotypes. Varieties plotted as 1, 2 … 17. locations are those written in blue color.

Conclusion

GEI is differential phenotypic performance of genetically uniform genotypes across test environments. It occurs because different genotypes have different genetic potentials to adjust themselves to variable environments, that is, adaptability. Large speckled common bean genotypes evaluated have highly significant genetic differences for seed yield performance and occurrence of significant GEI complicated selection of high yielding and broadly adapted genotypes.

GGE biplot enabled identification of both high seed yielding and broadly adapted genotypes better than AMMI biplot, ASV and GSI. Among the evaluated genotypes DAB-361 (G4) was both high seed yielding and broadly adapted genotype. Locations, Bako 2015 and Bako 2016 are high seed yield potential locations and ideal for commercial production of common bean genotypes broadly adapted to them. GGE biplot analysis suggested presence of one mega-environments and enabled identification of specifically adapted genotypes.

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Genotypes by Environment Interaction and Grain Yield Stability of Common Bean (*Phaseolus vulgaris L.*) Genotypes in the Western Oromia, Ethiopia

Meseret Tola[1]*, Adane Arega[1], Chala Debela[1], Alemayehu Dhabesa[1], Zerihun Abebe[1] and Solomon Bekele[1]

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

Corresponding author: meserettola342@yahoo.com

Abstract

Common bean (Phaseolus vulgaris L.) is the world's most important food legume for direct human consumption. In Ethiopia, common bean is one of the most important cash crop and source of protein for farmers in many lowlands and mid-land areas.Genetic improvement is a crucial component that contributes to agriculture productivity. Fourteen promising common bean genotypes including standard checks(Anger and SER-125) were evaluated using RCBD with three replications at Bako main research station and Billo Boshe and Gute research sub sites during 2014 and 2015 main cropping seasons. All agronomic and disease data were analysed and based on this results, three promising genotypes were found to be superior as compared to standard checks across the test environmenst. Based on analysis of grain yield stability and adaptability, genotype KW-006 *showed better stability followed by* KW-013 *across locations with grain yield of 2857Kg/ha and 2558Kg/ha respectively.*

Key words: Bean, GxE interaction, Grain yield, Stability

Introduction

The common bean (*Phaseolus vulgaris* L.) is the world's most important food legume for direct use, with a production of about 12 million metric tons per year. It is the chief source of dietary protein for most of Latin American and sub-Saharan African people, supplying about 20% of the protein intake per person (Akibode and Maredia, 2011; Argaw *et al*., 2015). It is largely self-pollinated plant though cross pollination is possible if the stigma contacts with pollen coated bee when extended. Common bean shows variation in growth habits from determinate bush to indeterminate extreme climbing types. The bushy type bean is the most predominant type grown in Africa (Buruchara, 2007). In Ethiopia, common bean production is increasing and according to CSA (2016) report, common bean (white and red) was produced on about 357,299.89ha of land and 540238.9 tons produced in 2016 main cropping season with the productivity of 1.48 t ha^{-1}; which is low as compared to world average of 2.6 t ha^{-1}. This low yield of common bean may be attributed to a combination of several production constraints among which low soil fertility, rainfall variability, diseases and insect-pests, weeds, poor accessibility to good seed and poor crop management practices play a major role (Katungi *et al*., 2010).

Common bean is adapted to areas with altitudes ranging from below sea level to nearly 3000 meter above sea level (CIAT, 2001). However, it does not grow well below 600 m due to poor pod setting caused by high temperature (Cobley, 1976). Suitable production areas of bean in Ethiopia has been indicated as areas with altitude between 1200-2200 m, mean maximum and minimum temperature of 32 ^oC and 10 ^oC, respectively with a rainfall ranging from 350 to 700 mm well distributed over 70-90 days (Imru,1985; Amare and Haile, 1989).

In Ethiopia, common bean is one of the most important cash crop and source of protein for farmers in many lowlands and mid-land areas. The country's export earnings is estimated to be over 85 % of export earnings from pulses, exceeding that of other pulses such as lentils, faba bean and chickpea (Negash, 2007). Overall, common bean ranks third as an export commodity in Ethiopia, contributing about 9.5 % of total export value from agriculture (Katungi*et al*., 2010). Apart from being food and a source of income, common bean is also replenishes soil fertility through nitrogen fixation.

Materials and Methods

Fourteen common bean genotypes were evaluated at three locations (Bako, Billo Boshe and Gute) for two consecutive years (2014 and 2015). Except four improved and released common bean varieties, the remaining genotypes included in this study were landrace collections which were collected from different districts in Kellem Wellega Zone. The experimental land was ploughed, and harrowed by tractor. The first ploughing was done before on- set of rainfall. The planting was done in mid-June at each location using a Randomized Complete Block Design with three replications. Each plot consists of six rows of 4m length with 40 and 10cm spacing between rows and seeds respectively. Fertilizer was applied at the rate of 100kg DAP (Di Ammonium Phosphate) per hectare. Among the recorded data grain yield is used for analysis.

Multivariate method, Additive Main Effects and Multiplicative Interaction (AMMI) model was used to assess genotype by environment interaction (GEI) pattern. The model used for AMMI analysis is as follow:

$$Y_{ij} = \mu + Gi + Ej + (\sum \lambda_k \alpha_{ik} \gamma_{jk}) + P_{ij} + e_{ij}$$

Where Y_{ijl} is the yield of genotype (G) in environment (E) for replicate (r), μ is the total yield mean, G_i is the main effect of genotype or the genotype (G) mean deviation (genotype mean minus total mean yield), E_j is the main effect of environment or the environment (E) mean deviation, λ_k is the singular value for IPCA axis N (N is the number of remaining PCA axis in AMMI model: α_{ik} is the genotype (G) eigenvector value for IPCA axis N, γ_{jk} environment (E) eigenvector value for IPCA axis, P_{ij} is the is the residual or noise and $+\ e_{ijl}$ is the error (Gauch, 1992; Umma Kulsum *et al*, 2014).

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

$$ASV_i = \sqrt{\left[\frac{SS_{IPCA1}}{SS_{IPCA2}}[IPCA1_{score}]\right]^2 + [IPCA2_{score}]^2}$$

Where, SS_{IPCA1}/SS_{IPCA2} is the weight given to the $IPCA_1$ value by dividing the IPCA1 sum of squares by the IPCA2 sum of squares.

Based on the rank of mean grain yield of genotypes (RYi) across environments and rank of AMMI stability value (RASVi) a selection index called Genotype Selection Index (GSI) was calculated for each genotype, which incorporates both mean grain yield (RYi) and stability index in single criteria (GSIi) as suggested by Purchase, *et al.,* 2000.

GSIi = RASVi + RYi

Environmental index (Ii) was calculated by subtracting the mean of each environment from the grand mean. Genotype plus genotype by environment variation (GGE) was used to assess the performance of genotypes in different environments. The environmental effects were removed from the data and results obtained from the data were used to calculate environment and variety scores and these scores were used to plot the standard principal component bi-plots (Yan and Kang, 2003).

Analysis of variance was carried out using a Statistical Analysis System (SAS) version 9.3 software (SAS Institute Inc., 2002). Additive Main Effect and Multiplicative Interaction (AMMI) analysis and GGE bi- plots were performed using Gen Stat 18th edition statistical package (GenStat, 2016).

Table 1. Lists and sources of genotypes used in this study

S.N	Genotypes	Source
1	ALB-123	MARC
2	ALB-210	MARC
3	ALB-87	MARC
4	KW-001	landrace
5	KW-006	landrace
6	KW008	landrace
7	KW-011	landrace
8	KW-013	landrace
9	KW-018	landrace
10	KW-020	landrace
11	KW-028	landrace
12	KW-031	landrace
13	KW-036	landrace
14	Anger	BARC

BARC: Bako Agricultural Research Center; MARC: Melkassa Agricultural Research Center

Results and Discussion

Combined Analysis of Variance

The results of analysis of variance showed that there is statistically significant differences (P<0.01) among genotypes, environments and their interactions for seed yield (Table 2). This indicated the presence of genetic variation among the common bean genotypes and possibility to select high yielding and stable genotype (s), and similarly, the environments are variable and showed the differential response of common bean genotypes across the test environments. Similar result was reported for common bean and groundnut varieties, linseed and niger seed varieties, respectively by Zeleke *et al*. (2016), Alemayehu *et al*. (2016) and Tamesgen *et al*. (2014)

Table 2. Combined analysis of variance for grain yield of common bean genotypes evaluated at three environments for two years during 2014 and 2015 main cropping seasons.

Source of variation	Degree freedom	Mean square
Environments	5	7583916**
Genotypes	13	2377416**
Block within environments	2	665270^{ns}
Interaction	65	835009**
Error	166	225999
LSD (0.05)	766.4	
CV (%)	21.6	

LSD =Least Significant differences, CV= Coefficient of Variation, ** = significant at P = 0.01, ns = non-significant

Performance of common bean genotypes across environments

Table 3 showed the average mean grain yield of fourteen common bean genotypes across six environments (year x location). The pooled mean yield was ranged from 1397 to 2857 kg ha^{-1}. Among the tested genotypes, genotype ALB-87 (G3) was the lowest yielding, whereas, the highest grain yield was obtained from genotype KW-006 (G5) followed by KW-013 (G8), KW-011 (G7) and ALB-123 (G1). This difference is attributed to their genetic constitution. KW-006 (G5) genotype was the top ranking genotype at Bako-2014, and Billo Boshe 2015. The yield performance of each genotype at each location and season is presented in detail in Table 3. This difference in yield rank of common bean across the environments revealed that there is high crossover type of GxE interaction.

Table: 3. Mean grain yield (kg ha^{-1}) of fourteen common bean genotypes evaluated at three locations during 2014 and 2015 main cropping seasons

No	Genotypes	2014			2015			Pooled means
		Bako	Billo Boshe	Gute	Bako	Billo Boshe	Gute	
1	ALB-123	2514	2974	1568	3067	2688	1885	2449
2	ALB-210	2224	2000	2055	1152	1088	1962	1747
3	ALB-87	2202	2718	2019	397	428	615	1397
4	KW-001	2782	2895	2077	2352	2370	892	2228
5	KW-006	3679	3017	2641	2264	3266	2277	2857
6	KW008	2399	2492	1377	1749	2419	1472	1985
7	KW-011	3086	2693	1336	2455	3314	2076	2493
8	KW-013	3175	2591	2926	2382	2367	1676	2520
9	KW-018	2378	2641	1990	1846	1620	1376	1975
10	KW-020	2955	2855	2350	2141	2780	1027	2351
11	KW-028	1937	2441	2226	1828	2757	2817	2334
12	KW-031	2471	3291	1885	1048	2362	2426	2247
13	KW-036	2783	2581	2150	1110	2526	1971	2187
14	Anger (St.ch)	3127	1895	1057	2323	2621	940	1994
	Env. means	2694	1865	2649	2329	1975	1672	2197
	LSD (0.05)	932.0	836.7	793.2	383.8	692.5	441.3	766.4
	CV (%)	20.6	18.8	23.9	12.1	17.7	15.7	21.6

AMMI Model Analysis: The AMMI model analysis of variance for grain yield is presented in Table 3. This analysis also revealed that presence of highly significant ($p < 0.01$) differences among common bean genotypes for grain yield performance. From the total treatment sum of squares, the largest portion was due to GEI main effect (33.5%) followed by environments main effect (23.4%) and the effect of genotype was 19.1%. This also indicated the existence of a considerable amount of deferential response among the evaluated common bean genotypes to changes in growing environments and the differential discriminating ability of the test environments. Similar result was reported by Alemayehu *et al.* (2016). Substantial percentage of G x E interaction was explained by IPCA-1 (46.5%) followed by IPCA-2 (28.8%) and totally the tow IPCAs explained 75.3% of the total GxE interaction and therefore used to plot GGE biplot. Amare and Tamado (2014) suggested the most accurate model for AMMI can be predicted by using the first two IPCAs.

Table 4: Partitioning of the total explained sum of square (SS) and mean square (MS) from AMMI analysis for seed yield of fourteen common bean genotypes

Source of variation	DF	Sum of square	Explained SS (%)	Mean square
Total	251	161947857	100	645211
Treatments	83	123101559	76.01	1483151**
Genotypes	13	30906410	19.1	2377416**
Environments	5	37919578	23.4	7583916**
Block	12	10974576	6.7	914548ns
Interactions	65	54275571	33.5	835009**
IPCA 1	17	25214410	46.6	1483201**
IPCA 2	15	15608892	28.8	1040593**
Residuals	33	13452269		407645
Error	156	27871722		178665

ns= non- significant, **= significant at 1% and *= significant at 5% probability level. SS= sum of square, DF= degree of freedom.

AMMI Biplot Analysis: AMMI biplot (Figure 1) with X-axis plotting mean seed yield and Y-axis plotting IPCA1 scores illustrate stability and adaptability of common bean genotypes. It has been reported that the IPCA1 scores of a genotypes in AMMI analysis are an indication of the stability or adaptation over environments. It is further stated that the greater the IPCA scores, negative or positive, the more specific adaptation of a genotypes to certain environments. The more the IPCA scores close to zero, the more stable or adapted the genotypes is over all the environments sampled.

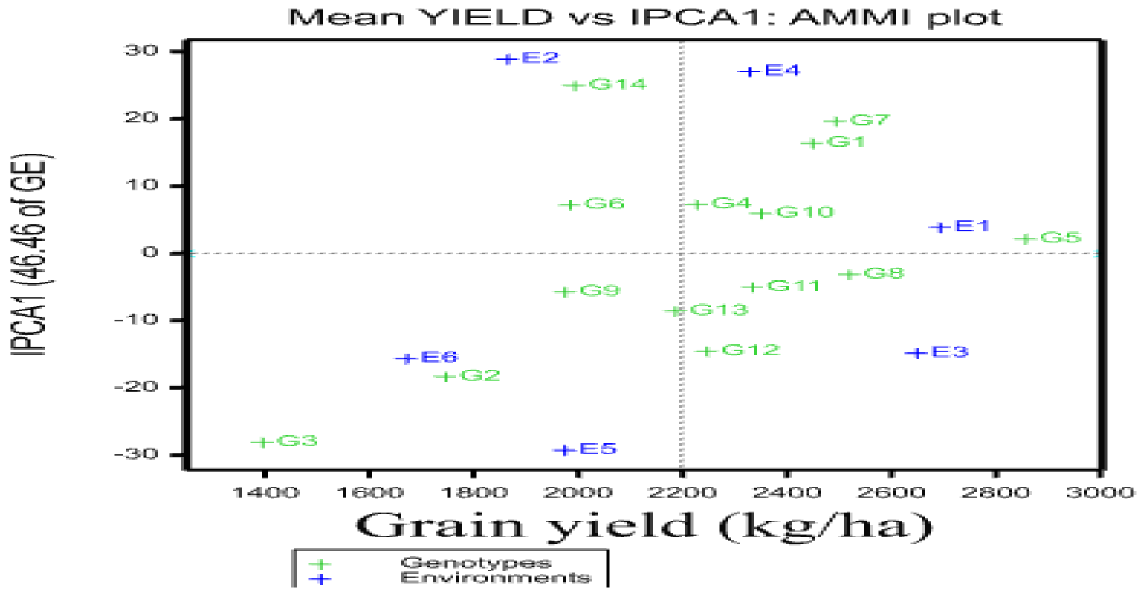

Fig:1 GEI biplot analysis of common bean varieties

GGE Biplot Analysis: An ideal genotype is defined as genotype with the greatest PC1 score (mean performance) and with zero GEI, as represented by an arrow pointing to it (Figure 2). A genotype is more desirable if it is located closer to the ideal genotype. Thus, using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype. Therefore, the ranking based on the genotype-focused scaling assumes that stability and mean yield are equally important. In this study, G5 which fell closest to the ideal genotype was identified as the most desirable genotype as compared to the rest of the tested common bean genotypes (Figure 2). Similarly, Alemayehu *et al*. (2016) and Abate *et al*. (2015) identified ideal genotype based on the genotype-focused scaling assumes that stability and high mean yield of studied genotypes.

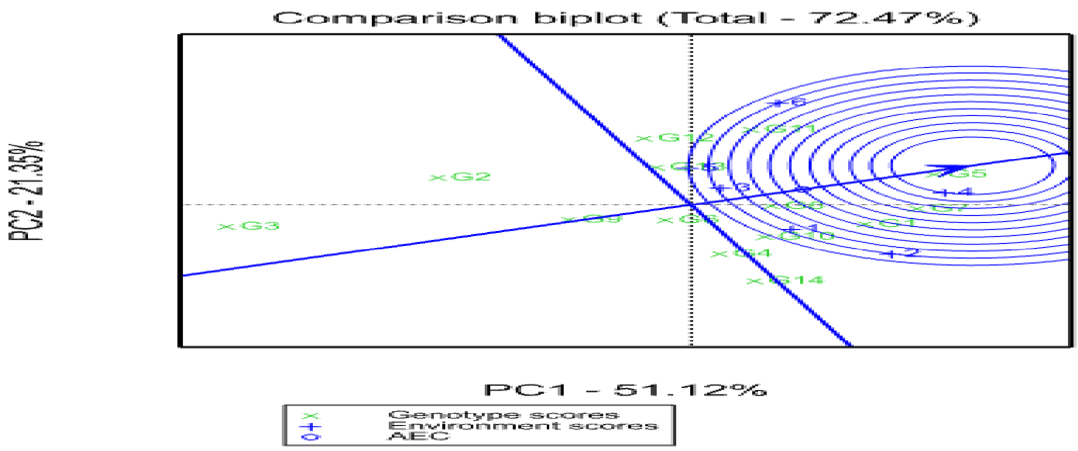

Figure 2. GGE biplot based on genotype-focused scaling for comparison the genotypes with the ideal genotype.

Ideal test environment is an environment which has more power to discriminate genotypes in terms of the genotypic main effect as well as environment effect represent the overall environments. But such type of environment may not exist in real conditions. Therefore, by assuming a small circle which located in centre of concentric circles and an arrow pointing on it as ideal environment (Figure 3), it is possible to identify desirable environments which are found closer to the ideal environment (Yan and Rajcan, 2002). Therefore, among the testing environments, Billo Boshe-2015 (E4), which fell near to this ideal environment was identified as the best desirable testing environment in terms of being the most representative of the overall environments and powerful to discriminate common bean genotypes.

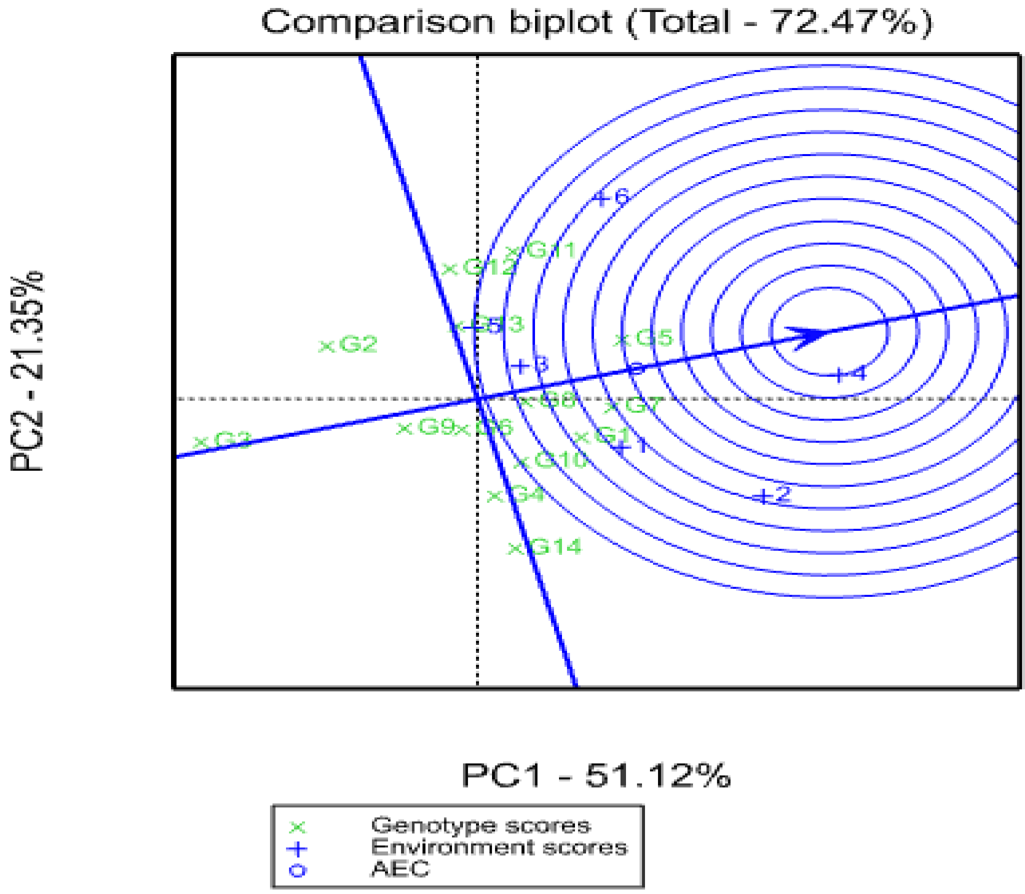

Figure 3. GGE biplot based on environment-focused scaling for comparison the environments with the ideal environment. AEC: average environment coordinator; PC: principal component

Conclusion

GEI is differential phenotypic performance of genetically uniform genotypes across test environments. It occurs because different genotypes have different genetic potentials to adjust themselves to variable environments, that is, adaptability. Common bean genotypes evaluated showed highly significant genetic differences for seed yield performance and occurrence of significant GEI complicated selection of high yielding and broadly adapted genotypes. GGE biplot enabled the identification of both high yielding and broadly adapted genotypes better than AMMI biplot. Among the evaluated genotypes KW-006 (G5) was both high yielder and broadly adapted genotype to the tested environments. Environment, Gute-2015 is high yielding environment and ideal for commercial production of common bean genotypes. GGE biplot analysis identified ideal environment among the tested environments and also enabled to identify common bean genotypes with specific adaptation.

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Registration of Lammiif and Jiidhaa Field pea (*Pisum sativum*. L) Varieties at Bako

[1]Solomon Bekele, [1]Alemayehu Dabesa, [1]Zerihun Abebe, [1]Chala Debele, [1]Ishetu Mogasa, [1]Getahu Abera and [1]Marara Gidisa

[1]Bako Agricultural research Center, P O Box 03, Bako, West Shewa, Ethiopia

Corresponding Author: slmnbkl092@gmail.com

Abstract

Lammiif and Jiidhaa are the name given for field pea (Pisum sativum L.) varieties with accession number of EH08010-3 and EH08033-2, respectively after selected and released by Bako Agricultural Research Center for mid and high lands of Western Oromia and similar agroecologies of Ethiopia. Two years (2014 and 2015) test across three locations (Gedo, Shambu and Arjo). These variety showed greater grain yield advantage of 13.4-15.8%, and had better disease resistance than the standard check, Gedo-1. The result of Genotype and Genotype by Environment interaction (GGE) demonstrated that these two varieties were more stable and high yielder than the check. Further, Lammi was released as Shiro type while Jiidhaa was released as Kik type for Agrjo, Shambu and Gedo high land and similar agroecologies.

Key Words: Field pea;GGE-billet, *Pisum sativum*; Variety Registration.

Introduction

Ethiopia holds the number one spot in Africa and sixth in the world in field pea production(FAOSTAT, 2014). Field pea is produced at mid and high altitude areas of Oromia, Central, and Western and southern Tigray, Amahara and SNNPR in Ethiopia. It is a cheap source of protein with essential amino acids (23-25%) for resource poor households (Nawab, *et al*., 2008). Field pea well perform at high (2300 to 3000) and mid (1800 to 2300 masl) altitude areas. The rainfall requirement of field pea is 800 to1100 mm for highland and 700 to 900 mm for mid laltitude.The optimum temperature for growth of the crop is ranged 20 to 25^0C.

Even though, the productivity of field pea is low as 0.5-0.6 tones/ha under low level of farmers practice and rain fed conditions, it can give higher yield 4-6 tones/ha at research fields if improved technologies and inputs are used (Smykal *et al.*, 2012). Some of the production constrains of field pea are, biotic stresses (pests) and lack of improvement seed with poor crop management and environmental factors (a biotic stresses) (Telaye *et al*.,1994). Breeding is one of the components that develop good varieties that resist or tolerate biotic or a biotic constraints and improve yield potential; this is taken as one of the goal and success of breeding activities.

Materials and Methods: In 2012, 69 field pea accessions were obtained from Holeta Agricultural Research Center and tested at nursery stage. Luckily, these accessions had different color that can be used as *Shiro* (grey) and as *Kik* (white). Out of these genotypes, sixteen of them were tested in multi location trial as RVT in 2014 and 2015 at Shambu, Gedo and Arjo testing sites. Result of multi-location trial indicated that, accession EH08010-3 and EH08033-2 were the best two with grain yield advantage of 13.4% and 15.8% over of the standard check, Gedo-1, respectively. These two candidate varieties with accessions No. EH08010-3 and EH08033-2 were tested in variety verification trial against the standard check (Gedo-1) and respective local checks at Shambu, Arjo and Gedo-1 in year 2016. The national variety technical committee the release of EH08010-3 with name of Lammiif and EH08033-2 with name of Jiidhaa were approved.Variety Lammiif and Jiidhaa were recommended to be used as S*hiro* and *Kik* type, respectively.

Varietal character: Variety Lammiif (EH08010-3) has grey seed color and 100 seed weight of 21.1g and mean plant height of 152cm.Variety Lammiif has white seed color, 20g of 100 weed weight and 137cm average plant height. Both varieties have seed with irregular shapes and semi smooth character.The detailed agronomic descriptions of the two varieties are indicated in Table1.

Table: 1 Agronomic and Morphological Characteristics of Lammiif and Jiidhaa field pea varieties

Variety	**Lammiif(EH08010-3)**	**Jiidhaa (EH08033-2)**
Adaptionarea	Shambu,Gedo-1 and Arjo	Shambu,Gedo-1 and Arjo
Altitude(ma.s.l	2000-2600	2000-2600
Rainfall(mm)	1000-1200	1000-1200
DAP	100	100
Seedrate(kg/ha)	180-200	165-185
Spacing(cm)	20x5(Interand Intrarows)	20x5(Interand Intrarows)
Daystoflowering	58-64	58-70
Daystomaturity	105-130	110-140
Plantheight(cm)	146-156	130-140
No.ofpodsperplant	7-18	8-17
Seedshapeand character	Irregular andsemi smooth	Irregular andsemi smooth
Seedcolor	Grey	White grey
Cotyledoncolor	Black	Lightorange
Flower color	Brown	White
100seedweight(g)	21.1	20
Croppestreactions	Resistant to major disease and insect pests	Resistant to major disease and insect pests
Researchfield yield (q/ha)	28-35	27-36
Farmersfield (q/ha)	23-30	22-32
Breederseedmaintainer	OARI/BARC	OARI/BARC

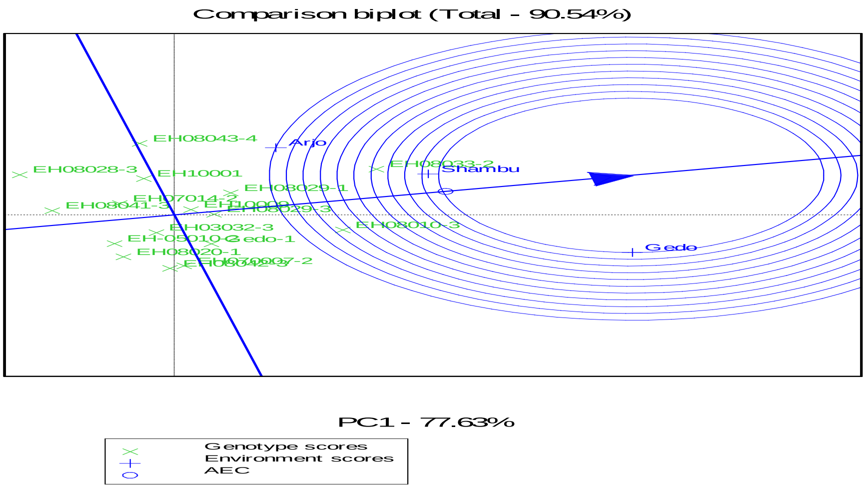

Figure 1: GGE- biplot based on environment focused comparison for their suitability as an ideal environment and their relationships.

Yield performance: The average seed yield of Lammif and Jidhaa over locations and years in multi-location trial was 3303.3 kgha^{-1}, and 3375.7 kgha^{-1}, respectively while that of the standard check, Gedo-1 was 2912.7 kgha^{-1}. Lammif and Jidhaa have grain yield advantage of 13.41% and 15.89% over the check, Gedo-1, respectively.

Reaction to disease: The common field pea diseases in the high land of Arjo, Gedo and Shambu are bacterial blight, powdery mildew and downy mildew. Both Lammif and Jidhaa were moderately resistant to these diseases.

Grain Yield Stability: The result of stability analysis using the method of GGE-biplot showed that both Lammiif and Jiidhaa were stable varieties for their grain yield performance (see Figure 1)

Conclusion

Lammiif and Jiidhaa field pea varieties were well adapted, stable and gave high mean grain yield when compared with standard check Gedo-1. Variety Lammiif was released for its high mean grain yield and for specific use for *Shiro* while *Jiidhaa* was to be used for *kik*. Both varieties were recommended for Arjo, Gedo and Shambu high lands and similar agroecologies.

Acknowledgement

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Registration of "Haydaroo" Newly Released Emmer Wheat (*Triticum dicoccum L.*) Variety for Bale Highlands

[1]Mulatu Aberra, [2]Tesfaye Letta and [1]Tilahun Bayisa
[1]*Sinana Agricultural Research Center, Cereal Crop Research, Bale-Robe, Ethiopia P.O.B 208,*
[2]*Oromia Agricultural Research Institute (OARI), Addis Ababa, Ethiopia*
Corresponding author: guluma.info@gmail.com

Abstract

Ethiopia has suitable environmental condition for emmer wheat production, however, the productivity of emmer wheat is very low when compared with existing suitable agro-ecologies. This is mainly attributed to lack of stable, high yielding, disease resistant and easly threshable genotypes. Therefore, the objective of this study was to evaluate different promising genotypes and thne to verify the most stable, high yielding, easy to thresh and disease resistant emmer wheat genotype for highlands of Bale. The experiment was carried out at two locations namely Sinana and Goba. Including two checks, fifteen genotypes were evaluated in randomized complete block design (RCBD) with three replications for three consecutive years (2013, 2014 and 2015) during the main cropping seasons. Based on multi-location and multi-year evaluation result, genotypes sinana-01/dz2212//sinana-01 was selected and verified in the year (2016) at multilocations and eventually released by the name 'Haydaroo' which gave above average grain yield performance in all conducted environments where the standard checks gave lower yield.Besides, this variety has a stable yield and uniformity. After evaluation by national variety releasing committee, this cultivar was recommended for release in 2017 for highlands of Bale and similar agro-ecologies.

Keywords: emmer wheat, variety, grain yield, varity character, disease reaction

Introduction

Emmer (*Triticum dicoccum*) is a member of the wheat family of annual grasses. Wild emmer wheat (*T. turgidum* spp. dicoccoides (Körn.) Thell.), is an annual predominantly self-pollinated (Golenberg 1987) tetraploid (genome constitution AABB) species (Zohary & Hopf 2000), is considered to be the progenitor of cultivated durum and bread wheats (Mc Fadden & Seares 1946). Wild emmer is fully compatible with the tetraploid (AABB) durum wheat, it can be crossed with the hexaploid (AABBDD) bread wheat (Feldman & Sears 1981), and it harbors wide genetic diversity relevant to the improvement of various economically important traits in cultivated wheat (Nevo et al. 2002). Cultivated emmer wheat, *T. dicoccum* [syn.*T. turgidum* L. subsp. dicoccon (Schrank) Thell.], is a tetraploid species (AB-genomes) belonging to the *Triticum L.* genus (Zaharievaet al. 2010). It is predominantly awned with spikelet's consisting of two well developed kernels. Emmer glumes are long and narrow with sharp beaks. Genetic information like heritability and genetic advance for different yield contributing traits would be of great value enabling the breeder to use best genetic stock for improvement in breeding programme (Yadawad et al., 2015). Emmer wheat possesses valuable traits of resistance to pests and diseases and tolerance to abiotic stresses and is increasingly used as a reservoir of useful genes in wheat breeding. The genomic constitution AA of emmer is thought to be derived from *T. monococcum*. Various sources of the BB genome have been suggested, *T. speltoides, T. searsii*, and *T. tripsacoides* (Morris and Sears 1967; Kimber and Sears 1987). Due to the addition of the BB genome cultivated emmer could be grown in a wider range of environments including regions having high growing season temperatures. Emmer is an ancient wheat crop which 20 years ago was considered an underutilized or neglected crop and which it seemed was probably going to be completely abandoned because of its low productivity and threshing and other agro technical problems (Perrino & Fares, 2003; Vita et al., 2006). Today the increase in interest in natural and organic products has led to a "rediscovery" of this hulled wheat, which has health characteristics associated with high starch-resistant content (Strehlow et al., 1994; Marconi and Cubadda, 2005). Breeding of emmer has rarely been given attention and its productivity does not usually achieve that of modern bread wheat cultivars (Vita et al. 2006). Meanwhile, some literature presents a similar productivity level of emmer and bread wheat, if varieties are grown in arid conditions (Marconni and Cubadda 2005). Another advantage of emmer, published in the literature is a high quality of production (Zaharieva et al. 2010). Emmer wheat has been traditionally grown and used as a part of the human diet (Marconi and Cubadda 2005), and as requirements for the diversity and high quality of food products become more demanding interest in this wheat variety is increasing (Hammer and Perinno, 1995). The grains contain more crude protein than the grains of modern varieties (Marconi et al., 1999); whole meal flour is a valuable source of dietary fibre in its insoluble forms, cellulose and hemicelluloses, and it contains high quantities of P, Zn, Cu, K, Mg and Mn (Marconi and Cubadda 2005). In Ethiopia emmer wheat, locally known as Hayisa (Aja), is used in various ways. Some is ground into flour and baked into special bread (Kita). Some is crushed and cooked with milk or water to make porridge (Genfo), and some is mixed with boiling water and butter to produce gruel. As some literature indicates, emmer's high protein content and smooth and easily digestible starch, infants and nursing mothers especially favor the gruel. In Ethiopia, emmer wheat production is very low as compared to other crop. This is due to lack of improved variety; threshability problem, low cultural practices, and other biotic and abiotic factors. The objective of the current study isto evaluate and release disease resistance, high yielding, threshable, quality, stable and uniform emmer wheat genotype for highlands of Bale and similar agro-ecologies.

Materials and Methods

The experiment was carried out at two locations namely; Sinana and Goba. Sinana Agricultural Research Center is located to South Eastern of Ethiopia at 7°N Latitude and 40°E Longitude; and is located at altitude of 2400 m.a.s.l. The center is 463km far from Addis Ababa to South East and 33km far from Robe capital city of Bale zone to East direction. The other location, Goba is about 48km far from Sinana Agricultural Research Center to South West and 13km far from Robe to South direction.

The test materials were crossed at Sinana Agricultural Research Center with objective to improve yield and threshability. Cross was made between geneotypes of emmer wheat and durum wheat (emmer wheat as female and durum wheat as pollen source) then, two times backcrosses was done with emmer wheat genotype (sinana-01). After different filial generations were evaluated at different breeding stages for consecutive years, better lines were selected and promoted to yield trial. Then, yield trial which included about 50 lines were evaluated for one year at Sinana Research Center of which thirteen genotypes were retained from yield trial and promoted to regional variety trial for further evaluation at two environments (Sinana and Goba) for three consecutive years. Planting was conducted at both locations during 2013, 2014 and 2015 main cropping seasons. Complete block design (RCBD) with three replication with plot size of 1.2m wide (6 rows with 20 cm apart) by 2.5m length was used. Four central rows were harvested for grain yield estimate. The seed rate used was 100kg/ha. Besides, fertilizer rate 18/46 kg/ha N and P_2O_5 46 was used. All agronomic practices and crop managemet were applied as per recommendation for each location. The genotypes were evaluated for their yield performance, threshability, disease resistance and other agronomic performances. Data were collected on plant and plot basis for morpho-agronomic traits of emmer wheat; days for heading, days for mature, bio-mass weight, grain yield, disease data were assessed on plot basis. On the other hand plant height was assessed on single plant basis of three selected and random sample of plant from each plot and the mean data of the three plants were used for analysis. Yield data was taken per plot basis and converted to quintal ha^{-1} for carrying out subsequent statistical analysis. After the trial was conducted in different environments for three consecutive years under variety trial, two best performed emmer wheat genotypes were selected out of 13 genotypes and promoted to variety verification stage.

Including one standard check (Sinana-01) and one local check the two promising genotypes (Sinana_01/ DZ2212// Sinana_01and Snana-01/ Gedilfa// Sinana-01) were planted and evaluated at multilocation during 2016/17 main cropping season. Sinana_01/ DZ2212// Sinana_01 (Haydaroo) showed superior performance over checks across all locations and years. After it was evaluated at multi-locations, the National Variety Releasing Committee has approved this variety to be released and recommended for the highlands of Bale and similar agro-ecologies and eventually the same variety registered on crop variety registry book.

Result and Discussion

Agronomic and Morphological Characteristics

Haydaroo is awned with spikelet's consisting of two well developed kernels. Its glumes are long and narrow with sharp beaks. The average plant height is 108cm, and considered as medium height similar to most moder bread wheat varieties. The height of plant has its own merits and demerits. Varieties with high plant height are more competitive to weeds, but they might have some drawbacks such as lodging problem. Haydaroo has medium height and has strong stalk which help withstanding the lodging problem. The variety has erected leaf structure. It has also high bio-mass and good plant stand with 81% average stand percent across all locations (Table 1).

Varietal characteristics

A varietal character of Haydaroo includes better disease resistance/tolerance . Also its relative better threshability as compared to the previously released emmer wheat is the peculiar characterstics of this variety which is transferred from durum wheat via crossing followed by backcrosses. The variety has good tillering capacity with high plant stand counts. It took 72 days to head and also took 127 days to reach physiological maturity (Table 1). It has erected growth habit, deep green at vegetative stage, has compact and slightly black awn ear type.The seed color of variety is amber. Details of the characteristics of variety is presented in appendix 1.

Table 1.Combined over locations and years (2013-2015) grain yield, other agronomic traits and disease reaction of 15 emmer wheat genotypes tested in emmer wheat regional variety trial (EWRVT)

		Agronomic, yield and disease data					
SN	Genotypes	DH	DM	PLH	St	Gyld/ha	Lr
1	Sinana-01/Ude//Sinana-01(1)	67	127	109	81	2894.1	30s
2	Sinana-01/Ude//Sinana-01(4)	68	126	106	78	2917.6	40s
3	Sinana-01/Ude//Sinana-01(22)	70	126	108	80	2933.6	30s
4	Sinana-01/Cocorit 71//Sinana-01(4)	65	125	105	79	2753.9	40s
5	Sinana-01/Cocorit 71//Sinana-01(12)	69	126	110	84	3175.5	40s
6	Sinana-01/Gedilfa//Sinana-01(1)	66	127	112	82	3229.6	30ms
7	Sinana-01/Gedilfa//Sinana-01(8)	64	128	114	84	2915.3	40s
8	Sinana-01/Gedilfa//Sinana-01(9)	68	128	109	80	2725.7	40s
9	Sinana-01/Gedilfa//Sinana-01(11)	70	126	107	83	2927.6	30s
10	Sinana-01/Gedilfa//Sinana-01(12)	70	126	106	82	2984.5	30s
11	Sinana-01/DZ2212//Sinana-01(3)	70	126	106	82	2935.2	25sms
12	Sinana-01/DZ2212//Sinana-01(10)	72	127	108	81	3023.8	30ms
13	Sinana-01xDZ2212//Sinana-01(13)	69	127	108	84	2972.8	40s
14	Sinana-01	72	125	105	82	2637.1	40s
15	Local	70	125	106	80	2646.3	40s
	Mean	68.6	126.5	126.5	81.4	2911.5	
	CV (%)	4.8	7.7	6.8	9.0	24.6	
	LSD (5%)	2.2	3.0	4.8	4.8	615.4	

Key: DH: days for heading, DM: days to maturity, PLH: plant height (cm), St: stand in percentage, Gylha: grain yield (kg/ha), Lr: leaf rust (%),S: Susceptible, MS: moderately susceptible, SMS: Suceptible to moderately susceptible, Mr: Moderately resistant, Tr: Trace, Trms: Trace with moderately susceptible, Trmr: Trace with moderately resistant, R: Resistant, CV(%): Coefficient of variations, LSD: Least significant differences, ns: non-significant differences based on the 0.05 probability level of LSD

Yield performance

Highly significant variations were observed among the studied emmer wheat genotypes. The mean grain yield of Haydaroo ranged from 17.8 to 45.7 Qt ha^{-1}. The average grain yield ranged from 24.6 to 45.3 quintal per hectare on research field, whereas, 17.8 to 45.7 quintal per hectare at farmers' field. The mean grain yield of Haydaroo combined over locations and years is 30.24 Qt ha^{-1}which is higher than standard check Sinana-01 (26.3 Qt ha^{-1}) and local check (26.4 Qt ha^{-1}) (Table 01). Total yield advantage of Haydaro variety over the standard check Sinana-01 was 14.7% and 14.3 % over the local check. At the stage of variety verification trial, which evaluated at multi-locations in the year 2016, the yield performance of the candidate was superior over checks (Table 2).

Table 2. Mean grain yield, agronomic performance and disease reactions of the candidates and the checks varieties evaluated at the verification stage (in 2016 cropping season)

S N.	Genotypes	Agronomic and disease data							
		DH	DM	Plh	Gy	ST	Sr	Yr	Lr
1	Snana-01/Gedilfa//Sinana-01(1)	56	132	112	27.50	75	0	15ms	10ms
2	Local check	59	133	106	29.10	80	Trms	5ms	20ms
3	Sinana-01/DZ2212//Sinana-01(Haydaroo)	55	134	108	41.50	95	0	5ms	5ms
4	Sinana-01(Standard check)	60	135	105	34.20	85	trms	10ms	15ms

Key: DH: days for heading, DM: days to maturity, Plh: plant height (cm), ST= Stand percent, Gy: grain yield (kg/ha), Sr: stem rust (%), Yr: yellow rust (%), Lr: leaf rust (%), S: Susceptible, MS: moderately susceptible, Mr: Moderately resistant, Tr, trace, Trms: Trace with moderately susceptible.

Disease Reaction

The major emmer wheat disease according to their importance in the growing area is rusts (Leaf rust, yellow rust and stem rust). Disease data across locations and years were scored and analyzed. Haydroo showed moderate resistance to leaf rust (5%) (Table 2). It is also showed tolerant to yellow and stem rusts (Table 2). Generally, Haydaroo variety is tolerant to diseases, insect pests and other abiotic factors.

Adaptation range

Haydaroo was released for highlands of Bale and similar-agro ecologies. It performs very well in areas having an altitude 2400-2500 m.a.s.l. and annual rainfall of 750-1500mm. planting date is from mid June to early September based on the agro-ecologies of the area. The recommended seed rate for the variety is 100kg/ha and fertilizer rate is 46 kg/ha of P_2O_5 and 18kg/ha of N..

Variety maintenance

The variety will be maintained by Sinana Agricultural Research center/Oromia Agricultural Research Institute.

Conclusion

The development of cultivars, which are adapted to a wide range of diversified environments, is ultimate aim of breeders in crop improvement program. Analysis of genotypes by environment interaction is vital for breeders in order to design the dissemination strategies for new varieties. Precise recommendation of lines for general and specific adaptation requires clear understanding of the real pattern of genotypes by environment interaction. The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is grown. Based on yield performance, disease reaction and agronomical parameters evaluated, the newly released variety (Haydaroo) is very suitable for the studied environments. It is the most preferred variety with multiple merits (high yielder, disease tolerant, better plant stand, relatively better threshablity and better bio-mass weight) when compared to the checks.

Acknowledgement

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Appendix I

Agronomic and morphological descriptors Haydaroo variety

1. Variety Name: Haydaroo (Sinana-01/DZ2212//Sinana-01)
2. Adaptation area: Highlands of Bale and similar agro ecology
   Altitude (m.a.s.l): 2300-2600 m.a.s.l
   Rainfall: 750-1500mm
3. Seed rate: 100kg/ha
4. Planting date: Mid June to early September in Bale based on the agro-ecologies of the area
5. Fertilizer rate (kg/ha):
   P2O5=46
   N=18
6. Days to heading: 72
7. Days to mature: 127
8. Plant height: 108
9. Growth habit: Erect and deep green at early stage
10. Ear type: compact type having of black awn
11. Seed color: Amber
12. Crop pest reaction: Resistance/tolerance to major emmer wheat disease
13. Yield (qt/ha):
    Research field: 24.6- 45.3
    Farmers field: 17.8- 45.7
14. Year of release=2017
15. Breeder/maintainer: Sinana Agricultural Research Center/Oromia Agricultural Research Institute

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Registration of "Hortu and Weyib" field pea varieties released for the highlands of Bale and similar agro-ecologies

Tadele Tadesse, Amanuel Teklign, Gashaw Sefera, and Behailu Mulugeta

Sinana Agricultural Research Center, P.O. Box 208, Bale-Robe, Ethiopia

Corresponding author: tadyeko20@gmail.com, tadeleta20@yahoo.com

Abstract

A total of 15 advanced field pea genotypes were tested under regional variety trial for three years (2012/13 to 2014/15) at three locations (Sinana, Sinja and Agarfa), Bale highland. Among those, Hortu and Weyib, the two newly developed field pea varieties were released for the highlands of Bale and similar agro-ecologies for their best performance than the checks and other genotypes. The two varieties were high yielder and stable across the testing location and years. Accordingly, variety EH02081-8 (Hortu) has a yield advantage of 26.28 % and 43.09%; whereas EH03014-1 (Weyib) has 21.72% and 37.92% yield advantage over the standard check (Urji) and local check, respectively. Furthermore, these varieties are stable, best adapted, having large number of pods per plant and tolerant to powdery mildew (Erysiphe polygoni), Downey mildew (Pernospora pisi) and ascochyta blight (Mycosphaerella pinnodes). Hortu mainly used for kik purpose, but Weyib is used for shiro. Due to these merits "Hortu and Weyib" were released in the 2017 cropping season for the highlands of Bale and similar agro-ecologies.

Key words: Field pea, Hortu, Stability, Weyib.

Introduction:

Agronomic and Morphological Characterstics

Hortu is semi-erect with white seed coat, yellow cotyledon, and white flower. On average, Hortu has an average plant height of 141cm, and requires 67 days for flowering, and 134 days to reach physiological maturity. Average thousand seeds is 197.5gm, and on average, 12 medium length pods per plant (Table 1). On the other hand Weyib has semi erect growth type with gray seed coat, yellow cotyledon, and pink flower. This variety has also plant height of 141cm, and requires 68 and 135 days to give flowers and reaches to physiological maturity respectively. A Morphological and agronomic characteristics of the varieties is summarized in Table 1.

Yield performance:

The average seed yield of Hortu combined over locations and over years is 4.20t/ha whereas for Weyib it is 4.05t/ha which is higher than Urji (standard check) (3.73t/ha), and the local check (2.94t/ha). Under research field Hortu yields 3.8 to 5.4t/ha; weyib gave an average grain yield of 3.6 to 5.2t/ha.

Table 1 Mean seed yield and other agronomic traits of field pea variety, Hortu and Weyib and checks in multi-location testing, 2015/16

Entry	Days to flower	Days to maturity	Plant height cm	NO. of Pods/plant	No. of seeds/pod	1000 Seed wt g	PM[a]	DM	ASB	SY t/ha
EH02081-8 (Hortu)	67	134	141	12	4	197.5	4	3	4	4.20
EH03014-1(Weyib)	67	135	142	12	5	195.4	4	4	4	4.05
Urji	68	135	139	14	4	183.4	5	6	5	3.33
Local check	66	134	150	13	4	142.2	6	65	4	2.94
Mean	67	135	143	13	4	179.6				3.63

Key: PM. = Powdery Mildew; DM. =Downey Mildew; ASBLT. = Ascochyta blight [a] Disease score based on 1-9 scale where 1 is highly resistance and 9 is highly susceptible

Stability performance

The two varieties were tested in 9 environments (G x E) in order to see their stable performance over the testing sites during the multi-location trial in the regional variety trial. Accordingly, these two varieties were selected since they showed mean gain yield better than the checks with yield advantage of more than 25%. Furthermore the varieties have regression coefficient nearly unity, and they have also the least deviation from regression and the lowest AMMI Stability Value (ASV). This indicates that the varieties are stable over the testing environments. Genotype with the least deviation from regression, with the lowest ASV indicates that the genotype is stable over the testing environment.

Diseases Reaction

The major field pea diseases according to their importance in the growing areas are powdery mildew *(Erysiphe polygoni*), Downey mildew *(Peronospora pisi) and* Aschochyta blight (*Mycosphaerella pinnodes*) (Asfaw *et al*., 1993). In 1-9 rating scale, with a score of 1 most resistant, the two varieties scored a mean of 4 for all the above mentioned diseases, and be characterized as moderately resistant (Table 1).

Quality

Field pea is one of the best components in day- to- day dish in the form of *wet* either in its crashed form locally called *kik.* or in its powder form called *shiro.* Accordingly, variety Hortu is highly preferred for *kik*, whereas variety Weyib is mainly used for *shiro.*

Adaptation

Hortu and Weyib are released for the highlands of Bale, southeastern Ethiopia. It is well adapted in areas having an altitude of 1800 to 2600 m.a.s.l and annual rain fall of 750 to 1000mm. Furthermore; production of these two varieties can be extended to areas having similar agro-ecologies. The two varieties performs best if they are produced with recommended fertilizer rate of 100kg/ha DAP and with seed rate of 75 kg/ha in clay-loam soil. The recommended planting date is from the end of July to early August in Meher season and end of March in Belg season.

Variety Maintenance

Breeder and foundation seed of the variety is maintained by Oromia Agricultural Research Institute (OARI), Sinana Agricultural Research Center Ethiopia.

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Genotype by Environment Interaction (GEI) and Stability analysis of White bean genotypes in the mid altitude of Bale zone, Southeastern Ethiopia

Tadele Tadesse[1]*, [1]Amanuel Tekalign, [1]Behailu Mulugeta and [1]Gashaw Sefera

Oromia Agriculture Research Institute, Sinana Agriculture Research Center, Bale-Robe, Ethiopia

* Corresponding author: tadyeko20@gmail.com/tadeleta20@yahoo.com

Abstract

Twelve white common bean genotypes were evaluated along with two checks at three diverse locations in the mid altitude of Bale zone, southeastern Ethiopia for two consecutive years (2014 and 2015). The objective of this work was to see the effect of GEI and evaluate the adaptability and stability performance of twelve white common bean genotypes using AMMI (Additive main effect and multiplicative interaction) model. The combined analysis of variance over locations revealed highly significant differences among the genotypes, locations and genotypes by location interaction. Among the 14 genotypes, the maximum grain yield over locations was recorded by genotype (G5) ICN Bunsi X S X B 405/5C-1C-1C-51(2.05t/ha) followed by (G11) ICN Bunsi X S X B 405/7C-1C-1C-30 (1.96t/ha) and the site that gave the maximum grain yield was Ginir (2.16t/ha). The results of AMMI analysis indicated that the first four AMMI (AMMI-AMMI4) were highly significant (P<0.01). The GE interaction was two times higher than that of the genotype effect, suggesting the possible existence of different environment groups. Based on the AMMI Stability Value (ASV), G12, G5, G7, G11, G3 and G13 showed stability than others. As stability per se is not a desirable selection criterion and the most stable genotypes would not necessarily give the best yield performance, simultaneous consideration of grain yield and ASV in a single non-parametric index was also considered in identification of best varieties. Based on the Genotype Selection Index (GSI), which considers both the ASV and mean grain yield, genotype G5 and G11 were identified as stable genotypes for the study areas.

Key Words: AMMI Stability Value (ASV), Common bean, Genotype Selection Index (GSI)

Introduction

Common bean (*P. vulgaris* L.) germplasm was introduced into Africa from each of the two gene pools in Latin America during the past four centuries (Allen, 1995). Africa is now the second most important common bean producing region in the tropics, following Latin America (Allen, 1995). Beans are now recognized as the second most important source of human dietary protein and the third most important source of calories of all agricultural commodities produced in Eastern and Southern Africa (Pachico, 1993). Bean is a major crop in many parts of Africa, and especially in eastern Africa. An important food to people of all income categories, it is especially important to the poor as a source of dietary protein. Its production is agronomically diverse, being grown in many different crop associations. Bean is grown primarily by small-scale farmers in eastern Africa. Unfortunately, the rate of increase in bean production has been exceeded by the rate of population growth. The Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) recognizes research on beans as being of high importance. Bean is an important source of cash for small scale farmers in Africa, whether as part of the total farm income or for providing a marketable product at critical times when farmers have nothing else to sell such as before the maize crop is harvested (Pachico, 1993).

Common bean is a well-established component in Ethiopian agriculture and is regarded as the main cash crop and protein source of the farmers in many lowland and mid-altitude regions of Ethiopia with an estimated production area of 239,000 ha (Wortmann and Allen, 1994). The national average yield is 500–700 kg/ha and yield from research station plots is in the range of 2000–3000 kg/ha (Mekbib, 1997). The most suitable bean production areas in Ethiopia are characterized by an altitude range of 1200–2200 masl and mean maximum temperature of less than 32^{o}C, and well distributed rainfall of 350–500 mm throughout the growing season. Genotype by environment interactions are of major importance to the plant breeder in developing improved cultivars (Kang, 1993).

When cultivars are compared over a series of environments, the rankings usually differ and this may cause difficulty in demonstrating the superiority of any cultivar across environments. Since production is highly affected by the effect of environment identifying stable cultivar for maximum yield is essential. A major challenge for plant breeders is determining the appropriate common bean genotypes due to genotype x environment (GE) interactions, which determine the differential response of genotypes among environments. To reduce the effects of GE interactions, it is convenient to know their magnitude and to identify more stable genotypes adapted to specific environments (Cruz and Regazzi, 2007). In this context, several methods to study adaptability and stability have been used to measure GE interactions in common bean (Coimbra *et al*., 1999; Carbonell *et al*., 2004; Ribeiro *et al*., 2009; Pereira *et a*l., 2009, 2011; Torga *et al*., 2013), predominantly based on linear regression models (Eberhart and Russell, 1966) and multivariate analyses such as additive main effects and multiplicative interaction analysis (AMMI) (Gauch, 2006). Traditional methods that predict genotype performances in multiple environments are based on a classic approach to statistics, which estimates one or more parameters from a set of observations.

Although there are many stability parameters, Eberhart and Russel (1996) model's parameters S^2di appeared to be very important. Since the variance of S^2di is a function of number of environments hence several environment with minimum replications per environmental are advocated being necessary to obtain reliable estimates of S^2di. To identify the stable genotypes having adaptability over a wide range of agro-climatic conditions is of major significance in crop improvement. Therefore, this study mainly emphasizes to see the effect of GEI and evaluate the adaptability and stability of productivity of twelve white common bean genotypes using AMMI (Additive main effect and multiplicative interaction) model.

Materials and Methods

In this study 14 white common bean genotypes (Table 1) were evaluated during the main/meher seasons for two consecutive years (2014-2015) across three districts (Ginir, Goro and Dellomena) representing the mid altitude of Bale zone. The was randomized complete block design with four replications. Plot size used was 6.4m^2 (4 rows at 40cm spacing and 4m long). The two central rows were used for data collection. Combined analysis of variance LSD multiple range test were done using Cropstat software. The additive main effect and multiplicative interaction (AMMI) analysis was performed using the model suggested by Crossa *et al.*(1991). The stability parameters like regression coefficient (bi), deviation from regression were also calculated using Cropsta program. AMMI Stability Value (ASV) the distance from the coordinate point to the origin in a two dimensional of IPCA1 scores against IPCA2 scores was computed by the model suggested by Purchase *et al.*, 2000. ASV= $\sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1score)\right]^2 + [IPCA2]^2}$

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

Genotype Selection Index (GSI) also calculated by the formula suggested by Farshadfar, 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 ($RASV_i$).

$GSI_i = RASV_i + RY_i$

Table 1. List of Genotypes used in the trial

SN	Genotype Code	Genotype name
1	G1	ICN Bunsi X S X B 405/4C-1C-1C-50
2	G2	ICN Bunsi X S X B 405/3C-1C-1C-87
3	G3	ICN Bunsi X S X B 405/9C-1C-1C-70
4	G4	ICN Bunsi X S X B 405/5C-1C-1C-98
5	G5	ICN Bunsi X S X B 405/5C-1C-1C-51
6	G6	ICN Bunsi X S X B 405/1C-1C-1C-31
7	G7	ICN Bunsi X S X B 405/7C-1C-1C-69
8	G8	ECAB-0632
9	G9	ICN Bunsi X S X B 405/7C-1C-1C-58
10	G10	ICN Bunsi X S X B 405/3C-1C-1C-49
11	G11	ICN Bunsi X S X B 405/7C-1C-1C-30
12	G12	ICN Bunsi X S X B 405/4C-1C-1C-80
13	G13	Roba-1
14	G14	Awash Melka

Result and Discussion

The combined analysis of variance revealed that significant differences among the genotypes, environment and genotypes by environment interaction (Table 2). Corte *et al.* (2002) also reported significant differences for mean grain yield of common bean for environments. Similarly Raffis *et al.* (2004); Dar *et al.* (2009) and Mwale *et al.* (2009) also reported significant differences for genotypes by environment interaction for mean grain yield of common bean. The variance due to genotypes by environment interaction was found significant for various traits by Singh *et al*. (2007). Mean comparison for the tested genotypes indicated that maximum grain yield was obtained from G5 (2.05t/ha) followed by G11 (1.96t/ha) and G6 (1.76t/ha) whereas the least mean grain yield was obtained from G8 (1.52t/ha).

Table 2. Combined analysis of variance for mean seed yield of white common bean tested at three locations (Ginir, Goro and Dello mena) for two years (2014-2015)

Source of Variation	DF	Mean Squares
Year (Y)	1	7066210**
Location (L)	2	27962200**
Replications	3	341310**
Genotypes (G)	13	565441**
Y*L	2	12546500**
Y*G	13	361761**
L*G	26	255351**
Y*L*G	26	226430**
Residual	249	150569**
TOTAL	335	451281**
CV%		22.7%

**, Significant at 1 % of probability level

The regression analysis (Table 3) revealed that the main effects of genotypes, and GE interaction were accounted only for 6.52% and 15.29% of the total sum of square (TSS), respectively (Table 3). Liner GE interaction was not significant and accounted for 5.55% of the variability in the GE interaction. As a general rule the effectiveness of regression analysis is when 50% of the total sum squares is accounted for by liner GE interaction Hayward *et al.,* (1993), hence regression analysis is not useful for stability analysis of genotypes (Wade *et al*., 1995).

Table 3. Regression analysis of phenotypic stability for white common bean genotypes

Source of variation	D.F.	S.S.	M.S.	TSS%
Genotype (G)	13	1.83768	0.14136**	6.52
Location (L)	5	22.0209	4.40418**	78.17
G X L	65	4.3073	0.066266**	15.29
G X Site Reg	13	0.239104	0.018393	5.55
Deviations	52	4.0682	0.078235**	94.45
Total	83	28.17		

** Significant at 1% level of probability

The result of AMMI analysis indicated that 6.52% of the total variability was justified by genotypes, 78.17% by environment and 15.29% by genotype. The partitioning of total sum of squares indicated that the environment effect was a predominant source of variation followed by GE and genotype effect. A large SS for environments indicated that the environments were diverse, with large differences among environmental means causing most of the variation in grain yield. The GE interaction effect was two times higher than that of the genotype effect, suggesting that there were sustainable differences in genotypic response across environments. Furthermore, the AMMI analysis revealed that high significant difference for IPCA1, IPCA2, IPCA3 and IPCA4. This made it is possible to construct the biplot and calculate genotypes and environment effects (Guach and Zobel, 1996; Yan and Hunt, 2001; Kaya *et al.* 2002). The first IPCA1 accounted for 35.74% of the variability of GE, followed by IPCA2 (35.43%), IPCA3 (20.63%) and IPCA4 (4.7%). The first two IPCA scores were cumulatively accounted for 71.2% of the total GE interaction. This indicated that the use of AMMI model fit the data well and justifies the use of AMMI2 (Table 4). The Interaction Principal Component Axes (IPCA) scores of a genotype in the AMMI analysis indicate the stability of a genotype across environment. The closer the IPCA scores to zero, the more the stable the genotypes across their testing environments.

Table 4. Analysis of Variance for grain yield of white common bean for the AMMI model

Source of Variation	D.F	S.S.	TSS%	M.S. F
Genotypes (G)	13	1.83768	6.52	0.14136**
Locations (L)	5	22.0209	78.17	4.40418**
G x L	65	4.3073	15.29	0.066266**
AMMI 1	17	1.53941	35.74	0.090554**
AMMI 2	15	1.5262	35.43	0.101747**
AMMI 2	13	0.888585	20.63	0.068353**
AMMI 4	11	0.202411	4.70	0.018401**
GXE RESIDUAL	9	0.150694	3.50	
TOTAL	83	28.1659		

** Significant at 1% level of probability

Table 5 shows effects of genotypes and site values from the additive genotype x environment model. The large differences of effects both on genotypes and on environments were observed. Environments A (0.69 t ha^{-1}) and C (0.21) have the main high significant positive grain yield effects. Environments E (-0.22t/ha) has the main significant negative grain yield effects. Genotypes 5 (0.34t/ha) and G11 (0.26 t/ha) had a positive grain yield significant effect across all environments. The majority of white common bean varieties had a small positive none significant main effect.

Table 5. Effects of white common bean varieties grain yield (t/ha) from the AMMI GE model

Variety Code	Environments						
	Gin2014 (A)	Goro2014 (B)	Gin2015 (C)	Goro2015 (D)	DM2014 (E)	DM2015 (F)	Genotypes effects
G1	0.08	-0.20	0.02	-0.07	0.34	-0.34	0.05
G2	0.02	0.89	-0.22	0.01	0.18	-0.08	-0.09
G3	0.18	-0.33	-0.07	-0.14	0.15	-0.09	0.00
G4	0.27	-0.74	-0.11	0.10	0.12	-0.30	-0.14
G5	0.41	0.13	0.10	-0.20	-0.12	-0.32	0.34**
G6	0.01	-0.15	0.30	0.06	-0.38	0.17	0.06
G7	-0.06	0.12	0.09	-0.10	-0.20	0.16	-0.14
G8	0.031	0.11	0.09	0.27	-0.41	-0.09	-0.18
G9	-0.47*	-0.17	-0.06	0.17	0.08	0.30	-0.16
G10	-0.07	-0.26	-0.59*	-0.01	0.62**	0.31	0.04
G11	0.45	0.15	-0.27	-0.05	-0.38	0.10	0.26*
G12	-0.10	0.96	-0.13	0.08	-0.16	0.22	0.02
G13	-0.21	0.54	0.33	-0.11	0.14	-0.20	-0.09
G14	-0.52*	-0.19	0.53*	0.00	0.03	0.15	0.03
Locations Effects	0.69**	-0.91	0.21**	-0.17	- 0.22**	0.39	1.71**

Key: *, ** significant probability level at 0.05 and 0.1 %, respectively

Table 6 indicates the different stability parameters that can determine the stability of a given genotypes across the tested environment. Accordingly the regression coefficient (bi), mean grain yield and deviation from regression should be simultaneously seen before deciding about the stability of a genotype. Furthermore, the AMMI Stability Value (ASV) which is the distance from the coordinate point to the origin in a two dimensional scatter gram of IPCA1 scores against IPCA2 score should also seen to decide the stability of a genotypes (Purchase *et al.*, 2000). In ASV method, the genotype with least ASV score is the most stable. From this study (Table 6), AMMI Stability Value (ASV) discriminated genotypes G 12, G5, G7, G13 and G3 as the stable genotypes respectively.

However, since stability in itself should not be the only parameter for selection, as the most stable genotype wouldn't necessarily gives the best yield performance (Mohammadi *et al.*, 2007), hence, simultaneous consideration of grain yield and ASV in single non-parametric index is needed. Therefore, based on the Genotype Selection Index (GSI) G5 and G11 were considered as the most stable genotypes with high grain yield compared to the others (Table 6).

Table 6. Regression coefficient, deviation from regression, IPCA scores, ASV and GSI of genotypes

Genotypes	MEAN	SLOPE (bi)	MS-DEV	IPCA1	IPCA2	IPCA3	IPCA4	ASV	GSI
G1	1.75	0.925	0.06	-0.17	-0.15	-0.43	-0.09	0.23	11
G2	1.61	0.882	0.02	-0.15	-0.19	-0.02	-0.16	0.25	18
G3	1.7	1.062	0.02	-0.20	-0.09	-0.12	0.18	0.22	13
G4	1.57	1.045	0.05	-0.31	-0.04	-0.18	-0.19	0.32	20
G5	2.05	1.072	0.09	-0.38	0.30	-0.24	0.14	0.20	3
G6	1.76	1.219	0.05	0.22	0.35	0.15	0.20	0.41	14
G7	1.57	0.995	0.02	0.11	0.16	0.14	0.16	0.20	14
G8	1.52	0.966	0.07	0.02	0.37	0.16	-0.39	0.37	24
G9	1.55	0.84	0.08	0.41	-0.24	0.23	-0.20	0.48	25
G10	1.75	1.038	0.22	-0.11	-0.82	0.20	0.15	0.83	18
G11	1.96	1.054	0.10	-0.41	0.25	0.41	0.14	0.21	6
G12	1.72	0.951	0.03	0.08	0.01	0.33	-0.07	0.09	8
G13	1.62	0.863	0.05	0.21	0.05	-0.41	-0.01	0.22	15
G14	1.74	0.987	0.15	0.67	0.04	-0.22	0.15	0.68	19

Key:. MS-DEV= deviation from regression, IPCA= Interaction Principle Component Analysis axis, ASV= AMMI Stability Value, GSI= Genotype Selection Index

The last stage of the AMMI analysis is the graphical representation of genotypes and environment in the biplot (Gabriel, 1971) and identification of mega-environment. The biplot graphics are used to analyze the description of genotypes, environments and the interaction between them. The first singular axis of the AMMI analysis captures the highest percentage of the "pattern" of the data (Gauch, 1988). A high percentage of the SS GEI (Sum Square of the GE interaction) is explained by the first two axes (71.2%) and the highest part of the "pattern" of the GEI will be captured.

According to the values of the two first principal components (IPCA1 and IPCA2) or by Fig. 1, G5, G11, G6, G1 and G10 are the genotypes with more productive in the environmental conditions prevailing during crop development. But G10, interact negatively to most of the environments, though it gives high grain yield above the grand mean. Regarding the stability, G5, G11, G12, G13 and G7 are considered as the stable genotypes. However, when we see their GSI (Genotype Selection Index) which associate both the ASV and the grain yield, G5 and G11 are the more stable genotypes with high grain yield across the testing sites. G10 is more specifically adapted environment E and G9 to environment F.

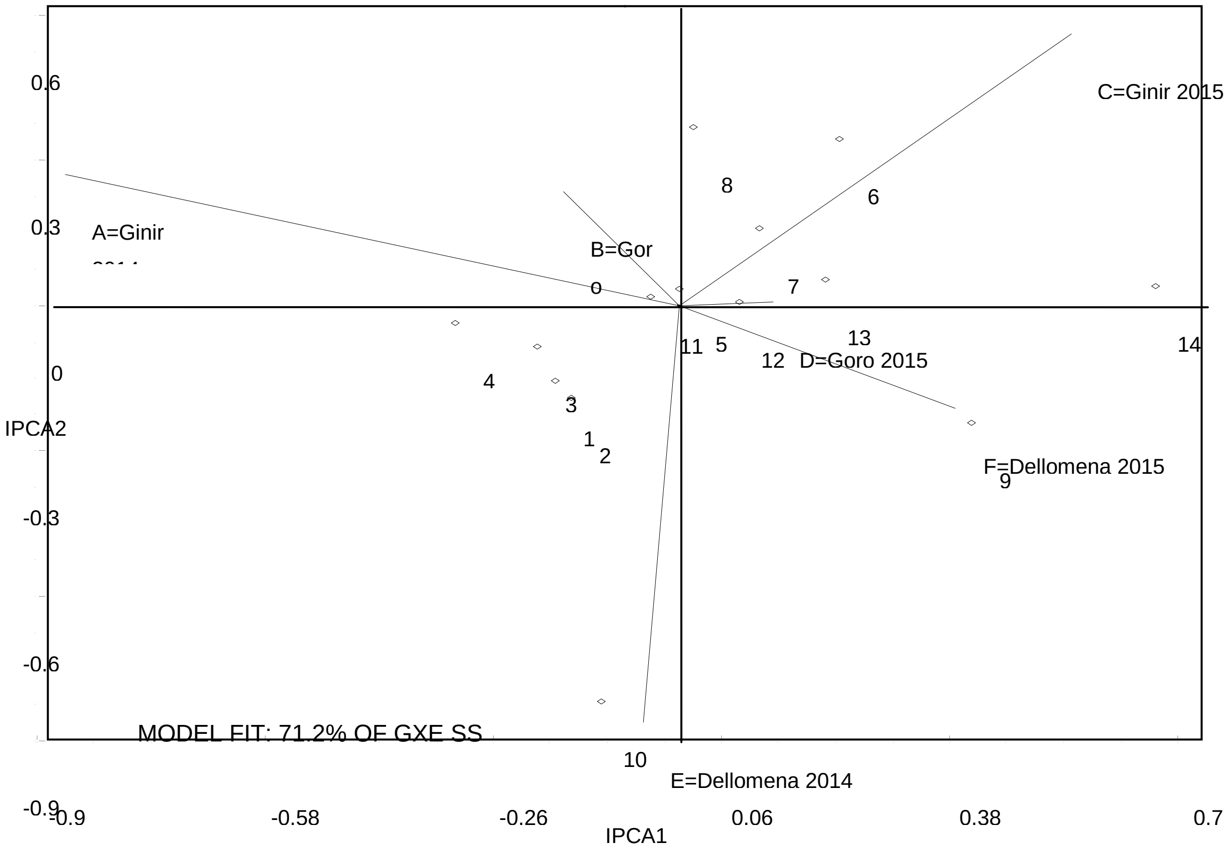

Fig. 1. Biplot analysis of GE interaction based on AMM2 model for the first two interactions principal component scores.

Conclusion

AMMI analysis of multi-environment yield trials serves for two main purposes: (i) understanding complex GEI, including delineating mega-environments and selecting genotypes to exploit narrow adaptations, and (ii) gaining accuracy to improve recommendations, repeatability, selections and genetic gain. Therefore, according to the present study, genotypes G5, G11 and G12 display higher adaptability and stability and thus recommended to be used in all environments included in the study. The genotypes G13 and G7 present high mean productivity. However, they were unstable and specific adaptation to the environments of high quality i.e. environment D. Environment A gives the highest mean grain yield (2.395t/ha) and environment B gave the lowest mean grain yield (0.80t/ha). These can be considered example of favorable and unfavorable environments respectively. Therefore, from this study G5 and G11 were considered as the most stable genotypes and therefore, identified as candidate genotypes for possible release.

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Adaptability and Stability Analysis of Small red bean Genotypes using Additive Main effects and Multiplicative Interaction (AMMI) Model

Tadele Tadesse[1]*, Amanuel Tekalign[1], Behailu Mulugeta[1] and Gashaw Sefera[1]

[1]Oromia Agriculture Research Institute, Sinana Agriculture Research Center, Bale-Robe, Ethiopia

* Corresponding author: tadyeko20@gmail.com/tadeleta20@yahoo.com

Abstract

Genotype x location interaction effects are of special interest for breeding programs to identify adaptation targets, adaptive traits and test sites. Sixteen small red seed bean genotypes were evaluated at Goro, Ginir and Dellomena districts of Bale zone during 2015 and 2016 main cropping season. The cultivars were arranged in a randomized complete block design with three replications. The combined analysis of variance for mean grain yield revealed significant variation for genotypes, environment and GE interaction. The analysis of variance for the AMMI revealed that significant variation for genotypes, environment and GE interaction. From this analysis 42.53% was explained by AMMI 1 followed by AMMI 2 (28.29%), AMMI 3 (19.76%) and AMMI 4 (7.10%) of the interaction sum of squares. Therefore, the first two AMMI components justified 70.82% of the GE interaction sum of squares. The stability parameters regression coefficient (bi), deviation from regression analysis and AMMI stability value ASV identified G7, G6, G11, G1 and G12 showed the least value for ASV indicating as these genotypes showed stable performance over the sites. However stable cultivar wouldn't necessarily gave the highest seed yield. Therefore based on Genotype Selection Index (GSI) which considers both the ASV and the mean yield, G8, G3, G6 an G7 were the most stable genotypes identified over the tested environments. Therefore, out of the tested genotypes, G8 and G3 were identified as stable cultivar to be selected for possible release during the coming cropping seasons.

Key words: Adaptability, AMMI, ASV, GSI, Stability

Introduction

The common bean (*Phaseolus vulgaris* L.) is the most important food legume for direct consumption in the world. Among major food crops, it has one of the highest levels of variation in growth habit,

seed characteristics (size, shape and color), maturity and adaptation. It also has a tremendous variability (> 40,000 germplasms). Germplasm collection in beans compares well with other important commodities on a worldwide basis. *Phaseolus vulgaris* is produced in a range of crop systems and environments in regions as diverse as Latin America, Africa, the Middle East, China, Europe, the United States, and Canada (Peters**,** 1993; Wortmann and Allen1994). Common bean is the most important crop for soil health due its excellent biological nitrogen fixation and food security crops for its source of starch, protein, dietary fiber, minerals and vitamins (Broughton, 2003).
It is the most important grain legume in nearly all lowland and mid altitude areas of Ethiopia. It is produced primarily by smallholder farmers both for cash and consumption. In 2014, it was cultivated by 3.34 million smallholders on 340 thousand hectare of land which is about 20% of total farm land allocated for pulses (CSA, 2014). It is also an important source of income for the farmers and an export commodity that generates foreign currency for the country. It ranks third as an export commodity in Ethiopia, contributing about 9.5 % of total export value from agriculture. Its fastest ripening at the critical hunger period earlier than other crops made it an ideal food security crop. It is double or triple cropped per year enabling cultivation of free land and engaging relatively cheaper labor after the harvest or failure of main season crops. Its high protein content made it the poor man's meat securing more than 16.7 million people against hidden hunger. Therefore, advanced small red common bean lines reported for their higher seed yield potential were introduced and evaluated at multiple locations.

The wide occurrence of genotype x environment interaction (GEI) is the basic cause of difference between genotypes in their yield stability, or in other words: ranking of the genotype depends on the particular environmental conditions where it is grown. Numerous stability parameters have been developed to investigate GEI (Huehn, 1990). Among them Additive main effects and multiplicative interaction (AMMI) analysis (Gauch 1992) is particularly effective for depicting adaptive responses (Crossa 1990; Annicchiarico 1997). Parametric stability statistics obtained by linear regression models (Finlay and Wilkinson, 1963; Eberhart and Russell, 1966; Shukla, 1972) are mathematically simple and biologically interpretable; however, few researchers use statistical measures of yield stability in their breeding programs. To maintain improved agricultural productivity, the development of varieties with high yielding potential is the ultimate goal of plant breeders in a crop improvement program. In the recent years of haricot bean breeding in Ethiopia, special focuses have been given to develop varieties with improved grain yield, good seed color and size, as well as resistant to major diseases. In addition to high yielding potential, a successfully developed new cultivar should have a stable performance and broad adaptation over a wide range of environments. However, frequent variation experienced both from season to season and from place to place within a shorter distance is among the most important features of the Ethiopian environmental conditions (EMA, 1988). The objectives of this study were therefore to identify the most stable bean lines across the studied environments.

Materials and Methods

A total of 16 small seeded red common bean genotypes were evaluated to evaluate their adaptability and the stability in grain yield performance (Table 1). The test locations were Goro, Ginnir, and dellomena districts, the mid-altitude of Bale zone, southeastern Ethiopiaduring bona 2015 and 2016 cropping season. The genotypes were arranged using randomized complete block design with four replications and plot size of 6.4m^2 (4 rows at 0.4m spacing of 4m row length). Combined analysis of variance using balanced ANOVA (Analysis of Variance) was computed using Cropstat program. AMMI analysis was performed using the model suggested by Crossa *et al.* (1991).

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

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

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

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

$GSI_i = RY_i + RASV_i$

Table 1. Lists of genotypes used in the trial along with their genotypic code

Genotype code	Genotype name
G1	ECAB-0295
G2	ECAB-0287
G3	SELIAN-97
G4	ECAB-020203
G5	SIMAMA
G6	SER-119
G7	ECAB-0281
G8	RBC-592
G9	ECAB-0236
G10	SER-118
G11	ECAB-0242
G12	625-BRB-183
G13	ECAB-0224
G14	MELKA DAME
G15	NASIR
G16	OMO-95

Result and Discussions

The combined analysis for the mean grain yield showed that genotypes (G), locations (L), years (Y), genotype x location (GL), genotypes x year (GY), location by year (LY), and genotypes x location x year (GLY) effects were highly significant ($p \leq 0.01$) (Table 2). This indicated the variability among genotypes, locations and years. Similar findings were reported by Mekbib (2003), Asfaw *et al.* (2008) and Tamene and Tadese (2014) for common bean varieties performance and their growing environments in Ethiopia. The significant GL, GY, LY, and GLY were also indicated that the relative performance of genotypes at different locations and years was not similar.

Table 2. Combined mean grain yield of Small red bean genotypes tested across locations (Goro, Ginnir and Dellomena) during meher 2015 to 2016.

Source of variation	DF	Sum of squares	Mean squares
Year (Y)	1	12.0496	12.0496**
Location (L)	2	31.9999	16.0**
Replication	3	0.844609	0.281536**
Genotype (G)	15	8.92123	0.594749**
Y X L	2	10.0307	5.01533**
Y X G	15	3.22062	0.214708**
L X G	30	8.1449	0.271497**
Y X LX G	30	8.34951	0.278317**
RESIDUAL	285	55.8643	0.196015
Total	383	139.425	0.364035

AMMI analysis: Genotype, location and genotype by environment interaction were assessed by the additive main effect and multiplicative interaction (AMMI) model (Table 3). The analysis of variance of AMMI model for grain yield showed significant effect for genotypes, environment, and GE interaction. These result showed that 65.05% of the total sum of square was attributed to environment effects, only 10.77 and 24.17% to genotype and GE interaction effects, respectively. The effect of environment was responsible for the largest part of the variation, tailed by genotype and genotype by environment interaction. The same result was reported by Reza *et al.*, 2007; Noorul *et al.*, 2015; Tarakanovas *et al.*, 2006 and. The GX E sum of squares was 2.24 times larger than for genotypes, which determined substantial differences in genotypic response across environment.

The GE interaction was partitioned into four parts of interaction principal component analysis (IPCA). AMMI 1 accounted for 42.53%, the second AMMI accounted for 28.29%, the third 19.76% and the fourth 7.10% respectively. The first two AMMI accounted for 70.82% of the GE sum of squares. This made as the construction of the biplot and genotype and environment effects (Gauch and Zobel, 1996; Yan and Hunt, 2001; Kaya *et al.*, 2002).

Table 3. Analysis of Variance for the AMMI model for small red bean grain yield (t/ha) of the genotypes across environments

Source of Variation	D.F.	S.S.	M.S.	%TSS
Genotypes (G)	15	2.23833	0.149222**	10.77
Locations (L)	5	13.5158	2.70316**	65.05
G X L	75	5.02163	0.066955**	24.17
AMMI COMPONENT 1	19	2.13592	0.112417**	42.53
AMMI COMPONENT 2	17	1.42043	0.083555**	28.29
AMMI COMPONENT 3	15	0.992167	0.066145**	19.76
AMMI COMPONENT 4	13	0.356746	0.027442**	7.10
GXE RESIDUAL	11	0.116365		2.32
TOTAL	95	20.7767		

Stability performance

The stability parameters such as regression coefficient (bi), deviation from regression (S^2di), IPCA scores, AMMI Stability Value (ASV) and Genotype Selection Index (GSI) for the grain yield of the genotypes are presented in Table 4.

The regression of coefficient (bi) value for genotypes G5 (1.035), G8 (1.04), G11 (1.065) and G13 (1.085) were close to unity implying these genotypes are stable over the environments. Furthermore, the deviation from regression for G8 (0.02), G6 (0.01), and G7 (0.01) were the lowest compared to others. The ASV was also lower for G7, G6, G11, G1, G12 and G2. But not all genotypes showing stable performance gave optimum grain yield. Therefore, only genotype G8, G3 and G6 showed stable high grain yield performance with relatively lower ASV value implying wider adaptability across test locations.

Table 4. Mean grain yield, regression coefficient, deviation from regression, IPCA scores ASV and GSI for small red bean genotypes across environments.

Genotypes Code	MEAN	Slop (bi)	MS-DEV (s^2di)	IPCA1	IPCA2	IPCA3	IPCA4	ASV	GSI
G1	1.83	0.876	0.05	0.15	-0.19	-0.32	0.20	0.31	12
G2	1.81	0.712	0.06	0.18	-0.26	-0.37	0.24	0.39	15
G3	2.04	0.763	0.06	-0.18	0.35	0.19	0.31	0.46	12
G4	1.86	0.866	0.05	-0.24	-0.12	-0.28	-0.18	0.41	15
G5	2.01	1.035	0.07	-0.19	0.38	0.06	-0.24	0.49	15
G6	2.01	0.939	0.01	-0.16	0.04	0.04	0.02	0.27	6
G7	1.78	0.918	0.01	-0.10	0.04	0.11	0.12	0.17	12
G8	2.04	1.04	0.02	0.20	-0.28	0.16	-0.33	0.43	10
G9	1.81	0.66	0.07	-0.38	-0.26	-0.26	0.03	0.67	23
G10	1.88	1.172	0.06	-0.19	-0.26	0.33	-0.25	0.40	12
G11	1.87	1.065	0.08	-0.01	-0.28	0.46	0.07	0.28	9
G12	1.73	0.898	0.03	-0.14	-0.30	-0.04	0.05	0.38	18
G13	1.64	1.085	0.08	0.12	0.41	-0.30	-0.20	0.45	25
G14	1.71	0.778	0.09	-0.31	0.46	-0.06	0.01	0.68	29
G15	1.76	1.133	0.08	0.35	0.14	0.33	0.26	0.59	25
G16	1.45	1.544	0.23	0.88	0.11	-0.07	-0.13	1.44	32

A graphic representation of grain yield showed in AMMI biplot was generated using the genotypic and environmental score of the first two IPCA (Fig. 1). Most of the genotypes showed negative interaction with environment B, E and F. On the other hand, G1, G2, G10, G11 and G12 showed positive interaction with environment B, E and F. Genotypes 5, G13 and G14 were more specifically adapted to environment A. Whereas, G15 was more adapted to environment D. G1, G2 and G11 were more adapted to environment B. Similarly G9, G10 and G12 were more adapted to environment E. The other genotypes which found around the origin (with the lowest vector from the origin) such as G6, G7, G8 and G3 were the most stable across the study environments.

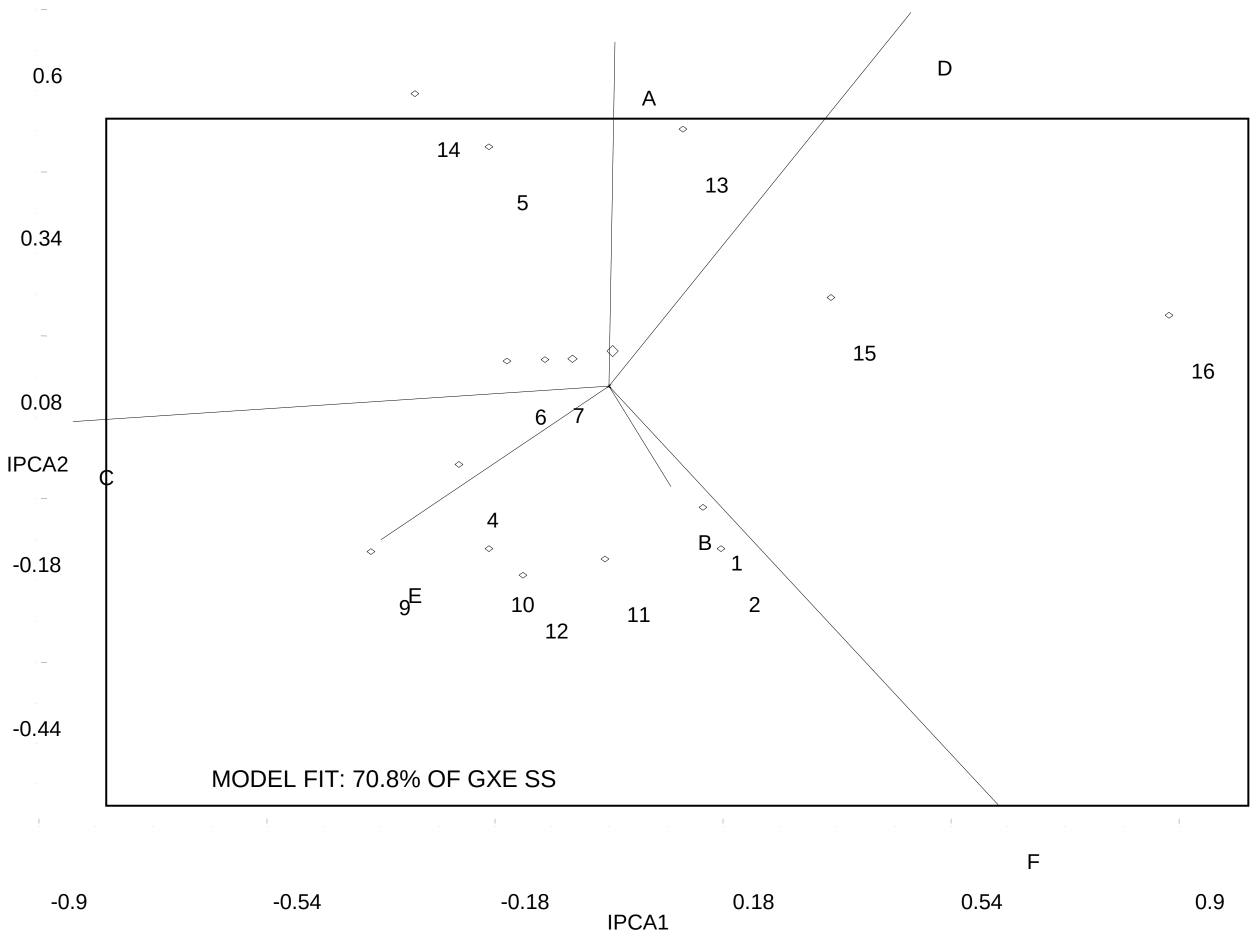

Fig. 1. Biplot analysis of GE interaction based on AMM2 model for the first two interactions principal component scores.

Conclusion

Genotypes evaluation must be conducted in multiple locations for a number of years to fully sample the target environment (Cooper *et al.,* 1997). Genotype in the presence of unpredictable GE interaction is a major problem in plant breeding (Bramel-Cox, 1996). To select for superior genotypes, it seems that there is no easier way other than to test widely (Troyer, 1996) and select for both average yield and stability (Lin and Binns, 1994; Kang, 1997). Accordingly, the present study revealed that the analysis result using coefficient of regression, deviation from regression, ASV,GSI accompanied by the mean grain yield performance, genotype G8 and G3 are the genotype with well adaptability in all the studied environments and therefore selected for the possible release in the coming cropping season.

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

Genotypes by Environment interaction and stability analysis for Ethiopian Mustard (*Brassica carinata* L.) genotypes

Tadele Tadesse[1]*, Amanuel Tekalign[1], Gashaw Sefera[1], and Behailu Mulugeta[1]

[1]Oromia Agriculture Research Institute, Sinana Agriculture Research Center, Bale-Robe, Ethiopia

* Corresponding author: tadyeko20@gmail.com or tadeleta20@yahoo.com

Abstract

The genotype x environment interaction (GEI) has an influence on the selection and recommendation of genotypes. To this end, G x E interaction and grain yield stability study was conducted for 17 advanced Ethiopian mustard genotypes across three districts (Sinana, Adaba and Agarfa) in the highlands of Bale zone during 2014 and 2015 main cropping season. The design used was randomized complete block design with four replications and plot size of 7.2m^2 (6 rows at 30cm spacing with row length of 4m). The combined analysis for the mean grain yield was highly significant (p≤0.01) for genotypes, environment and genotype x environment interaction. The mean seed yield of these six environments ranged from 0.9427 t ha^{-1} for Agarfa in 2014 to 2.645 t ha^{-1} for Sinana in 2014. Five genotypes namely G4, G7, G8, G9 and G14 gave mean seed yield above the grand mean. The analysis of variance for the AMMI model indicated that 49.59% of the total sum squares (TSS) was accounted by AMMI1 followed by AMMI 2(27.08%), AMMI 3(10.16) and AMMI 4 (7.87%), respectively. Therefore, 76.7% of the GE sum squares was justified by the first two AMMI (AMMI1 and AMMI 2) components. The regression coefficient (bi) of genotypes ranged from 0.629 to 1.345. Genotypes G7 was the most stable and well adaptive with optimum grain yield (2.21 t ha-1), bi- value nearer to unity (bi = 1.03) and minimum value of deviation from regression (0.12). Based on the AMMI Stability Value (ASV), G12, G10, G17, G5, G3, G2, G7, and G8 showed the lowest ASV indicating as they are most stable. However the most stable genotypes would not necessarily give the highest yield. Therefore, based on mean grain yield and the result of stability parameters such as ASV, bi and Genotypes Selection Index (GSI), genotype G7 was found the best candidate variety and thus recommended for possible release for the test environments and similar agro-ecologies.

Key words: AMMI, ASV, Biplot, GSI, mustard, Stability

Introduction

Brassica carinata (2n=34) is an amphidiploid (an allopolyploid behaving as a diploid) derived from an ancient cross between *Brassica oleracea* (2n=18) and *Brassica nigra* (2n=16) (Mabberley, 2008; Stace, 2010). Throughout most of Africa, where it is cultivated, it is used as leafy vegetable, but in Ethiopia, it is also grown for its seed oil (Mnzava and Schippers, 2007; NGRP, 2014; Taylor *et al*., 2010; Warwick *et al*., 2006). Wild forms of *Brassica carinata* have not been reported but there are diverse ecotypes (Alemayehu and Becker, 2002).

The species is currently being bred to improve a variety of traits *Brassica carinata* likely originated in Ethiopia a few thousand years ago (Mnzava and Schippers, 2007; Warwick *et al*., 2006). Its exact native distribution is not well understood because it has been cultivated for a long time in Africa. Furthermore, it is often confused with *B. juncea* (Mnzava and Schippers, 2007). It is currently cultivated, native, and/or escaping from cultivation in many countries in Africa (Mnzava and Schippers, 2007). "Truly wild types are not known" (Mnzava and Schippers, 2007). Stability of yield under different environments is an important concern in plant breeding programs. The goal of plant breeders in crop improvement programs is to develop varieties, which are widely adapted to diversified environments. Some genotypes perform well in some environments but not so well in others (Dhillon *et al.*, 1999). This variability in response is due to genotype × environment (G × E) interaction. These interactions of genotypes with environments can be attributed to environmental stresses like drought, temperature, rainfall, soil texture and diseases. The adaptability of a variety over diverse environments is usually tested by its degree of interaction with different growing environments. A variety or genotype is considered to be more adaptive or stable if it has a high mean yield but low degree of fluctuation in yielding ability when grown over diverse environments (Falconer, 1981). Failure of genotypes to respond consistently to variable environmental conditions is attributed to Genotype x Environment Interaction (GEI). Knowledge of GEI is advantageous to have a cultivar that gives consistently high yield in either a broad range of environments or to specific areas. It also helps to increase efficiency of breeding program and selection of best genotypes. Therefore, this work was initiated to see the adaptability and stability of mustard genotypes for the highlands of Bale zone.

Materials and Methods

Seventeen mustard genotypes (Table 1) including two released varieties and local cultivar were evaluated for two consecutive years (2014 to 2015) at three locations (Sinana, Adaba and Afarfa) in the highlands of Bale zone, southeastern Ethiopia. The genotypes were arranged using randomized complete block design with four replications with plot size of 7.2m^2 (6 rows at 30cm spacing in rows of 4m long). The four central rows were used for data collection and as net harvestable area. Combined analysis of variance using balanced ANOVA (Analysis of Variance) was computed using Cropstat software program. The additive main effect and multiplicative interaction (AMMI) analysis was performed using the model suggested by Crossa *et al.* (1991).

The AMMI Stability Value (ASV) is the distance from the coordinate point to the origin in a two dimensional of Interaction Principal Component Axis (IPCA 1) score against IPCA2 scores in the AMMI model (Purchase *et al*., 2000). This weight is calculated for each genotypes and environment according to the relative contribution of IPCA1 to IPCA2 to the interaction SS as follows,

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

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

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

$GSI_i = RY_i + RASV_i$

Table 1 Lists of Genotypes used in the study

Genotype code	Genotype name
G1	YDZ1-A088/A
G2	PGRC/E 21257
G3	PGRC/E 210102
G4	PGRC/E 208594/1
G5	PGRC/E 20140/B
G6	PGRC/E 21013
G7	PGRC/E 21207/A
G8	PGRC/E 208419/1
G9	YDZ1-A088/5
G10	PGRC/E 208524/3
G11	PGRC/E 21007/B
G12	PGRC/E 21312
G13	PGRC/E 210114
G14	PGRC/E 208584/4
G15	Shaya
G16	Yellow dodola
G17	Local check

Result and Discussion

The pooled analysis of variance for mean grain yield revealed that highly significant differences ($p \leq 0.01$) for genotypes, environment and GE interaction (Table 2). Similar findings has been reported by Ali *et al*. (2001); Mirza *et al*. (2002); Khan *et al*. (1988); Wani (1992); Aslam *et al.* (2015); Maqbool *et al.* (2015).

Table 2. Combined analysis variance for mean seed yield of mustard tested at three locations (Sinana, Agarfa, and Adaba) for two years (2014-2015)

Source of variation	DF	Mean square
Year (Y)	1	4.58072**
Location (L)	2	64.6334**
Replication	3	0.367477**
Genotype (G)	16	0.556143**
Y x L	2	7.29348**
Y X G	16	0.484343**
L XGL	32	0.385236**
Y X L X G	32	0.278298**
Residual	303	0.371115**
Total	407	0.736771

** Significant at 1% level of probability

The significant G × E interaction (GEI) showed that ranking of genotypes were changed over locations for the grain yield performance due to the presence of crossover. This shows the difficulties that crop breeders encountered in selecting widely adapted varieties. These difficulties arise from the masking effects of variable environment (Goncalves *et al.*, 2003) over the genetic performance of the variety. Mean comparison for the tested genotypes indicated that maximum grain yield was obtained from G7 (2.21t/ha) followed by G9 (1.82t/ha) and G8 (1.78t/ha), whereas the least mean grain yield was obtained from G17 (1.55t/ha). Agarfa 2014 gave the lowest mean grain yield (0.94t/ha) whereas the highest yield was obtained at Sinana 2014 (2.65t/ha) (Table 3).

Table 3. Mean Grain yield (t/ha) of seventeen mustard genotypes across locations

Genotype code	Sinana 2014 (A)	Adaba 2014 (B)	Agarfa 2014 (C)	Sinana 2015 (D)	Adaba 2015 (E)	Agarfa 2015 (F)	Genotypes MEANS
G1	2.52	0.49	0.99	2.72	1.76	1.36	1.64
G2	2.38	0.97	1.08	2.18	1.83	1.46	1.65
G3	2.49	1.22	1.15	2.02	1.34	1.42	1.61
G4	2.56	1.94	0.89	1.78	1.66	1.65	1.75
G5	2.54	1.17	1.03	2.04	1.71	1.45	1.65
G6	2.33	1.43	0.94	2.02	1.37	1.59	1.61
G7	3.10	1.97	0.98	3.32	1.77	2.13	2.21
G8	2.77	1.26	0.76	2.73	1.52	1.64	1.78
G9	2.81	0.86	0.99	3.09	1.71	1.47	1.82
G10	2.29	1.14	1.01	2.24	1.80	1.38	1.64
G11	2.65	0.70	1.06	1.83	1.61	1.51	1.56
G12	2.57	1.27	0.86	2.23	1.33	1.63	1.65
G13	2.66	0.74	0.65	2.54	1.54	2.07	1.70
G14	3.11	1.59	1.11	1.98	1.51	1.46	1.79
G15	3.03	1.75	0.49	2.27	1.23	1.10	1.64
G16	2.78	0.71	1.00	2.80	1.27	1.59	1.69
G17	2.40	1.21	1.06	2.08	1.18	1.35	1.55
Mean	2.65	1.20	0.94	2.35	1.54	1.54	1.70
LSD 1 %	0.71	1.19	0.29	0.85	0.68	0.44	0.95
CV%	19.4	18.0	21.1	24.3	21.0	20.0	18.2

The regression analysis for seventeen mustard genotypes grain yield (t/ha) tested in six environments 79.67% of the total sum of square was attributed to the environmental effect, only 4.78% for genotypic effect and 15.55% for GE interaction effects (Table 4). The environments were diverse and caused the greatest variation in the mea grain yield. The GE interaction sum of squares was 3.25 times larger than that of the genotypic effect which determined substantial differences in genotypic response across environment. Similar result was reported by Tarakanovas *et al*.(2006).

Table 4. Regression analysis of phenotypic stability for mustard genotypes

Source of variation	D.F.	S.S.	M.S.	%TSS
Genotype(G)	16	2.22457	0.13904**	4.78
Location (L)	5	37.1087	7.42173**	79.67
G X L	80	7.24564	0.09057**	15.55
G X Site Reg	16	1.86429	0.11652*8	25.73
Deviation	64	5.38135	0.08408**	74.27
TOTAL	101	46.5789		

** Significant at 1% level of probability

AMMI analysis: The results of the AMMI model analysis were interpreted on the basis of two AMMI biplots- a biplot that showed the main and first interaction principal components analysis axis effects of both G and E and a biplot that showed the nominal yield (expected yield from the AMMI model Equation without environmental deviation) of genotypes across IPCA 1 scores (Gauch and Zobel, 1997). AMMI analysis of variance for the mean grain yield of the genotypes tested across the studied environments revealed that significant variation was observed for genotypes, environment, and GE interaction. It was observed that 49.59% of the GE interaction sum of squares was accounted for AMMI 1, followed by AMMI 2, (27.08%), AMMI 3 (10.16%) and AMMI 4 (7.87%) (Table 5). The first two IPCA scores were cumulatively accounted for 76.67% of the total GE interaction. This indicates the importance of taking GE interaction into consideration when targeting mustard into specific location. Furthermore, the use of AMMI model fit the data well and justifies the use of AMMI2 (Table 5).

Table 5. AMMI analysis for variance for the effect of genotypes, environment and GE interaction on grain yield of mustard

Source of Variation	D.F.	S.S.	%TSS	M.S.
Genotype (G)	16	2.22457	4.78	0.139036**
Location (L)	5	37.1087	79.67	7.42173**
G X L	80	7.24564	15.55	0.090571**
AMMI 1	20	3.59298	49.59	0.179649**
AMMI 2	18	1.96212	27.08	0.109007**
AMMI 3	16	0.735865	10.16	0.045992**
AMMI 4	14	0.570418	7.87	0.040744**
GXE RESIDUAL	12	0.38426	5.30	
TOTAL	101	46.5789		

The stability parameters: The stability parameters from seed yield were calculated for 17 the genotypes (Table 6). The regression coefficient (bi) of genotypes ranged from 0.629 to 1.345. G9 had the highest regression coefficient (bi =1.345) followed by G16 (bi =1.306). The genotypes G11 (bi=0.925), G12 (bi=0.954), G14 and (bi=0.958) had regression coefficient lower than unity (bi <1) indicating that these genotypes are suitable for unfavorable environments. The G7 (bi= 1.03) had regression coefficient close to unity and low deviation from regression indicated that this genotype is the most stable, adaptable and suitable for commercial cultivation across the tested environments. Similar results have been reported by Ali *et al*. (2002). Furthermore, the AMMI Stability Value (ASV) which is the distance from the coordinate point to the origin in a two dimensional scatter gram of IPCA1 scores against IPCA2 score should also seen to decide the stability of a genotypes (Purchase *et al.*, 2000). AMMI Stability Value (ASV) discriminated genotypes G 12, G10, G17, G5, G3, G2, G8, and G7, as the stable genotypes respectively. However, stability itself should not be the only parameter for selection, as the most stable genotype may not necessarily gives the best yield performance (Mohammadi *et al.,* 2007). Hence, simultaneous consideration of grain yield and ASV in single non-parametric index is needed. Therefore, based on the Genotype Selection Index (GSI) and all other parameters, genotypes G7 was considered as the most stable genotypes with high grain yield compared to the others (Table 6).

Table 6. Mean grain yield, regression coefficient (bi), deviation from regression (s^2di), IPCA scores ASV and GSI for 17 mustard genotypes tested across the environments

Genotypes Code	MEAN	Slop (bi)	MS-DEV (s^2di)	IPCA1	IPCA2	IPCA3	IPCA4	ASV	GSI
G1	1.64	1.198	0.16	-0.570	0.177	-0.161	0.201	1.06	27
G2	1.65	0.824	0.05	-0.072	0.375	0.031	0.216	0.40	14
G3	1.60	0.786	0.02	0.180	0.176	-0.077	-0.041	0.37	21
G4	1.74	0.629	0.15	0.650	0.062	0.252	0.092	1.19	22
G5	1.65	0.833	0.02	0.122	0.262	-0.040	0.079	0.34	12
G6	1.61	0.728	0.02	0.277	0.074	0.259	0.040	0.51	24
G7	2.21	1.03	0.12	-0.064	-0.590	0.293	0.137	0.60	11
G8	1.78	1.212	0.02	-0.150	-0.297	0.073	0.032	0.40	12
G9	1.82	1.345	0.10	-0.536	-0.162	-0.215	0.203	0.99	17
G10	1.64	0.801	0.03	-0.001	0.258	0.071	0.391	0.26	13
G11	1.56	0.925	0.10	-0.042	0.453	-0.145	-0.339	0.46	25
G12	1.65	0.954	0.01	0.095	-0.064	0.147	-0.121	0.19	8
G13	1.70	1.231	0.13	-0.381	-0.043	0.452	-0.412	0.70	17
G14	1.79	0.958	0.12	0.400	-0.005	-0.373	-0.273	0.73	15
G15	1.64	1.23	0.21	0.389	-0.596	-0.376	0.041	0.93	25
G16	1.69	1.302	0.09	-0.461	-0.144	-0.139	-0.246	0.86	20
G17	1.55	0.812	0.02	0.160	0.066	-0.053	-0.002	0.30	20

Fig. 1 represents the AMMI biplot for grain yield of mustard genotypes grown in six environments. The mean performance and IPCA1 scores for both the genotypes and environments used to construct the biplots are presented in Table 6. In AMMI biplot presentation, when a variety and environment have the same sign on IPCA1 axis, their interaction is positive and if different their interaction is negative. If a variety or an environment has a IPCA1 score of nearly zero, it has small interaction effects and thus considered as stable over wide range of environments. However, varieties with high mean performance and large IPCA1 scores were considered as having specific adaptability to favorable environments. From this study, four genotypes G8, G15, G9 and G16 were positively interacted with Environment A, B and D whereas other genotypes interact with these environments negatively. In similar fashion the rest genotypes were positively interacted with environment C, E and F. Those genotypes found around the origin are considered to be more stable. G4, G7, G8, G9 and G14 gave mean seed yield above the grand mean. However, regarding their stability G4, G14, G8 and G9 were though they had high mean performance these genotypes are more suited to specific environments. On the other hand G7 which gave the highest grain yield and having lower GSI is considered as the most stable genotypes for all the environments under study.

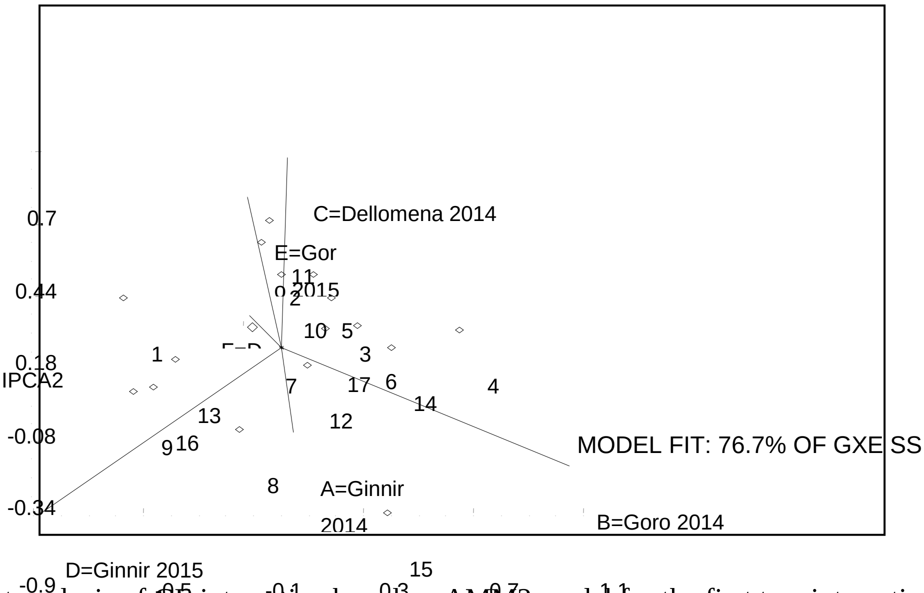

Fig. 1. Biplot analysis of GE interaction based on AMM2 model for the first two interactions principal component scores.

Conclusion

This paper demonstrated the usefulness of AMMI model, and biplot analyses in interpretation of grain yield data from a multi environment experiment in identifying stable genotypes. The AMMI model analysis provided estimates of the magnitude and significance of the effects of GE interaction and its interaction principal components relative to G and E effects. Stability and adaptability of genotypes were estimated through AMMI biplots. Generally, based on mean grain yield, coefficient of regression and deviation from regression, ASV and GSI genotype G7 is the genotype with well adaptability in all the studied environments and therefore selected for the possible release in the coming cropping season.

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Grain Yield Stability and GxE Interaction Study in Black Seeded Finger Millet (*Eleusine Coracana Sub Spp. Coracana)* Genotypes

Kebede Dessalegn[1]*, Dagnachew Lule[2], Girma Chemeda[1], Girma Mengistu[2], Kassa Mamo[1] Megersa Debela[1] and Chemeda Birhanu[1]

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

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

**Corresponding author: E-mail: kebelem@gmail.com*

Abstract

Field trial was conducted using twelve black seeded finger millet (Eleusine coracana)genotypes across two locations (Bako and Gute) for three years (2014 - 2016) to identify stable high yielding and widely adaptable genotypes. These genotypes were evaluated against local and standard checks (Degu) for grain yield, disease reaction and other agronomic traits. The additive main effect and multiplicative interaction (AMMI) model analysis of variance revealed highly significant (P≤0.01) variations among environments, genotype, GxE interaction and Interaction Principal Component Analysis (IPCA-I). This indicates that, the genotypes respond differently over environments and the test environments are highly variable. Only the first IPCA-I was significant (p < 0.01) and contributed to 48.39 % of the total genotype by environment interaction. It is found that BKFM0020, Acc. BKFM0006 and Acc. BKFM0010 were high yielder, have IPCA value closer to zero. Analysis using Eberhart and Russell model showed that genotypes BKFM0020, Acc. BKFM0006 and Acc. BKFM0010 were the most stable. Further, those selected potential candidate genotypes showed resistance to blast which is a major threat for finger millet production particularly in western Ethiopia. Genotype and genotype by environment interaction (GGE) analysis also revealed that these candidate genotypes were stable and high yielder. Therefore these genotypes were selected for possible release in the tested areas of western Oromia and similar agro-ecologies.

Keyword: Genotypes; Finger millet *(Eleusinecoracana); Magnaportheoryze*, GxE, GGE biplot, AMMI

Introduction

Fingermillet (*Eleusinecoracana* (L.)Gaertn) is an allotetraploid (2n = 4× = 36) annual cereal crop that includes two distinct subspecies: subsp. *Coracana* (cultivated finger millet) and subsp. *Africana* (wild finger millet) (Hilu, 1994). It is potentially a climate-resilient with highly nutritious and antioxidant properties (Kumar *et al*, 2017). Very importantly, finger millet grain is gluten-free, rich in calcium, fiber, iron and, has excellent malting qualities (Chandrashekar, 2010 and Pradhan, *et al*, 2010). Beside its importance there are production limiting factors and productivity of finger millet crop including blast disease caused by *Magna porthegrisea (anamorph pyriculariagrisea).*Limited availability of stable high yielding and disease tolerant finger millet variety is one of the major production constraints in the country.

Exploitation of genetic variability is the most important tool in plant breeding and this has to be inferred by phenotypic expression. The performance of a genotype is dependent on its genetic potential, the environment, and the interaction between the genotype and the environment (Yan, 2001; Yan and Hunt, 2001). Genotypes by environment (GxE) interactions are considered to be among the major factors limiting response to selection and the efficiency of breeding programs. Plant breeders need to identify adaptable and stable high yielding genotypes with other desirable traits under varying environmental conditions prior to release as a variety (Flores *et al.*, 1998; Mustapha *et al.*, 2001).

An appropriate analytical model such as additive main effects and multiplicative interaction (AMMI) can treat both the additive main effect and multiplicative interaction component employing the analysis of variance (ANOVA) and Interaction Principal Components (IPCA) (Gauch and Zobel, 1996). Furthermore, AMMI bi-plot and GG bi-plot analysis are considered as an effective graphical tool to diagnose genotype by environment interaction patterns (Gauch and Zobel, 1996; Yuksel *et al.*, 2002. Also the regression model suggested by Eberhart and Russell (1966) allows for the computation of a complete analysis of variance with individual stability regression coefficient (bi) estimates and deviation from regression line (s^2di). The model considers a stable variety as the one with a high mean yield, bi = 1 and $s^2di = 0$. The Eberhart and Russell (1996) model and AMMI stability analysis could be the preferable tools to identify stable, high yielding and adaptable genotype (s) for varied or specific environments. The plant breeders need to identify adaptable and stable high yielding genotypes with other desirable traits under varying environmental conditions prior to release as a variety (Flores *et al.*, 1998; Showemimo *et al.*, 2000; Mustapha *et al.*, 2001). Therefore, Bako Agricultural Research Center collected different accessions of black seeded finger millet in order to address farmers' preference for disease resistance and yield related traits. Thus, the primary objective of the study is to develop adaptable, stable high yielding and disease tolerant finger millet varieties for western Oromia and similar agro ecologies.

Materials and method

Twelve black seeded finger millet (*Eleusin ecoracana* (L.) Gaertn) genotypes including local and standard check (Degu) were tested at Bako and Gute for three cropping seasons (2014-2016). Genotypes were planted in a randomized completely block design (RCBD) with three replications in which each plot comprises of five rows having 5 m length. The spacing between rows and plants were 40 cm and 10 cm, respectively. Seed rate of 15 kg ha^{-1} and fertilizer rate of 110 kg ha^{-1} DAP (NPS) and 65 kg ha^{-1} UREA were used. UREA was applied in split form; half at planting and the rest half at 35 days after emergence. Management practices were done as per recommendations. The middle three rows were harvested and grain yield analysis was carried out using regression (Eberhart and Russell) and AMMI and GGE biplot to identify stable and widely adaptable high yielding genotypes.

Data Analysis: Grain yield analysis was carried out using regression (Eberhart and Russell, 1966) and AMMI models in Agrobase software (Agrobase, 2000) and GGEBiplot using Gstat 15th edition soft ware. Additive main effect and multiplicative interaction (AMMI) model: The AMMI model equation: $Yger = \mu + \alpha g + \beta e + \sum n\lambda n\gamma gn\delta en + \varepsilon ger + \rho ge$; Whereas: Yger is the observed yield of genotype (g) in environment (e) for replication (r); *Additive parameters:* μ is the grand mean; αg is the deviation of genotype g from the grand mean, βe is the deviation of the environment e; *Multiplicative parameters:* λn is the singular value for IPCA, γgn is the genotype eigenvector for axis n, and δen is the environment eigenvector; εger is error term and ρge is PCA residual. Eberhart and Russell Regression Model: $Yij = \mu i + biIj + S2dij$; where Yij is the mean performance of the ith variety (I = 1, 2, 3…, n) in the jth environment; μi is the mean of the ith variety over all the environments; bi is the regression coefficient which measures the response of ith variety to varying environments; S^2dij is the deviation from regression of ith variety in the jth environment and Ij is the environmental index of the jth environment.

Result and Discussion

Analysis of variance: The Analysis of Variance revealed significant differences between genotypes for the grain yield in all environments except Gute 2015 and 2016 (Table 1). Indicate that the presence of genetic variability among the genotypes in the wide-range of environments. The mean grain yield over the eleven tested genotypes ranged from 1.775 ton ha^{-1}(Degu) to 2.763ton ha^{-1} (BKFM0020) with a grand mean of 2.18 ton ha-1 (Table 1).

Table 1: Finger millet black seeded Genotypes Mean Grain yield (ton ha^{-1}) over location across years

	Mean Grain Yield tonha^{-1}							
	Bako			Gute				
Genot	2014	2015	2016	2014	2015	2016	Mean	BSS
215984	1.136	3.205	1.821	1.841	1.406	2.146	1.93	2
216035	1.301	2.531	2.177	2.557	1.657	2.535	2.13	1
216045	1.042	3.064	1.412	2.304	1.374	2.670	1.98	1
BKFM0001	1.469	3.342	2.184	3.059	1.204	2.427	2.28	1
BKFM0006	1.814	3.263	2.562	2.776	2.015	2.886	2.56	1
BKFM0010	1.196	3.694	2.247	3.228	1.376	2.508	2.38	1
BKFM0014	1.578	2.979	1.748	2.776	1.338	1.813	2.04	2
BKFM0020	2.560	3.849	2.721	2.889	2.146	2.410	2.78	1
BKFM0023	1.617	3.367	1.984	3.327	1.788	1.900	2.33	2
BKFM0024	0.938	2.92	1.669	3.189	1.458	2.44	2.10	2
Degu	1.590	2.636	1.926	1.526	1.343	1.628	1.78	2
Local	0.972	2.68	2.264	1.723	1.313	2.544	1.92	2
Mean	1.435	3.127	2.06	2.6	1.535	2.325	2.180	
LSD	0.579	0.794	0.712	0.977	0.7692	0.945	0.796	
CV	23.80	15.00	20.30	22.2	29.200	23.900	00.00	
F-value	**	*	*	**	ns	ns	ns	

BSS Blast Severity Score (1-5), CV=coefficient of variation, LSD= Least Significant Difference

Additive Main Effects and Multiplicative Interaction (AMMI) Model:The combined analysis of variance revealed highly significant (P≤0.01) variations among environments, Genotypes, and Principal Component Analysis IPCA-1 and IPCA-II but showed non-significant difference for genotype x environment interactions and the remaining (IPCA) interaction (Table 2). This indicates that, the genotypes respond differently over environments or genotypes responses were affected by an environment and the test environments are highly variable. The mean grain yield across six environments ranges from 1.435 ton ha^{-1} at Bako in 2014 to 3.127 ton ha^{-1} at Bako location in 2015 main cropping seasons (Table 1). i.e., not only the genotypes and locations, but also variations inseasons, and environmental conditions during different seasons significantly influence the grain yield performance. Similar results were reported by (Girma *et al*, 2011) in field pea and (Dagnachew *et al*, 2014) in Triticale.

In the present study, considerable percentage of GxE interaction (48.39%) is explained by IPCA-I followed by 28.63% and 13.91% for IPCA-II and IPCA-III, respectively. The first and second IPCA were significant, but the remaining IPCA axes were non-significant (Table 2). In the present study, we preferred the first IPCA used to describe genotype by environment interaction and placement on the bi-plots. Accordingly, the AMMI analysis result revealed that BKFM0020, BKFM006 and BKFM0010 were attained IPCA values (0.3531, -0.6458 and -0.2144) relatively close to zero and gave better yield, hence are better stable and widely adaptable genotypes across location with higher yield (Table 3).

BKFM0014, Acc. 216035, BKFM001 and Acc. 215984, with IPCA value close to zero (0.1353, -0.1529, 0.2232 and -0.2789) and relatively stable but gave lower grain.Whereas, Degu and BKFM0024 were gave lower mean grain yield and scored IPCA value deviating from zero (-0.6818 and 0.5276), indicated, these genotypes are not stable (Table 3). AsnakeWorku *et al*. (2013) and Yuksel *et al.* (2002) reported results that are in agreement with the present study. The environments of Bako 2015 gave the higher environmental mean yields (3.13 ton ha^{-1}). Similarly BKFM0020 followed by BKFM0010 gave the highest grain yield (3.849 and 3.694 ton ha^{-1}) respectively at Bako location during the 2015 cropping season than they did at other locations and years (Table. 1). Therefore, BKFM0020, BKFM0006 and BKFM0010 genotypes could be potential candidates for variety verification as revealed using AMMI model and observed in the actual field condition. Further analysis was made using the Eberhart and Russell regression model for confirmation of the result obtained by AMMI model and for proper recommendation of the genotypes.

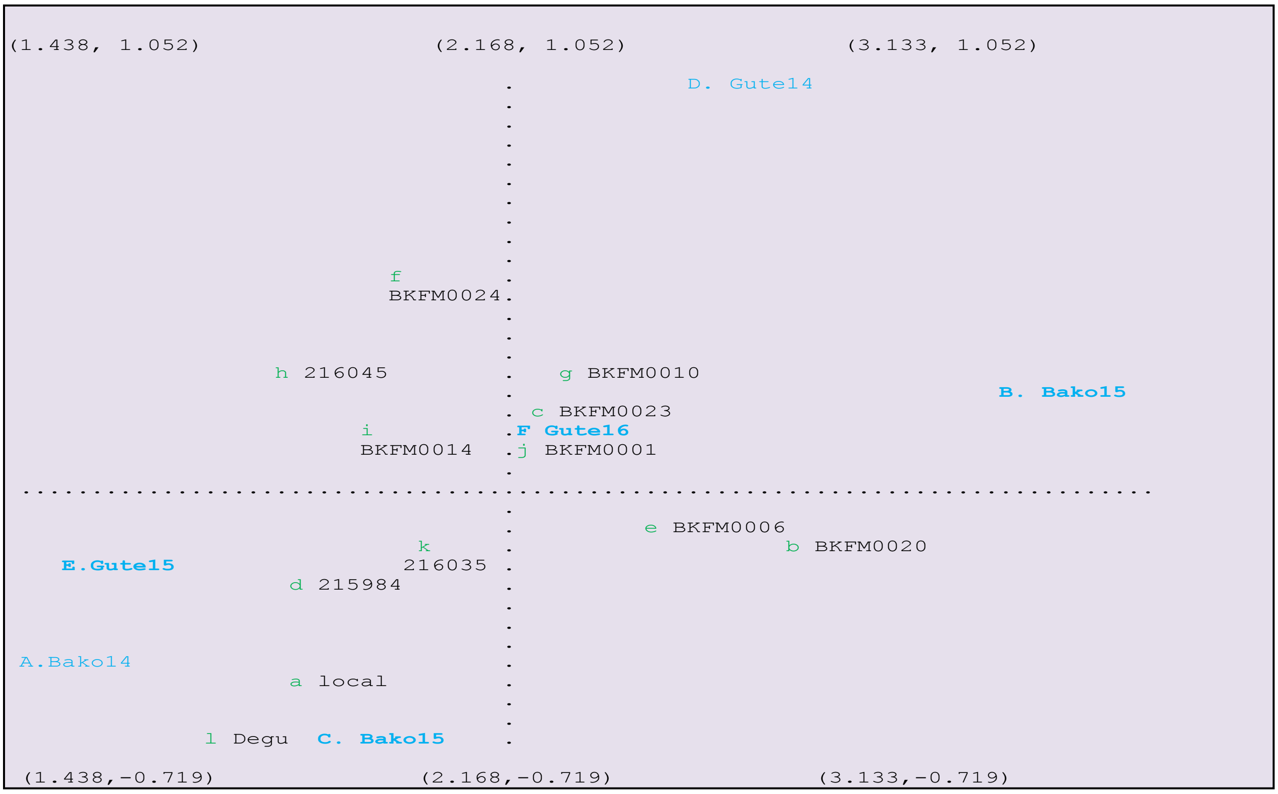
Table 2: Analysis of variance for Additive Main effects and Multiple Interaction (AMMI)

Source	Df	SS	MS	% GXE Explained	% cumulative interaction
Environments	5	75.606	15.121**		
Genotypes	11	16.710	1.519**		
Genotype x Envt. Interactions	55	23.544	0.428*		
IPCA I	15	11.394	0.760 **	48.39	48.39
IPCA II	13	6.740	0.518 *	28.63	77.02
IPCA III	11	3.276	0.298^{ns}	13.91	90.93
Residuals	132	35.702	0.270		

Grand mean = 2.18*; R2 = 0.7719; Coefficient of variation (CV, %) = 23.98%; *, ** = Significant at P < 0.05 and P < 0.01 levels, respectively.*

Table 3: Mean grain yield (GY) (ton ha^{-1} and IPCA1 scores of genotypes

Description of genotypes	Genotype name	IPCA1 score	Mean GY ton ha^{-1}
a	Local	-0.4924	1.92
b	BKFM0020	-0.3531	2.78
c	BKFM0023	0.3325	2.34
d	215984	-0.2789	1.93
e	BKFM0006	-0.2144	2.56
f	BKFM0024	0.5276	2.10
g	BKFM0010	0.6458	2.38
h	216045	0.3091	1.91
i	BKFM0014	0.1353	2.05
j	BKFM0001	0.2232	2.28
k	216035	-0.1529	2.13
l	Degu	-0.6818	1.78
Environments			
A	Bako 2014	-0.4415	1.44
B	Bako2015	0.2633	3.13
C	Bako2016	-0.7193	1.97
D	Gute 2014	1.0516	2.61
E	Gute2015	-0.2344	1.55
F	Gute2016	0.0804	2.31



AMMI Biplot showing genotypes grain yield stability and preferential adaptation over environment using Agro-base soft

Regression Analysis Based on Eberhart and Russell Model : Ebrehart and Russell (1996) model indicates, genotypes with high mean yield and regression coefficient (bi) equal to unity and deviation from regression (s^2di) approach to zero would be selected. An ideal genotype has the highest average grain yield, a regression coefficient (bi) value of approximately one and a mean square deviation from regression (s^2di) value close to zero. According to the model analysis result, pipeline genotypes BKFM0020, BKFM0006 and BKFM0010 were the most promising candidates gave high grain yield (2.78, 2.56 and 2.38 ton ha^{-1}), with regression coefficients (bi) approaching one (0.742, 0.8176 and 1.0578) and acceptable deviation from regression (s^2di) (0.0385, -0.0661 and -0.0248), respectively, implying that they are stable, widely adaptable and high yielder than the other genotypes (Table 3). Kebede *et al*., 2016 also reported similar result on stability and wide adaptability of finger millet genotypes tested over locations. These results are consistent with those reported by Farshadfar (2008).

The regression coefficients were significantly different from unity and square deviation from regression (s^2di) value deviate from zero for accession 216045 and regression coefficients was highly deviate from unity for Degu (Table 3). This indicates that these genotypes are less stable and adaptable over the environments. Genotypes, 215984, BKFM0023 and BKFM0014 were showed better stability and had wide adaptable over environment but inferior in grain yield. The result obtained using Eberhart and Russell (1996) model is highly agreed with AMMI model. Dogan *et al.* (2011) reported results that are in agreement with those in the present study.

Table 4: Analysis of variance for grain yield using the Eberhart and Russell Regression Model

Source	Df	SS	Mean square (MS)
Total	215	38.62	
Varieties	11	5.57	0.506**
Env.+ in Var.x Env.	60	33.05	0.551
Env. in linear	1	25.20	
Var. x Env. (linear)	11	2.01	0.184[Ns]
Pooled deviation	48	5.82	0.121

- *Grand mean* = 2.18; *R2* = 0.8239; *Coefficient of variation (CV, %) = 24.51%, ** = *, ** = Significant at P < 0.05 and P < 0.01 levels, respectively.*

Table 5: Regression coefficient (bi) and squared deviation from linearity of regression (s2di) by the test genotypes revealed using Eberhart and Russell model.

Genotypes	Regression coefficient (bi)	Squared deviations from regression (S2di)	Grain yield (ton ha-1)
Local	0.8531	0.1408	1.92
BKFM0020	0.7416	0.0385	2.78
BKFM0023	1.1115	0.0702	2.34
215984	1.0165	0.0095	1.93
BKFM0006	0.8176	-0.0661	2.56
BKFM0024	1.2493	0.0580	2.10
BKFM0010	1.0578	-0.0284	2.38
216045	1.1817	0.1351	1.91
BKFM0014	0.9784	-0.0117	2.05
BKFM0001	1.2590	-0.0387	2.28
216035	0.7171	-0.0184	2.13
Degu	0.4956	0.0358	1.78
Local	0.8531	0.1408	1.92
BKFM0020	0.7416	0.0385	2.78
BKFM0023	1.1115	0.0702	2.34

- *Standard error of beta = 0.2403; t = Tons; ha = Hectare*

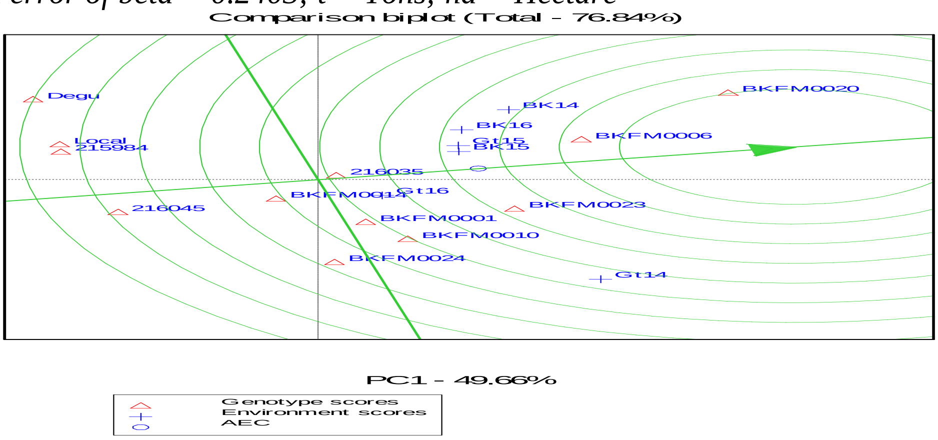


Fig 1:GGEBiplotanalysis showing grain yield stability of genotypes and environments

In generally, analysis, AMMI, GGE biplot and Eberhart and Russell model revealed that genotype BKFM0020, BKFM006 and BKFM0010 were stable and high yielding genotypes and therefore, selected and proposed to VVT for possible release under wider environmental conditions western Oromia and similar agro-ecologies of the country.

Conclusion

The experiment was conducted using twelve finger millet genotypes and evaluated against standard and local checks for three years at Gute and Bako. Analysis of variance (ANOVA) showed significant variation among the genotypes for grain yield at all environments except Gute 2015 and 2016.

The candidate finger millet genotypes (BKFM0020, BKFM0006and BKFM0010) gave high grain yield, showed better adaptability and stable performance than the standard and the local check. The genotypes were also relatively tolerant to blast disease. Considerable percentage of GxE interaction (48.39%) is explained by IPCA-I followed by 28.63 and 13.91% for IPCA-II and IPCA-III, respectively. The first and second IPCA were significant, but the remaining IPCA axes were non-significant. AMMI analysis result revealed that BKFM0020, BKFM006 and BKFM0010 were attaining IPCA values (0.3531, -0.6458 and -0.2144) relatively close to zero and gave better yield, hence are better stable and widely adaptable genotypes across location with higher yield. BKFM0014, Acc. 216035, BKFM001 and Acc. 215984, with IPCA value close to zero (0.1353, -0.1529, 0.2232 and -0.2789) relatively stable but gave lower grain yield. Whereas, Degu and BKFM0024 were gave lower mean grain yield and scored IPCA value deviating from zero (-0.6818 and 0.5276), indicated, these genotypes are not stable

According to Eberhart and Russell models (regression analysis), the genotypes BKFM0020, BKFM006 and BKFM0010 were stable and widely adapted. The regression coefficients were significantly different from unity and square deviation from regression (s^2di) value deviate from zero for 216045 and regression coefficients was highly deviate from unity for Degu . This indicates that the genotypes are less stable and adaptable over the environments.

Based on the regression, AMMI and GGE biplot analyses, therefore, BKFM0020, BKFM006 and BKFM0010 were the most stable and high yielding genotypes and as a result, they were proposed for variety verification at Bako, Gute and similar agro-ecologies.

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Combining Ability and Heterotic Grouping of Maize (*Zea mays* L.) Inbred Lines for Yield and Yield Related Traits

[1]Natol BakalaHundera, [2] Birahanu Abate, [3]Mandefro Nigussie

[1]Yabello Pastoral and Dry Land Agricultural Research Center

[2]School of Plant and Horticultural Science, Hawassa University, Ethiopia

[3] Oxfam America Deputy Regional Director, Ethiopia

Corresponding Author: E-mail:-natymartyko@gmail.comFax:+2510464460261, P.O.Box 85

Abstract

A field experiment was conducted at Hawassa during the 2015 cropping season to estimate combining ability of elite maize genotypes. Line x tester analysis involving 64 crosses was generated by crossing 32 selected maize inbred lines with two testers. The experiment was designed using alpha-lattice design with two replications. Analysis of variance showed that, mean squares of genotypes were significant for all traits except, ear position and cob per plant. Cross L31xT2 manifested highest mean grain yield (8.68 t/ha) and highest specific combining ability's effect (1.85 t/ha). L8 exhibited the highest GCA whereas L32 exhibited the lowest GCA effect. Based on their mean grain yield, and SCA L31XT2, L8XT1, L26XT1, L23XT2, L12XT2, L16XT1, L23XT1, L21XT1, L21XT2, L8XT2 and L15XT2 are promising crosses that could go forward across location testing or next steps in the breeding process.

Keywords: Combining ability, Cross, Heterotic grouping, Inbred line, Zea mays.

Introduction

Improving yield is the main objective of breeding programs in grain crops. Developing high yielding hybrids along with other favorable traits is receiving considerable attention to increase yield per unit area. Hybrid cultivars played a great role in increments of maize per unit area. Early in the development of hybrid maize, information on combining ability among maize germplasms is essential in maximizing the effectiveness of hybrid development (Kanagarasu*et al.*, 2010). Combining ability is one of the powerful tools to identify the best combiner parents in a series of its crosses and it provides information on the nature and magnitude of gene actions (Uddin *et al.*, 2008).

The two types of combining ability are: general combining ability (GCA) and specific combining ability (SCA). GCA is the average performance of parents in a series of crosses and SCA designates those cases in which certain combinations perform relatively better or worse than would be expected on the basis of average performance of parents. Heterotic grouping is a group of related or unrelated genotypes from the same or different populations that indicate similar combining ability and heterotic response when crossed with testers from other genetically diverse germplasm groups (Melchinger et al., 1998).

Line x tester mating design is an efficient procedure as it allows the inclusion of a large number of entries, estimate combining ability, gene effects, male and female relationship, heterotic grouping and aid to select desirable parents and crosses (Sharma, 2006). The knowledge of combining ability is important to develop desired hybrids (Mwimali*et al*., 2015). Thus, this study was carried out to estimate general and specific combining abilities of maize inbred lines for yield and yield related traits, to identify suitable parents for developing maize hybrids and to determine heterotic groups of inbred lines.

Materials and Methods

Inbred lines (32) coded as L1, L2…L32 and two testers coded as T1 and T2 were crossed in line x tester mating scheme to generate 64 crosses (Kempthorne, 1957). Crosses were planted along with similarly maturing checks BHQPY-545 and BH-546 at Hawassa. The house is situated in 7°4′N and 38°31′E latitude and longitude, respectively, at an altitude of 1700 m.a.s.l. in the central rift valley of Ethiopia. The experiment planted by using α-lattice design 6 x 11 arrangement with two replications (Kempthorne, 1957). Each block comprises of 11 units having 5.1 m long and 9.75 m width with the spacing of 0.75 m between rows and 0.30 m between plants. All cultural practices performed as per required. Data like days to maturity (DM), field weight, seed moisture content and thousand kernel weight (TKW) were collected plot based while data like plant height (PH), ear height (EH), ear length (EL), number of rows per ear (NRPE), ear diameter (ED) and number of kernels per row (NCPR) collected in plant bases. Biomass (BM) and grain yield (GY) calculated by using the following formula

Grain yield (t ha^{-1}) $=\frac{Fresh\ ear\ weight\ x\ (100-MC)x0.8*17\ x\ 10{,}000}{n\ x\ 85\ x\ 3.85\ x\ 100\ kg}$

Where: MC = Moisture content of grain at harvest, 0.8= Shelling percentage, 85= Standard moisture content of grain, n = number of plants harvested, 17= Total number of plants in a plot, 10000 = Area of hectare in square meters

Data Analysis

Analyses of variance for all crosses were computed using SAS computer software.

The mathematical model used for the combining ability analysis is given as:

$Y_{ijk}=\mu+r_k+l_i+t_j+(l\ x\ t)_{ij}+e_{ijk}$

Where; Y_{ijk}= the value of a character measured on ith x jth progeny in kth replication, μ = general mean, r_k=effect of kth replication, l_i = general combining ability (GCA) effects of ith line, t_j = general combining ability (GCA) effect of the jth tester, $(l\ x\ t)_{ij=}$ specific combining ability (SCA) of the ith line and jth tester, e_{ijk}= experimental error of ijkth observation

Estimation of general combining ability effects (GCA)

Means of each cross were used for analysis of combining ability. For each trait, general combining ability (GCA) effects were estimated using the formula suggested by (Patterson and Williams, 1976)

GCA of lines : $gi=\frac{Xi\ldots}{tr}-\frac{X\ldots}{lrt}$

Where; xi… total of ith lines over testers, x…= grand total, l = number of lines, t = number of testers and r= number of replications

GCA of testers: $gi=\frac{X.j.}{lr}-\frac{X\ldots}{lrt}$

Where; x.j =total of the jth tester over lines, x…= grand total, l = number of lines, j = number of testers and r = number of replications

Estimation of specific combining ability effects (SCA)

SCA effects were estimated as deviation of each cross mean from all hybrids mean adjusted for corresponding GCA of parents.

Specific combining ability of line x tester

$$Sij = \frac{Xij}{r} - \frac{Xi.}{tr} - \frac{Xj}{rl} + \frac{X\ldots}{lrt}$$

Where; xij= value of the j^{th} lines with i^{th} testers, Xi= total of i^{th} over all tester, xj..= total of j^{th} tester over all lines, x…= grand total crosses, l= number of lines, t= number of testers and r= number of replication.

Heterotic grouping: Groupings of inbred lines were conducting based on SCA effect of crosses and mean grain yield performance. Inbred lines showing positive SCA effect and with greater or equal mean grain yield with tester (A) CML 159 were grouped under heterotic group "A". Similarly, inbred lines displaying positive SCA effect with tester "B" and mean grain yield greater or equal to mean yield of the hybrid grouped under heterotic group "B" (Menkir*et al.,* 2008).

Results and Discussion

Mean squares due to crosses were significant P < .05 for days to maturity, number of rows per ear, number of kernels per row, ear length, grain yield, thousand-kernel weight and biomass. This indicates that, the crosses were sufficiently different from each other for these traits and hence, selection is possible to identify the most desirable crosses. In line with this finding, (Shushay *et al.* 2013) found significant differences among crosses for yield and yield related traits. The mean square due to lines showed significant P < .01 for traits like grain yield, thousand kernel weight, ear length and days to maturity (Table 1). Significant differences among lines indicate greater diversity in the parental lines. (Hailegebrial *et al.* 2015) found a significance difference between GCA effects of lines in grain yield, days to maturity, plant height, ear height, ear length, number of rows per ear and number of kernels per row. Different authors (Mosa, 2010 and Girma *et al.,* 2015) reported similar results. The mean square due to testers showed significant differences at P <.05 for days to maturity and ear diameter (Table 1). These results were consistent with (Melkamu *et al*., 2013). In contrast to this finding, (Shushay *et al.* 2013) and Ram *et al.* 2015) reported significance difference between testers in grain yield and ear height of maize.

Estimation of General Combining Ability Effects: Estimates of GCA effects of the 32 lines and 2 testers are presented in table 2. Line L8 exhibited the maximum GCA effect (1.97 t/ha) followed by L23 which exhibit (1.72 t/ha), whereas L32 exhibited the lowest GCA effect of all (-1.51 t/ha) followed by L2 which exhibit (-1.21 t/ha), the result revealed the existence of the best and poorest general combiners in the group of inbred lines studied, respectively.

Inbred lines possesses good GCA effect were L2, L12, L21, L23 and L31 based on grain yield which could be utilized in maize grain yield improvement programs. Both positive and negative GCA effects reported for grain yield in maize by several investigators (Chandel and Mankotia, 2014 and Melkamu *et al.,* 2013). In contrast to the current finding, (Bayisa, 2008) found non-significant GCA effects for grain yield in line x tester analysis of maize inbred lines. For days to maturity three lines L13, L18 and L27 showed negative GCA effects. Negative GCA effects indicate that they may be good sources of genes for earliness and positive GCA increases the tendency of late maturity. The current results are in general agreement with the findings of many researchers (Mosa, 2010; Rahman *et al.*, 2010 and Girma *et al.*, 2015) reported significant positive and negative GCA effects for days to maturity. The GCA estimates ranged from -18.55 to 23.95 cm in plant height. Among all lines, thirteen inbred lines showed positive GCA effects. Line, L5 and L31 showed significant positive GCA effects indicating that these lines significantly contributed to taller plant stature. On the other hand, nineteen lines showed negative GCA effects. Line L15 showed significant negative GCA effects, indicating that these lines contributed to reduced plant stature in their crosses. None of the testers showed significant GCA effects in plant height. In line with the present finding (Rahman *et al.*, 2010 and Girma *et al.,* 2015) found significant positive and negative GCA effects for plant height.

With respect to ear height, GCA estimate of lines ranged from -5.98 to 4.02cm (Table 2). Three lines L7, L11 and L30 showed negative and significant GCA effects, whereas, six lines L5, L8, L12, L17, L19 and L31 showed positive and significant GCA effect. L7 (-5.98 cm), L11(-4.84 cm) and L30 (-3.73 cm) were good general combiners while L8 and L12 showed the highest GCA effects (4.02 cm), which indicates the tendency to increase ear height.

Table 1. Mean squares for yield and yield related traits of 64 maize testcrosses and 2 checks evaluated at Hawassa, 2015

Source variation	df	DM (days)	PH (cm)	EL (cm)	NRPC (no)	NCPR (no)	ED (cm)	TSW (g)	GY (t/ha)	BM (t/ha)
Crosses	63	15.4**	441.3^{ns}	5.67*	0.54*	13.9*	0.13^{ns}	4579**	3.00**	3.44**
Line (GCA)	31	11.9**	414.3^{ns}	7.23**	0.46**	13.5*	0.12^{ns}	5626**	2.96**	2.96*
Tester(GCA)	1	40.5**	30.0^{ns}	0.28^{ns}	0.002^{ns}	5.28^{ns}	0.48*	6684^{ns}	5.48^{ns}	2.01^{ns}
Line x Tester (SCA)	31	18.0**	481.6^{ns}	4.24^{ns}	0.6**	14.5*	0.13^{ns}	3464^{ns}	295.60**	3.97*
Error	60	3.82	290.34	3.01	0.32	8.55	0.09	50.0	1.58	1.42
Cv		2.01	9.44	12.53	5.50	9.17	7.33	20.34	27.02	22.01

Table 2. Estimates of general combining ability effects for grain yield and yield related traits of maize lines and tester studied in line x tester crosses at Hawassa 2015

Lines	DM	PH(cm)	EH(cm)	EL(cm)	NRPC	NKPR	ED(cm)	TKW(g)	GY (t/ha)
L1	-0.42	-5.55	-1.98	-0.39	0.87**	-0.67	0.04	-2.70	-0.01
L2	2.33	-12.55	-1.23	-1.22	-0.33*	-1.77	-0.07	-1.45	-1.21**
L3	1.08	-13.05	-1.98	-0.68	0.17	0.63	-0.13	-30.20**	-0.32
L4	-0.67	-2.05	0.27	0.27	-0.03	1.98	-0.08	-8.95*	0.08
L5	-0.17	23.45*	3.52*	0.80	-0.28	-0.97	0.16	21.05**	0.51
L6	1.83	-8.05	-1.98	-3.26**	-0.33*	-2.82	-0.24*	-66.45**	-0.52
L7	-0.17	-5.55	-5.98*	-0.41	-0.23	-1.87	0.00	-21.45**	-0.54*
L8	1.83	16.95	4.02*	2.29**	0.27	1.93	0.31*	39.80**	1.97**
L9	0.58	-11.05	-1.73	-1.70	0.32*	-1.67	-0.14	-30.20**	-0.77*
L10	2.83	-7.05	-1.23	0.27	0.27	0.93	-0.09	-28.95**	-0.41
L11	5.08	-18.55*	-4.48*	-2.12**	-0.03	-1.47	-0.15	-33.95**	-0.72**
L12	-2.42	16.45	4.02*	1.19	0.02	1.78	0.20	41.05**	1.23**
L13	-0.92	-0.05	1.02	0.24	0.17	0.78	0.26*	49.80**	0.35
L14	1.58	3.45	0.27	-1.39	-0.38*	-0.97	-0.24*	-23.95**	-0.98**
L15	-2.42	3.45	0.52	-0.27	0.27	-0.47	0.13	9.80*	0.43
L16	-1.17	-2.05	1.02	0.65	-0.08	0.48	0.18	6.05	0.40
L17	0.83	4.45	3.52*	1.16	0.32	0.18	0.18	24.80**	-0.77**
L18	-0.67	7.45	-0.23	0.24	0.27	-2.62	0.08	21.05**	0.32
L19	-0.17	2.45	3.77*	-1.65*	-0.38*	-1.27	-0.16	-38.95**	-0.19
L20	0.33	-2.05	-0.48	-0.21	-0.18	0.78	-0.26*	-50.20**	-0.70*
L21	-3.42	1.45	-2.48	2.44**	0.17	0.98	0.18	49.80**	1.36**
L22	-0.67	-2.05	2.52	0.73	-0.43*	-0.07	-0.01	-7.70*	-0.0001
L23	-2.17	10.95	0.27	2.89**	-0.03	3.23*	0.28*	116.05**	1.72**
L24	-0.42	-9.55	1.27	-0.46	-0.23	-1.62	-0.33**	-28.95**	0.49
L25	0.08	-4.05	-0.98	-0.24	-0.7**	-2.12	-0.05	29.80**	-0.64*
L26	-0.17	5.95	-0.23	1.91*	0.07	1.18	-0.08	41.05**	0.20
L27	-2.17	-1.55	-1.23	-0.31	0.17	4.78**	-0.13	-33.95**	-0.60*
L28	-0.67	3.45	0.27	0.54	0.62*	1.03	0.14	-12.70**	0.08
L29	-0.92	-2.05	-0.98	-1.14	-0.03	-1.02	-0.14	-25.20**	-0.93**
L30	0.33	-6.55	-3.73*	-0.29	-0.13	0.73	0.03	-12.70**	0.25
L31	1.33	23.95*	3.77*	0.89	-0.03	2.73	0.09	28.55**	1.48**
L32	-0.17	-10.55	1.02	-0.77	-0.23	-2.87	-0.03	-20.20**	-1.51**
SE (m±)	0.84	6.90	2.89	0.61	0.19	1.07	0.09	2.50	0.19
SE (gi – gj)lines	1.38	12.05	6.06	1.23	0.40	2.07	0.21	5.00	0.84
Tester 1	0.56	-0.48	-0.88	0.05	-0.02	-0.20	0.06	7.2**	0.21**
Tester 2	-0.56	0.48	0.88	-0.05	0.02	0.20	-0.06	-7.2**	-0.21**
SE m±	0.24	2.13	1.07	0.22	0.07	0.37	0.04	0.88	149.26
SE(gi – gj)	0.35	3.01	1.51	0.31	0.10	0.52	0.05	1.25	0.211

*SE (m±)= standard error of mean, SE (gi – gj) lines =standard error of difference in lines, SE (gi – gj) testers = standard error of difference in testers **highly significant P < .01 * significant P≤ 0.05*

The GCA estimates in ear length ranged from -3.26 to 2.89 cm (Table 2). Four lines, (L8, L21, L23 and L26) showed positive and significant GCA effects. Positive GCA effect contributes to increased grain yield in its hybrid combinations. On the other hand, three lines (L8, L11 and L19) showed negative GCA effects. The GCA estimates of number of rows per cob of parental lines ranged from -0.73 to 0.62 (Table 2). Three lines (L1, L9 and L28) showed positive and significant GCA effects. Similarly, Girma *et al.* (2015) reported significant positive and negative GCA effects in ear height and number of rows per cob.

Positive GCA effect in the number of rows per cob is very important yield parameter directly contributes to increased grain yield in its hybrid combinations. In contrast, six lines (L2, L6, L14, L19, L22 and L25) showed significant negative GCA effects (Table 2). Similarly, Melkamu *et al.*

(2013) reported significant positive and negative GCA effects in ear height and number of rows per cob. The GCA estimates of inbred lines ranged from -2.87 to 4.78 in number of kernels per rows (Table 2). Two lines (L23 and L27) showed positive and significant GCA effects indicate good general combination for this trait and contributes to increased grain yield in its hybrid combinations. Hence, lines with high GCA effects for this trait can be suitable parents for hybrid formation as well as for inclusion in future breeding programs. Such parents contribute favorable alleles in the process of synthesis of new varieties. Habtamu and Hadji (2010) reported similar result. The GCA of inbred lines ranged from -0.33 to 0.31cm in ear diameter (Table 2). Three lines L8, L13 and L23 showed positive and significant GCA effects to the desirable direction and contribute to increased grain yield in its hybrid combinations. Four lines L6, L14, L20 and L24 showed significant and negative SCA effects (Table 2). (Kamara *et al.* 2010) also reported significant positive and negative ear diameter. The GCA effects of inbred lines ranged from -66.45 to 116.05 g in thousand-kernel weight (Table 2). Lines L23, L13 and L21 were good general combiners while L6, L19 and L20 were poor combiners for thousand-kernel weight (Table 2). Lines with positive GCA effect could have vital potential for genetic improvement of this trait in breeding programs. Tester 1 is a best combiner for plant height (-0.48), ear height (0.88), ear length (0.05), ear diameter (0.06), thousand kernel weight (7.20), grain yield (0.21) while Tester 2 is a best combiner for days to maturity (-0.56), number of kernels per row (0.02) and number of rows per cob (0.2) (Table 2). Shushay et al. (2013) found best combiner tester for thousand kernels. Wali et al. (2010) reported best combiner tester for grain yield, number of rows per cob and ear length.

Estimation of Specific Combining Ability Effects: With respect to grain yield, both positive and negative significant estimates of SCA effects observed among crosses. Estimation of SCA effects in crosses ranged from -1.85 to 1.85 t ha^{-1} (Table 3). Crosses L6xT1, L15xT2, L17xT1, L25xT2, L26xT1 and L31xT1) were best specific combiners while crosses like L6xT2, L15xT1, L17xT2, L25xT1, L26xT2 and L31xT2 were poor specific combiners. Best combiner crosses in estimation of SCA to use in maize improvement program. A current finding is pact with the report of (Shushay *et al.,* 2013). For days to maturity, estimates of SCA effects ranged from (-4.69 to 4.69 days) (Table 3). Four crosses L10xT1, L11xT1, L12xT1, L18xT2 and four crosses L1xT2, L11xT2, L12xT2 and L18xT1 had significantly positive and negative SCA effects difference respectively. Significant negative SCA effects in days to maturity indicate that these crosses were good specific combiners and were effective if exploited to develop early maturing maize varieties. In agreement with current study, Melkamu *et al.* (2013) reported significant positive and negative estimates of SCA effects for days to maturity. Estimates of SCA effects in plant height crosses L2xT2 (29 cm) and L2xT1 (-29 cm) were good and poor specific combiners, respectively (Table 3). A cross with highest negative SCA effect is advantageous in case of lodging resistance development. Ali *et al.* 2012 and Ali *et al.* 2014 reported significant positive and negative SCA effects in maize.

For ear height crosses, L19xT2 (15.63cm) best specific combiner while cross L19xT1 (-15.63cm) poor specific combiner (Table 3). Positive SCA effects in ear height (ear placement) causes lodging while negative SCA effect increases wild animal attack, which could ultimately affect the quantity and quality of final grain yield. Likewise, EL-Hosary and Elgammaal (2013) and Shushay *et al.* (2013) reported significant negative and positive estimates of SCA effects. The estimates of SCA effects for crosses in number of row per cob ranged from -0.88 to 0.88 (Table 3). Crosses with significant positive SCA effects were (L7xT2, and L31xT2) were good specific combiners, while crosses with significant negative SCA effects (L7xT1 and L31xT1) were poor specific combiners for number of rows per cob (Table 3). For a number of kernels per row estimates of SCA effects ranged from -4.05 to 4.05 (Table 3). Cross with significant positive SCA effects (L25xT1) were good specific combiner. Similarly, (Shushay *et al*. 2013) reported significant positive and negative SCA effect for number of kernels per row. Estimates of SCA effects for ear diameter ranged from -0.37 to 0.37cm. Six crosses showed significant estimates of SCA effects (Table 3). Good specific combiner was L23xT2, while the poorest was L23xT2 cross. Crosses with positive and significant SCA effects L10xT2, L17xT1 and L23xT2 had desirable trait for this trait. In agreement with current funding Tajwar and Chakraborty (2013) found significant positive and negative SCA effects in maize ear diameter. Estimates of SCA effects of thousand-kernel weight of crosses ranged from -57.9 to 57.9 g (Table 3). Fifty crosses exhibited significant estimates of SCA effects (Table 3). Good specific combiner was L11xT1, while the poorest cross was L11xT2. Crosses with positive and significant SCA effects for this trait are desirable as this trait directly contributes to grain yield of maize. Rovaris et al. (2014) reported significant positive and negative SCA effects from thousand-kernel weigh

Table 3. Specific combining ability effects for 64 crosses in respect of thirteen traits tested at Hawassa 2015 cropping season

Crosses	DM (days)	PH (cm)	EH (cm)	EL (cm)	NRPC (no)	NCPC (no)	ED (cm)	TSW (g)	GY (t/ha)
L1xT1	0.44	7.98	6.88	0.87	-0.58	-0.30	-0.20	-0.90	0.07
L1xT2	-0.44	-7.98	-6.88	-0.87	0.58	0.30	0.20	0.90	-0.07
L2xT1	-0.81	-29.0**	-11.63*	-1.46	-0.38	-1.10	-0.08	-12.15*	-0.10
L2xT2	0.81	29.0**	11.63*	1.46	0.38	1.10	0.08	12.15*	0.10
L3XT1	-1.06	-0.52	-2.13	0.30	-0.08	0.80	0.09	-23.4**	-0.21
L3XT2	1.06	0.52	2.13	-0.30	0.08	-0.80	-0.09	23.4**	0.21
L4XT1	1.19	4.48	3.38	-0.05	0.02	-0.15	-0.06	-2.15	-0.29
L4XT2	-1.19	-4.48	-3.38	0.05	-0.02	0.15	0.06	2.15	0.29
L5XT1	-1.81	-15.02*	-3.13	-1.64	0.27	0.10	-0.06	-39.7**	-0.21
L5XT2	1.81	15.02*	3.13	1.64	-0.27	-0.10	0.06	39.7**	0.21
L6XT1	0.69	8.48	7.88	1.45	0.02	0.55	0.19	17.9**	1.24**
L6XT2	-0.69	-8.48	-7.88	-1.45	-0.02	-0.55	-0.19	-17.9**	-1.24**
L7XT1	-1.31	-9.02	3.88	-0.80	-0.88*	-3.20	-0.14	-22.2**	-0.86*
L7XT2	1.31	9.02	-3.88	0.80	0.88*	3.20	0.14	22.2**	0.86*
L8XT1	-0.81	11.48	5.88	-0.09	0.22	1.10	0.08	-5.90	0.52
L8XT2	0.81	-11.48	-5.88	0.09	-0.22	-1.10	-0.08	5.90	-0.52
L9XT1	1.44	7.48	-5.63	0.44	0.67	0.00	0.08	31.6**	0.54
L9XT2	-1.44	-7.48	5.63	-0.44	-0.67	0.00	-0.08	-31.6**	-0.54
L10XT1	4.69**	2.48	2.38	-0.17	0.22	0.00	-0.31*	-17.2**	-0.97*
L10XT2	-4.69**	-2.48	-2.38	0.17	-0.22	0.00	0.31*	17.2**	0.97*
L11XT1	4.44**	3.98	-1.13	1.03	-0.48	0.70	0.24	57.9**	0.82*
L11XT2	-4.44**	-3.98	1.13	-1.03	0.48	-0.70	-0.24	-57.9**	-0.82*
L12XT1	3.44*	1.98	1.88	-0.35	0.07	-1.85	0.01	-4.65	-0.42
L12XT2	-3.44*	-1.98	-1.88	0.35	-0.07	1.85	-0.01	4.65	0.42
L13XT1	2.44	-7.52	-2.13	-0.90	0.52	0.45	-0.04	-40.9**	0.49
L13XT2	-2.44	7.52	2.13	0.90	-0.52	-0.45	0.04	40.9**	-0.49
L14XT1	-0.06	13.98	-1.63	1.24	-0.33	2.40	0.24	55.4*	0.70
L14XT2	0.06	-13.98	1.63	-1.24	0.33	-2.40	-0.24	-55.4*	-0.70
L15XT1	-2.06	-9.02	-4.13	-0.73	0.42	-2.90	-0.03	-13.4*	-1.03**
L15XT2	2.06	9.02	4.13	0.73	-0.42	2.90	0.03	13.4*	1.03**
L16XT1	0.19	-5.52	-6.13	0.77	-0.03	0.75	0.10	45.4**	0.88*
L16XT2	-0.19	5.52	6.13	-0.77	0.03	-0.75	-0.10	-45.4**	-0.88*
L17XT1	0.19	7.98	-1.13	1.13	0.37	2.55	0.35*	39.1**	1.71**
L17XT2	-0.19	-7.98	1.13	-1.13	-0.37	-2.55	-0.35*	-39.1**	-1.71**
L18XT1	-3.81*	-2.02	2.38	0.10	-0.18	1.55	0.01	-27.2**	-0.56

Crosses	DM (days)	PH (cm)	EH (cm)	EL (cm)	NRPC (no)	NCPC (no)	ED (cm)	TSW (g)	GY (t/ha)
L18XT2	3.81*	2.02	-2.38	-0.10	0.18	-1.55	-0.01	27.2**	0.56
L19XT1	-0.31	-14.02*	-15.63**	0.13	0.37	-0.90	0.10	0.35	-0.30
L19XT2	0.31	14.02*	15.63**	-0.13	-0.37	0.90	-0.10	-0.35	0.30
L20XT1	0.69	8.48	1.88	1.25	-0.13	1.15	-0.03	14.1*	0.72
L20XT2	-0.69	-8.48	-1.88	-1.25	0.13	-1.15	0.03	-14.1*	-0.72
L21XT1	-2.56	-4.02	6.88	-1.34	0.32	-1.05	0.07	11.60*	-0.20
L21XT2	2.56	4.02	-6.88	1.34	-0.32	1.05	-0.07	-11.60*	0.20
L22XT1	-0.81	3.48	0.88	1.46	0.12	2.70	0.21	49.1**	0.83*
L22XT2	0.81	-3.48	-0.88	-1.46	-0.12	-2.70	-0.21	-49.1**	-0.83*
L23XT1	-2.31	3.48	1.38	-1.35	0.52	-3.30	-0.37*	-39.7**	-0.48
L23XT2	2.31	-3.48	-1.38	1.35	-0.52	3.30	0.37*	39.7**	0.48
L24XT1	-2.56	2.98	2.38	-0.58	-0.28	-1.35	0.07	-27.2**	-0.88*
L24XT2	2.56	-2.98	-2.38	0.58	0.28	1.35	-0.07	27.2**	0.88*
L25XT1	1.44	-3.52	-1.13	-1.68	0.22	-4.05*	-0.29	-15.9**	-1.25**
L25XT2	-1.44	3.52	1.13	1.68	-0.22	4.05*	0.29	15.9**	1.25**
L26XT1	-2.81	27.5**	8.38	0.95	0.42	3.05	0.29	30.4**	1.74**
L26XT2	2.81	-27.5**	-8.38	-0.95	-0.42	-3.05	-0.29	-30.4**	-1.74**
L27XT1	2.69	9.98	2.38	-0.25	-0.08	-1.15	-0.01	5.35	-0.73
L27XT2	-2.69	-9.98	-2.38	0.25	0.08	1.15	0.01	-5.35	0.73
L28XT1	-1.81	4.98	4.38	1.50	-0.53	3.30	-0.20	1.60	0.39
L28XT2	1.81	-4.98	-4.38	-1.50	0.53	-3.30	0.20	-1.60	-0.39
L29XT1	-1.06	-0.52	-1.13	0.26	0.02	2.75	-0.15	-13.4*	-0.07
L29XT2	1.06	0.52	1.13	-0.26	-0.02	-2.75	0.15	13.4*	0.07
L30XT1	0.19	-1.02	-4.63	1.03	0.42	-0.60	0.18	21.6**	0.67
L30XT2	-0.19	1.02	4.63	-1.03	-0.42	0.60	-0.18	-21.6**	-0.67
L31XT1	1.69	-22.5**	-8.63	-0.95	-0.88*	-0.80	-0.10	-29.65**	-1.85**
L31XT2	-1.69	22.5**	8.63	0.95	0.88*	0.80	0.10	29.65**	1.85**
L32XT1	0.19	-8.02	6.88	-1.61	-0.28	-1.30	-0.24	-45.9**	-0.90*
L32XT2	-0.19	8.02	-6.88	1.61	0.28	1.30	0.24	45.9**	0.90*
SE(m±)	1.19	9.76	4.09	0.87	0.27	1.51	0.12	3.54	0.27
SE(Sij –Skl)	1.95	17.04	8.57	1.73	0.57	2.92	0.30	7.07	1.19

SE (m) = standard error of mean, SE (S_{ij}-S_{kl}) = standard error of difference

Heterotic Groups: The results exhibited that, from thirty-two inbred lines, twelve inbred lines viz, L6, L8, L11, L13, L16, L17, L20, L22, L26, L28 and L30 were showing positive SCA effects, exhibiting negative SCA effects with CML 159 and grain yield greater than the mean grain yield when crossed to CML144. On the other hand fourteen inbred lines viz. L4, L5, L7, L10, L12, L15, L18, L19, L21, L23, L24, L25, L27 and L31 showed positive SCA effects, exhibited negative SCA effects with CML 144 and grain yield greater than the mean yield of lines when crossed to CML 159 (Table 4). Six inbred lines viz. L2, L3, L9, L14, L29 and L32 showed non-significant SCA and yield less than the mean grain yield when crossed to both testers were classified as C group (Table 4). Legesse *et al.* (2009) classified inbred lines into different heterotic groups based on mean grain yield and estimation of SCA effects. Similarly, Gurung and Koirala (2002) were classified ten inbred lines into three main groups A, B and AB heterotic groups based on SCA of grain yield and mean grain yield.

Table 4. Heterotic grouping of maize lines corresponding to testers

Lines	CML144 (group "B")	SCA	CML159 (group "A")	SCA	Heterotic group
L1	5.74	0.07	5.19	-0.07	B
L2	4.45	-0.1	4.24	0.1	C
L3	5.24	-0.21	5.25	0.21	C
L4	5.56	-0.29	5.73	0.29	A
L5	6.06	-0.21	6.07	0.21	A
L6	6.49	1.24**	3.59	-1.24**	B
L7	4.37	-0.86*	5.67	0.86*	A
L8	8.25	0.52	6.81	-0.52	B
L9	5.53	0.54	4.03	-0.54	C
L10	4.39	-0.97*	5.92	0.97*	A
L11	5.86	0.82*	3.81	-0.82*	B
L12	6.58	-0.42	7.00	0.42	A
L13	6.61	0.49	5.22	-0.49	B
L14	5.49	0.7	3.67	-0.7	C
L15	5.17	-1.03**	6.82	1.03**	A
L16	7.04	0.88*	4.88	-0.88*	B
L17	6.71	1.71**	2.88	-1.71**	B
L18	5.53	-0.56	6.23	0.56	A
L19	5.27	-0.3	5.46	0.3	A
L20	5.79	0.72	3.93	-0.72	B
L21	6.93	-0.2	6.91	0.2	A
L22	6.60	0.83*	4.52	-0.83*	B
L23	7.00	-0.48	7.56	0.48	A
L24	5.37	-0.88*	6.72	0.88*	A
L25	3.88	-1.25**	5.97	1.25**	A
L26	7.70	1.74**	3.82	-1.74**	B
L27	4.44	-0.73	5.48	0.73	A
L28	6.24	0.39	5.04	-0.39	B
L29	4.77	-0.07	4.49	0.07	C
L30	6.69	0.67	4.94	-0.67	B
L31	5.39	-1.85**	8.68	1.85**	A
L32	3.36	-0.90*	4.75	0.90*	C
Mean	5.77		5.35		

* and ** significant at (P≤0.05 and 0.01) respectively

Conclusion

The current study revealed the presence of considerable amount of variability among crosses and lines. These permit us to select promising lines and hybrids for future use. SCA variance played greater role in controlling most of the studied characters. The significant differences among hybrids and lines for most traits indicate the possibility of selection for improvement of yield and yield related traits. Inbred lines identified for desirable GCA effects were L1, L8, L9, L21, L23, L27 and L28. For grain yield, inbred lines L8 and L23 were the best general combiners. These lines also showed positive and highly significant GCA effects for ear length, ear diameter and thousand-kernel weight. These lines can possibly be used to develop high yielding and early maturing synthetic variety. Five crosses viz., L31XT2, L26XT1, L17XT1, L25XT2 and L6XT1 have shown high positive SCA effects for grain yield involving parents of positive GCA effects can be exploited for the development of single cross hybrids. The results of the current study identified inbred lines with positive GCA that can be used for OPV development and potential crosses with reasonable SCA that can be advanced to the next stage of breeding program. In addition, the information from this study may possibly be useful for researchers who would like to advance these breeding materials.

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Standard Heterosis of Maize (*Zea mays* L.) Inbred Lines for Grain Yield and Yield Related Traits at Southern Ethiopia

[1]Natol BakalaHundera[2] Birahanu Abate, [3]Mandefro Nigussie
[1]Yabello Pastoral and Dry Land Agricultural Research Center
[2]School of Plant and Horticultural Science, Hawassa University, Ethiopia
[3] Oxfam America Deputy Regional Director, Ethiopia
Corresponding Author: E-mail:-natymartyko@gmail.comFax:+2510464460261, P.O.Box 85

Abstract
Maize (Zea mays L.) is important cereal crop produced as most staple food in the world. A field experiment was conducted at Hawassa national maize research sub center site during 2015 cropping season for different agronomic traits. A line x tester analysis involving 64 hybrids generated by crossing 32 elite maize inbred lines with two testers. The experiment was planted by using alpha-lattice design (6x11) with two replications. Sixty four hybrids with 2 checks were tested in objected to estimate standard heterosis for yield and yield related traits. From this study, considerable standard heterosis was observed for all studied traits. The highest significant positive standard heterosis for grain yield was manifested by L31XT2 (102.33%). Hybrid L31XT2 was the best combination as evaluated through combining ability and standard heterosis. The presence of substantial heterotic potential that could be exploited in maize breeding program and possibility of developing desirable hybrid combinations and synthetic varieties through crossing and or recombination of inbred lines with desirable traits of interest.

Key words: Heterosis; hybrid; Line x tester; Maize; Yield.

Introduction

Maize (*Zea mays L)* is plant of the tribe *Maydeae* of the grass family *Poaceae*. Maize is cultivated globally leading total yield production of crop and third most important food crops after wheat and rice. It is a versatile crop grown over a range of agro climatic zones. The first three leading countries in production of maize in the world are United States, China, and Brazil and they produce approximately 79% of total maize production per year of the world.

Maize is one of the most important crop and mostly grown into six agro ecological zones based on altitude and annual rainfall in Ethiopia (MOA, 2005). Major cereal crops grown in Ethiopia are Teff (*Eragrostistef*), Maize (*Zea mays* L), Wheat (*Triticumaestivum* L.) and Sorghum (*Sorghum bicolor* L.). Maize is second in area of production whereas it ranks first in total grain production, followed by teff, wheat and sorghum (CSA, 2014).The popularity of maize in Ethiopia is partly because of its high value as a food, feed and source of fuel for rural families. Approximately 88 % of maize produced in Ethiopia is consumed as food, both as green and dry grain.

Hybrid varieties are the first generations of (F1) from crosses between two pure lines, inbred lines, open pollinated varieties, clones, or other populations that are genetically dissimilar. The production and development of hybrid maize is one of the breakthroughs and greatest accomplishments of plant breeding. Breeding strategies based on selection of hybrids require expected level of heterosis. Heterosis is important in breeding program especially for hybrid pollinated crop and is a great achievement to meet the world's food needs (Duvick, 1999). Standard heterosis is estimated over standard commercial hybrid. The study of standard heterosis among maize germplasm is essential in maximizing the effectiveness of hybrid cultivars selection especially in hybrid pollinated crops. It has practical importance in plant breeding. It is also referred as useful or economic heterosis. Therefore, the present study is objected to estimate standard heterosis in maize hybrids for yield and yield related traits and to identify potential hybrid for future breeding schemes.

Materials and methods

The experiment was conducted at Hawassa Research Center field in 2015 cropping season. Hawassa is situated at 7°4′N and 38°31′E latitude and longitude, respectively, at an altitude of 1700 meter above sea level (m.a.s.l). in the central rift valley of Ethiopia. The soil of the study area is characterized by well-drained sandy loam (46% sand, 28% silt and 26% clay), with pH of 7.1. It has 0.21% total Nitrogen, 15.65 ppm P, 14.52 ppm Iron and 20.30 meq/100 gm of Calcium (Waga Mazengia, 2011). The total annual rainfall for the past 12 years ranges from 776 mm to 1145 mm (average 988.1 mm) with an average maximum and minimum air temperature of 26.6 °C and 13.7 °C, respectively (Shiferaw *et al*., 2011; Sime and Aune, 2014).

The materials comprised of 32 inbred lines coded as L1, L2…L32 and two testers coded as T1 and T2. The inbred lines crossed with testers in line x tester mating design to generate 64 F1 hybrids at Bako National Maize Research Project (BNMRC) following procedure of Kempthorne (1957). The hybrids were planted along with similarly maturing hybrid maize varieties as a check viz BHQPY-545 and BH-546 during 2015 main cropping season at Hawassa. The experiment was planted by using α-lattice design 6x11 genotype arrangement (Patterson and Willianms, 1976) with two replications. Each block comprises of 11 units having 5.1 meter long and 9.75 meter width with the spacing of 0.75 meter between rows and 0.30 meter between plants. All cultural practices like weeding and cultivation was done manually throughout the entire growing season as required. Data of 12 quantitative traits were collected viz., days to 50% emergence, days to 50% anthesis, days to 50% silking, days to maturity, Plant height, Ear height, Ear length, Number of rows per ear, Ear diameter and Number of kernels per row, 1000 kernel weight and grain yield later converted to mean values.

Data analysis

Collected data were subjected to PROC MISED SAS computer software. The nature and magnitude of heterosis was estimated in relation to standard checks for traits that showed significant differences following the method suggested by Falconer and Mackay (1996):

$$\text{SH (\%)} = (F1 - \text{SV})/SV \ \text{X } 100$$

Where, F1 = Mean value of the hybrid, SV= Mean value of the standard variety and SH = standard heterosis

The differences in the magnitude of heterosis tested following the procedure of Panse and Sukhatme (1961). T-test was used for significance test among hybrids and checks. Standard error and critical difference were computed as:

$$\text{SE (d)} = (2MS_e/r)^{1/2}$$

$$CD=SE_{(d)}xt$$

Where; SE ($_d$) is standard error of the difference, MS_e = error mean square from analysis of variance, r = the number of replication, CD =Critical difference and t= value of t at error degree of freedom.

The computed t-value was tested against the t-value at error degree of freedom corresponding to 5 or 1% level of significance.

Results and Discussion

Analysis of Variance

Analysis of variance showed that, mean squares of genotypes were significant ($P<0.05$) for all traits except anthesis silking interval, ear position and cob per plant. Mean squares due to crosses were significant ($P<0.05$) for days to 50% anthesis, days to 50% silking, days to maturity, number of rows per ear, number of kernel per row, ear length, grain yield and thousand kernel weight (Table 1). This indicates that the hybrids were sufficiently different from each other and selection is possible to identify the most desirable hybrids. In line to these finding also different authors reported significant difference among hybrids in yield and yield related traits in different parts of Ethiopia (Legesse *et al*., 2009; Mossisa *et al*., 2009 and Shushay, 2014).

The Estimates of Standard Heterosis: The estimates of heterosis over the best standard check were computed for grain yield and yield related traits among genotypes were presented in (Table 2). Both standard checks used to estimate standard heterosis produce below mean grain yield per hectare. BHQPY-545 was relativity the best standard check in mean grain yield per hectare than BH-546. Significant amount of heterosis was observed for all the traits under study however the magnitude varied with traits (Table 2).

Among all hybrids none of them showed significant negative standard heterosis over BHQPY-545 in days to anthesis but eight hybrids showed highly significant positive standard heterosis (Table 2). One hybrid showed significant negative standard heterosis over BH-546 while three hybrids showed significant positive standard heterosis over BH-546 (Table 2). Three hybrids showed significant positive standard heterosis for days to maturity over both BH-546 and BHQPY-545. Hybrids showed heterosis in negative direction is considered to be desirable for days to 50 per cent tasseling, days to 50 per cent silking and days to maturity in developing early maturing varieties while for the hybrids shown positive and significant standard heterosis the reverse is true. Earliness is a desirable character as it is useful in multiple cropping and increases water and land use efficiency. The current finding is similar with the finding of Kumar *et al.*, (2012). Hybrids that showed negative days to anthesis, silking and days to maturity stands for earliness of the hybrids while for hybrids shown positive standard heterosis the reverse is true. Shushay, (2014) argued with current finding.

For ear length thirty three hybrids showed significant negative standard heterosis for ear length over BHQPY-545 while none of them showed significant positive heterosis over BHQPY-545. Six hybrids showed significant positive standard heterosis for ear height over BH-546 while only one hybrid showed significant positive standard heterosis for ear length over BH-546 (Table 2). Negative heterosis for plant height and ear height is desirable for breeding short statured hybrids and which implying that these hybrids would mature earlier. Ali *et al*., (2014) and Ziggiju *et al*., (2016) reported significant positive and negative standard heterosis for ear length and plant height

Table 1. Mean squares for grain yield and yield related traits in 64 hybrids and 2 checks evaluated at Hawassa, 2015

Source Variation	df	DA (days)	DS (days)	DM (days)	PH (cm)	EH (cm)	EL (cm)	NRPC (no)	NCPR (no)	ED (cm)	TSW (g)	GY (t/ha)	BY (t/ha)
Replication	1	1.09 ns	0.61ns	3.66 ns	1.94	303.30*	1.91ns	0.02ns	17.90ns	0.03 ns	37.12 ns	0.69 ns	1.08 ns
Incomplete block(b/r)	5	9.10**	10.50**	14.80**	813.9**	376.50**	9.87**	0.60 ns	9.80ns	0.17 ns	4687 ns	3.02*	4.47**
Genotypes	65	6.05**	6.00**	14.96**	442.11*	115.20**	5.91**	0.54*	13.52*	0.13**	4824**	2.94**	3.58**
Hybrids	63	6.09*	6.01**	15.4**	441.30 ns	115.50 ns	5.67*	0.54*	13.90*	0.13 ns	4579**	3.00**	3.44**
Error	60	3.12	2.73	3.82	290.34	73.43	3.01	0.32	8.55	0.09	50.0	1.588	1.42
CV (%)	-	2.931	2.803	2.005	9.44	9.43	12.53	5.5	9.17	7.33	20.34	27.02	27.2

DA=days to anthesis, DS=days to silking, DM=days to maturity, PH=plant eight, EH=ear height, EL=ear length, NRPC=number of row per cob, NCPR=number of kernel per cob, ED= ear diameter, TSW= thousand kernel weight, GY=grain yield, BY=biological yield, CPP=cob per plant. *and** significant at $P<0.05$ and $P<0.01$ respectively ns=non significance.

Based on number of kernels row per cobs two hybrids showed significant positive standard heterosis over BH-546. The highest significant positive standard heterosis for kernels row per cob was manifested by L1xT2 (16.7%) followed by L28XT2 (14.4%) (Table 2). Two hybrids showed significant positive standard heterosis for number of kernels per row over BHQPY-545 while six hybrids showed significant negative standard heterosis. Two hybrids showed significant positive standard heterosis for number of kernel per row over BH-546 while five hybrids showed significant negative standard heterosis. The highest significant positive standard heterosis for number of kernel per row manifested by L23 X T2 followed by L28 X T2 (16.1%). (Table 2) Amiruzzaman *et al*., (2010) and Senthil *et al*., (2014) observed significant positive and negative standard heterosis for number of rows per cob.

Based on thousand kernel weight fifty one hybrids showed significant negative standard heterosis for thousand kernel weights over BHQPY-545 while two hybrids showed significant positive standard heterosis for thousand kernel weights over BHQPY-545 and forty nine hybrids showed significant positive standard heterosis for thousand kernel weights over BH-546 while ten hybrids showed significant negative standard heterosis for thousand kernel weights over BH-546 (Table 2). Ali *et al.,* (2014) were observed significant positive standard heterosis for thousand grain weight.

Grain yield improvement is one of the most important objectives in maize breeding program and is the main selection criteria in maize. Percent heterosis over standard checks for grain yield was presented in Table 2. For grain yield fourteen hybrids showed significant positive standard heterosis over BHQPY-545 and seventeen hybrids showed significant positive standard heterosis over BH-546. None of hybrids showed significant negative standard heterosis over both BHQPY-545 and BH-546. (Table 2) The highest significant positive standard heterosis obtained by hybrid L31 X T2 (102.33%) which is followed by hybrid L8XT1 (93.02%). Our results are matching to the earlier findings by Leggese (2009); Mosa *et al*., (2010); Rodrigo *et al.,* (2012), Ziggiju *et al.,* (2016); Ali *et al.,* (2014); Elmyhum (2014); Girma *et al.,* (2015). Zeleke (2015) also reported standard heterosis for grain yield ranging from -8.9% to 28.9%.

Table 2. The magnitude of standard heterosis for 64 hybrids over BHQPY-545 and BH-546 for grain yield and yield related traits evaluated at Hawassa, 2015.

Crosses	DA		DS		DM		PH		EH	
	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546
L1xT1	6.90**	4.03*	6.71**	3.25	0.97	0.97	-7.93	-3.24	-6.67	0.00
L1xT2	2.76	0	3.36	0.00	-0.32	-0.32	-14.50	-10.2	-16.6*	-10.7
L2xT1	4.14*	1.34	4.70**	1.30	1.94	1.94	-27.30	-23.6	-20.8**	-15.2*
L2xT2	0.69	-2.01	0.67	-2.60	2.26	2.26	-1.32	3.70	0.00	7.14
L3XT1	6.21**	3.36	7.38**	3.90*	0.97	0.97	-14.90	-10.60	-14.2*	-8.04
L3XT2	0.69	-2.01	0.67	-2.60	1.61	1.61	-14.10	-9.72	-9.17	-2.68
L4XT1	-0.69	-3.36	0.00	-3.25	1.29	1.29	-7.93	-3.24	-5.83	0.89
L4XT2	4.83*	2.01	4.70**	1.30	-0.97	-0.97	-11.50	-6.94	-10.00	-3.57
L5XT1	1.38	-1.34	0.67	-2.6	-0.32	-0.32	-5.29	-0.46	-5.83	0.89

L5XT2	1.38	-1.34	1.34	-1.95	1.29	1.29	8.37	13.89	0.83	8.04
L6XT1	5.52**	2.68	5.37**	1.95	2.58	2.58	-8.81	-4.17	-5.83	0.89
L6XT2	6.90**	4.03*	6.71**	3.25	0.97	0.97	-15.9	-11.6	-17.5*	-11.60
L7XT1	2.07	-0.67	2.68	-0.65	0.00	0.00	-15.4	-11.1	-15.8*	-9.82
L7XT2	6.21*	3.36	6.04**	2.6	0.97	0.97	-7.05	-2.31	-20.8**	-15.2**
L8XT1	4.83**	2.01	5.37**	1.95	1.61	1.61	3.52	8.8	2.50	9.82
L8XT2	0.69	-2.01	0.67	-2.60	1.94	1.94	-6.17	-1.39	-5.83	0.89
L9XT1	3.45	0.67	3.36	0.00	2.26	2.26	-10.60	-6.02	-16.70*	-10.7**
L9XT2	6.21**	3.36	5.37**	1.95	-0.32	-0.32	-16.70	-12.5	-5.83	0.89
L10XT1	4.14*	1.34	4.70**	1.30	5.81**	5.81**	-11.00	-6.5	-9.17	-2.68
L10XT2	2.76	0.00	2.68	-0.65	-0.97	-0.97	-12.80	-8.3	-13.30	-7.14
L11XT1	7.59**	4.70*	7.38**	3.90*	7.10**	7.10**	-15.40	-11.1	-17.50*	-11.60
L11XT2	4.14*	1.34	4.03*	0.65	0.65	0.65	-18.50	-14.35	-15.00	-8.93
L12XT1	2.76	0.00	2.68	-0.65	1.61	1.61	-0.88	4.17	-0.83	6.25
L12XT2	3.45	0.67	3.36*	0.00	-3.55	-3.55	-2.20	2.78	-2.50	4.46
L13XT1	-1.38	-4.03*	-0.67	-3.90*	1.94	1.94	-12.30	-7.87	-9.17	-2.68
L13XT2	0.69	-2.01	0.67	-2.6	-1.94	-1.94	-5.29	-0.46	-5.00	1.79
L14XT1	4.14*	1.34	4.70**	1.3	1.94	1.94	-1.32	3.7	-10.00	-3.57
L14XT2	6.21**	3.36	6.04**	2.6	1.29	1.29	-13.2	-8.8	-5.83	0.89
L15XT1	-1.38	-4.03*	-0.67	-3.90*	-1.94	-1.94	-11.45	-6.94	-13.3	-7.14
L15XT2	4.14*	1.34	5.37**	1.95	0.00	0.00	-3.08	1.85	-3.33	3.57
L16XT1	0.00	-2.68	3.36*	0.00	0.32	0.32	-12.33	-7.87	-12.5	-6.25
L16XT2	3.45	0.67	3.36*	0.00	-0.65	-0.65	-7.05	-2.31	-0.83	6.25
L17XT1	4.14*	1.34	4.70**	1.30	1.61	1.61	-3.52	1.39	-4.17	2.68
L17XT2	3.45	0.67	4.03*	0.65	0.65	0.65	-10.13	-5.56	-0.83	6.25
L18XT1	0.00	-2.68	0.67	-2.6	-1.94	-1.94	-6.61	-1.85	-7.50	-0.89

Continuation of table 2…

Crosses	DA		DS		DM		PH		EH	
	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546
L18XT2	0.00	-2.68	0.00	-3.25	2.26	2.26	-4.41	0.46	-10.00	-3.57
L19XT1	3.45	0.67	4.70**	1.3	0.65	0.65	-14.1	-9.72	-15.80	-9.82
L19XT2	3.45	0.67	4.03*	0.65	0.32	0.32	-1.32	3.7	11.70	19.6*
L20XT1	0.00	-2.68	0.00	-3.25	1.61	1.61	-6.17	-1.39	-8.33	-1.79
L20XT2	5.52**	2.68	6.04**	2.6	0.00	0.00	-13.22	-8.8	-10.00	-3.57
L21XT1	2.07	-0.67	2.01	-1.30	-2.9	-2.90	-10.13	-5.56	-7.50	-0.89
L21XT2	1.38	-1.34	2.01	-1.30	-0.32	-0.32	-6.17	-1.39	-17.5*	-11.6
L22XT1	4.14*	1.34	4.03*	0.65	0.00	0.00	-8.37	-3.7	-4.17	2.68
L22XT2	6.21**	3.36	5.37**	1.95	0.32	0.32	-11.01	-6.48	-4.17	2.68
L23XT1	1.38	-1.34	0.67	-2.6	-1.94	-1.94	-2.64	2.31	-7.50	-0.89
L23XT2	4.14*	1.34	4.03*	0.65	0.32	0.32	-5.29	-0.46	-8.33	-1.79
L24XT1	-1.38	-4.03*	-0.67	-3.90*	-0.97	-0.97	-11.89	-7.41	-5.00	1.79
L24XT2	2.76	0.00	3.36*	0.00	1.61	1.61	-14.10	-9.72	-7.50	-0.89
L25XT1	2.76	0.00	3.36*	0.00	1.94	1.94	-12.33	-7.87	-11.70	-5.36
L25XT2	3.45	0.67	3.36*	0.00	-0.65	-0.65	-8.81	-4.17	-8.33	-1.79
L26XT1	1.38	-1.34	1.34	-1.95	-0.97	-0.97	5.73	11.11	-2.50	4.46
L26XT2	2.76	0.00	2.68	-0.65	1.94	1.94	-18.06	-13.89	-15.00	-8.93
L27XT1	-0.69	-3.36	-0.67	-3.90	1.29	1.29	-5.29	-0.46	-9.17	-2.68
L27XT2	-1.38	-4.03*	-1.34	-4.55**	-2.90	-2.90	-13.66	-9.26	-13.30	-7.14
L28XT1	3.45	0.67	3.36*	0.00	-0.65	-0.65	-5.29	-0.46	-5.00	1.79
L28XT2	1.38	-1.34	1.34	-1.95	0.97	0.97	-9.25	-4.63	-10.8	-4.46
L29XT1	2.76	0.00	3.36	0.00	-0.32	-0.32	-10.13	-5.56	-13.30	-7.14
L29XT2	6.90**	4.03*	6.71**	3.25	0.32	0.32	-9.25	-4.63	-8.330	-1.79
L30XT1	4.14*	1.34	4.03*	0.65	1.29	1.29	-12.33	-7.87	-19.2*	-13.4
L30XT2	6.90**	4.03*	6.71**	3.25	0.32	0.32	-11.01	-6.48	-10.00	-3.57
L31XT1	4.14*	1.34	4.03*	0.65	2.90	2.90	-8.37	-3.7	-10.00	-3.57
L31XT2	5.52**	2.68	5.37**	1.95	0.00	0.00	11.89	17.59	5.83	13.4
L32XT1	4.83**	2.01	4.70**	1.30	0.97	0.97	-17.18	-12.96	-1.67	5.36
L32XT2	1.38	-1.34	1.34	-1.95	0.00	0.00	-9.69	-5.09	-11.70	-5.36
SE(m±)	3.12		2.73		3.82		290.34		73.43	
CD 0.05	3.53		3.3		3.91		34.06		17.14	
CD 0.01	4.7		4.4		5.2		45.3		22.79	

DA=days to anthesis, DS=days to silking, DM=days to maturity, PH=plant eight, EH=ear height, EL=ear length, NRPC=number of row per cob, NCPR=number of kernel per cob, ED= ear diameter, TSW= thousand kernel weight, GY=grain yield, BY=biological yield, CPP=cob per plant.SE (m±) =standard error of a mean, CD =critical difference

Continuation of table 2…

Crosses	EL		NRPC		NCPR		TSW		GY	
	BHQP Y -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546
L1xT1	-14.70	7.90	7.60	1.40	-5.12	-3.83	-25.30**	15.20**	29.50	32.60
L1xT2	-23.5**	-3.30	16.7**	10.0*	-2.43	-1.09	-28.4**	10.50**	18.20	20.90
L2xT1	-29.9**	-11.30	0.00	-5.70	-10.20	-9.00	-27.7**	11.40**	2.30	4.70
L2xT2	-16.3*	5.80	6.06	0.00	-3.23	-1.91	-25.3**	15.20**	-4.50	-2.30
L3XT1	-18.8*	2.70	6.06	0.00	1.35	2.73	-37.6**	-3.80*	18.20	20.90
L3XT2	-22.2*	-1.58	7.60	1.40	-1.89	-0.55	-29.6**	8.60**	18.20	20.90
L4XT1	-15.90	6.25	5.30	-0.71	2.43	3.83	-27.2**	12.40**	27.30	30.20
L4XT2	-15.90	6.30	5.30	-0.71	4.31	5.74	-29.6**	8.60**	29.50	32.60
L5XT1	-21.0*	-0.12	5.30	-0.71	-4.85	-3.55	-29.0**	9.50**	38.60	41.90
L5XT2	-5.80	19.20*	1.50	-4.30	-4.31	-3.01	-12.96	34.30**	38.60	41.90
L6XT1	-25.7**	-6.10	3.00	-2.90	-8.63	-7.38	-36.4**	-1.90	47.70	51.20
L6XT2	-40.1**	-24.2**	3.00	-2.90	-10.50	-9.29	-48.7**	-21.0**	-18.20	-16.30
L7XT1	-22.8**	-2.37	-3.00	-8.60	-16.2**	-15.0**	-35.2**	0.00	0.00	2.3.00
L7XT2	-15.60	6.70	10.60*	4.30	2.16	3.55	-27.8**	11.4**	29.50	32.60
L8XT1	16.4*	18.3*	9.10*	2.90	5.66	7.10	16.05*	16.1**	88.6**	93.0**
L8XT2	-6.040	18.8*	6.10	10.00	0.81	2.19	-16.67	28.6**	54.50*	58.10*
L9XT1	-23.0**	-2.70	12.9**	6.40	-7.01	-5.74	-24.1**	17.10**	25.00	27.90
L9XT2	-27.7**	-8.60	3.00	-2.90	-5.93	-4.64	-43.2**	-12.4**	-9.10	-7.00
L10XT1	-16.6*	5.50	9.10*	2.90	0.00	1.37	-35.8**	-0.95	0.00	2.30
L10XT2	-15.40	7.00	6.10	0.00	1.08	2.46	-30.9**	6.70**	34.10	37.20
L11XT1	-22.3**	-1.70	1.50	-4.30	-4.58	-3.28	-18.5*	25.7**	34.10	37.20
L11XT2	-32.6**	-14.70	9.10*	2.90	-7.28	-6.01	-50.6**	-23.8**	-13.60	-11.60
L12XT1	22.9**	20.10*	6.10	0.00	-2.70	-1.37	-15.4*	30.5**	50.00	53.50*
L12XT2	-10.10	13.70	5.30	-0.71	8.36	9.84	16.7*	28.6**	59.10**	62.80*
L13XT1	-20.1*	0.97	10.60*	4.30	0.81	2.19	-22.2**	20.0**	50.00	53.50*
L13XT2	-11.90	11.30	3.00	-2.90	-0.54	0.82	-5.56	45.7**	18.20	20.90
L14XT1	-17.8*	4.00	0.00	-5.70	1.35	2.73	-16.67*	28.6**	25.00	27.90
L14XT2	-30.1**	-11.60	5.30	-0.70	-10.50	-9.29	-47.5**	-19.1**	-15.90	-14.00
L15XT1	-21.8**	-1.15	10.60*	4.30	-11.6*	-10.4*	-25.3**	15.24**	18.20	20.90
L15XT2	-15.30	7.20	4.60	-1.40	5.12	6.56	-22.2**	20.00**	54.50*	58.10*
L16XT1	-10.20	13.50	4.60	-1.40	0.81	2.19	-11.73	36.2**	59.10*	62.80*
L16XT2	-18.0*	3.60	5.30	-0.70	-2.16	-0.82	-37.7**	-3.8*	11.40	14.00
L17XT1	-6.00	18.90*	10.60*	4.30	4.85	6.28	-8.64	41.00**	52.30*	55.8*
L17XT2	-17.3*	4.60	5.30	-0.70	-7.82	-6.56	-31.5**	5.7**	-34.10	-32.6
L18XT1	-15.40	6.90	6.10	0.00	-5.39	-4.10	-25.93	14.3**	25.00	27.90

Continuation of table 2…

Crosses	EL		NRPC		NCPR		TKW		GY	
	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546	BHQPY -545	BH-546
L18XT1	-15.40	6.90	6.10	0.00	-5.39	-4.10	-25.93	14.3**	25.00	27.90
L18XT2	-16.8*	5.20	9.10*	2.90	-12.70*	-11.50*	-16.05*	29.5**	40.90	44.20
L19XT1	-24.3**	-4.20	5.30	-0.70	-8.40	-7.10	-33.95*	1.90	20.50	23.30
L19XT2	-26.0**	-6.40	0.00	-5.70	-2.43	-1.09	-37.7**	-3.80*	25.00	27.90
L20XT1	-11.90	11.30	3.03	-2.90	2.70	4.10	-33.3**	2.86	31.80	34.90
L20XT2	-24.5**	-4.50	5.30	-0.70	-2.43	-1.09	-43.8**	-13.3**	-11.40	-9.30
L21XT1	-11.80	11.60	9.10*	2.90	-2.70	-1.37	-9.26	40.00**	56.8*	60.50*
L21XT2	0.67	27.30*	4.60	-1.40	4.04	5.46	-18.52*	25.70**	56.8*	60.50*
L22XT1	-6.50	18.30*	3.00	-2.90	4.58	6.01	-14.2	32.40**	50.00	53.5**
L22XT2	-20.9*	-0.06	1.50	-4.30	-8.89	-7.65	-41.98*	-10.5**	2.30	4.70
L23XT1	-9.60	14.30	9.10*	2.90	-2.70	-1.37	-5.56	45.7**	59.1*	62.80*
L23XT2	22.90	30.1**	1.50	-4.30	16.2**	17.8**	10.49	70.40**	72.7**	76.70**
L24XT1	-21.90	-1.33	1.50	-4.30	-10.50	-9.30	-38.3**	-4.80**	22.70	25.60
L24XT2	-16.9*	5.10	6.10	0.00	-2.16	-0.82	-28.4**	10.50**	52.3*	55.80*
L25XT1	-26.2**	-6.70	1.50	-4.30	-19.1**	-18.0**	-20.9**	21.90**	-11.40	-9.30
L25XT2	-10.60	13.10	-1.50	-7.10	3.77	5.19	-16.67*	28.60**	36.40	39.50
L26XT1	23.3**	22.3**	9.10*	2.90	8.89	10.40	6.79	43.80**	75.0**	79.10**
L26XT2	-12.90	10.20	3.03	-2.90	-6.47	-5.19	-25.3**	15.20**	-13.6	-11.60
L27XT1	-19.7*	1.58	6.10	0.00	7.28	8.74	-31.5**	5.70**	0.00	2.30
L27XT2	-17.6*	4.00	7.60	1.43	14.6*	16.1**	-37.7**	-3.80*	25.00	27.90
L28XT1	-7.20	17.3*	6.10	0.00	9.20	10.70	-27.2**	12.40**	40.90	44.20
L28XT2	-22.1**	-1.46	14.40*	7.90	-7.55	-6.28	-31.5**	5.70**	13.60	16.30
L29XT1	-21.2*	-0.36	5.30	-0.70	2.16	3.55	-33.9**	1.90	9.10	11.60
L29XT2	-24.2**	-4.10	5.30	-0.70	-11.6*	-10.40	-30.9**	6.7**	2.3	4.70
L30XT1	-13.40	9.50	7.60	1.40	-2.16	-0.82	-22.2**	20.0**	52.3*	55.80*
L30XT2	-23.8**	-3.60	1.50	-4.30	2.16	3.55	-36.4**	-1.9	11.4	14.00
L31XT1	-17.3*	4.60	-1.50	-7.10	2.70	4.10	-24.8**	16.2**	22.7	25.60
L31XT2	28.60	25.50	12.10*	5.70	8.09	9.56	-13.58	33.3**	97.7**	102.3**
L32XT1	-28.4**	-9.50	1.50	-4.30	-13.80*	-12.60*	-40.7**	-8.6**	-22.7	-20.90
L32XT2	-13.40	9.50	6.10	0.00	-5.66	-4.37	-21.6**	20.9**	6.8	9.30
SE(m±)	3.01		0.32		8.55		50		1.43	
CD 0.05	3.47		1.13		5.83		14.14		2.39	
CD 0.01	4.61		1.5		7.76		18.81		3.18	

DA=days to anthesis, DS=days to silking, DM=days to maturity, PH=plant eight, EH=ear height, EL=ear length, NRPC=number of row per cob, NCPR=number of kernel per cob, ED= ear diameter, TSW= thousand kernel weight, GY=grain yield, BY=biological yield, CPP=cob per plant.SE (m±) =standard error of a mean, CD =critical difference

Rank	Hybrids	Grain yield ton/ha	Grain yield Heterosis over BH QPY-545	Grain yield Heterosis over BH-546	Days to maturity Days taken to mature	Days to maturity Heterosis over BH QPY-545	Days to maturity Heterosis over BH- 546
1	L31XT2	8.68	97.73**	102.33**	155.0	0.00	0.00
2	L8XT1	8.25	88.64**	93.02**	157.5	1.61	1.61
3	L26XT1	7.70	75.00**	79.07**	153.5	-0.97	-0.97
4	L23XT2	7.56	72.73**	76.74**	155.5	0.32	0.32
5	L12XT2	7.04	59.09*	62.79*	149.5	-3.5*	-3.5*
6	L16XT1	7.00	59.09*	62.79*	155.5	0.32	0.32
7	L23XT1	7.00	59.09*	62.79*	152.0	-1.94	-1.94
8	L21XT1	6.93	56.82*	60.47*	150.5	-2.90	-2.90
9	L21XT2	6.91	56.82*	60.47*	154.5	-0.32	-0.32
10	L8XT2	6.82	54.55*	58.14*	158.0	1.94	1.94
	Checks						
1	BHQPY-545	4.4			155		
2	BH-546	4.3			155		

Potential hybrids

From current study, eleven potential hybrids were identified either for release as hybrids or for further use in maize breeding program after further verification of the results. The yield potential of the hybrids ranged from 6.82 to 8.68 ton/ha (Table 3). A hybrid with higher standard heterosis over standard checks was used for hybrid maize development. The first ten hybrids L31XT2, L8XT1, L26XT1, L23XT2, L12XT2, L16XT1, L23XT1, L21XT1, L21XT2, L8XT2 had high mean performance and standard heterosis over both checks for grain yield and other yield contributing traits like number of kernels per row, 1000 kernel weight, number of kernel rows per ear, ear diameter and ear length.

Table 3. List of potential hybrids identified based on grain yield evaluated at Hawassa in 2015.

Conclusions

Significant differences observed among hybrids for yield and yield related traits indicate presence of genetic variability and high magnitude of standard heterosis over commercial check. In the current finding, considerable amount of heterosis was obtained over best standard check (BHQPY-545) from hybrid (L31XT2) 97.73% in grain yield. The same hybrid gives 102.33% yield advantage over BH-546. Top ten yield advantages hybrids over both standard checks are L31XT2, L8XT1, L26XT1, L23XT2, L12XT2, L16XT1, L23XT1 and L21XT1in range of 54.55% to 102.33%.

Among these ten hybrids five of them have negative heterosis of days to maturity over both hybrids. Negative standard heterosis is required for traits like plant height, disease and pest reaction, ear height and days to maturity. Hybrids L31XT2, L8XT1, L26XT1, L23XT2 and L12XT2 have positive ear length, number of kernel per row, number of rows per cob, and thousand kernel weight over standard check. These results indicate most hybrids are earlier than commercial check. Positive standard heterosis is desirable for breeding long statured hybrids and varieties for grain yield. Among hybrids L31XT2 was the most prominent combination for grain yield. It is suggested to evaluate these hybrids in multi-environment for years on large scale for adaptation to wider agro-climatic conditions before their commercial cultivation.

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Genetic Analysis of Inbred Lines in Line × Tester Mating Design for Grain Yield and Traits Related Yield in Maize (Zea Mays L.)

[1]Natol Bakala* [2]Berhanu Abate [3]Mandefiro Nigusie

[1]Oromia Agricultural Research Institute Yabello Pastoral and Dryland Agricultural Research Center

[2]School of Plant and Horticultural Science, Hawassa University, Ethiopia

[3]Oxfam America Deputy Regional Director, P.O. Box 85 Ethiopia

Corresponding Author: E-mail:-natymartyko@gmail.comFax:+2510464460261,

Abstract

Maize is one the most important cereal crop widely grown in the world. Maize crosses along with similar maturing checks were evaluated at Hawassa in 2015-2016 cropping season to understand the nature of gene action governing yield and its attributes through line × tester analysis and to study genetic contribution of line, tester and the interaction of line × tester to total variation. The experiment was planted by using α-lattice design 6×11 arrangement. Cross $L_{31} \times T_2$ *showed the highest mean grain yield than both checks. The result showed that, lines played an important role towards days to anthesis, days to silking, ear length, number of rows per cob and number of kernels per row, indicates predominant of maternal lines. Based on analysis of genetic variance, for traits variance due to specific combining ability* (σ^2_{SCA}) *was higher than variance due to general combining ability* (σ^2_{GCA}) *indicated, non-additive gene action was important than additive gene action in the inheritance of these traits. These best cross combinations could be effectively utilized in maize breeding for the improvement of yield components and thus their incorporation in further breeding program is suggested.*

Key words: Additive, non-additive, Cross, Genotypes, line × tester

Introduction

Maize is one of the most important cereal crops in the world after wheat and rice. Maize is being nutritionally an important crop used as food and feed. It is a source of industrial materials for the production of fuel, oil, starch, syrup; gluten, alcohol, glucose, ethanol and many more products. Its cultivation extends over a wide range of geographical and environmental conditions ranging from 58^0N to 40^0S. Portuguese traders introduced maize to Ethiopia in 16^{th} or 17^{th} century (Haffnagel, 1961). Currently, in Ethiopia, maize is one of the most important cereal crops grown in almost all parts of the country. The popularity of maize in Ethiopia is partly because of its high value as a food, fodder and source of fuel for rural area. Approximately 88% of maize produced in Ethiopia is consumed as food, both as green and dry grain (Abate *et al.* 2015).The total annual production and productivity of maize in Ethiopia exceeds all other cereal crops except Tef in area coverage (Mosisa *et al*. 2011.

Objective of maize breeding programs is evaluation of best yielding and adaptive. Improvement of varieties (genotypes) needs well documented information of genetic information. Breeders conducted a genetic analysis for yield and yield related traits of genotypes. In fact, maize has been subjected to extensive genetic studies than any other crops (Hallauer and Miranda, 1988). Several biometrical techniques were used to study genetic analysis of quantitative traits. Among, line × tester is suggested by Kempthorne (1957) and is used to breed both self and cross pollination plants. This method efficient study large number of lines and provides reliable estimates of genetic components, estimates of specific combining ability (SCA), general combining ability (GCA) and gene action governing quantitative traits. Therefore, the current study is objected to understand the nature of gene action governing yield and its attributes through line × tester analysis and to study genetic contribution of line, tester and the interaction of line × tester to total variation.

Materials and Methods

Field experiment was conducted at Hawassa research center located at 7°4′N and 38°31′E latitude and longitude, respectively, at an altitude of 1700 m.a.s.l. in the central rift valley of Ethiopia. Sixty-four crosses developed by crossing 32 inbred lines with two testers in line × tester mating design (Kemperton, 1957). Inbred lines (32) were coded as L_1, $L_2 \ldots L_{32}$ and two testers CML-144 (F2) -21-2-2-1- 1/CML144 and CML-144 (F2) -15-2-2-2-1/CML159 were coded as T_1 and T2. Sixty-four crosses were planted along with similarly maturing checks BHQPY-545 and BH-546 at Hawassa. The experiment was planted by using α-lattice design 6×11 arrangement (Patterson and Williams, 1976) with two replications. Each block comprises of 11 units having 5.1 meters long and 9.75 meters width with the spacing of 0.75 meter between rows and 0.30 meter between plants. All cultural practices were performed as per required. Data like days to maturity (DM), field weight, seed moisture content and thousand kernel weight (TKW) were collected plot bases while data like plant height (PH), ear height (EH), ear length (EL), number of rows per ear (NRPE), ear diameter (ED) and number of kernels per row (NCPR) collected in plant bases. Biomass (BM) and grain yield (GY) calculated by using the following formula

Grain yield (t ha^{-1}) $=\frac{\text{Freshearweighx}\ (100-\text{MC})\text{x}0.8*17\ \text{x}\ 10{,}000}{\text{nx}\ 85\ \text{x}\ 3.85\ \text{x}\ 100\ \text{kg}}$ Where: MC =moisture content of grain at harvest, 0.8=shelling percentage, 85=standard moisture content of grain, n=number of plants harvested, 17=total number of plants in a plot, 10000 = Area of hectare in square meters.

Table 1. Lists of crosses and checks used in the experiment

Stock ID	Pedigree	Code
BK152-1	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-4-1-1-1-1/CML144	L_1×T_1
BK152-2	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-4-1-1-1-1/CML159	L1×T2
BK152-3	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-4-2-2-1-1/CML144	L2×T1
BK152-4	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-4-2-2-1-1/CML159	L2×T2
BK152-5	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-4-3-2-1-1/CML144	L3×T1
BK152-6	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-4-3-2-1-1/CML159	L3×T2
BK152-7	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-1-1-1-1/CML144	L4×T1
BK152-8	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-1-1-1-1/CML159	L4×T2
BK152-9	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-1-1-1/CML144	L5×T1
BK152-10	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-1-1-1/CML159	L5×T2
BK152-11	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-1-1-2/CML144	L6×T1
BK152-12	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-1-1-2/CML159	L6×T2
BK152-13	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-1-2-1/CML144	L7×T1
BK152-14	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-1-2-1/CML159	L7×T2
BK152-15	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-2-2-1/CML144	L8×T1
BK152-16	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-2-2-1/CML159	L8×T2
BK152-17	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-3-1-1/CML144	L9×T1
BK152-18	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-3-1-1/CML159	L9×T2
BK152-19	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-3-2-1/CML144	L10×T1
BK152-20	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-15-2-3-2-1/CML159	L10×T2
BK152-21	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-17-3-1-1-1/CML144	L11×T1
BK152-22	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-17-3-1-1-1/CML159	L11×T2
BK152-23	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-17-3-1-2-1/CML144	L12×T1
BK152-24	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-17-3-1-2-1/CML159	L12×T2
BK152-25	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-17-3-2-1-1/CML144	L13×T1
BK152-26	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-17-3-2-1-1/CML159	L13×T2
BK152-27	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-21-2-2-1-1/CML144	L14×T1
BK152-28	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-21-2-2-1-1/CML159	L14×T2
BK152-30	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-48-1-1-1-1/CML144	L15×T1
BK152-31	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-48-1-1-1-1/CML159	L15×T2
BK152-32	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-48-2-1-1-1/CML144	L16×T1
BK152-33	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-48-2-1-1-1/CML159	L16×T2
BK152-34	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-50-3-1-1-1/CML144	L17×T1
BK152-35	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-50-3-1-1-1/CML159	L17×T2
BK152-36	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-50-3-1-2-1/CML144	L18×T1
BK152-37	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-50-3-1-2-1/CML159	L18×T2
BK152-38	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-61-1-2-1-1/CML144	L19×T1
BK152-39	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-61-1-2-1-1/CML159	L19×T2
BK152-40	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-61-1-2-1-2/CML144	L20×T1
BK152-41	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-61-1-2-1-2/CML159	L20×T2
BK152-42	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-61-2-1-1-1/CML144	L21×T1
BK152-43	BK02-Z-311-28(F2)-B-1 × CML-144(F2)-61-2-1-1-1/CML159	L21×T2
BK152-44	BK02-Z-311-28(F2)-B-1-1-1-1-1/CML144	L22×T1
BK152-45	BK02-Z-311-28(F2)-B-1-1-1-1-1/CML159	L22×T2

BK152-46	BK02-Z-311-28(F2)-B-1-1-2-1-1/CML144	L23×T1
BK152-47	BK02-Z-311-28(F2)-B-1-1-2-1-1/CML159	L23×T2
BK152-48	BK02-Z-311-28(F2)-B-1-1-2-2-1/CML144	L24×T1
BK152-49	BK02-Z-311-28(F2)-B-1-1-2-2-1/CML159	L24×T2
BK152-50	BLWBAM-QPM2006 F2 -15-2-1-1-1-1/CML144	L25×T1
BK152-51	BLWBAM-QPM2006 F2 -15-2-1-1-1-1/CML159	L25×T2
BK152-52	BLWBAM-QPM2006 F2 -15-2-1-1-2-1/CML144	L26×T1
BK152-53	BLWBAM-QPM2006 F2 -15-2-1-1-2-1/CML159	L26×T2
BK152-54	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-1-2-1-	L27×T1
BK152-55	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-1-2-1-	L27×T2
BK152-56	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-1-2-1-	L28×T1
BK152-57	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-1-2-1-	L28×T2
BK152-58	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-2-1-1-	L29×T1
BK152-59	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-2-1-1-	L29×T2
BK152-60	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-2-2-1-	L30×T1
BK152-61	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-2-2-1-	L30×T2
BK152-62	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-2-2-1-2	L31×T1
BK152-63	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-2-2-1-2	L31×T2
BK152-64	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-3-1-1-1/	L32×T1
BK152-65	(CML-142 × 144-7-b(F2) × 144-7-b(F2) × 144-7-b)-B-12-1-3-1-1-	L_{32}×T_2
Checks	BHQPY-545	BHQPY-545
	BH-546	BH-546

Data analysis

All collected data were subjected to SAS computer software to test the significance genotypes (Gomez and Gomez, 1984). Genetic parameter analysis and proportional contribution of line tester and line × tester were done only for treatment

Genetic parameter analysis

$\sigma^2GCA = \frac{MSl - \frac{MSlxt}{rt} + MSt - \frac{MSlxt}{lr}}{rtl}$, $\sigma^2SCA = MSt - \frac{MSlxt}{r}$

The ratio of σ²GCA to σ²SCA was express as $\frac{\sigma^2GCA}{\sigma^2SCA}$

Additive variance

$\sigma^2l=[Ms(l)-Mse]/rt=1/2\sigma^2A$, $\sigma^2A=2\sigma^2l$

$\sigma^2t=[Ms(t)-Mse]/rl=1/2\sigma^2A$ $\sigma^2A=2\sigma^2t$

$\sigma^2A=[2\sigma^2l+2\sigma^2t]/2=\sigma^2l+2\sigma^2t$

σ²D=dominance variance

$\sigma^2lt=[Ms(l\times t)-Mse]/r= \sigma^2D$

Average degree of dominance (ā) was calculated according to the following equation:

$\bar{a}=\sqrt{2}\sigma^2D/\sigma^2A$, if ā = 0 no dominance, if ā = <1> 0 partial dominance, if ā = 1 complete dominance, if ā > 1 over dominance

Where: σ²GCA=variance of General Combining ability, σ²SCA=variance of Specific Combining Ability, MSl=mean square of line, MSt=mean square of tester, MSl×t=mean square of line × tester, l=line, t=tester, r=replications. Proportional contribution of line, tester and line × tester to total variation in hybrid combinations

The percentage contribution of lines (females), testers (males) and line × tester to the hybrids were calculated according to Abuali *et al*., (2016):

- Percentage contribution of line $=\frac{SS\,(l)}{SS\,(c)}x100$
- Percentage contribution of tester $= \frac{SS\,(t)}{SS\,(c)}x100$
- Percentage contribution of Line ×Tester $=\frac{SS\,(L\times T)}{SS\,(c)}x100$

Where, SS (c) =sum square of cross, SS (l) =sum square line, SS (t) =sum square tester, SS (L×T) = sum square of Line ×Tester, l=line, t=tester, r=replications.

Results and Discussion

Genetic Parameters Analysis

The analysis of variance showed that, there was a significance difference between genotypes for all traits. The analysis of variance indicated that, sufficient genetic variability present among genotypes for all characters (Table 1).Variance due to SCA (σ^2_{SCA}) was higher than variance due to general combining ability (σ^2_{GCA}) and the ratio of σ^2_{GCA} to σ^2SCA was less than one for traits like days to anthesis, days to silking, days to maturity, ear diameter, thousand kernel weight, grain yield and cob per plant which indicate, non-additive gene action was more important than additive gene action in the inheritance of these traits (Table 1).Non additive gene action is not easily fixable, implies that best hybrids were not easily identified for the following traits.

Similarly, Liaqat *et al*. (2015) reported that, non-additive gene effects were important than additive gene effect for grain yield. Kamara *et al*. (2014) also found similar result for ear diameter and thousand kernel weights. σ^2_{GCA} was larger than σ^2_{SCA} in plant height, ear length, number of rows per cob, number of kernels per row and biomass which indicates the additive gene action played the great role in governing the inheritance of these traits than non-additive gene action (Table 1). Additive gene action is easily fixable implies that, best hybrids were easily identified for the following traits. Alamnie *et al*. (2006) reported that, additive gene effects were more important than non-additive gene effects for plant height and number of kernels per row. The result was pact with that of Sharma *et al.* (2004) who found preponderance of additive genetic effects in the control of traits like plant height, ear length, number of rows per cob, number of kernels per row and biomass. Similar result has been reported by different researchers Irshad-El-Haq *et al*. (2010); El-Badawy (2012); Aminu *et al*. (2014) for grain yield.

The value of additive gene effects was more than the value of dominance gene effect for plant height, ear length, number of kernels per row, number of rows per cob, while the value of dominance gene effects was higher than the value of additive gene effects for days to anthesis, days to silking, days to maturity, ear height, ear diameter, thousand seed weight and grain yield (Table 2).The average degree of dominance was more than one for days to anthesis, days to silking, days to maturity, ear height, ear diameter, thousand seed weight and grain yield indicating these traits were under control of the over dominance gene effect, whereas the average dominance was zero for traits like plant height, ear length, number of kernels per row, number of row per cob indicate there was no dominance for the traits (Table 2).

Table 2.Analysis of variance for phenological, growth parameters and yield of maize in maize crosses

Source Variation	DF	DA (days)	DS (days)	DM (days)	PH (cm)	EH (cm)	EL (cm)	NRPC (no)	NCPR (no)	ED (cm)	TSW (g)	GY (t/ha)
Replication	1	1.09 ^{ns}	0.61^{ns}	3.66 ^{ns}	1.94	303.03*	1.91^{ns}	0.02^{ns}	17.89^{ns}	0.03 ^{ns}	37.12 ^{ns}	0.69 ^{ns}
Block	5	9.10**	10.5**	14.8**	813.9**	376.5**	9.87**	0.60 ^{ns}	9.81^{ns}	0.17 ^{ns}	4687 ^{ns}	3.02*
Genotypes	65	6.05**	6.00**	14.96**	442.11*	115.2**	5.91**	0.54*	13.52*	0.13**	4824**	2.94**
Error	60	3.12	2.73	3.82	290.34	73.43	3.01	0.32*	8.55	0.09	50	1.58
σ^2_{GCA}		0.11	0.08	0.37	2.47	1.25	0.05	0.0001	0.12	0.01	88.9	0.06
σ^2_{SCA}		5.53	1.83	31.5	-210.8	26.9	-1.84	-0.29	-1.97	0.41	4952	4.01
$\sigma^2_{GCA}/\sigma^2_{SCA}$		0.02	0.04	0.01	-0.01	0.05	-0.03	0	-0.06	0.02	0.02	0.01
σ^2_A		0.43	0.31	1.49	9.89	5.01	0.2	0.01	0.47	0.02	355.93	2.39
σ^2_D		22.12	7.32	126	-843.2	107.6	-7.36	-1.19	-7.88	1.66	19808	1.6
Ā		10.1	6.91	13.01	0	6.55	0	0	0	13.71	10.55	1.16

** highly significant at $P<0.01$,* significant difference at $P<0.05$, ns=non-significant, DA=days to anthesis, DS=days to silking, DM=days to maturity, PH=plant height, EH=Ear height, EL=ear length, NRPC=number of rows per cob, NCPR=number of kernel per row, ED=ear diameter, TSW=thousand seed weight, GY=grain yield, (blk/R)=incomplete blocks with in replication, σ^2_{GCA}=variance of general combining ability, σ^2_{SCA}=variance of specific combining ability, σ^2_A=additive variance, σ^2_D=dominance variance, ā= average degree of dominance.

Mean performance of genotypes (crosses and check): The mean performances of genotypes are presented in (Table 2). Top ten high yielding crosses in relative to both checks were L31×T2 (8.68 t ha^{-1}), L8×T1 (8.25 t ha 1), L26×T1 (7.70 t ha^{-1}), L23×T2 (7.56 t ha^{-1}), L12×T2 (7.04 t ha^{-1}), L16×T1 (7.00 t ha^{-1}), L23×T1 (7.00 t ha^{-1}), L21×T1 (6.93 t ha^{-1}), L21×T2 (6.91 t ha^{-1}) and L8×T2 (6.82 t ha^{-1}). The mean grain yield of check BHQPY-545 and BH-546 were 4.4 t ha^{-1} and 4.3 t ha^{-1} respectively.

Low yielding crosses in relative to checks were L2×T2 (4.24 t ha^{-1}), L6×T2 (3.59 t ha^{-1}), L7×T1 (4.37 t ha^{-1}), L9×T2 (4.03 t ha^{-1}), L11×T2 (3.81 t ha^{-1}), L14×T2 (3.67 t ha^{-1}), L17×T2 (2.88 t ha^{-1}), L20×T2 (3.93 t ha^{-1}), L25×T1 (3.88 t ha^{-1}), L26×T2 (3.82 t ha^{-1}) and L32×T1 (3.36 t ha^{-1}) (Table 2). The grain yield ranged from 2.88 t ha^{-1} (L17×T2) to 8.68 t ha^{-1} (L31×T2) with an overall mean of 5.55 t ha^{-1} (Table 1). Those crosses that had better mean values over standard checks indicate that, the possibility of obtaining promising hybrid variety with desirable traits. Highest mean number of days to maturity was obtained for cross L11×T1 (166 days) while the lowest mean number of days to maturity was recorded for cross L12×T2 (149.5 days). Three crosses L12×T2 (-5.5 days), L21×T2 (-4.5) and L27×T2 (-4.5 days) were early as compared to both standard checks BHQPY-545 and BH-546. Plant height for genotypes ranges from 165cm (L2×T1) to 254cm (L31×T2) with the mean 207.5cm. Ear height for genotypes ranges from 95cm (L_7×T_2) to 134cm (L19×T2) with the mean of 110cm (Table 2).

Proportional Contribution of Line, Tester and Line × Tester : The proportional contribution of lines, testers and the interaction of line × tester to the total variances were presented in (Table 3). The result showed that, lines played an important role towards days to anthesis, days to silking, ear length, number of rows per cob and number of kernels per row, indicates predominant of maternal (lines) influence for these traits and higher estimates of variance due to GCA (Table 3). The contribution of testers was low for all traits, which indicates higher estimates of variances due to SCA. The contribution of line × tester interactions played an important role towards days to maturity, plant height, ear height, ear diameter, thousand kernel weight and grain yield, which indicate higher estimates of variances due to non-additive genetic effects and the importance of SCA. Shams *et al.* (2010) observed higher estimates of SCA variance due to line × tester. Aminu *et al.* (2014) also found the proportional contribution of line × tester was greater than tester for grain yield, plant height, ear height, thousand kernels weight and ear length of their study of combining ability and heterosis for phenologic and agronomic traits in maize under drought conditions. In contrary, Shams *et al.* (2010) found proportional contribution of line × tester interaction was greater than line and tester for number of kernels per row and proportional contribution of tester was greater than line and the interaction line × tester in number of rows per cob in maize using line × tester method.

Table 3. Mean performance of 64 maize crosses and 2 checks for phenological, growth parameters, grain yield and yield related traits at southern Ethiopia, Hawassa

Crosses	DA (days)	DS (days)	DM (days)	PH (cm)	EH (cm)	EL (cm)	NRPC (no.)	NCPR (no.)	ED (cm)	TW (g)	GY (t ha^{-1})
L_1×T_1	77.5^{ab}	79.5^{ab}	156.5^{b-g}	209^{b-e}	112^{b-g}	17.8^{a-i}	14.2^{a-g}	35.2^{b-g}	4.53^{a-g}	303^{b-j}	5.74^{a-m}
L1×T2	74.5^{a-h}	77^{a-f}	154.5^{c-i}	194^{d-f}	100^{d-g}	16.0^{d-j}	15.4^{a}	36.2^{a-g}	4.80^{a-g}	290^{b-j}	5.19^{c-m}
L2×T1	75.5^{a-f}	78^{a-e}	158^{b-e}	165^{f}	95^{g}	14.6^{h-j}	13.2^{e-g}	33.3^{c-g}	4.53^{a-g}	293^{b-j}	4.45^{d-m}
L2×T2	73^{a-k}	75^{c-f}	158.5^{b-d}	224^{a-e}	120^{a-e}	17.5^{a-g}	14.0^{a-g}	35.9^{a-g}	4.57^{a-g}	303^{b-j}	4.24^{d-m}
L3×T1	77^{a-c}	80^{a}	156.5^{b-g}	193^{d-f}	103^{d-g}	16.9^{b-i}	14.0^{a-g}	37.6^{a-f}	4.65^{a-g}	253^{d-j}	5.24^{c-m}
L3×T2	73^{c-j}	75^{c-f}	157.5^{b-e}	195^{d-f}	109^{b-g}	16.2^{d-j}	14.2^{a-g}	36.4^{a-g}	4.34^{b-g}	285^{b-j}	5.25^{c-m}

L4×T1	72^{e-g}	74.5	157^{b-f}	209^{b-e}	113^{a-g}	17.5^{a-g}	13.9^{b-j}	38.0^{a-f}	4.55^{a-g}	295^{b-j}	5.56^{b-m}
L4×T2	76^{a-e}	78^{a-e}	153.5^{c-i}	201^{c-f}	108^{b-g}	17.5^{a-g}	13.9^{b-j}	38.7^{a-e}	4.54^{a-g}	285^{b-j}	5.73^{a-m}
L5×T1	73.5^{b-g}	75^{c-f}	154.5^{c-i}	215^{a-e}	113^{a-g}	16.5^{d-j}	13.9^{b-j}	35.3^{b-g}	4.78^{a-g}	288^{b-j}	6.06^{a-l}
L5×T2	73.5^{b-g}	75.5^{b-f}	157^{b-f}	246^{ab}	121^{a-d}	19.7^{a-e}	13.4^{d-f}	35.5^{b-g}	4.78^{a-g}	353^{a-g}	6.07^{a-l}
L6×T1	76.5^{a-d}	78.5^{a-d}	159^{bc}	207^{b-f}	113^{a-g}	15.5^{e-j}	13.6^{c-j}	33.9^{c-g}	4.63^{a-g}	258^{c-j}	6.49^{a-k}
L6×T2	77.5^{ab}	79.5^{ab}	156.5^{b-g}	191^{ef}	99^{e-g}	12.5^{j}	13.6^{c-j}	33.2^{c-g}	4.13^{g}	208^{ij}	3.59^{k-m}
L7×T1	74^{a-i}	76.5^{a-f}	155^{b-i}	192^{ef}	101^{d-g}	16.1^{d-j}	12.8^{g}	31.1^{fg}	4.55^{a-g}	263^{c-j}	4.37^{d-m}
L7×T2	77^{a-c}	79^{a-c}	156.5^{b-g}	211^{b-e}	95^{g}	17.6^{a-g}	14.6^{a-e}	37.9^{a-f}	4.70^{a-g}	293^{b-j}	5.67^{b-m}
L8×T1	76^{a-e}	78.5^{a-d}	157.5^{b-e}	235^{a-d}	123^{a-c}	19.5^{a-e}	14.4^{a-f}	39.2^{a-e}	5.07^{ab}	340^{a-g}	8.25^{ab}
L8×T2	73^{c-j}	75^{c-f}	158^{b-e}	213^{a-e}	113^{a-g}	19.6^{a-e}	14.0^{a-g}	37.4^{a-f}	4.79^{a-g}	338^{a-h}	6.81^{a-g}
L9×T1	75^{a-g}	77^{a-f}	158.5^{b-d}	203^{c-f}	100^{d-g}	16.1^{d-j}	14.9^{a-c}	34.5^{c-g}	4.62^{a-g}	308^{b-j}	5.53^{b-m}
L9×T2	77^{a-c}	78.5^{a-d}	154.5^{c-i}	189^{ef}	113^{a-g}	15.1^{f-j}	13.6^{c-j}	34.9^{c-g}	4.34^{b-g}	230^{g-j}	4.03^{e-m}
L10×T1	75.5^{a-f}	78^{a-e}	164^{a}	202^{c-f}	109^{b-g}	17.4^{a-g}	14.4^{a-f}	37.1^{a-g}	4.29^{c-g}	260^{c-j}	4.39^{d-m}
L10×T2	74.5^{a-h}	76.5^{a-f}	153.5^{c-i}	198^{c-f}	106^{b-g}	17.7^{a-g}	14.0^{a-g}	37.5^{a-f}	4.78^{a-g}	280^{b-j}	5.92^{a-l}
L11×T1	78^{a}	80^{a}	166^{a}	192^{ef}	99^{e-g}	16.2^{d-j}	13.4^{d-f}	35.4^{a-g}	4.78^{a-g}	330^{a-i}	5.86^{a-l}
L11×T2	75.5^{a-f}	77.5^{a-f}	156.5^{b-g}	185^{ef}	103^{d-g}	14.1^{ij}	14.4^{a-f}	34.4^{a-g}	4.17^{d-g}	200^{j}	3.81^{l-m}
L12×T1	74.5^{a-h}	76.5^{a-f}	157.5^{b-e}	225^{a-e}	119^{a-e}	18.2^{a-g}	14.0^{a-g}	36.1^{a-g}	4.89^{a-e}	343^{a-g}	6.58^{a-j}
L12×T2	75^{a-g}	77^{a-f}	149.5i	222^{a-e}	117^{a-f}	18.8^{a-g}	13.9^{b-j}	40.2^{ab}	4.75^{a-g}	338^{a-h}	7.00^{a-e}
L13×T1	71.5^{fg}	74^{ef}	158^{b-e}	199^{c-f}	109^{b-g}	16.7^{c-j}	14.6^{a-e}	37.4^{a-f}	4.90^{a-d}	315^{b-j}	6.61^{a-j}
L13×T2	73^{b-j}	75^{c-f}	152^{h-j}	215^{a-e}	115^{a-g}	18.4^{a-g}	13.6^{c-j}	36.9^{a-g}	4.86^{a-f}	383^{a-c}	5.22^{c-m}
L14×T1	75.5^{a-f}	78^{a-e}	158^{b-e}	224^{a-e}	108^{b-g}	17.2^{a-g}	13.2^{e-g}	37.6^{a-f}	4.69^{a-g}	338^{a-d}	5.49^{b-m}
L14×T2	77^{a-c}	79^{a-c}	157^{b-f}	197^{d-f}	113^{a-g}	14.6^{h-j}	13.9^{b-j}	33.2^{c-g}	4.08^{g}	213^{h-j}	3.67^{j-m}
L15×T1	71.5^{fg}	74^{ef}	152^{h-j}	201^{c-f}	106^{b-g}	16.3^{d-j}	14.6^{a-e}	32.8^{d-g}	4.79^{a-g}	303^{b-j}	5.17^{c-m}
L15×T2	75.5^{a-f}	78.5^{a-d}	155^{b-i}	220^{a-e}	116^{a-g}	17.7^{a-g}	13.8^{b-j}	39.0^{a-e}	4.72^{a-g}	315^{b-j}	6.82^{a-g}
L16×T1	72.5^{c-g}	77^{a-f}	155.5^{b-i}	199^{c-f}	105^{d-g}	18.7^{a-g}	13.8^{b-j}	37.4^{a-f}	4.97^{a-c}	358^{a-f}	7.04^{a-d}
L16×T2	75^{a-g}	77^{a-f}	154^{d-j}	211^{b-e}	119^{a-e}	17.1^{b-i}	13.9^{b-j}	36.3^{a-g}	4.64^{a-g}	253^{d-j}	4.88^{c-m}
L17×T1	75.5^{a-f}	78^{a-e}	157.5^{b-e}	219^{a-e}	115^{a-g}	19.6^{a-e}	14.6^{a-e}	38.9^{a-e}	5.22^{a}	370^{a-e}	6.71^{a-i}
L17×T2	75^{a-g}	77.5^{a-f}	156.5^{b-g}	204^{b-f}	119^{a-e}	17.2^{a-g}	13.9^{b-j}	34.2^{c-g}	4.39^{b-g}	278^{c-j}	2.88^{m}
L18×T1	72.5^{d-g}	75^{c-f}	152^{h-j}	212^{a-e}	111^{b-g}	17.6^{a-g}	14.0^{a-g}	35.1^{c-g}	4.77^{a-g}	300^{b-j}	5.53^{b-m}
L18×T2	72.5^{d-g}	74.5^{d-f}	158.5^{b-d}	217^{a-e}	108^{b-g}	17.4^{a-g}	14.4^{a-f}	32.4^{e-g}	4.63^{a-g}	340^{a-g}	6.23^{a-l}
L19×T1	75^{a-g}	78^{a-e}	156.5^{b-g}	195^{d-f}	101^{d-g}	15.8^{e-j}	13.9^{b-j}	34.0^{c-g}	4.62^{a-g}	268^{c-j}	5.27^{b-m}
L19×T2	75^{a-g}	77.5^{a-f}	155.5^{b-i}	224^{a-e}	134^{a}	15.4^{e-j}	13.2^{e-g}	36.2^{a-g}	4.30^{c-g}	253^{d-j}	5.46^{b-m}
L20×T1	72.5^{d-g}	74.5^{d-f}	157.5^{b-e}	213^{a-e}	110^{b-g}	18.4^{a-g}	13.6^{c-j}	38.1^{a-f}	4.39^{b-g}	270^{a-e}	5.79^{a-m}
L20×T2	76.5^{a-d}	79^{a-c}	155^{b-i}	197^{d-f}	108^{b-g}	15.8^{e-j}	13.9^{b-j}	36.2^{a-g}	4.33^{c-g}	228^{g-j}	3.93^{f-m}
L21×T1	74^{a-g}	76^{a-f}	150.5^{d-j}	204^{b-f}	111^{b-g}	18.4^{a-g}	14.4^{a-f}	36.1^{a-g}	4.93^{a-c}	368^{a-e}	6.93^{a-e}
L21×T2	73.5^{b-g}	76^{a-f}	154.5^{d-j}	213^{a-e}	99^{e-g}	21.0^{ab}	13.8^{b-j}	38.6^{a-e}	4.67^{a-g}	330^{a-i}	6.91^{a-f}
L22×T1	75.5^{a-f}	77.5^{a-f}	155^{b-i}	208^{b-e}	115^{a-g}	19.5^{a-e}	13.6^{c-j}	38.8^{a-e}	4.89^{a-e}	348^{a-g}	6.60^{a-j}
L22×T2	77^{a-c}	78.5^{a-d}	155.5^{b-i}	202^{c-f}	115^{a-g}	16.5^{d-j}	13.4^{d-f}	33.8^{c-g}	4.34^{b-g}	235^{f-j}	4.52^{d-m}
L23×T1	73.5^{b-g}	75^{c-f}	152^{h-j}	221^{a-e}	111^{b-g}	18.9^{a-g}	14.4^{a-f}	36.1^{a-g}	4.59^{a-g}	383^{a-c}	7.00^{a-e}
L23×T2	75.5^{a-f}	77.5^{a-f}	155.5^{b-i}	215^{a-e}	110^{b-g}	21.5^{a}	13.4^{d-f}	43.1^{a}	5.21^{a}	448^{a}	7.56^{a-c}
L24×T1	71.5^{fg}	74^{ef}	153.5^{c-i}	200^{c-f}	114^{a-g}	16.3^{d-j}	13.4^{d-f}	33.2^{c-g}	4.42^{b-g}	250^{e-j}	5.37^{b-m}
L24×T2	74.5^{a-h}	77^{a-f}	157.5^{b-e}	195^{d-f}	111^{b-g}	17.3^{a-g}	14.0^{a-g}	36.3^{a-g}	4.16^{e-g}	290^{b-j}	6.72^{a-h}
L25×T1	74.5^{a-h}	77^{a-f}	158^{b-e}	199^{c-f}	106^{b-g}	15.4^{e-j}	13.4^{d-f}	30.0^{g}	4.34^{b-g}	320^{b-j}	3.88^{g-m}
L25×T2	75^{a-g}	77^{a-f}	154^{d-j}	207^{b-f}	110^{b-g}	18.7^{a-g}	13.0^{fg}	38.5^{a-e}	4.80^{a-g}	338^{a-d}	5.97^{a-l}
L26×T1	73.5^{b-g}	75.5^{b-f}	153.5^{c-i}	240^{a-c}	117^{a-f}	20.2^{a-d}	14.4^{a-f}	40.4^{a-c}	4.89^{a-e}	378^{a-d}	7.70^{a-e}
L26×T2	74.5^{a-h}	76.5^{a-f}	158^{b-e}	186^{ef}	102^{d-g}	18.2^{a-g}	13.6^{c-j}	34.7^{c-g}	4.19^{d-g}	303^{b-j}	3.82^{h-m}
L27×T1	72^{e-g}	74^{ef}	157^{b-f}	215^{a-e}	109^{b-g}	16.8^{b-j}	14.0^{a-g}	39.8^{a-d}	4.55^{a-g}	278^{c-j}	4.44^{d-m}
L27×T2	71^{g}	73.5^{f}	150.5^{ij}	196^{d-f}	106^{b-g}	17.2^{a-g}	14.2^{a-g}	42.5^{ab}	4.44^{b-g}	253^{d-j}	5.48^{b-m}
L28×T1	75^{a-g}	77^{a-f}	154^{d-j}	215^{a-e}	114^{a-g}	19.4^{a-e}	14.0^{a-g}	40.5^{a-c}	4.63^{a-g}	295^{b-j}	6.24^{a-l}
L28×T2	73.5^{b-g}	75.5^{b-f}	156.5^{b-g}	206^{b-f}	107^{b-g}	16.3^{d-j}	15.1^{ab}	34.3^{c-g}	4.90^{a-d}	278^{c-j}	5.04^{c-m}
L29×T1	74.5^{a-h}	77^{a-f}	154.5^{c-i}	204^{b-f}	106^{b-g}	16.4^{d-j}	13.9^{b-j}	37.9^{a-f}	4.39^{b-g}	268^{c-j}	5.77^{c-m}
L29×T2	77.5^{ab}	79.5^{ab}	155.5^{b-i}	206^{b-f}	110^{b-g}	15.8^{e-j}	13.9^{b-j}	32.8^{d-g}	4.57^{a-g}	280^{b-j}	4.49^{d-m}

L30×T1	77.5^{ab}	77.5^{a-f}	157^{b-f}	199^{c-f}	97^{fg}	18.1^{a-g}	14.2^{a-g}	36.3^{a-g}	4.90^{a-d}	315^{b-j}	6.69^{a-i}
L30×T2	77.5^{ab}	79.5^{ab}	155.5^{b-i}	202^{c-f}	108^{b-g}	15.9^{d-j}	13.4^{d-f}	37.9^{a-f}	4.41^{b-g}	258^{c-j}	4.94^{c-m}
L31×T1	75.5^{a-f}	77.5^{a-f}	159.5^{b}	208^{b-e}	108^{b-g}	17.3^{a-g}	13.0^{fg}	38.1^{a-f}	4.68^{a-g}	305^{b-j}	5.39^{b-m}
L31×T2	76.5^{a-d}	78.5^{a-d}	155^{b-i}	254^{a}	127^{ab}	19.1^{a-e}	14.8^{a-d}	40.1^{a-d}	4.75^{a-g}	350^{a-g}	8.68^{a}
L32×T1	76^{a-e}	78^{a-e}	156.5^{b-g}	188^{ef}	118^{a-f}	14.9^{g-j}	13.4^{d-f}	32.0^{e-g}	4.41^{b-g}	240^{f-j}	3.36^{lm}
L32×T2	73.5^{b-g}	75.5^{b-f}	155^{b-i}	205^{b-f}	106^{b-g}	18.1^{a-g}	14.0^{a-g}	35.0^{c-g}	4.77^{a-g}	318^{b-j}	4.75^{c-m}
BH545QPY	72.5^{d-g}	74.5^{d-f}	155^{b-i}	227^{a-e}	120^{a-e}	20.9	13.2	37.1^{a-g}	5.00^{a-c}	405^{ab}	4.43^{d-m}
BH-546	74.5^{a-h}	77^{a-f}	155^{b-i}	216^{a-e}	112^{b-g}	16.5	14.0	36.6^{a-g}	4.53^{a-g}	263	4.33^{d-m}
CV (%)	2.93	2.80	2.01	9.44	9.43	12.5	5.5	9.2	7.31	20.36	26.79
R^2	0.70	0.73	0.82	0.65	0.69	0.71	0.65	0.64	0.64	0.69	0.71
Grand (m)	74.7	76.8	155.8	207.5	110	17.3	13.9	36.4	4.62	299.8	5.58

Means with the same letter are not significantly different from each other. DA=days to anthesis, DS=days to silking, DM=days to maturity, PH=plant height, EH=Ear height, EL=ear length, NRPC=number of rows per cob, NCPR=number of kernel per row, ED=ear diameter, TSW=thousand seed weight, GY=grain yield, CV=coefficient of variance.

Table 4. Proportional contribution of line, tester and line × tester interaction to total variance for 11 traits of maize hybrids tested at Hawassa

Source Variation	DA (days)	DS (days)	DM (days)	PH (cm)	EH (cm)	EL (cm)	NRPC (no)	NCPR (no)	ED (cm)	TSW (g)	GY (t/ha)
Line (%)	58.00	55.00	38.00	46.00	44.70	60	52.30	63.10	42.20	47.90	44.20
Tester (%)	2.10	1.20	4.20	0.10	1.30	0	3.30	0.10	0.00	0.60	5.90
Line × Tester (%)	39.90	44.00	58.00	54.00	54.00	40	44.20	36.80	57.80	51.50	49.80

DA=days to anthesis, DS=days to silking, DM=days to maturity, PH=plant height, EH=Ear height, EL=ear length, NRPC=number of rows per cob, NCPR=number of kernel per row, ED=ear diameter, TSW=thousand seed weight, GY=grain yield.

Conclusions

The analysis of variance showed sufficient genetic variability among genotypes for all characters. σ^2_{SCA} was greater than σ^2_{GCA} for traits like days to anthesis, days to silking, days to maturity, ear diameter, thousand kernel weight, grain yield. σ^2_{GCA} was larger than σ^2_{SCA} in plant height, ear length, number of rows per cob, number of kernels per row and biomass. The proportional contribution of line is greater than tester and the interaction of line × tester for traits like days to anthesis, days to silking, ear length, number of rows per cob and number of kernels per row. The proportional contribution of line × tester is greater than line and tester for traits days to maturity, plant height, ear height, ear diameter, thousand kernel weight and grain yield.

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Character Association and Path Analysis for Yield and Yield Related Traits in Sesame (*Sesamum Indicum* L.) genotypes

Chemeda Daba[1]

[1]Bako Agricultural Research Center

Corresponding author email: chemeda2012@gmail.com

Abstract

Determinations of seed yield components that affect seed yield to the maximum extent are important in formulating an effective breeding program in sesame. Ten sesame genotypes were evaluated in randomized complete block design with three replications at four locations for two cropping seasons (2011 and 2012) with an objective to determine the association among seed yield and its related traits. Association between days to flowering, days to maturity, plant height, branches per plant and seed yield per plant was assessed by correlation coefficient and path analysis. Capsules per plant had significant positive phenotypic and genotypic correlation with seed yield per plant. Days to flowering, days to maturity, plant height and branches per plant had low positive or negative non-significant phenotypic and phenotypic correlations with seed yield per plant. The path analysis based on seed yield as a dependent variable showed that days to maturity had the highest positive direct effect on seed yield at genotypic level. Days to flowering had the highest positive indirect genotypic effect on seed yield through days to maturity. Capsules per plant had high positive phenotypic and genotypic direct effect on seed yield. The direct effects of capsules per plant was almost equal to correlation coefficients with seed yield per plant, indicating that this trait is important for indirect selection. From this study, to improve seed yield in sesame, emphasis should be give on selection of plants with more capsules.

Keywords: Breeding, characters, correlation coefficients, sesame genotypes

Introduction

Sesame is indigenous important oilseed produced by small-scale farmers for domestic use and as cash crop in Ethiopia. Its growing areas are in the trend of increasing due to area expansion; however, there is high completion for land with high yielding crops like maize and sorghum. Comparatively, low seed yield is one of the most important reasons that sesame needs breeding to provide more yield (Furat and Uzun, 2010). There is a need of developing high yielding varieties that can be used commercially in Ethiopia.

Determinations of seed yield components that affect yield to the maximum extent are important in formulating an effective breeding program in sesame. Breeding process in sesame is not an easy because its seed yield is a complex phenomenon involving several contributing factors which are highly correlated with environmental interaction and thus these factors influence seed production both directly and indirectly (Raus *et al* 2004). Direct selection for yield could be difficult because successful seed selection depends on the information on genetic variability and association of yield components with seed yield (Ibrahim and Khidir, 2012). A study of nature and degree of association of component characters with yield assumes greater importance for fixing up characters that play a decisive role in influencing yield. Selection would, therefore, be more effective, if it is based on component characters rather than yield.

The understanding of the relationship between yields and its components is crucial in selection process and this relationship can be explained by means of correlation and path coefficient analysis. Correlation studies provide reliable information on the nature, extent and direction of selection (Yol *et al*., 2010). However, it may not give satisfactory results because its analytical resolution is limited to identification of mutual association among parameters. In crop breeding path analysis has been widely used to identify traits that have significant effect on yield for potential use in selection (Ibrahim and Khidir, 2012; Rao *et al*., 2013; Bharathi, *et al.*, 2015).This technique is useful in determining the direct influence of one variable on the other and also separate the correlation coefficient into direct effect (path coefficient and indirect effect (extents exerted through other independent variables (Yucel, 2004).

Correlation studies, together with path analysis provide a better understanding of the association of different characters with seed yield in sesame. Several researchers (Salehi *et al.,* 2010; Sumathi and Muralidharan, 2010; Yol, *et al*., 2010; Azeez and Morakinyo, 2011; Begum and Dasgupta, 2011; Kurdistani *et al.,* 2011; Ibrahim and Khidir, 2012)); Desawi *et al*.2014; Mohammed, 2015) have worked out character associations to create proper database for sesame breeding practices. Their results differ widely for trait to trait which could be attributed due to differences in genetic material used for their studies. Therefore, this experiment was designed to estimate the degree of association among seed yield and its related traits in sesame genotypes from Ethiopia.

Materials and methods

The experimental materials for the present study comprised of two released varieties viz., Obsa and Dicho, seven elite breeding lines and a local check, Wama (Table 1). These genotypes were selected among the different landraces collected from Western Ethiopia based on their relative yield performance and disease resistance by Bako Agricultural Research Center. The local check was a cultivar mostly grown by farmers in the Wama Valley. All the test genotypes are white seeded, that fetch high price in the market. The ten sesame genotypes were grown in four locations (Angar, Uke, Wama and Bako) in 2011 and 2012 crop seasons. The genotypes were planted in the mid June each year at each location in randomized complete block design, with three replications. The seeds were drilled in each row at rate of 5 kg ha^{-1} in plot consisting of six rows with spacing of 40 cm. A fertilizer rate of 46 kg N ha^{-1} was applied at planting. Twenty days after planting, thinning was done to 10 cm spacing between plants. Four times hand weeding was done at two weeks interval, starting 15 days after planting. Seed yield per plot of the middle four rows were taken and used to estimate and report yield kg ha^{-1}. Data were recorded on days to flowering, days to maturity, plant height, and capsules per plant and yield per plant.

Table 1. List of genotypes used in this study and their silent features

No.	Genotype	Collection zone	Altitude (masl)	DM	PH	BP	CPP	YPP	BB
1	EW002	East Wellega	1470	124	140	9	143	17	R
2	BG006	Benshangul-Gumuz	1000	123	138	7	141	16	R
3	EW023- 2	East Wellega	1580	125	142	5	109	12	MR
4	EW003-1	Horo-Guduru Wellega	1400	122	145	7	141	17	R
5	EW0011-4	East Wellega	1384	124	140	8	124	14	R
6	EW008-1	East Wellega	1402	121	137	7	138	16	MS
7	EW011-2	East Wellega	1342	124	139	7	144	16	R
8	Obsa	Horo-Guduru Wellega	1395	119	135	7	125	14	R
9	Dicho	East Wellega	1460	120	140	8	130	16	MR
10	Wama (Local)	East Wellega	1430	121	137	6	131	15	MR

R=resistant, MR=moderately resistant, MS= moderately susceptible ; Source: Bako Agricultural Research Ceneter

Statistical Analysis

Phenotypic, genotypic and environmental correlation coefficients were estimated using the formulae of Al-Jibouri *et al. (*1958). Path coefficient analysis was used for exhibiting the direct and indirect effect on seed yield according to methods suggested by Dewey and Lu (1959).The inter association between the important yield components were ascertained by working out the path coefficient analysis at phenotypic and genotypic correlation coefficients. This was accomplished by partitioning the direct and indirect effects of various yield components upon seed yield. Seed yield was considered as resultant variable, whereas days to flowering, days to maturity, plant height, number of branches and capsules per plant were supposed to be the causal variables.

Results

Analysis of variance revealed that there was highly significant ($p<0.01$) difference among the genotypes for all characters studied (Table 2). The correlation coefficient of seed yield and yield components was shown in Table 3. Seed yield is the trait of primary interest and showed highly significant positive correlation with capsules per plant at genotypic, phenotypic and environment levels. It had weak negative association with days to flowering and days to maturity both at phenotypic and genotypic levels. Seed yield had positive non-significant positive association with plant height and branches per plant at phenotypic level. The genotypic correlation of plant height and branches per plant with seed yield was non- significant and negative. Days to flowering had highly significant positive association with days to maturity at phenotypic and genotypic levels. This character had a non- significant positive association with plant height both at phenotypic and genotypic level. Days to flowering had showed highly significant and positive genotypic with branches per plant. At phenotypic level, the association between days to flowering and branches per plant was positive but non-significant. Days to maturity had showed positive association with plant height and branches per plant at both genotypic and phenotypic levels. On the other hand, this character had weak negative association with capsules per plant at both phenotypic and genotypic levels. Plant height had positive correlation with branches per plant at all levels. At both phenotypic and genotypic levels the correlation between plant height and capsules per plant was non-significant and negative. The correlation between branches per plant and capsules per plant was positive at levels. In most cases the magnitude of genotypic correlation coefficients was higher than the corresponding phenotypic coefficients. All the traits except capsules per plant had non-significant positive or negative correlation with seed yield per plant at both phenotypic and genotypic levels.

Table 2. Analysis of variance for different characters in sesame

Source	DF	Mean square	DM	PH	BP	CP	SY
Location	3	385.9**	388.04**	23064.57**	45.62**	8798.5200	101.64**
Rep	2	1.800	26.400*	18.050^{ns}	10.17**	9630.80**	125.49**
Year	1	4.300	640.20**	18779.70**	156.81*	5133.750*	77.230*
Genotype	9	70.5**	77.91**	220.410*	5.87**	3058.59**	42.00**
Genotype x Year	9	45.4**	85.630*	185.8400	7.660^{ns}	1315.06^{ns}	10.910^{ns}
Genotype x Location	27	9.310	5.6700	87.8300	0.870^{ns}	1191.28^{ns}	15.28ns
Location x Year	3	116.15**	118.17*	2125.60**	25.69**	134358.6**	1175.92**
Genotype x Location x Year	27	11.210*	8.400	187.40**	1.410^{ns}	1591.94^{ns}	16.350^{ns}
Error	158	7.070	7.630	98.4300	1.6000	1070.390	14.0100
Mean		67.00	124.00	132.00	7.44	135.00	15.10
CV%=		3.96	2.23	7.49	17.01	24.23	25.10

DF=Days to flowering, DM=Days to maturity, PH= Plant height, BP= Branches per plant, CP= Capsules per plant, YP= Yield per plant

Table 3. Combined correlation coefficient across years and locations among six quantitative traits in sesame at genotypic, phenotypic and environmental levels

Traits		DF	DM	PH	BP	CP
DM	rP	0.6801*				
	rG	0.8384**				
	rE	0.1172				
	rP	0.1134	0.3004			
Ph	rG	0.2794	0.5858			
	rE	-0.0734	-0.008			
	rP	0.5274	0.2884	0.2705		
BP	rG	0.8048**	0.4033	0.3761		
	rE	0.0402	0.0831	0.3423		
CP	rP	-0.0263	-0.0706	-0.0284	0.1668	
	rG	-0.0875	-0.1506	-0.3113	0.1190	
	rE	0.0636	0.0495	0.1456	0.4327	
SY	rP	-0.0618	-0.1190	0.0951	0.1807	0.9545**
	rG	-0.1714	-0.2230	-0.0460	-0.0291	0.9813**
	rE	0.1173	0.0542	0.1930	0.3057	0.9378**

DF= days to flowering, DM = Days to maturity, PH = plant height (cm), BP= branch per plant, CP =capsules per plant, SY =seed yield per plant (g)

Estimates of direct and indirect effects at phenotypic and genotypic levels are presented in Table 3. At phenotypic level, the highest positive direct effect was exerted by capsules per plant on seed yield per plant. Days to flowering exhibited positive direct effect on seed yield at phenotypic level. On the other hand, this trait had the highest negative direct effect on seed yield at genotypic level. Days to flowering *via* days to maturity and branches per plant gave high positive genotypic indirect effect on seed yield per plant. At genotypic level, high negative direct effect was shown on seed yield per plant by days to maturity. At the same level plant height and branches per plant had positive direct effect on seed yield per plant. Maximum positive direct genotypic effect was exerted on seed yield per plant by days to maturity. Branch per plant and capsules per plant exerted high positive direct effect on seed yield per plant at genotypic level. Maximum direct negative genotypic effect was shown by days to flowering. At genotypic level plant height indirectly contributed to seed yield through days to maturity. Branches per plant had positive indirect effect on seed yield *via* plant height and capsules per plant at phenotypic level. This trait also had positive indirect effect through days to maturity and capsules per plant. In general, all traits except days to maturity had positive but non-significant direct effect on seed yield at phenotypic level. At genotypic level days to maturity, branches per plant and capsules per plant exhibited positive direct effects on seed yield per plant.

Table 4.The estimates of direct (bold and underlined diagonal values) and indirect effects at phenotypic (P) and genotypic (G) levels of five traits of sesame

		DF	DM	PH	PB	CP	rP or rG
DF	P	0.0220	-0.0770	0.0173	0.0008	-0.0250	-0.0618
	G	-1.6517	0.9356	-0.0887	0.7035	-0.0701	-0.1714
DM	P	0.015	-0.1133	0.0460	0.0004	-0.0671	-0.1190
	G	-1.3848	1.1159	-0.1860	0.3525	-0.1206	-0.2230
PH	P	0.0025	-0.0340	0.1532	0.0004	-0.0270	0.0951
	G	-0.4614	0.6537	-0.3175	0.3287	-0.2494	-0.0460
BP	P	0.0116	-0.0326	0.0414	0.0016	0.1586	0.1807
	G	-1.3293	0.4500	-0.1194	0.8742	0.0953	-0.0291
CP	P	-0.0005	0.0080	-0.0043	0.0002	0.9511	0.9545**
	G	0.1445	-0.1680	0.0993	0.1040	0.8014	0.9813**

DF= days to flowering, DM = Days to maturity, PH = plant height (cm), BP= branch per plant, CP =capsules per plant, SY =seed yield per plant (g)

Discussion

The correlation between capsules per plant and seed yield was significant and positive at both genotypic and phenotypic levels, suggesting that a unit increase of the capsules per plant may increase the seed yield. Such correlations have been attributed to pleiotropy or genetic linkage (Yassin, 1973), or they may be due to developmentally induced relationships between these characters that are only indirectly a consequence of gene action (Adams, 1967). Begum and Dasgupta (2011),Siva Prasad *et al*. (2013) andMohammed (2015) also found that the highest magnitude of positive correlation coefficient between seed yield per plant and number of capsules per plant. Therefore, one should consider capsule per plant as a component to be used during selection for high seed yield. The days to flowering and days to maturity showed low and negative association with seed yield per plant at both phenotypic and genotypic levels. This association indicated that if days to flowering and days to maturity increases, the seed yield per plant decreases moderately in most of the cultivars studied. In contrast, Alake *et al.* (2010) and Sumathi and Muralidharan (2010) reported high correlation of seed yield per plant with days to flowering and days to maturity. Ahmed and Ahmed (2012) also noticed high correlation of days to maturity with seed yield at both phenotypic and genotypic levels. Negative correlations may occur due to competition between two developing structures of a plant for limited resources like nutrient and water supply (Adams, 1967). Newell and Eberhart (1961) take the view that it would be difficult to exercise simultaneous selection for characters that show negative correlation with each other.

Plant height and branches per plant had also low negative correlation with seed yield per plant at phenotypic level, demonstrating that these two traits had no adverse effect on seed yield. On the contrary, Sumathi and Muralidharan (2010) reported significant and positive correlation of seed yield per plant with days to 50% flowering, days to maturity and number of branches per plant. Kurdistani and Tohidinejad (2011) observed that seed yield per plant had highly significant and positive correlation with plant height. Biabani *et al*. (2008) noticed that in addition to capsule per plant, plant height is also important for sesame breeding program for high seed yield. Positive and significant correlation at phenotypic level was observed by branches per plant with days to flowering, which indicates that due to increase in number of days to flowering branches per plant also increased. The association of branches per plant with capsules per plant at phenotypic and genotypic levels was positive and non-significant, signifying that the improvement in the branches per plant would not have any bad effect on capsules per plant. According to Gnanasekaran *et al*.(2008) number of branches per plant and number of capsules per plant should be given importance in selection program to get high seed yields in sesame. The correlation between branches per plant and seed yield was small and positive. In line with the present result, Desawi *et al*. (2014) reported positive and significant phenotypic and genotypic correlation of branches per plant with seed yield per plant. Days to flowering was significantly and positively correlated with days to maturity at both phenotypic and genotypic levels, suggesting that the number of days to mature is highly dependent on the number of days to flower.

The association between plant height and branches per plant was positive at both levels. Earlier reports of Sumathi and Muralidharan, (2010) revealed the positive association of plant height with number of branches per plant and number of capsules per plant. At both phenotypic and genotypic levels, the correlation between plant height and capsules per plant was non-significant and negative.

In most cases genotypic correlation coefficients were slightly higher than their corresponding phenotypic correlation coefficients, indicating that there was a close agreement between phenotypic and genotypic correlations in most of the cases. This close similarity may be due to the reduced environmental variance. Thus the phenotypic correlation reflects more or less the real association among characters in this study.

The high positive direct effect of capsules per plant on seed yield was observed at phenotypic level. These positive direct effect point out that with other characters held constant increasing capsules per plant will increase seed yield per plant. However, the more complex indirect effects play a more important role and may mask the direct influence. Different findings (Yol, et al., . 2010; Salehi *et al*., 2010; Azeez and Morakinyo, 2011; Ibrahim and Khidir, 2012; Bharathi *et al*., 2015) suggested that, capsules per plant can be good selection criteria for single plant seed yield in sesame.

The negative genotypic association of days to flowering with seed yield per plant resulted largely from its high negative direct effects and indirect effects through plant height and capsules per plant. On the contrary, Gidey *et al*. (2013) reported that days to flowering exerted positive direct effect on seed yield. Days to flowering *via* days to maturity gave the highest positive genotypic indirect effect on seed yield per plant.

Days to maturity had the highest positive genotypic direct effect on seed yield per plant; however, it exerted high negative indirect effect on seed yield per plant through days to flowering, plant height and capsule per plant. The net system of opposing influences diluted the positive direct and largely contributed to its negative correlation with seed yield per plant. Contrasting result was reported by Gidey *et al*. (2013) in which days to maturity had negative direct effect on seed yield.

The positive phenotypic association of plant height with seed yield was mainly due to the positive phenotypic direct effect. On the other hand, the negative direct genotypic effect of plant height was resulted in negative genotypic correlation of plant height with seed yield per plant. Quite the reverse, Yol *et al*. (2010) observed that plant height had the highest positive direct effect on seed yield. Khan *et al*. (2001) reported that the number of capsules per plant contributed the highest towards seed yield followed plant height. According to these workers, selection emphasis on these traits could result in improvement in seed yield in sesame.

The positive high genotypic direct effect of branches per plant on seed yield was removed by the high negative indirect effect through days to flowering and resulted in its negative association with seed yield per plant. Siva Prasad *et al*. (2013) also observed that the number of branches per plant recorded the highest magnitude of direct effect on seed yield. Branches per plant had positive phenotypic and genotypic indirect effect on seed yield via capsules per plant. Similarly, Ibrahim and Khidir (2012) observed that that number of branches per plant via number of capsules per plant gave the highest positive indirect effect on seed yield per plant. The positive and significant correlation of capsules per plant with seed yield per plant and its positive direct effect on seed yield per plant indicated that indirect selection based on this attribute may be helpful in producing high yielding sesame varieties. Chowdhury *et al.* (2010) and Aremu *et al.* (2011) reached similar conclusion.

Conclusion

The correlation between capsules per plant and seed yield was significant and positive at both genotypic and phenotypic levels indicating that the indirect selection for seed yield based on this trait was effective. Therefore, capsule per plant can be considered as the best criteria for improving seed yield in sesame breeding program. Branches per plant had positive phenotypic and genotypic direct effect on seed yield indicating that this trait can be considered, as is an important trait for indirect selection by far next to capsules per plant.

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Grain Yield Stability Analysis for Advanced Emmer Wheat (*Triticum dicoccum*) Genotypes in Bale Highland

Tilahun Bayisa[1]*, Tesfaye Letta[2], Mulatu Abera[1]

[1] *Sinana Agricultural Research Center, P.O.Box 208, Bale-Robe, Ethiopia*

[2] *Oromia Agricultural Research Institute, P.O.Box:81265, Addis Abeba, Ethiopia*

Corresponding, author: Email: tilahunbayisa@gmail.com

Abstract

Emmer wheat landraces are locally adapted to diverse ecological zones. The diversity of emmer wheat is seriously threatened by genetic erosion due to the increase in bread wheat production. It comprises about 7% of Ethiopia's entire wheat production. The objective of this study was to evaluate the stability of advanced emmer wheat genotypes in Bale highland. The field experiment was conducted at two locations including Sinana and Goba during 2013 to 2015 main cropping seasons using 15 emmer wheat genotypes. The treatments were arranged in a randomized complete block design with three replications. Pooled analysis of variance for gain yield indicated the main effect differences among genotypes, environments, and the interaction effects were highly significant ($p \leq 0.01$). The environmental effect is accounted for 86.5% of the total yield variation, whereas, genotype and G × E interaction effects were only accounted for 3.1% and 10.4% of the total variation, respectively. The average environmental grain yield ranged from the lowest of 1865.5 kg ha^{-1} at Goba in 2014 to the highest of 4617.5 kg ha^{-1} at the same location in 2015, with a grand mean of 2917.1kgha^{-1}. Genotypes G2, G10 and G9 showed first interaction principal component axis (IPCA1) scores close to zero, indicating stable performance across the test environments. Environments Sinana 2013 and Sinana 2014 were the best environments with the high mean yield of from the first four AMMI selected per environments. The proportion of the first interaction principal component axis sum of squares 34.00% to the interaction sum of squares and the second interaction principal component 28.23%. This indicated that the existence of differential yield responses among the genotypes across the testing environments due to the presence of significant G × E interaction effect.

Keywords: AMMI, Emmer wheat, GxE interaction, PCA

Introduction

Wild emmer wheat (*T. turgidum* ssp. *dicoccoides* (korn.) Thell) is the tetraploid ($2n=4x=28$; genome BBAA) progenitor of both domesticated tetraploid durum wheat (*T. turgidum* ssp.*durum*(Desf.) MacKey) and hexaploid ($2n = 6x = 42$; BBAADD) bread wheat (*T. aestivum* L.). It is thought to have originated and diversified in the Near East Fertile Crescent region through adaptation to a spectrum of ecological conditions. It is genetically compatible with durum wheat (*T. turgidum* ssp. *durum*) and can be crossed with bread wheat (*T. aestivum* L.) (Feldman, 2001). It is expected that early immigrants of Hamites brought emmer wheat to Ethiopia, some 5,000 years ago and was introduced into the Ethiopian Highlands from Egypt along the Nile River (Fuller et al., 2011 and Oliveira et al., 2012). Emmer wheat comprises about 7% of Ethiopia's entire wheat production (BOSTID, 1996). The major production areas in Ethiopia include Bale, Arsi, Shewa, Harerge, Wollo, Gojam and Gondar. It is known by different vernacular names such as "Aja" (in Amharic), "Hayssa" or "Matajebo" (in Afaan Oromo). Emmer wheat landraces are locally adapted to diverse ecological zones. The diversity of emmer wheat is seriously threatened by genetic erosion due to the increase in bread wheat production. The urgent need to preserve and utilize landrace genetic resources as a safeguard against an unpredictable future is evident (Haile *et al.,* 2012).

Targeting variety selection onto its growing environments is the prime interest of any plant-breeding program. To realize this, a rigorous genotypes performance evaluation across locations and years mostly at the final stage of variety development process. Selecting genotypes for high mean yield and yield stability has been a challenge for breeders. The requirement for stable genotypes that perform well over a wide range of environments becomes increasingly important as farmers need reliable production quantity (Gauch et al., 2008). Therefore, identifying most stable genotypes is an important objective in many plant breeding programs for all crops, including emmer wheat. The performance of a genotype is determined by three factors: genotypic main effect (G), environmental main effect (E) and their interaction (Yan et al., 2007). The GE interactions structure is an important aspect of both plant breeding programs and the introductions of new improved crop cultivars as yield stability analysis (Neacşu, 2011). The objective of this study was to evaluate the stability and grain yield performance of advanced and promising emmer wheat genotypes in Bale highland.

Materials and Methods

The field experiment was conducted at two locations including Sinana and Goba during 2013 to 2015 main cropping seasons using 15 emmer wheat genotypes, year location combination being considered as environment. Sinana is characterized by bimodal rainfall pattern and annual total rainfall ranges from 750 to 1400 mm. The main season receives 270 to 842 mm rainfall, while the short season receives from 250 to 562 mm. Goba is characterized as high-altitude environment receiving enough rainfall with even distribution throughout the cropping season. Full description of the 2 test locations and 15 emmer wheat genotypes are given in Table 1 and Table 2, respectively. The treatments were arranged in a randomized complete block design with three replications. The plot size was $3m^2$ with six rows of 2.5m long and spacing of 20cm between rows. 150kgha $^{-1}$ seed rate was used at both test sites. For statistical analysis, yield from net plot area of $2m^2$ was harvested and converted into kg ha^{-1} base at 12% standard grain moisture content.

Table 1. Description of the test locations

Locations	Geographical position		Altitude (m.a.s.l)
	Latitude	Longitude	
Sinana	07^o 07'N	40^o 10'E	2400
Goba	07^o 01'N	40^o 00' E	2550

Table 2. Description of the 15 emmer wheat genotypes tested across 2 different environments during 2013-2015 cropping season

SN	Genotype	Source	SN	Genotype	Source
1	Sinana-01/Ude//Sinana-01#1	SARC Cross	9	Sinana-01/Gedilfa//Sinana-01#11	SARC Cross
2	Sinana-01/Ude//Sinana-01#4	SARC Cross	10	Sinana-01/Gedilfa//Sinana-01#12	SARC Cross
3	Sinana-01/Ude//Sinana-01#22	SARC Cross	11	Sinana-01/DZ2212//Sinana-01#3	SARC Cross
4	Sinana-01/Cocorit 71//Sinana-01#4	SARC Cross	12	Sinana-01/DZ2212//Sinana-01#10	SARC Cross
5	Sinana-01/Cocorit 71//Sinana-01#1	SARC Cross	13	Sinana-01/DZ2212//Sinana-01#13	SARC Cross
	Sinana-01/Gedilfa//Sinana-01#1	SARC Cross		Sinana-01	Standard
6	Sinana-01/Gedilfa//Sinana-01#8		14		check
7	Sinana-01/Gedilfa//Sinana-01#	SARC Cross	15	Local	Landrace
8	Sinana-01/Gedilfa//Sinana-02#	SARC Cross			

* SARC Cross = Sinana Agriculture Research Center cross

Statistical Procedures: The grain yield data was subjected to analysis of variance using the Genstat 15th Edition Statistical Package. Variance combined analysis of variance was done using the procedure to partition the total variation into components due to genotype (G), environment (E) and G × E interaction effects. The following model was used for combined
ANOVA:

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

Where Y_{ijk} is an observed value of genotype i in block k of environment j; μ is a grand mean; G_i is effect of genotype i; E_j is an environmental effect; GE_{ij} is the interaction effect of genotype i with environment j; $B_{k(j)}$ is the effect of block k in environment j; ϵ_{ijk} is an error effect of genotype i in block k of environment j. Genotype was regarded as a fixed effect while environment was regarded as a random effect. The main effect of E was tested against the replication within environment, the main effect of G was tested against the G × E interaction, and the G × E interaction was tested against pooled error. Separation of the main effect was done using least significant difference Test at 5% probability level.

Result

Genotype performance: Pooled analysis of variance for gain yield (kg ha^{-1}) of the 15 emmer wheat genotypes tested across six environments was shown in (Table 3). The main effect differences among genotypes, environments, and the interaction effects were highly significant ($p \leq 0.01$). The environmental effect is accounted for 86.5% of the total yield variation, whereas, genotype and G × E interaction effects were only accounted for 3.1% and 10.4% of the total variation, respectively (Table 3). This shows that grain yield of emmer wheat genotypes was found to be significantly affected by changes in the environment, followed by G × E interaction and genotypic effects (Table 3). This may indicated the existence of a considerable amount of deferential response among the genotypes to changes in growing environments and the differential discriminating ability of the test environments. Such circumstances are believed to minimize the usefulness of cultivars (Pham and Kang 1988) by confounding their yield performances. Thus, it is very important to study in depth the yield levels, adaptation patterns and stability of emmer wheat genotypes in multiple environments. The average environmental grain yield across genotypes ranged from the lowest of 1865.5 kg ha^{-1} at Goba in

2014 to the highest of 4617.5 kg ha^{-1} at Goba in 2015, with a grand mean of 2917.1kg ha^{-1} (Table 4). The genotypes grain yield across environments ranged from the lowest of 2637.1 kg ha^{-1} for G14 to 3229.6 kg ha^{-1} for G6 (Table 4). Therefore, genotype by environment interaction that makes it difficult to select the best performing and most stable genotypes is an important consideration in plant breeding programs (Bramel-Cox, 1996)

Table 3. Combined analysis of variance for grain yield of 15 emmer wheat genotypes grown at 6 environments

Source	DF	SS	MS	F
Treatments	89	186640138	2097080	11.45**
Genotypes	14	5746041	410431	2.24**
Environments	5	161426464	32285293	64.16**
Interactions	70	19467634	278109	1.52*
IPCA	18	7205042	400280	2.19**
IPCA	16	6272475	392030	2.14**
Residuals	36	5990117	166392	0.91
Error	168	30761142	183102	

**=Significant at 0.05 probability level, **= significant at 0.01 probability level, df= degree freedom, SS= sum of square, MS= mean square and F= F- value*

Genotype stability: The relative magnitude and direction of genotypes along the horizontal and vertical axis of the graph is important to understand the response pattern of genotypes across environments. Genotypes with IPCA1 scores close to zero expressed general adaptation whereas the larger scores depict more specific adaptation to environments with IPCA1 scores of the same sign (Ebdon and Gauch 2002). Accordingly, genotypes G2, G10 and G9 , with their relative IPCA1 scores close to zero, have less response to the interaction and showed general adaptation to the test environments. Genotype G5 demonstrated large positive IPCA1 score and found better adapted to environment Sinana 2014 with larger and same sign IPC1 score followed by G3 and G7. In contrast, genotypes G13, G6 and G12, with their larger negative IPC1 scores were adapted to environments Goba 2013 and Goba 2014 (Figure 1). The best cultivar should hold high yield with stable performance across a range of environments. Environments Sinana 2013 and Sinana 2014 were the best environments with the mean yield of 3891kgha^{-1} and 2835kgha^{-1}, respectively from the first four AMMI selected per environments.

AMMI Analysis: The application of AMMI model for partitioning the G × E interaction effect revealed that only the first two terms of AMMI were significant based on Gollob’s F-test (Gollob, 1968). These two multiplicative component sum of squares, with their cumulative were captured 62.23% of the G × E interaction sum of squares. In this study, the proportion of the first interaction principal component axis sum of squares (IPCA1 = 34.00%) to the interaction sum of squares and the second interaction principal component (IPCA2 = 28.23%) (Table 3). This indicated that the existence of differential yield responses among the genotypes across the testing environments due to the presence of significant G × E interaction effect.

Prediction assessments were indicated that AMMI with only the first two multiplicative component axes was adequate for cross-validation of the variation explained by the G × E interaction (Zobel et al., 1988). The present investigation also revealed that the first two multiplicative components of the interaction term were significant at $p \leq 0.01$ (Table 3). Thus, the interaction pattern of the 15 emmer wheat genotypes with the 6 environments scattered over the first two AMMI multiplicative components of genotypes and environments visualized the pattern of affinity between the genotypes and the environments.

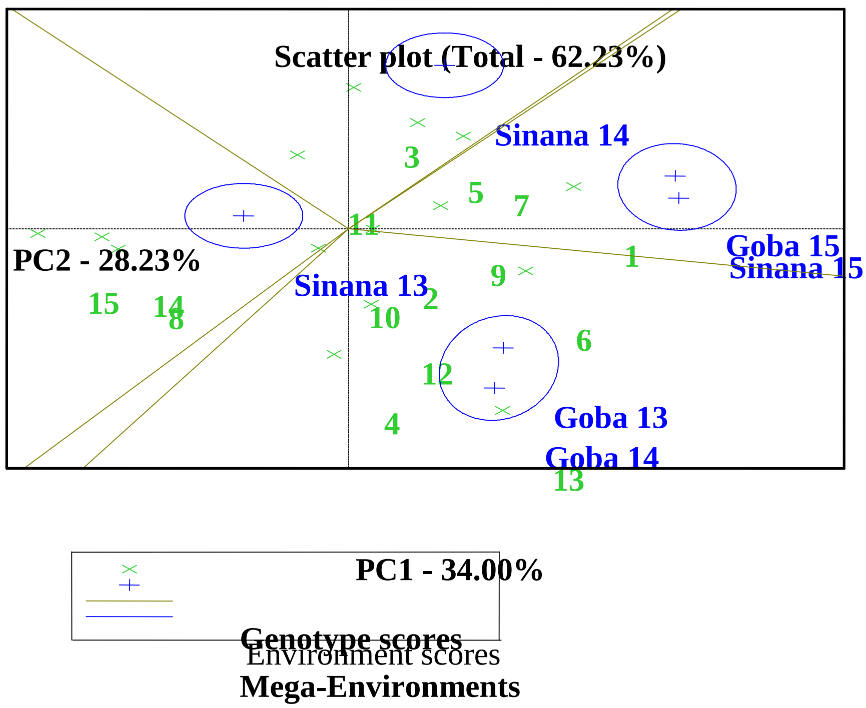

Figure 1. AMMI biplot analysis showing the mega-environments and their respective high yielding genotypes.

Table 4. Mean grain yield (kgha^{-1}) of 15 emmer wheat genotypes evaluated over 6 environments

Code	**Genotypes**	Environments*						Mean
		E1	E2	E3	E4	E5	E6	
G1	Sinana-01/Ude//Sinana-01#1	3573.17	2972.50	2411.3	2325.7	2169.2	4413.0	2977.5
G2	Sinana-01/Ude//Sinana-01#4	3973.33	2737.58	2343.3	1899.3	1812.8	4738.7	2917.5
G3	Sinana-01/Ude//Sinana-01#22	4102.50	3278.33	2389.0	1941.8	1579.7	4310.3	2933.6
G4	Sinana-01/Cocorit 71//Sinana-01#4	3645.83	2110.83	2206.7	1790.8	1928.2	4841.0	2753.9
G5	Sinana-01/Cocorit 71//Sinana-01#12	4034.17	3472.50	2234.0	2030.8	2105.3	5176.0	3175.5
G6	Sinana-01/Gedilfa//Sinana-01#1	4225.00	2885.83	2416.0	2145.2	2699.8	5005.7	3229.6
G7	Sinana-01/Gedilfa//Sinana-01#8	3631.67	3197.50	2374.5	2119.3	1939.2	4229.7	2915.3
G8	Sinana-01/Gedilfa//Sinana-01#9	3911.67	2830.83	1747.5	1351.8	2109.8	4402.5	2725.7
G9	Sinana-01/Gedilfa//Sinana-01#11	3627.50	3043.33	2393.0	1897.0	2159.7	4444.3	2927.5
G10	Sinana-01/Gedilfa//Sinana-01#12	4272.50	2442.50	2013.0	2108.0	2107.8	4963.0	2984.5
G11	Sinana-01/DZ2212//Sinana-01#3	4161.67	2964.00	2286.5	1803.0	1807.3	4595.3	2936.3
G12	Sinana-01/DZ2212//Sinana-01#10	4421.33	2491.67	2414.2	1782.5	2465.8	4567.0	3023.8
G13	Sinana-01/DZ2212//Sinana-01#13	3575.83	2678.33	2218.5	1845.5	2602.3	4911.5	2972.0
G14	Sinana-01	3716.67	2714.17	1558.7	1489.2	2238.8	4105.0	2637.1
G15	Local	3990.83	2715.83	1473.3	1453.0	1686.0	4558.8	2646.3
Mean		3924.24	2835.72	2165.3	1865.5	2094.1	4617.5	2917.1
CV (%)		10.29	18.96	19.73	15.8	24.5	11.1	24.6
LSD (5%)		675.22	899.41	714.5	492.5	857.1	856.2	615.4

* E1= Sinana 2013, E2= Goba 2013, E3= Sinana 2014, E4= Goba 2014, E5= Sinana 2015, E6= Goba 2015, CV (%)= Coefficient of variations, and LSD= Least significant differences,

Conclusion

Whenever genotypes are proposed for high production, information on G × E interaction and stability clearly indicating their general and specific adaptations needs to be available to the users. The present study revealed that emmer wheat yield was liable to significant fluctuations with changes in the growing environments followed by the interaction but genotypic effect contributing the least. Genotypes G2, G10 and G9 IPC1 scores close to zero IPCA1 score, have less response to the interaction and showed adaptation to the test environments. Environments Sinana 2013 and Sinana 2014 were the best environments with the high mean yield from the first four AMMI selected per environments. The proportion of the first interaction principal component axis sum of squares 34.00% to the interaction sum of squares and the second interaction principal component 28.23%. This indicated that the existence of differential yield responses among the genotypes across the testing environments due to the presence of significant G × E interaction effect.

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Evaluation of Open Pollinated Maize (*Zea mays* L.) Varieties for mid altitude areas of Western Guzi Zone, Southern Oromia

[1*]Natol Bekele, [1]Tolasa Taye, [1]Yonas Shimeli and [1]Zelalem Teku
Oromia Agricultural Research Institute, Yabello Pastoral and Dryland Agricultural Research
*Corresponding author: e-mail:natymartyko@gmail.com

Abstract

Maize is one of the most important cereals crop broadly adapted to different agro-ecologies worldwide. Different genotypes have different performance in each region that can be capitalized to maximize productivity. Six open pollinated maize varieties were brought from Bako National Maize Research Center and planted in RCBD with three replications at Galana and Abaya sub site of Yabello Pastoral and Dryland Agriculture Research Center for three respective years. Analysis of variance showed that, significant yield difference was recorded among genotypes. The combined analysis of variance indicated that highest average grain yield of 5.85 *t/ha was obtained from Gibe-2 followed by* 5.63 *t/ha for Kulani variety across years and locations. Stability analysis revealed Kulani was the most stable variety among all while Gibe 2 was unstable. The Additive main and multiplicative interaction stability value (ASV) of Kulani and ABO-Bako were close to zero (0.08 and 0.27, respectively), while the ASV of Gibe 2 was relatively higher (1.62) deviating from zero. Therefore, Kulani was stable and high yielder across environments while Gibe 2 was high yielder in specific environment (unstable). So, and Kulani had been promoted for cultivation in Galana and Abaya districts of southern Oromia and areas with similar agro ecologies, while Gibe 2 was recommended for Galana district.*

Keywords: Adaptation, ASV, Genotypes, Stability, *Zea mays*

Introduction

Maize (*Zea mays* L.) (2n=20) is also known as corn, belongs to the family *Poceaceae* and is a versatile crop that adapts easily to a wide range of production environments (Gerpacio and Pingali, 2007; Riedelsheimer *et al*., 2012). Maize is the third most important crop in the world in terms of growing area, production and grain yield (Shiri *et al.*, 2010) and it is important basic crop of trade product and recurring ingredient for millions of people in sub-Saharan Africa (Nzuve *et al.*, 2013). Maize is a multipurpose crop that acclimates effortlessly to a wide variety of production set of conditions (FAO, 2015). Maize occupies a crucial role in the world economy and is traded widely. Maize demand is proposed to increase by 50% worldwide and by 93% in sub-Saharan Africa between 1995 and 2020 (FAO, 2016). Maize is one of the staple foods in Ethiopia, whose importance in consumption as well as production has significantly increased.

In Ethiopia average maize grain yield is low due to problems like insect pest damage, lack of high yielding varieties and poor crop management practices. The most important problem reported by farmers in Western Guji Zone was the lack of adaptable maize varieties and majority of the farmers in the area are growing local varieties. So far, no effort has been made in the zone to introduce and adapt improved maize varieties.

Genotype by environment interactions are the most importance to the plant breeder in selecting appropriate variety for appropriate environmental condition. Different genotypes may have different performance in each region that can be capitalized to maximize productivity (Souza *et al*., 2008). Variability in grain yield is due to difference in genetic potential among genotypes and environment effect. Grain yield is quantitative in nature, which usually exhibits GEI, which necessitates evaluation in multi-environment trials before doing advanced selection (Khalil *et al*, 2010).The presence of genotype by environment interaction (GEI) frequently changes the varieties ranks in different environments due to cross interaction making their proper selection difficult. Therefore, it is essential to analyze and converse genotype by environment interaction which help us in getting information on adaptability and stability of performance of genotypes. The method commonly used for analysis of G×E interaction is AMMI (Additive Main Effects and Multiplicative Interaction) approach as a measure of stability and adaptability. The AMMI model is a better model for analysis of GxE interaction in multiplication varietal trials (Zobel *et al*., 1988). It does not only give estimate of total GxE interaction effect of each genotype but also partitions it into interaction effects due to environments. Thus, the current experiment is aimed at evaluation of open pollinated maize varieties for the adaptability and stability of grain yield and yield related traits for mid altitude areas of Western Guji Zone

Materials and Methods

Experimental Materials and Design

Table 1. Lists and description of materials used in an experiment Source: (EARO, 2004)

Six open pollinated maize varieties (table 1) were brought from Bako National Maize Research Center and planted at Yabello Pastoral and Dryland Agriculture Research Center sub site Galana and Abaya for three consecutive years. A completely randomized block design with three replications was used. The plants were grown according to the recommended agronomic practices. Each plot was 12.6 m^2 sizes with 6 rows of 3m length and 25cm x75cm spacing was used. The harvested plot size was 8.4 m2 four (4) rows at the middle of each plot. The recommended fertilizer rate was used for all genotypes at each site.

Collected data: All agronomic data such as days to physiological maturity (DM), hundred kernels weights, plant height, ear length, ear height, number of kernels per row and number of row per cob were collected following method used by Natol et al., (2017).

Data analysis: Analysis of variance for phenological, yield and yield related data were done with the PROC ANOVA procedure in SAS software with genotypes being considered as fixed effects and replication within environment being as random effect as per the method described by Gomez and Gomez (1984). Least significant different (LSD) was used for mean separation. Adaptability and stability of the genotypes was estimated using the Genstat 15^{th} edition. G x E biplots were generated to evaluate the genotypes simultaneously for yield and stability. ASV (AMMI Stability Values) were estimated for both genotypes and environments. The AMMI (Additive Main Effect and Multiplicative Interaction) model, which combines standard analysis of variance with principal component analysis, was used to investigate of G × E interaction. In AMMI model the contribution of each genotype and each environment to the G x E interaction is assessed by using the biplot graph display in which yield means are plotted against the scores of the IPCA (Interaction Principal Component Axis) (Zobel *et al.* 1988). The AMMI model is:

$Y_{ij}=\mu + g_i +e_j +\Sigma\lambda k +\alpha ik\ yjk +R_{ij}$

Where, Y_{ij} is the yield of i^{th} genotypes in j^{th} environment; μ the overall mean; g_i is the effect of the i^{th} genotype; e_j is the effect of the j^{th} environment; λk is the square root of the eigenvalue of the PCA axis k. Then α_{ik} and y_{jk} are the principal components scores for PCA (Principal Component Axis) k of the i^{th} genotype and j^{th} environment, respectively, and R_{ij} is the residual. Environment and genotype PCA scores are expressed as unit vector times the square root of λk

Variety	Year of release	Altitude (masl)	Rain fall (mm)	Maturity date	Yield on research field (kg/ha)	Production status
Kulani	1995	1700-1400	1000-1200	150	6000-7000	Under production
ABO-Bako	1985	500-1000	1000-1200	150	5000-7000	Under production
Gutto	1988	1000-1700	800-1200	126	3000-5000	Under production
Gibe 1	2001	1000-1800	1000-1700	145	6000-7000	Under production
Gambella	2002	500-1000	1000-1200	110	6000-7050	Under production

(environment PCA score = λk0.05yik, genotype PCA score = λk0.05αik (Zobel *et al*., 1988). In order to rank the genotypes used for this study in terms of stability, AMMI stability value (ASV) was calculated for each genotype following the procedure proposed by Purchase (1997) as follows:

$$ASV = \sqrt{\left[\frac{(IPCA1\ scores)\ x\ (IPCA1ss)}{IPCA1SS}\right]^2 + [IPCA2score]^2}$$

Where, ASV=AMMI Stability Value; IPCA1SS= Interaction Principal Component Axis 1 sum of squares; IPCA1score = Interaction Principal Component Axis 1 score; IPCA2score = Interaction Principal Component Axis 2 score.

Results and Discussion

Mean performance of Varieties across locations

Days to maturity: Analysis of variance showed that, there is significant difference among varieties in days to maturity ($P<0.01$) for three consecutive years for both sites. Kulani was late mature among all genotypes which took 153days and 150.67days in 2014 and 2015 cropping season respectively. Gambella matured earlier than other genotypes under study for Galana site (table 3). At Abaya site, Kulani was late maturing one among all genotypes under study, which took 150.67, 152.00 and 151.67days in 2014, 2015 and 2016 cropping season respectively. Gambella took 103.67, 111.33 and 110.32days to mature in 2014, 2015 and 2016 cropping seasons. (table 3). Taye *et al.* (2015) found significant differences among genotypes in their study of high land maize evaluation.

Grain yield: Analysis of variance showed significant different among genotypes in grain yield in all cropping season. The higher grain yield was obtained from Kulani 6.48t/ha in 2014, 4.65t/ha in 2015 and 5.01t/ha in 2016 cropping season while, the lowest grain yield was obtained from Gutto LMS 4.31t/ha, 4.28t/ha and 4.28t/ha in 2014, 2015 and 2016 cropping seasons respectively (table 3). The yield variability observed among genotype, showed the potential of the variety and specific adaptability of the genotype. For Abaya site, maximum grain yield was obtained from Gibe 2 (5.08, 6.50 and 6.71t/ha in 2014, 2015 and 2016 cropping season respectively. Bassa and Goa (2016) reported that different maize varieties produce significantly different grain yields at different locations over years. Taye *et al*. (2016) also reported significant yield difference among diifferent maize genotypes

Table 2. Mean performance of days to maturity and grain yield for Abaya and Galana site

Varieties	Days to maturity (days)						Mean	Grain yield (t/ha)						Mean
	Galana site			Abaya Site				Galana site			Abaya Site			
	2014	2015	2016	2014	2015	2016		2014	2015	2016	2014	2015	2016	
Gibe-1	143b	141.67b	143.67c	141.67b	146b	146.33b	144.83b	5.21b	4.52ab	4.35b	4.52ab	4.47c	6.28a	5.42c
Gibe-2	132c	135.00c	137.67d	135.00c	139c	137.00c	136.17c	5.41b	4.65a	4.57b	4.65a	6.50a	6.65a	5.85a
ABO-Bako	152a	145.67b	152.33a	145.67b	149ab	150.67a	149.83a	5.44b	4.25c	4.68ab	4.25c	4.57c	5.49b	4.93e
Gutto-LMS	124d	127.33d	126.67e	127.33d	125d	126.00d	125.83d	4.31c	4.28bc	4.28b	4.28bc	4.26c	4.21c	4.03f
Gambella	110e	103.67e	110.67f	103.67e	111.33e	110.32e	110.11e	5.54b	4.52ab	4.67ab	4.52ab	4.15c	6.20a	5.16d
Kulani	153a	150.67a	147.67b	150.67a	152a	151.67a	151.06a	6.48a	4.42abc	5.01a	5.08a	5.47b	6.71a	5.63b
LSD	7***	4.45***	3.48***	4.45***	4.13***	3.34***	1.45***	0.76***	0.24**	0.42*	0.24**	0.42***	0.59***	0.22***
CV (%)	1.88	2.27	1.40	2.27	1.66	1.34	1.60	4.41	2.92	5.03	2.92	4.75	5.48	6.45

*, **, *** = significant at P < 0.05, at P < 0.01 and at P< 0.001, respectively, ns = non-significant. DM=days to maturity, Yld=grain yield, LSD=least significant difference, CV=coefficient of variance

Combined Analysis of Variance: Combining analysis of variance (ANOVA) across locations for grain yield showed a significant in genotype × location interaction suggesting that genotypes x environment interactions influenced the yield performance of maize genotypes. Similarly, Workie *et al*. (2013) reported different genotypes perform differently for yield and yield related traits under different environmental conditions.

Combined analysis of variance showed that a very highly significant ($P<0.0001$) variation was observed between genotypes, environment and the genotypes x environment interaction for plant height, ear height, Cob diameter, hundred seed weight and grain yield (Table 4). This indicated that the varieties and the test environments are variable, and the varieties performed differently across locations and years for almost all traits. Combined analysis of variance indicated that genotypes and environment showed significant effect ($P<0.05$) while G x E had non-significant effect on number of rows per cob and number of seeds per row. Traits less affected by environments are high heritability (Epinat-Le Signor *et al*., 2001).

Table 3. Over all mean of maize genotypes for yield, yield related traits and phonological growths

Varieties	Traits mean							
	DM (days)	PH (cm)	EH (cm)	NRPC (no)	CD (cm)	NSPR (no)	HSW (g)	YLD (t/ha)
Gibe-1	144.83b	144.28c	97.48ab	13.69ab	4.39c	35.26ab	31.72b	5.42c
Gibe-2	136.17c	178.39a	90.41c	13.33bc	4.32c	34.04abc	31.67bc	5.85a
ABO-Bako	149.83a	181.57a	94.73bc	13.39b	4.34c	35.56ab	29.58cd	4.93e
Gutto-LMS	125.83d	163.53b	89.56c	12.44c	5.87b	33.56bc	29.03de	4.03f
Gambella	110.11e	180.78a	95.35bc	14.44a	4.27c	35.83a	27.64e	5.16d
Kulani	151.06a	181.74a	103.60a	13.33bc	6.33a	32.97c	34.00a	5.63b
Significance level								
Replication	9.36ns	6.48ns	138.50ns	4.08ns	0.04ns	30.07*	3.21ns	0.03ns
Genotype	4568.84***	4119.92***	470.81***	7.44**	15.45***	24.88*	9.36***	5.52***
Environment	27.55***	822.90***	296.06**	19.04***	38.68***	307.08***	66.07***	7.87***
Genotype x Environment	12.84**	327.37***	267.90***	1.85ns	16.35***	13.11ns	42.24***	1.20***
Error	4.83	113.91	85.13	1.96	0.15	9.36	6.85	0.09
CV (%)	6.22	1.61	9.69	10.13	7.86	8.86	8.57	5.61

*, **, *** = significant at P < 0.05, at P < 0.01 and at P< 0.001, respectively, ns = non-significant. DM=days to maturity, PH=plant height, EH=ear height, NRPC=number of rows per cob, NSPR=number of seeds per row, HSW=hundred seed weight, CD=cob diameter and Yld=grain yield.

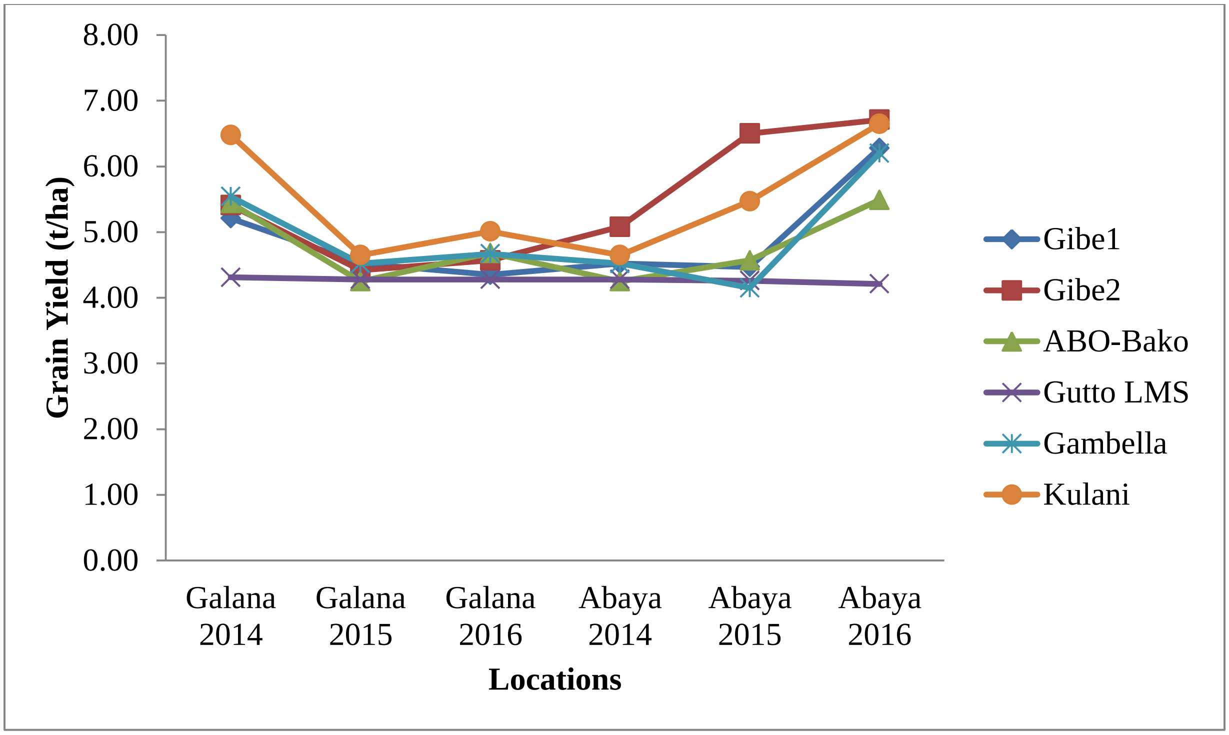


Figure 1: The performance of maize varieties across three years at Abaya and Galana sub sites

GEI is existing when the reaction norms for different genotypes are not parallel (Van Eeuwijk *et al*., 2005). An extreme form of GEI is by cross-over interaction, where the ranking of the genotypes varies with the environmental conditions (Crossa *et al*., 2004). There was a rank change of varieties across years which may mean the presence of crossover interaction. Kulani and Gambella were relatively well performed and high yielder across years, while Gutto LMS showed poor but consistent yield performance across years and locations (Fig 1). There was a change in rank of genotypes across years which may suggest the presence of crossover interaction. Similarly, Akbar *et al*. (2009) and Hussain *et al*. (2011) reported significant differences among maize cultivars for grain yield under different environmental condition.

Stability Analysis: The AMMI analysis provides a graphical representation to précis the information of main effect and interaction effect for genotypes and environments on the same graph. Variance of the data on yield showed that all the three components genotype (G), environment (E) and G x E interaction were highly significant indicating broad range of diversity existed among varieties, location and seasonal variations (Table 5). Further, the mean squares from AMMI analysis indicated variation among G, E and G x E interaction showed highly significant different level at ($P < 0.01$) (Table 6). G x E interaction was further partitioned into two principal component analysis axis (IPCA) interactions. This variability was may be due to larger dissimilarity in rainfall, number of rainy days in each environment and high variation in mean sunshine hours among the environments. Several authors also reported supportive results (Nzuve *et al*., 2013; Kumar and Singh, 2015 and Miah *et al*., 2016).

Table 4. Combined analyses of variance using AMMI Model.

Source of variation	df	Sum Square	Mean Square	Sum Squares Explained % total	% G x E
Total	107	101.25	0.5		
Genotypes	5	27.60	5.52**	27.26	
Environments	5	39.36	7.87**	38.87	
Genotype x environment	25	26.22	1.05**	25.90	
IPCAI	9	13.63	1.51**		51.98
IPCAII	7	7.47	1.07**		28.49
Residuals	9	5.13	0.57**		
Error	60	5.13	0.0900		

** P <0.01

Table 5. IPCA 1 and IPCA 2 scores, genotypes mean and six open pollinated maize varieties tested at six locations.

Genotypes	Graph ID	Genotype mean	IPCAg[1]	IPCAg[2]	ASV
ABO-Bako	ABO	4.93	0.46	0.01	0.29
Gambella	Gambella	5.16	0.40	0.52	0.49
Gibe-1	Gibe1	5.42	-0.61	0.54	0.79
Gibe-2	Gibe2	5.85	-0.92	-0.69	1.62
Gutto-LMS	Gutto	4.30	0.74	-0.68	1.20
Kulani	Kulani	5.63	-0.06	0.28	0.08
Grand mean		5.22			

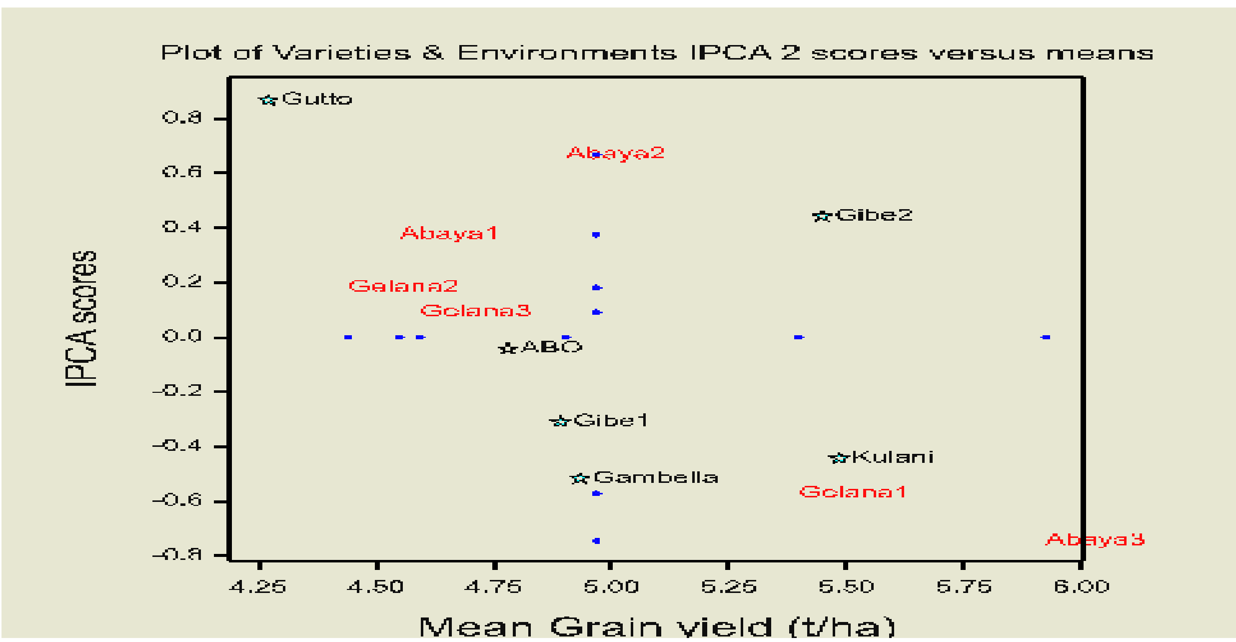
IPCA=Interaction Principal Component Axis, ASV=AMMI stability value.

By plotting both the genotypes and the environments on the same graph, the relationship between genotypes and the environments can be seen clearly. The larger the IPCA scores, either positive or negative, as it is a comparative value, the better specifically a genotype is adapted to certain environments (Table 6). The more IPCA scores approximate to zero, the more stable the genotype is to overall environments. Accordingly, Kulani has IPCA value close to zero, high yielder and stable genotypes across environments (table 6). ABO-Bako was a variety IPCA value relatively close to zero (stable) but gave lower yield below the average. Whereas, Gibe 1 and Gibe 2 were high yielder but, relatively higher IPCA score value deviating from zero, indicating that these varieties were not stable and thus adaptable for specific environment. The genotypes with high ASV were most unstable and while genotypes with low ASV were stable. The ASV indicated that the genotypes Kulani and ABO were most stable across environments and the genotypes, Gibe 2 and Gutto-LMS performed superiorly in certain environments (table 6). The sign of the scores indicate the pattern of interaction of the genotypes across environments and the reaction of environments for the different genotypes. Genotypes and environments with similar sign of IPCA1 scores interact positively for yield (tone/ha). But, if they have opposite sign of IPCA1 scores, their interaction is negative and the environment is not favorable for the genotype (Zobel *et al.*, 1988; Crossa *et al.*, 1991). Similar results were reported by Abera *et al*. (2013) and Anley *et al*. (2013).

Figure 2. AMMI-1 model for grain yield (t/ha) showing the means of genotypes (numbers) and environments (upper case letter followed by number).

Genotype Gibe 2, Gibe 1 and Kulani were the genotypes with the above average grain yield. Conversely, genotypes Gutto, ABO-Bako and Gambella had yield below mean grain yield (figure 2). Genotypes Kulani and Gibe 2 had higher mean grain yield at favorable environment while Gutto and ABO had lower mean grain yield at unfavorable environment. With regards to environment, Galana1 and Abaya3 had higher grain yield than mean grain yield of environments and were considered as favorable environments while environments like Abaya1, Abaya2, Galana2 and Galana3 had below average grain yield and were considered as unfavorable environments (figure 2).

AMMI 2 bi-plot: the AMMI 2 bi plot with IPC1 in X-axis and IPC2 in the Y-axis were plotted below (figure 3). The first interaction principal component (IPC1) explained 73.19% and the second interaction principal component (IPC2) explained 14.79% of the sum of square of GEI. The two IPC's cumulatively explained about 87.98% of the sum of squares of GEI (figure 3). Purchase (1997) stated that, genotypes close to origin are stable while those far from origin are considered



to as unstable genotypes. Regarding adaptability the genotype closest to a given vector in any environment is adaptive to that specific environment and the farthest from a given vector in any environment is less adaptive to that specific environment. Inline to the following principle Gibe 2 was adaptable to Abaya2 and Abaya1 environments while Kulani and Gibe 1 were adaptable to Abaya3, Galana1 and Galana3 environments.

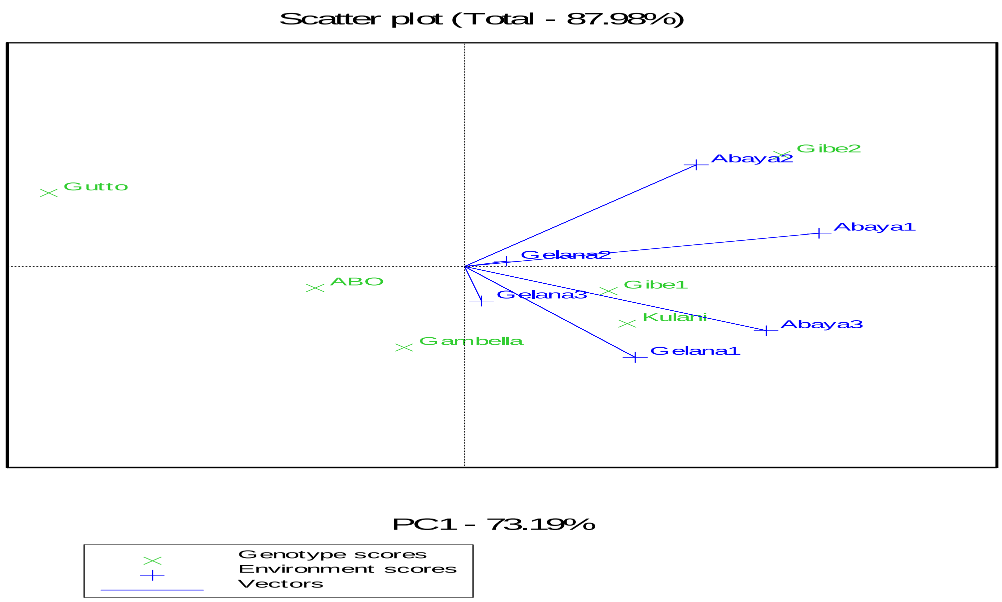


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Fig. 3. AMMI-2 model for grain yield (t/ha) showing the IPCA scores of open pollinated maize genotypes (numbers) planted across environments (upper cases followed by numbers)

Conclusion

A total of six open pollinated maize varieties were evaluate for their adaptability and grain yield performance in West Guji zone. Analysis of variance for Phenological, yield and yield related traits across locations and years indicated the presence of significance difference among genotypes. The result revealed that Kulani variety gave high yielder at Abaya which is followed by Gambella variety. Gibe 2 was high yielder at Galana followed by Kulani. The result from stability analysis revealed that Kulani was high yielder and stable across test environments relative to other genotypes. ABO-Bako was also relatively stable but gave lower yield below the average. Gibe-1 and Gibe-2 varieties were high yielder but adaptable for specific environment. ASV analysis showed that Kulani and ABO-Bako were most stable across environments but Gibe 2 performed superiorly in certain environments. Generally, Kulani was recommended for wider adaptability, but Gibe 2 showed specific adaptability and recommended for specific area.

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Registration and release of Sanete and Mandoyu bread wheat varieties for Highlands of Bale

Tilahun Bayisa[1]*, Tesfaye Letta[2] Mohammed Abinas[3], Wubshet Alemu[1], Bekele Hundie[4] and Ayalneh Tilahun[5]

[1]Sinana Agricultural Research Center, P.O. Box 208, Bale-Robe, Ethiopia, [2]Oromia agricultural research institute, [3]International Center for Agricultural Research in Dry Areas (ICARDA), Kulumsa, [4]Kulumsa agricultural research center, [5]International center for wheat and maize improvement (CIMMYT)

*Corresponding author: tilahunbayisa@gmail.com

Abstract

Fifteen bread wheat genotypes which were introduced from International Center for Agricultural Research in Dry Areas (ICARDA) were evaluated across different years and location to identify high yielding, stable and disease resistant wheat cultivars for the highlands of Bale and similar agro-ecologies. Out of the tested entries, bread wheat genotypes 14F/HAR 1685 and WORRAKATTA/PASTOR)were found to be the highest yielding and disease resistant as compared to the standard checks (Madda walabu and K6295-4a). These genotypes were eventually evaluated by the National Variety Release Committee (NVRC) and officially recommended for release for Highlands of Bale and Similar agro ecologies. Genotypes 14F/HAR 1685 and WORRAKATTA/PASTOR were named as Sanate and Mandoyu respectively.

Keywords: Bread wheat, ICARDA NVRC

Introduction

The development of cultivars, which are adapted to a wider range of diverse environments, is the ultimate aim of plant breeders in a crop improvement program. The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is grown. Wheat is the major and strategic crop in Ethiopia. Lack of improved bread wheat varieties is among the major constraints to crop production. Even though, many bread wheat varieties were released for production in Bale over years, most of them are pushed out of production within few years of release mainly due to disease pressure (particularly rusts).To combat this problem, developing and releasing improved bread wheat varieties with different genetic background is imperative. With the effort of releasing bread wheat varieties in the highlands of Bale, a number of wheat genotypes introduced from International Center for Agricultural Research in Dry Areas (ICARDA) were evaluated across locations and years. These genotypes were tested at Sinana on station in a preliminary and advanced observation nursery followed by preliminary yield trial. At later stage, multi location testing was conducted in 2011/12 and 2012/13 cropping seasons to identify superior genotypes for eventual release.

Materials and Methods

About fifteen bread wheat genotypes along with two standard checks (Madda walabu and K6295-4a) and one local check (Hollandi) were evaluated in multilocation trial across years (2011/12 and 2012/13 cropping seasons) and locations (Sinana, Selka, Goba and Agarfa) to identify high yielding and disease resistant wheat genotypes .The experiment was laid out in Randomized Complete Block Design with four replications and with plot area of 1.2 m (6 rows, 20cm apart) x 2.5m (3m^2). The seed rate of 150kg/ha and fertilizer rates of 41/46 (N/P_2O_5) was used, respectively. Grain yield and disease data were collected.

Result

Sanete (14F/HAR 1685)

Agronomic and morphological characteristics

The agronomic and morphological characteristics of variety Sanete were presented in appendix I. **Yield Performance**

Multi location testing was conducted within the regional variety trial, which consists of 15 including standard check Madda Walabu, K6295-4a and local check Hollandi. Yield performance of the overall location presented in table 1.

Table 1. Mean agronomic traits and yield data of the released bread wheat Sanete and check in multi-location testing, 2011-2012

SN	Variety	DH	DM	PLH	TKW	HLW	GY (kg/ha)
1	Sanete (14F/HAR 1685)	71	141	102	39.5	80.0	4480.5
2	Madda Walabu	71	143	99	43.2	69.6	3518.2
3	K6295-4a	73	145	113	35.3	72.8	4107.8
4	Hollandi	66	141	120	40.3	71.5	3108.3

DH= days to heading, DM= Days to mature, Plh(cm)= plant height in cm, TKW= thousand kernel weight in gm HLW= Hectoliter weight and Yield(qt/ha)= grain yield in quintal in hectare.

The results of combined yield over locations and over years showed that, variety Sanate gave 44.8 qt/ha yield which is higher than standard checks Madda walabu (35.2qt/ha) and K6295-4a (41qt/ha). Locations by year mean of Sanete have showed a yield advantage of 26.2% over standard check Madda walabu and 42.7% over local check Hollandi (Table 1).

Disease Reaction

The released variety 'Sanete' showed resistance reaction to stem rust and yellow rust. The maximum score of stem rust overall location was 10mr where as standard check Madda walabu and K6295-4a were showed a of score 50s and 5ms respectively (Table 2).

Table 2. The Disease reaction of variety Sanete and checks

SN	Variety	SR	YR	LR
1	Sanete (14F/HAR 1685)	10mr	10mr	10ms
2	Madda Walabu	50s	20mr	5ms
3	K6295-4a	5ms	trms	20ms
4	Hollandi	30s	20mr	10ms

Sr= stem rust (%), Yr= Yellow rust (%), Lr= leaf rust (%), s= susceptible reaction, ms= moderately susceptible reaction, mr= moderately resistance reaction and tr= trace level of disease percentage less than 5%

Adaptation

Sanete is released for the Highlands of Bale and for the areas having similar agro ecologies. The cultivar has wide range of adaptation area within altitude ranging from 2300 m.a.s.l to 2600 m.a.s.l and an annual rain fall of 750mm to 1500mm (Appendices I). It could be possible to extend the production of this variety to other similar agro-ecologies. This variety gives a better yield if produced with recommended fertilizer rate of 100kg DAP/ha and 50kg Urea/ha at the seed rate of 150kg/ha for broadcasting.

Mandoyu (WORRAKATTA/PASTOR)

Agronomic and Morphological characteristics

The agronomic and morphological characteristics of variety Mandoyu is presented in appendix 2.

Yield Performance

Multi location testing was conducted within the regional variety trial, which consists of 18 bread wheat genotypes including standard check Sofumer, Tusie and local check Hollandi. The trial was evaluated at three districts for two consecutive years in the highlands of Bale. Yield performance of the overall locations is presented in table 3.

Table 3. Mean agronomic traits and yield data of the released bread wheat variety Mandoyu and check in multilocation testing, 2011-2012

SN	Variety	DH	DM	PLH	TKW	HLW	Yield (qt/ha)
1	Mandoyu (WORRAKATTA/PASTOR)	68	139	85.3	36.2	70.6	4275.5
2	Sofumer	67	136	96.8	39.9	72.0	3571.5
3	Tusie	68	139	98.8	34.6	73.0	3684.0
4	Hollandi	66.4	138	119.9	40.4	71.9	3126.2

DH= days to heading, DM= Days to mature, Plh(cm)= plant height in cm, TKW= thousand kernel weight in gm HLW= Hectoliter weight and Yield(qt/ha)= grain yield in quintal in hectare.

The results of combined over locations and years showed that, variety Mandoyu gave 42.8qt/ha yield which is higher than standard check Sofumer 35.7qt/hat and Tusie 36.8qt/ha. Locations by years mean of yield of Mandoyu showed yield advantage of 20% and 16% over standard checks Sofumer and Tusie respectively and 42.7% over local check Hollandi.

Disease Reaction

The released variety Mandoyu showed resistance reaction to stem rust and moderately susceptible to yellow rust (Table 4). The maximum score of stem rust overall locations was Trr (less than 5%) where as standard check Sofumer and Tusie were showed stem rust scores of 30s and 50s respectively.

Table 4. The maximum disease reaction of variety Mandoyu and checks

SN	Variety	SR	YR	LR
1	Mandoyu (WORRAKATTA/PASTOR)	trr	10ms	5ms
2	Sofumer	30s	5ms	5ms
3	Tusie	50s	10ms	5ms
4	Hollandi	30s	60s	5ms

Sr= stem rust (%), Yr= Yellow rust (%), Lr= leaf rust (%), s= susceptible reaction, ms= moderately susceptible reaction, mr= moderately resistance reaction and tr= trace level of disease percentage less than 5%

Adaptation

Madoyu is released for the Highlands of Bale and areas having similar agro ecologies. The cultivar has wide range of adaptation ranging from 2200 m.a.s.l to 2500 m.a.s.l and with an annual rain fall of 750mm to 1500mm (Table 5). It could be possible to extend the production of this variety to other similar agro-ecologies. This variety gave a better yield if produced with recommended fertilizer rate of 100kg DAP/ha and 50kg Urea/ha at the seed rate of 150kg/ha for broadcasting.

Variety Maintenance

The breeder and pre-basic seeds of these two released bread wheat varieties will be maintained by Sinana Agricultural Research Center of Oromia agricultural research institute (IQQO).

Apendix 1. Agronomic and morphological descriptors of Sanete variety

- Variety Name: **Sanete** (14F/ HAR 1685)
- Adaptation area: Highlands of Bale and similar agro ecology
  - Altitude (m.a.s.l): 2300-2600m.a.s.l
  - Rainfall (mm): 750-1500
- Seed rate (kg/ha): 150
- Planting date: Mid June to early September in Bale based on the agro-ecology of the area
- Fertilizer rate (kg/ha):
  - P_2O_5=46
  - N= 41
- Days to heading: 71
- Days to mature: 141
- Plant height(cm): 102
- Growth habit: Erect
- Ear type: Compact
- 1000 seed weight(g): 39.5
- Seed color: Red to Amber
- Hectoliter weight(kg/hl): 80.0
- Yield (qt/ha^{-1}):
  - Research field: 52.8-66.9
  - Farmers' field: 32.5-42.9
- Year of release: 2014

Apendix 2. Agronomic and morphological descriptors of Mandoyu variety

- Variety Name: **Mandoyu** (WORRAKATTA/PASTOR)
- Adaptation area: Highlands of Bale and similar agro ecology
  - Altitude (m.a.s.l): 2200-2500m.a.s.l
  - Rainfall (mm): 750-1500
- Seed rate (kg/ha): 150
- Planting date: Mid June to early September in Bale based on the agro-ecology of the area
- Fertilizer rate (kg/ha):
  - P_2O_5=46
  - N= 41
- Days to heading: 68
- Days to mature: 139
- Plant height(cm): 85.3
- Growth habit: Erect
- Ear type: Compact
- 1000 seed weight(g): 36.2
- Seed color: White
- Hectoliter weight(kg/hl): 81.5
- Crop pest reaction resistant to stem rust
- Yield (qt/ha^{-1}):
  - Research field: 49.5-58.6
  - Farmers' field: 27.7-42.6
- Year of release: 2014

Conclusion and recommendation

Bread wheat varieties Sanate and Mandoyu were released for the Highlands of Bale, however, these varieties mighty perform well under agro-ecologies similar to Highlands of Bale and hence, these varieties should be evaluated *via* adaptation trial to recommend in areas similar to Bale highlands. These varieties showed resistant to moderately resistant to currently existing yellow and stem rust races and hence can be used as alternative varieties where these two rusts are important.

CROP MANAGEMENT

Effect of Fertilizer Rate on the Yield and Yield Component of Sesame(*Sesamum indicum*L.)in Moisture Stress environments of east Harerghe Zone

Adugna Hunduma[1 *]and Habte Birhanu[1]

Fedis Agricultural Research Center P.O. Box, 904 Harar, Ethiopia.

*Corresponding author: adgnhund@gmail.com

Abstract

Field experiments were conducted with the objective of identifying and recommending optimum combined phosphorus and nitrogen fertilizer rates for sesame production at Fadis Boke and Errer sub-sites in 2014 and 2015 cropping seasons. Four different phosphorus rates (0, 40, 60, and 80 kg ha^{-1}) in the form of P_2O_5 and four nitrogen nutrient rates (0, 10, 20,and 30 kg N ha^{-1}) were combined and used as treatments using sesame variety "Tate". The experiment was laid out in RCBD with three replications. Data were collected and analyzed for sesame seed yield, number of sesame branches and pods per plant, and number of seeds per pod under the different combinations of the fertilizers rates. The results of the study showed analysis of over location and season of the different NP fertilizer rates combination significantly ($p<0.05$) affected the yield components and seed yield of sesame. The highest sesame seed yield (891), number branches per plant (28.71)) and number of pods per plant (68.67) were obtained from sesame crops received 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} NP integrations of the fertilizers rates. The yield of sesame seed achieved from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} NP fertilizer rates was 35.7 and 72% greater than the average yields of all the rest fertilizer combinations and the no fertilizer application, respectively. Similarly, the highest number of sesame branches per plant obtained from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} NP fertilizer rates was 66.4 and 43.6% greater than the average number of branches per plant of all the rest fertilizer combinations and the no fertilizer application, respectively. Furthermore, the combined mean number of sesame pods per plant recorded from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} NP fertilizer rates was 42.4% greater than the no fertilizer application treatment. Therefore, to sesame growing farmers in Haraghe zone application of the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizer rates can be recommended for improved sesame production and productivity particularly to at Fedis, Errer and other similar environments of the area.

Key word: Nitrogen, Phosphorus, Sesame seed yield, number of branches, pods

Introduction

Sesame (*Sesamumindicum)* is grown in areas with annual rainfall of 625to1100mm and temperature of greater than 27 degree Celsius . The crop is tolerant to drought, but not to water logging and excessive rainfall. Sesame is well adapted to a wide range of soils, but requires deep, well-drained, fertile sandy loams. Oromia National State is a major producer of sesame crop next to Tigray and Amhara National Regional States of Ethiopia. Sesame contributes to more than 80% of the export earning of oil seeds and become the second foreign currency earning crop after coffee in the country. Ethiopian sesame seed market covers quiet a wide range of countries all over the world. The growing demand in the world market and the available capacity to expand sesame production could contribute to the economic growth of Ethiopia (Haile Abera, 2009). At present, the Ethiopian government devotes considerable resources to research and extension in view of encouraging small scale farmers to increase their oil seed, particularly sesame, productivity for international high market demand of the crop to increase export earnings of the country. The oilseeds sector is one of Ethiopia's fastest growing and important sectors, both in terms of its foreign exchange earnings and as a main source of income for over three million Ethiopians.

Study reports indicate that Ethiopia is among the six producers of sesame seed, linseed and Niger seed in the world (Wijnands*et al*., 2009). The major sesame seed producing regions are situated in the North West and South West Ethiopian in Humera, north Gondar and Wollega (Wijnands*et al*., 2007; CSA, 2013). For instance, the main source of farmers' income in western Tigray is sesame sales.Sesame is deep rooted and scavenges for fertility below the wheat root zone, but that only works once. The sesame strips lower nutrient reserve, and the fertility will not be available for future sesame crops. Research results have shown that nitrogen and phosphorus (NP) fertilizersare critical for high sesame seed yields, particularly in acidic soils. The major constraints in sesame production worldwide are lack of wider adapting cultivars, shattering of pods at maturity, nonsynchronous maturity, poor stand establishment, lack of fertilizer responses, profuse branching, and low harvest index (Ashri, 1994).

Similarly, besides unavailability of improved sesame varieties with good production traits, lack recommendations of NP fertilizers rates in Hararghe in general and in Fedis sesame growing environments is limiting the production and productivity of the crop. Thusan experiment initiated with the objective of identifying NP fertilizers rate combinations that can increase the productivity of sesame in growing environments of east Hararghe.

Materials and Methods

Description of Experimental Site: The study was conducted under rain fed conditions at two location (Fadis; Boke site) and Errer sub-site. The sub-site is geographically located at the latitude of 9^{o} 07'N and longitude of 42^{o} 04'E at an altitude of 1702 meters above sea level. The area is situated at a distance of 24 km north of Harar city. The soil of the experimental site is black with surface soil texture of sand clay loam that contains 8.2% organic matter, 0.13% total nitrogen, 4.99ppm available phosphorus, $1.68C_{mol}{}^{(+)}$ kg^{-1} soil exchangeable potassium and a pH value of 8.26. It received mean annual rainfall of 860.4mm in the last five years. The area is characterized by a bimodal rainfall distribution pattern and maximum rain received from April to June while irregular and erratic rains are received from August to October. The mean maximum and minimum annual temperatures of the area are 27.7 and $11.3^{o}{}_{C}$, respectively, for the past five years (Fadis Agriculture Research Center Metrological Station, 2015 unpublished).

The second experimental area of our experiment Errer Sub-site is located at Errer valley of Babiledistrict, located at 34km east of Harar cit. The area receives an average annual rainfall of 400 to 600mm and suited at an altitude range of 950 to 2000 meters above sea level. The environment is characterized as extremely lowland suitable for the production of sesame.

Experimental Materials, Treatments and Designs

This experiment were planted at Fadis, Boke station and Errer experimental sub-site with the objectives of evaluating,identifying and, recommending the best combination of NP fertilizers rates that can maximize sesame yield and it components in lowland and mid-altitude environments of Eastern Harerghe sesame producing areas. The treatments consisted of a combinations of four nitrogen fertilizer rates (0, 10, 20 and 30kgNha^{-1}) in the form of UREA and four phosphorus levels (0, 40, 60 and 80kgP_2O_5ha^{-1}) in the form Di-Ammonium Phosphate (DAP). Sesame variety "Tate" was used for the experiment. Sixteen (16) factorial combinations of NP fertilizers rates were arranged in a Randomized complete block design (RCBD) with three replications. The experimental field was ploughed, harrowed and ridged 40 cm apart. A mixture of one part of sesame seed and two parts of course river sand were sown manually at depth about 1cm depth at and the emerged plants were later thinned at 10cm intra-row spacing of plant per stand two weeks after sowing to keep crop population densities of 250,000 plants per hectare. All Phosphorus fertilizer rates were applied at planting to all the plots and all the nitrogen fertilizer rates were divided in to two equal amounts and applied at two and six weeks after sowing. All other cultural and agronomic practices were applied uniformly to all the experimental plots.

Data Collection: Data were collected for number of branches per plant, number of pods per plant, number of seed per pod, and seed yield per hectare (kg/ha)for analysis and interpretations.

Data Management and Statistical Analysis: Analysis of variance (ANOVA) was computed for all collected data using GenStat 15th edition. Treatment means were separated using Duncan least significant difference method (LSD) at 5% probability level for all statistically different means.

Results and Discussion

Response of sesame seed yield and its components to the combination of different NP fertilizers rates

The analysis of variance for 2014 cropping season revealed that the interaction of phosphorus and nitrogen fertilizers rate resulted in statistically significant differences ($p<0.05$) for sesame seed yield and number of branches per plant at Boko and Errer experimental sub-sites. These interactions also significantly ($p<0.05$) affected the number of pods per plant at Errer sub-site but did not at Boke sub-site. Number of seeds per pod was not affected by the interaction effect of the fertilizers at both experimental sub-sites (Table 1).

In contrary, except the number of seeds per pods at Errer sub-site, all the seed yield of sesame, number of branches and pods per plant and seed per pod were significantly affect by the interaction effects of the fertilizers during 2015 cropping season(Table 2)Accordingly, in 2014, the highest mean seed yield (867.8) and number of branches per plant (23.33) were recorded for sesame crops that received the combination of 60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1} and 40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1} phosphorus and nitrogen fertilizers rates, respectively at Boke experimental sub-site while fertilizer combination of 60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1} resulted in the highest mean values of sesame seed yield and number of branches at Errer sub-site (Table 1). This maximum yield achieved at Boke from the combination of 60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1} was superior to yields obtained when all the nitrogen fertilizer rates are applied without phosphorus, combination of 40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}, and 80 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1} while the maximum number of branches per plant obtained at the same sub-site from the combination of fertilizer rates at 40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1} was significantly higher than all the rest fertilizer combinations except for 0 P_2O_5 kg ha^{-1} and 10, 20, 30 N kg ha^{-1}, 60 P_2O_5 kg ha^{-1} and 10 and 30 N kg ha^{-1} phosphorus and nitrogen fertilizer combinations (Table 1). Significantly the highest maximum sesame seed yield (912.5) was obtained at Errer experimental sub-site from the combination of 60 P_2O_5

kg ha^{-1} and 30 N kg ha^{-1} phosphorus and nitrogen rates which was superior to all the rest fertilizer combination rates. At Error, again significantly a maximum number of branches per plant (22.33) was achieved from combining 60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1} rates of phosphorus and nitrogen fertilizers which was superior to the number of branches obtained from no fertilizer treatment, 0 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}, 40 P_2O_5 kg ha^{-1} and 0 and 10 N kg ha^{-1}, 40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}, 60 P_2O_5 kg ha^{-1} and 0 to 20 N kg ha^{-1}, and 80 P_2O_5 kg ha^{-1} and 0 to 30 N kg ha^{-1} combinations of the fertilizers.

The number of pods per plant (67.33 and 67.00) of sesame was highest at Errer sub-site from the combination of 40 and 80P_2O_5 kg ha^{-1} and 0 N kg ha^{-1} rates of the fertilizers and these were only superior to the number of sesame pods per plat achieved by the combination of 0P_2O_5 kg ha^{-1} and 30N kg ha^{-1}, and 80 P_2O_5 kg ha^{-1} and 20 and 30N kg ha^{-1} phosphorus and nitrogen fertilizers rates (Table 1). Similar to 2014, in 2015 cropping season 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1}combination of the fertilizers resulted in the highest maximum sesame seed yields (964.2 and 897.2), and number of branches and pods per plant (15.17 and 9.6; and 96.43 and 74.67), respectively at Boke and Errer experimental sub-sites and these numbers were a superior to all the rest fertilizer combination treatments (Table 2) The results obtained from the study on sesame yield differences at different combinations of NP fertilizer rates is in agreement with the results of Siddik*etal*. (2016) who reported increased and significant sesame seed yields when varying rates of NP fertilizers were combined for different environments. Similarly, (Reddy, 2004) reported that integrationof nitrogen and phosphorus fertilizers of different rates showed variations in number of pods and branches per plant.

Over cropping season and location effects of NP fertilizers rate combinations on sesame seed yield

Combined analysis of variance over location and cropping seasons showed statistically significant differences ($p<0.05$) for sesame seed yields due to combination of the different rates of phosphorus and nitrogen fertilizers (Table 3). The maximum and superior sesame seed yield (891) to all the rest of NP fertilizer combination rates was obtained from the integration of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizers. This sesame seed yield achieved from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 35.7 and 72% greater than the average yields of all the rest fertilizer combinations and the no fertilizer application, respectively. This result confirms the finding of (Shiferaw*et al.*, 2012) who reported 35% sesame seed yield increment due to application of 38/29 kg ha^{-1} NP_2O_5 fertilizers at planting. Similarly, Hossein*et al*. (2007) recorded the highest sesame seed yield with the application of 60 kg N ha^{-1} and Okpara*et al*. (2007) found that application of 75 kg N ha^{-1} and 26 kg P ha^{-1} significantly increased sesame seed yield per hectare.

Over cropping season and location effects of NP fertilizers rate combinations on sesame number of branches per plant

Combined analysis of variance over location and cropping seasons showed statistically significant differences ($p<0.05$) for sesame number of branches per plant as a result of combining different rates of phosphorus and nitrogen fertilizers (Table 3). The maximum and superior number of branches per plant (28.71) to all the rest of NP fertilizer combination rates was obtained from the integration of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizers. This highest sesame number of branches per plant achieved from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 66.4 and 43.6% greater than the average number of branches per plant of all the rest fertilizer combinations and the no fertilizer application, respectively. This result confirms the finding of Olowe and Busari (2000) who found that application of 60 kg N ha^{-1} and 13kg P ha^{-1} produced significantly the highest number of branches per plant.

Over cropping season and location effects of NP fertilizer rate combinations on sesame number of pods per plant and seeds per pod

Combined analysis of variance over location and cropping seasons showed statistically significant differences ($p<0.05$) for sesame number of pods per plant as a result of combining different rates of phosphorus and nitrogen fertilizers, however, the interaction did not affect the number of seeds per pod (Table 3). The maximum number of pods per plant (68.67) was obtained from the integration of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizers. This combined mean number of sesame pods per plant achieved from the combination of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 42.4% greater than the no fertilizer application treatment. This result confirms the finding of Olowe and Busari (2000) who found that application of 60 kg N ha^{-1} and 13kg P ha^{-1} produced significantly the highest number of sesame capsules/pods per plant.

Conclusion and Recommendations

The results of these experimental researches from both locations across the experimental years indicated that sesame seed yield, and number of branches and pods per plant were significantly influenced by the combination of different phosphorus and nitrogen fertilizer rates across locations and experimental seasons. Sesame plantsreceived $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1}NP integrations of the fertilizers rates resulted in significantly the highest combined means of sesame seed yield (891), number of branches per plant (28.71) and number of pods per plant (68.67) compared to crops treated with most of the fertilizer combinations and the no fertilizer control plots. The yield of sesame seed achieved from the combination of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 35.7 and 72% greater than the average yields of all the rest fertilizer combinations and the no fertilizer application, respectively. Similarly, the highest number of sesame branches per plant obtained from the combination of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 66.4 and 43.6% greater than the average number of branches per plant of all the rest fertilizer combinations and the no fertilizer application, respectively. Furthermore, the combined mean number of sesame pods per plant recorded from the combination of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 42.4% greater than the no fertilizer application treatment. Therefore, to sesame growing farmers in Haraghe zone application of the combination of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizer rates can be recommended for improved sesame production and productivity particularly to at Fedis, Errer and other similar environments of the area.

Table.1 Yield and some yield parameters of sesame as affected by the interaction of different NP fertilizer rate combinations at Boke and Errer experimental sub-sites (2014)

Fertilizer Combinations	Sesame seed yield and yield component, at Fadis (Boke)				Sesame seed yield and yield component, at Errer			
	Seed yield (kg ha^{-1})	Number of Branches per plant	Number of Pod per plant	Number of Seeds per pod	Seed yield (kg/ha)	Number of Branches per plant	Number of Pod per plant	Number of Seeds per pod
$0P_2O_5$ kg ha^{-1} and 0N kg ha^{-1}	525.00c	14.33cd	57.67	31.67	616.70c	15.00bc	56.33ab	28.67
$0P_2O_5$ kg ha^{-1} and 10kg N ha^{-1}	680.6bc	17.7abc	66.33	34.00	720.8bc	21.67ab	55.67ab	31.00
$0P_2O_5$ kg ha^{-1} and 20 kg N ha^{-1}	628.9bc	18.33ab	47.33	33.00	763.9bc	19.33ab	44.67b	30.00
P_2O_5 kg ha^{-1} and 30 kg N ha^{-1}	522.20c	16.7abc	57.00	32.33	648.6c	20.67ab	6.00ab	29.33
40 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	759.7ab	12.7cd	58.00	33.33	754.2bc	16.67bc	67.330a	30.33
40 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	754.4ab	11.3cd	56.67	31.67	697.2bc	15.33bc	55.67ab	28.67
40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	731.9a-c	23.33a	56.67	32.67	847.20b	20.0abc	55.67ab	29.67
40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	641.7bc	11.7cd	57.00	33.00	625.00c	15.67bc	56.33ab	30.00
60 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	709.4abc	8.67d	67.00	32.33	679.2bc	16.67bc	56.00ab	29.33
60 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	794.2ab	18.3ab	57.00	32.00	630.60c	18.33bc	56.67ab	29.00
60 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	759.7ab	12.7cd	56.67	33.00	675.0bc	16.67bc	55.67ab	30.00
60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	867.80a	18.3ab	67.33	31.67	912.50a	22.33a	56.00ab	28.67
80 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	610.8bc	13.3cd	67.33	32.67	673.6bc	17.3bc	67.000a	29.67
80 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	686.1abc	12.3cd	56.67	32.67	683.3bc	16.3bc	56.00ab	29.67
80 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	697.2abc	9.00d	57.00	32.67	691.7bc	13.00c	44.670b	29.67
80 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	818.10ab	8.00d	57.00	33.67	677.8bc	12.00c	55.67ab	30.67
CV (%)	15.4	11.4	12.3	4.4	18.8	10.9	19.9	4.9
LSD (5%)	*	*	NS	NS	*	*	*	NS

NS=Not significant, Means with the same letters in a column are non-significant at 5% probability level.

Table.2 Yield and some yield parameters of sesame as affected by the interaction of different NP fertilizer rate combinations at Boke and Errer experimental sub-sites (2015)

Fertilizer Combinations	**Sesame seed yield and yield components at Fadis (Boke)**				**Sesame seed yield and yield components at Errer**			
	Seed yield (kg ha^{-1})	Number of Branches per plant	Number of Pod per plant	Number of Seeds per pod	Seed yield (kg ha^{-1})	Number of Branches per plant	Number of Pod per plant	Number of Seeds per pod
$0P_2O_5$ kg ha^{-1} and 0N kg ha^{-1}	598.60b	7.4bc	65.5bc	44.33b	652.50d	5.67c	69.67ab	46
$0P_2O_5$ kg ha^{-1} and 10kg N ha^{-1}	664.40b	6.00c	56.00c	53.0ab	746.10c	6.33c	64.33ab	42
$0P_2O_5$ kg ha^{-1} and 20 kg N ha^{-1}	715.0ab	6.33c	56.33c	44.00b	772.2bc	6.33c	62.33ab	45
$0P_2O_5$ kg ha^{-1} and 30 kg N ha^{-1}	650.80b	4.33c	49.33c	54.0ab	702.80c	6.00c	61.00ab	44
40 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	700.60b	5.8bc	59.8bc	55.7ab	756.90c	7.67b	73.67ab	44
40 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	886.7ab	6.5bc	87.2ab	53.7ab	748.90c	7.00b	72.00ab	44
40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	865.3ab	7.53b	89.8ab	57.0ab	807.5ab	7.33b	71.33ab	46
40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	804.2ab	6.83c	56.83c	44.33b	799.70b	6.67b	62.67ab	44
60 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	723.60b	5.2bc	67.7ac	59.33a	727.80b	6.33c	62.33ab	44
60 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	938.90a	6.3bc	60.3bc	55.7ab	760.60c	9.00a	69.00ab	46
60 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	741.1ab	12.4ab	59.2bc	49.3ab	780.00b	7.67b	59.670b	44
60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	964.20a	15.17a	96.40a	61.0ab	897.20a	9.67a	74.670a	44
80 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	898.6ab	5.33c	50.33c	53.7ab	653.60d	6.67b	64.67ab	46
80 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	672.5ab	7.0bc	75.0ac	48.3ab	643.90d	5.67c	59.670b	44
80 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	891.4ab	5.17c	52.17c	49.7ab	774.2bc	6.00c	66.00ab	45
80 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	842.8ab	6.5bc	65.5bc	47.0ab	646.10d	7.33b	74.330a	43
CV (%)	19.10	25.80	25.80	13.10	16.70	7.30	7.30	6.40
LSD (5%)	269.70	7.6	27.6	11.42	170.68	1.33	11.70	NS

NS=Not significant, Means with the same letters in a column are non-significant at 5% probability level.

Table.3 The overall mean interaction of sesame yield of the two locations (Erer and Fadis) in 2014 & 2015

Fertilizer Combinations	Seed yield (kg ha^{-1})	Number of Branches per plant	Number of Pods Pod per plant	Number of Seeds per pod
$0P_2O_5$ kg ha^{-1} and 0N kg ha^{-1}	518.10d	20.00b	48.21b	41.58
$0P_2O_5$ kg ha^{-1} and 10kg N ha^{-1}	703.0bc	17.42b	58.21ab	40.00
$0P_2O_5$ kg ha^{-1} and 20 kg N ha^{-1}	670.0bc	17.33b	57.50ab	38.08
$0P_2O_5$ kg ha^{-1} and 30 kg N ha^{-1}	651.6bc	19.42b	57.75ab	39.92
40 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	692.8bc	15.71b	57.83ab	41.00
40 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	696.9bc	19.21b	57.46ab	39.67
40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	763.00b	23.62b	57.004b	41.50
40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	617.6cd	14.21c	57.67ab	37.83
60 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	617.7cd	15.02c	58.00ab	41.42
60 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	652.2bc	20.00b	58.58ab	40.83
60 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	639.00c	14.54c	58.21ab	39.08
60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	891.00a	28.71a	68.670a	38.83
80 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	659.2bc	18.92b	58.54ab	40.50
80 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	614.0cd	13.33c	58.33ab	38.67
80 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	663.6bc	17.54b	57.58ab	39.33
80 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	693.7bc	12.46c	58.17ab	38.67
CV (%)	18.30	13.60	19.80	9.60
LSD (5%)	126.00	3.62	11.28	NS

NS = Non-significant; Means with the same letters in column are non-significant at 5% probability level.

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Effect of Nitrogen Fertilizer Rates on Growth, Yield and Shelf-Life of Onion (*Allium cepa* L.)Varieties in east Hararghe, Ethiopia

[1]Gebisa Benti, [2]Nigussie Dechassa and [2]Tamado Tana
[1]Fedis Agricultural Research Center, Oromia Agricultural Research Institute, Ethiopia
[2]Department of Plant Sciences, Haramaya University, Ethiopia
Corresponding author:GebisaBenti, Email: bantiig@gmail.com

Abstract

Farmers in Fedis district of east Hararghe zone where onion is grown produce onion from unknown seed sources which results in small bulb sizes leading to low total and marketable bulb yieldswith much reduced shelf life. The framers also apply different Nitrogen fertilizer rates due to lack of information how much to be applied. Therefore, fieldexperiment was conducted at Fedis Agricultural Research Center (FARC), during the main cropping season of 2014 to investigate the effect of application of different Nitrogen fertilizer rates on growth, yield, and shelf life of onion varieties. The results revealed that nitrogen fertilizer rates significantly affected onion bolting percentage, ($P<0.001$), marketable bulb yields and percent dried stored bulb weight losses ($P<0.05$). similarly, the results of this study revealed there were significant ($P<0.01$) differences in bolting percentage, number of leaves per plant, days to physiological maturity, percent bulb dry mater content and dried stored bulb weight loss, and marketable bulb yield among the onion varieties tested. The results confirmed application of 150 and 200 kg N ha^{-1} significantly reduced the shelf life of dried stored onion bulbs reducing their shelf life and did not increase bulb yields of the onion varieties compared to the application of 50 or 100kg N ha^{-1} both of which resulted in significantly improved bulb yields and prolonged shelf life of stored dried bulbs through reducing physiological bulb weight losses. According to the results obtained, application of 100 kg N ha^{-1} significantly reduced physiological weight loss of stored onion bulbs by 4 and 9% compared to the application of 150 and 200 kg N ha^{-1}at 90 days of storage period, respectively. The study also identified Bombay Red onion variety to be recommended for its high total and marketable bulb yields, early maturity and superior storage shelf life quality over the other two varieties. Therefore, Bombay Red variety with the application of 50 to 100 kg N ha^{-1} can be recommended to onion growing areas of Fedis and similar environments in east Hararghe zone.

Key words: Adama Red, Bombay Red, Nasik Red, nitrogen, shelf life, bulb, marketable yield

Introduction

Onion (*Allium cepa*L.) is an important vegetable crop belonging to the family *Alliaceae*. It is the most widely grown and popular crop among the *Alliums*. It is an indispensable item in every kitchen as a vegetable and condiment used to flavor many of the food stuffs. Therefore, onion is popularly referred to as "Queen of Kitchen" (Selvaraj, 1976).

Onion is produced all round seasons and has comparatively low storage ability and bulbs are usually stored until the harvest of next season crop or for longer periods due to seasonal glut of onion in the market. Significant losses in quality and quantity of onion occur during storage. Storage of onion bulbs has, therefore, become a serious problem in the tropical countries like Ethiopia. The losses, where no bottom ventilation is provided, are estimated to the extent of 30 to 35 percent due to drainage, 10 to 12 percent by decay and 8 to 12 percent on an account of sprouting, depending upon the relative humidity and temperature during the rainy season (Maini and Chakrabarti, 2000).Farmers sometimes apply excess amount of fertilizers targeting only for bulb yield, but they do not consider postharvest effects of nitrogen fertilizers. High nitrogen supply favors poor postharvest quality of onion bulbs (Olsen and Kurtz, 1982). In Ethiopia, Ethiopia Institute of Agricultural Research (EIAR) recommended nitrogen fertilizer of 150 kg ha^{-1} in the form of UREA as a blanket recommendation (Lemma and Shimelis, 2003), which was not practiced in eastern part of Harerghe; where farmers mainly produceKhat (*Catha edulis*Forsk.), sorghum, groundnut, and onion during lean periods.In Eastern Ethiopia, whenever available, growers use farmyard manure as well as nitrogen fertilizer to increase bulb yields.However, no data are available to substantiate the belief that benefits can be obtained from fertilization of onion, especially under low soil moisture conditions of eastern Hararghe(KebedeWoldetsadik, 2003). In areas of eastern Hararghe where onion is produced, the land size is small which led to the use of chemical fertilizers and animal manure intensity to high levels (BezabihEmana and Hadera Gebremedhin, 2007). The farmers of the area also produce onions from unknown seed sources, which have small bulb sizes with low bulb yields. About 31% of vegetable producing Hararghe farmers used local varieties and improved varieties needed to produce the desired product are said to be unavailable. The principal aims of bulb crops storage are to maintain the 'quality capital' present at harvest and to satisfy consumer demand for extended availability of bulbs of satisfactory quality (Gubb and Tavis, 2002). Farmers store onion bulbs in their living house immediately after harvest without curing and shortly they sell bulbs cheap due to the surplus of the onion bulbs in the markets. Generally, a better understanding of the nitrogen fertilizer requirements of onion is needed in order to develop management strategies, which optimize fertilizer use of the crop. Moreover, improved varieties and fertilizer management for onions may help improve quality, particularly bulb size and storability, and thus offer growers premium prices. It was assumed that onion varieties would vary in their responses to nitrogen fertilization levels. It is important to investigate the nitrogen fertilizer requirement of the onion varieties at the area and justify its effect on the storage life of onion. Therefore, field experiment was conducted with the objective of investigating the effects of nitrogen fertilizer rates on plant growth, bulb yield and shelf-life of onion varieties.

Materials and Methods

Description of the Study Area: A field study was conducted under rain fed conditions at Fedis Agricultural Research Center (FARC) at Boke sub-site. The sub-site is geographically located at the latitude of 9^{o} 07'N and longitude of 42^{o} 04'E at an altitude of 1702 meters above sea level. The area is situated at a distance of 24 km north of Harar city. The soil of the experimental site is black with surface soil texture of sand clay loam that contains 8.2% organic matter, 0.13% total nitrogen, 4.99ppmavailable phosphorus, 1.68$C_{mol}^{(+)}$ kg^{-1} soil exchangeable potassium and a pH value of 8.26. It received mean annual rainfall of 860.4mm in the last five years. The area is characterized by a bimodal rainfall distribution pattern andmaximum rain received from April to June while irregular and erratic rains are received from August to October. The mean maximum and minimum annual temperaturesof the area are 27.7 and11.3^o_C, respectively, for the past five years (Fadis Agriculture Research Center Metrological Station, 2015 unpublished).

Experimental Materials, Treatments and Designs: The experiment was composed of factorial combinations of three improved varieties of onion namely *Adama* Red, *Nasik* Red, and *Bombay* Red) five nitrogen fertilizer rates (0, 50, 100, 150, and 200 kg ha^{-1}) and arranged in a randomized complete block (RCB) design with three replications during 2014 cropping season. Each treatment combination was assigned randomly to experimental units within a block. The gross plot size of each experimental plot was 2m long and 3m wide (6m^2) and net plot size of 4.8m^2 was used for data collection.All the seeds of the onion varieties were sown on well prepared seed beds to raise seedlings on a 5m long and 1.2m wide raised beds in 5cm spaced rows. Watering and weeding of seedling at nursery were carried out manually. Single row transplanting of onion seedlings was used at a spacing of 20cm and 10cm between rows and plants, respectively after seedlings grown to 3 to 4 leaves reaching height of 12 to 15 cm five weeks after sowing. Only disease free and uniform seedlings were transplanted. Nitrogen was side dressed in the form of Urea (46% N) in two splits of equal amounts 3 and 6 weeks after transplanting depending on the specified rate. Experimental plots were supplemented with irrigation at transplanting and two weeks after transplanting due to shortage of rainfall. All other agronomic and cultural practices were uniformly applied to the treatments as per recommendations. Plants in the middle eight rows were considered for recording data. Plants on the border rows and at both ends of each row were also excluded to avoid border effects.A storage experiment was also conducted after harvesting. Bulbs from each treatment were cured for five days and subjected to storage treatments in clean and cemented room on wooden shelf used for storage. Onion bulbs of uniform size numbering 200 were obtained from each treatment and stored. The onion bulbs were stored for three months at average maximum and minimum temperatures of 29.4^o_C and 8.6^o_C, respectively at mean relative humidity of 40.3 percent.Data bulbon bulb weight loss were recorded at 10 days intervalfor 90 days of storage period.

Data Collection

Days to maturity: The number of days required to reach physiological maturity was recorded when most leaves dried and fell off. Onion is considered to be matured when the leaves become senesced and fallen off.

Number of leaves per plant: Number of leaves per plant was recorded at maturity counting from 10 plants samples per treatment.

Bolting (%): Plants that showed flower capes during vegetative growth were counted and calculated as the ratio of bolters per total plants in the plot and the values were expressed in percentage.

Bulb dry matter content (%): The fresh weight of 15 randomly collected mature bulbs of the sample plants was measured and averaged after curing for five days and the average bulb fresh weight was determined and expressed in gram. The randomly sampled fifteen mature bulbs from each plot were chopped to small pieces and samples of 200 g chopped bulbs were sampled for each plot and oven dried at 70$^0_C$to obtain percent dry matter after weighing as follows:

$$DW (\%) = [(DW+CW)-CW]/[(200\ g] \times 100$$

Where: DW = dry weight; CW = container weight; and FW = fresh weight

Marketable bulb yield (ton ha^{-1}): Marketable bulb yield refers to the weight of healthy bulbs ranging from 20g to 160g in weight. Bulbs below 20g in weight were considered too small to be marketed whereas those above 160 g were considered oversized (Lemma and Shimelis, 2003). Accordingly, this parameter was determined from all plants in the central rows at the final harvest.

Unmarketable bulb yield (ton ha^{-1}): It includes diseased, under size (below 20g in weight), oversize (above 160g in weight) and split bulbs were considered as unmarketable bulbs.

Total bulb yield (ton ha^{-1}): To obtain the value of total bulb yield, marketable and unmarketable bulb yields were summed up and expressed in tons ha^{-1}.

Stored bulb (Physiological) weight loss (%): Bulb weight loss was determined using samples of 30 bulbs of medium size randomly taken from each treatment. Weight loss of bulbs was recorded in 10 days' intervals till 90 days of storage period. The physiological weight loss was calculated using the formula:

$$PWL (\%) = \frac{\text{Initial weight} - \text{Final weight at } 10^{th} \text{ intervals}}{\text{Initial weight}} \times 100$$

Where: PWL = Physiological Weight Loss

Statistical Data Analysis

Data were subjected to analysis of variance using the Generalized Linear Model of SAS Statistical Software package (SAS institute, 2003). Means that differed significantly were separated using the LSD (Least Significant Difference) test at 5% probably level of significance.

Results and Discussion

The effect of variety and different nitrogen rates on onion days to maturity, number of leaves and bolting percentages

The analysis of variance showed that the main effect different rates of nitrogen fertilizer was resulted in statistically significant differences ($p<0.05$) for onion bolting percentages, however had no effect on plant days to maturity and number of leaves. But, these growth parameters were significantly affected by the main effect of varieties (Table 1). No variety by nitrogen fertilizer rates interaction effect was observed for these parameters. Accordingly, onion varieties with no nitrogen fertilizer application resulted in superior bolting percentage (5.6%) to plants received all the nitrogen fertilizer rates. The result showed, high amount of nitrogen fertilization (200 kg ha^{-1}) resulted in reduced bolting (3.8) percentage. The analysis indicated increasing the rate of nitrogen fertilizer from nil up to 50 and 100 kg N ha^{-1}, reduced bolting percentage by 18 and 23%, respectively compared to the no fertilizer treatment. Similarly, increasing the rate of nitrogen fertilizer further to 150 and 200 kg N ha^{-1} reduced bolting percentage by 27 and 32%, respectively compared to control (Table 1).The result of this study confirmed the findings of Abdissa*et al*. (2011) who reported the proportion of onion bolters decreased by about 11 and 22% in response to the application of 69 and 92kg N ha^{-1}, respectively compared to no fertilizer application.

Considering the main effects of varieties, Nasik red matured later than (131.9 days) the other two varieties while variety Bombay red significantly matured earlierthan Nasik red and Adama red varieties by 19 and 11 days, respectively. (Table 1). This result is in line with the report of MandefroNigussie*et al*. (2009), who indicated differences in maturity periods of the tested varieties.

The highest mean number of leaves were recorded for Nasik red and Bombay red varieties.Both varieties exceeded Adama Red by 18 and 22%, respectively in number of leaves produced. Adama red and

Bombay red varieties achieved the highest mean percentage of bolting (Table 1). This showed that bolting is a genetic characteristic in addition to being under the influences of different agronomic practices such as nitrogen application The onion genotypes also differ in ease of seed stalk development and kinds of physiological defects like pre-mature bolting (MandefroNigussie*et al*., 2009).

The effect of variety and different nitrogen rates on onion days to maturity, number of leaves and bolting percentages

The analysis of variance showed that the main effect different rates of nitrogen fertilizer was resulted in statistically significant differences ($p<0.05$) for onion marketable bulb yield.However, percent bulb dry mater content, unmarketable and total bulb yields were not affected. In contrary, the main effect of variety resulted in statistically significant differences ($p<0.05$) for percent bulb dry mater content, unmarketable and total bulb yields (Table 2). But, no variety by nitrogen fertilizer rates interaction effect was observed for these parameters. Accordingly, the highest bulb dry mater content was recorded for Nasil Red variety which achieved 9 and 15% more percentage of bulb dry content than Adama Red and Bombay red varieties, respectively.   This finding is in line with that MandefroNigussie*et al*.(2009) who also indicated that onion bulb dry contents are attributes of varietal differences.Similarly, significant ($P < 0.01$) difference was observed among the three varieties in marketable, unmarketable and total bulb yields. Variety Bombay Red was the highest in total and marketable bulb yields than Adama Red and Nasik Red. Bombay Red exceeded Adama and Nasik Red by 8% in total bulb yield, and also higher than the two varieties by 7 and 8% in marketable bulb yield respectively. The onion bulb yields also attributed due to the varietal differences. This result was in line with the study of Gautam*et al*. (2006) who reported that the mean highest bulb yield differs among different onion varieties and genotypes.

The effect of variety and different nitrogen rates on stored bulb physiological weight loss

The analysis of variance showed that application of different rates of Nitrogen fertilizer significantly affected ($p<0.05$) bulb weight losses starting 30 days after storage was made and for the rest storage times. But, stored bulb weight loss was not affected by the different Nitrogen fertilizer rates the first 20 days of storage period. Variety significantly ($P < 0.05$) affected bulb weight loss at storage periods of 10 and 20 days. Bulb weight loss increased by 18 to 23% as number of storage periods increased from 30 to 90 days for onion bulbs received the maximum N-fertilizer rate (200 kg ha^{-1}) compared to bulbs obtained from no N-fertilizer application (Table 3). Increasing nitrogen rate from nil to higher rates linearly increased stored bulb weight loss throughout all the storage periods. At early storage periods, variety Adama Red had 11.8 and 12% bulb weight losses over Bombay Red at 10 and 20 days after storage, respectively (Table 3). However, stored bulb weight loss among the varieties did not differ significantly as the storage period was prolonged beyond 20 days. This result is in conformity with findings of Kospell and Randle (1997) who reported loss in variety dehydrator ‘Number 3’ and cultivar ‘Granex 33’ during the first month of storage, which was gradual weight loss with increased storage time.The changes in the chemical composition of bulbs can accelerate or inhibit certain physiological processes (Jurgel-Malocka and Suchorska-Orlowska, 2008), and significantly affect the bulb shelf life.

Conclusion and Recommendations

Onion is the most important crop grown in eastern part of Ethiopia by smallholder farmers. Farmers produce onion from seeds of unknown sources ending with small bulb size with low bulb yield harvests. They apply different Nitrogen fertilizer rates where thre was no recommendations so far. Fedis district of east Hararghe zone where onion is grown is categorized as lowland, where suboptimalNitrogen fertilizer application was expected to improve the bulb yield and postharvest quality of onion due to low moisture conditions of the soil. Therefore, improved varieties and Nitrogen fertilizer management might help increase in bulb yield, bulb quality, particularly bulb size and storability, and thus offer growers premium prices.

This study generally confirmed that application of higher Nitrogen fertilizer roses of 150 and 200 kg N ha^{-1} did not significantly improve number of onionleaves, days to plant physiological maturity, percent bulb dry water content, marketable bulb yields, and highly reduced the shelf life of stored dried bulbs compared to application of 100 kg N ha^{-1}. But, application of 50 and 100 kg N ha^{-1} significantly reduced physiological dried bulb weightloss and resulted in significant increase of marketable bulb yields. The study also identified Bombay Red onion variety to be recommended for its high total and marketable bulb yields, early maturity and superior storage shelf life quality over the other two varieties. Therefore, Bombay Red variety with application of 50 to 100 kg N ha^{-1} can be recommended to onion growing areas of Fedis and similar environments in east Hararghe zone of Oromia National Regional State.

Table 1. The main effect of nitrogen fertilizer rates and varieties on days to maturity, number of leaves per plant and bolting of onion varieties

Nitrogen rate (kg ha^{-1})	Days to maturity	Number of Leaves	Bolting (%)
0	120.30	8.00	56.0a
50	120.80	9.89	45.8b
100	121.60	9.22	43.2bc
150	122.80	10.22	40.8cd
200	124.00	9.56	38.0d
LSD (0.05)	NS	NS	0.48
Varieties			
Adama Red	120.50b	8.00b	45.7a
Nasik Red	131.90a	9.80a	40.8b
Bombay Red	113.30c	10.27a	47.8a
LSD (0.05)	2.41	1.24	3.1
CV (%)	2.60	17.70	11.2

NS: non-significant. Means with the same letters in a column are non-significant at 5% probability level.

Table 2. The main effect of nitrogen fertilizer rates and varieties on percent bulb dry mater content, marketable, unmarketable and total bulb yields of onion varieties

Nitrogen rate (kg ha^{-1})	Bulb Dry Mater Content (%)	Marketable Bulb Yield (ton ha^{-1})	Unmarketable Bulb Yield (ton ha^{-1})	Total Bulb Yield (ton ha^{-1})
0	13.05	22.50b	5.62	28.12
50	13.68	24.02ab	5.58	29.6
100	13.97	24.25a	5.12	29.37
150	14.58	24.93a	5.27	30.2
200	14.88	23.37ab	5.38	28.75
LSD (0.05)	NS	0.95	NS	NS
Varieties				
Adama Red	13.87b	23.35b	5.10b	28.45b
Nasik Red	15.12a	23.08b	5.23b	28.31b
Bombay Red	13.11b	25.00a	5.87a	30.87a
LSD (0.05)	1.13	0.74	0.31	0.77
CV (%)	10.80	7.00	9.09	5.90

NS: non-significant. Means with the same letters in a column are non-significant at 5% probability level

Table 3. The main effect of nitrogen fertilizer rates and varieties on percent bulb weight losses of onion varieties

Treatments	Percentage of Bulb Weight Loss Across Storage periods								
	Storage Periods (Days)								
	10	20	30	40	50	60	70	80	90
Nitrogen Fertilizer Rates (Kg Ha^{-1})									
0	1.38	1.96	2.27b	2.55b	2.91c	3.24d	3.76d	4.10d	4.46d
50	1.33	1.91	2.36b	2.79b	3.24ab	3.71c	4.12c	4.51c	4.88c
100	1.31	1.88	2.37b	2.82b	3.33b	3.87bc	4.34bc	4.74bc	5.11bc
150	1.32	1.93	2.44b	2.90b	3.54ab	4.13ab	4.58ab	5.00ab	5.32b
200	1.38	2.06	2.77a	3.25a	3.88a	4.430a	4.90a	5.250a	5.60a
LSD (%)	NS	NS	0.33	0.34	0.37	0.36	0.32	0.31	0.28
Varieties									
Adama Red	1.44a	2.09a	2.49	2.86	3.38	3.85	4.37	4.8	5.18
Nasik Red	1.33ab	1.92ab	2.44	2.85	3.35	3.86	4.3	4.67	5.02
Bombay Red	1.27b	1.83b	2.39	2.88	3.42	3.92	4.35	4.69	5.02
LSD (%)	0.12	0.18	NS	NS	NS	NS	NS	NS	NS
CV (%)	12	12.5	14.1	12.5	11.3	9.6	7.8	6.8	5.7

NS: non-significant. Means with the same letters in a column are non-significant at 5% probability level.

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Determination of Intercropping Proportion in Maize for Moisture Stress Environments of Borana, southern Ethiopia

Natol Bekele[1], Tolasa Taye[1] and Yonas Shimelis[1]

[1]Yabello Pastoral and Dryland Agricultural Research Center, P.O.Box 85, Yabello

Abstract

Maize and common bean intercropping is one of the most commonly used agronomic practices in Ethiopia where maize and the legume are predominantly produced. Intercropping is the production of two or more crops simultaneously in both space and time. Field studies were conducted at Yabello Pastoral and Dry Land Agricultural Research Center on-station during 2011 and 2012 cropping seasons to identify the most productive and profitable maize and common bean intercropping arrangements suitable for moisture stress environments of Borana. The experiment was laid out in randomized complete block (RCB) design with three replications in both cropping seasons. The experiment used seven treatments consisting of three maize and common bean intercropping arrangements namely planting single, double and three rows of common bean between two maize rows, sole stand of both crops, broadcasting common bean under row planted maize, and farmers' practices (broadcasting of both crops mixtures) –to be used as a check for comparison.The results of the pooled mean analysis revealed statistically significant differences among the different maize and common bean intercropping arrangements, the usual farmer practices and sole production systems of the crops. These maize and common bean arrangements resulted in 28.5%, 27.1% and 21% more yields than independent sole production of maize, respectively. Similarly, these three arrangements recorded 91.6%, 89.6% and 80.6% more total yields than producing sole common bean, respectively. Intercropping one and two rows of common bean between two maize rows and broadcasting the legume under row planted maize produced the highest land equivalent ratio (LER) which resulted in123%, 135% and 108.5% more land equivalent coefficients (LEC) than the minimum acceptable value of 25% for LEC to be profitable and efficient for production of two crops under intercropping systems. The highest monetary advantage index (MAI) were also recorded for these three maize and common bean intercropping arrangements which achieved 58.2%, 62.9% and 52.8% more MAI than sole maize production as well as 41.6%, 45.8% and 36.8% more MAI than the sole production of common bean, respectively. The results of the two cropping seasons experiments, proved intercropping either one or two rows of common bean between two maize rows increased the land use efficiency, improved the total productivity of a given unit area of land and resulted better economic returns. Therefore, any of these maize and common bean intercropping combinations can be recommended for moisture stress environments of Borena and similar agro-ecologies of southern Oromia.

Keywords: *arrangement, intercropping, LER, LEC, MAI, sole cropping*

Introduction

Maize (*Zea mays* L.), is the third most important cereal crop after wheat and rice in the world (FAO, 2015). Maize exceeds all other cereal crops in terms of annual production and productivity in Ethiopia (CSA, 2016). Common bean (*Phaseolus vulgaris* L.) is one of the most important and widely cultivated species of bean in in Ethiopia. Both maize and common bean play key role in human nutrition and improved livelihood through improving household income for small and large scale farmers. Maize also supplies large amounts of energy and when fail to mature provides high quality feed for animals (Dahmardeh *et al.*, 2009). Common bean is considered as the main cash crop and a protein source of the farmers in many low lands and mid altitude environments of Ethiopia (Rahmeto, 2007).Intercropping is a commonly used agricultural cropping practice and is growing of two or more crops simultaneously on the same field in both time and space (Thobatsi, 2009). It is considered one among the many crop intensification strategies to increase agricultural productivity per unit area of a given land. The principal reasons for farmers to intercrop crops are flexibility, profit maximization, risk minimization against crop failure, soil conservation and maintenance, weed control and balanced nutrition (Ofori *et al*., 2014).

One way towards better farming is to look for the most effective associated cropping systems of legumewith non-leguminouscrops(Berglund, 2004). Maize and legume intercropping has become one of the solutions for food security among small scale maize producers. In most intercropping systems, growth and yield of legumes are usually suppressed by the dominant crop (Tamiru, 2013). The overall arrangement and the relative proportion of component crops are important in determining yields and production efficiencies of cereal and legume intercrop systems (Zardari *et al.*, 2013). Studies showed that mixtures of cereals and legumes produce higher grain yields than sole cropping systems (Dapaah, 2003).The vigor of a given crop in any production system in Ethiopian is governed by the amount and distribution of rain. In moisture stress areas like *Borana* lowlands, shortage and erratic distribution of rain has a direct effect on the amount of available food. Droughtis a significant and a common phenomenon in these areasand crop stability is a challenging for farmers in the environment. Two of among the many ways to overcome these challenges are useof drought tolerant crops and best agronomic practices particularly intercropping of maize andcommon bean which has become one of the solutions for food security among small scale maize producers (Thobatsi, 2009). In most part of Borana lowland environments, traditionally maize and common bean combination has been practiced by small scale farmers growing to increase total productivity of a given area of land. Most farmers practice broadcasting of both crops mixtures without knowing the negative effect of the association system when the population of the crops increase beyond the optimum plant population per hectare. Therefore, experimental research was developed to identify the best and optimum maize and common bean intercropping systems that can increase productivity, land use efficiency and in turn improve income from a given area of land in moisture stressed environments of Borena, sothern Oromia.

Materials and Methods

Decryption of the Study Area

Research experiments were conducted at Yabello Pastoral and Dryland Agricultural Research Center on station for two consecutive cropping seasons in 2012 and 2013. Geographically the research center is located 563km south of Addis Ababa. It liesat 04° 52' 49" and 038° 08' 55" latitude and longitude, respectively, at 1656meters above sea level. The soil of the experimental area is characterized as well-drained sandy loam (46% sand, 36% silt and 18% clay), with 7.03 pH value. It has 0.026% total nitrogen, 15.36ppm Phosphorus and 20.4 meq of/100gm soil cation exchange capacity(CEC). The total annual rainfall and average temperature in 2011 and 2012 were 851.6mm and 719.0mm; and 19.3°$_C$ and 20.6°$_C$, respectively. The major annual crops grown in the study area are maize (*Zea mays* L.), common bean (*Phaseolus vulgaris* L.), tef (*Eragrostis tef* L.) wheat (*Triticum aesvivum*L.) among which maize and common bean being the predominant and staple food crops in the area and Borena zone in general.

Experimental Materials and Design

Seven treatments consisting of three maize and common bean intercropping arrangements namely planting single, double and three rows of common bean between two maize rows, sole stand of both crops, broadcasting common bean under row planted maize, and farmers' practices (broadcasting of both crops mixtures) –to be used as a check for comparison. The experiment was laid out in a Randomized Complete Block (RCB) design with three replications. Open pollinated maize variety (OPV) *Melkassa-1* andcommon bean variety Omo-95 were used for this experiment. Recommended 75 and 25cm intra and inter-row spacing, respectively were used for maize planting in all treatments except for the farmers' practices where broadcasting was used. The common bean was planted between two maize rows of intercropping treatments at 10cm spacing between plants.

Data and Profitability Analysis: Analyses of variance(ANOVA) was computed using SAS computer software version 9.2 (SAS, 2002). Treatment means were separated using least significant difference method (LSD) at 5% probability level for statistically different means.(Gomez and Gomez, 1984).Analysis of productivity and economic benefits were also done using land equivalent ratio (LER) to access yield and land use efficiency of the different intercropping practices compared to sole production of both crops. The LER values were computed using the formula described by Willey (1991).

LER = Yab/Yaa + Yba/Ybb;

Where, *Yab*is yield per unit area of a crop in intercrop (maize), *Yaa* is yield per unit area of sole crop (sole maize), *Yba* is yield per unit area of crop b (common bean) in intercrop, *Ybb* is yield per unit area of sole crop b (common bean).

In addition, land equivalent coefficient (LEC)was calculated according to Ashenafi (2016) as follows;

LEC=LERm*LERcb;

Where, *LERm*=land equivalent ratio of maize and *LERhb*= land equivalent ratio of common bean

Similarly, monetary advantage index (MAI), an important index used to access the profitability of the yield obtained from maize and additional common in intercropping cropping systems compared to the usual independent sole production of the crops. Therefore, the monetary advantage index (MAI) was calculated according to (Mahapatra, 2011).

MAI= Mm+Mcb; Mm =Pm*Ym;Mcb = Pcb*Ycb

MAI = (Pm*Ym) + (Pcb*Ycb)

Where, Pm=price of maize; Ym=yield of maize; Pcb=price of common bean; Ycb=yield of common bean

The market prices of maize and common bean seeds per kg in Birr was collected from the Yabello grain markets during the cropping seasons. Accordingly, market prices of 6 and 10 Birr kg^{-1} for maize and common bean, respectively were used to compute the MAI for the cropping seasons.

Results and Discussion

Effect of intercropped common bean arrangements on maize yield and yield components

Analysis of variance showed statistically significant differences (Table 2) among treatments for maize ear length, ear diameter, plant height and maize grain yields($p<0.05$) across cropping seasons. But thousand maize seed weight showed statistically no difference among all the treatments. The highest maize ear length, ear diameter and maize grain yield were obtained from sole maize production system while all maize plots received different common bean arrangements statistically resulted in superior plant heights to broadcasted maize and common bean mixtures.

This implies all the common bean arrangements in maize and common bean intercropping systems reduced the ear length, ear diameter and grain yield of maize compared to sole maize production system. This result is similar to the results (Tolesa *et al*., 2016; Natol *et al*., 2017) who also reported reduced yield and yield components for different maize genotypes when intercropped with legumes in moisture stressed areas. These authors indicated that this might be due to the change in synergy of the two crops to compete for the limited availability of moisture under such environments. These results were also further justified by Hailu *et al.* (2015), who reported a contrast result in adequate moisture areas under maize-tomato intercropping.

Combined analysis of variance over cropping seasons showed statistically significant difference ($p<0.05$) for maize grain yield among the different maize and common bean arrangements under intercropping and sole production system (Tables 1and 2). The highest total grain yieldswere obtained when one, two and three rows of common bean were planted between two maize rows. Intercropping two rows of common bean in maize resulted in average total grain yields of 5.73t ha^{-1}followed by 5.67 t $ha^{-1}$and 5.12 t $ha^{-1}$when two and three rows of the food legume was intercropped in maize, respectively ensuring land use efficiency compared to independent sole production of both crops.

Productivity and Benefit of Maize and Common Bean Intercropping

Land equivalent ratio (LER): Land equivalent ratio (LER) is the relative area of land required to produce a given sole crop to produce yields achieved through intercropping. The result of the analysis showed that total and pooled mean LER across and over cropping seasons, respectively were greater than one for all maize and common bean combinations (Table 3). The highest total and pooled mean LER were obtained from intercropped maize with one and two rows of common bean across and over cropping seasons.These results indicated that intercropping of common bean and maize increased the land use efficiency than producing both crops independently which might contribute much to the production of more yield from a given unit area of land through intensification. Similar results were reported by Hirpha (2014) and Ashenafi (2016) who also obtained higher land equivalent ratio for maize and common bean intercropping.

Land equivalent coefficient (LEC): Under intercropping production system, the minimum acceptable land equivalent coefficient is 25% (Adetiloye *et al*., 1983) with values exceeding 25% indicating greater land use efficiency and yield advantage over sole crop production systems. Accordingly, the result of this study showed that all the maize and common bean combinations resulted in more than 25% LEC with the minimum value recorded for broadcasting both crops mixtures; the farmer practice while the highest was recorded for intercropping two rows of common bean between two maize rows (Table 3). This result is in line with the finding of Yesuf (2003); Egbe (2005); Ashenafi, (2016) and Belstie *et al*. (2016)who obtained LEC values greater than the minimum acceptable limit in their studies of intercropping maize with different legumes.

Monetary advantage index (MAI): Analysis of MAI values showed increased monetary values for maize and common bean combinations compared to sole and farmers' practices production systems (Table 3). Particularly higher MAI were found when one and two rows of common bean intercropped in maize as well as broadcasted common bean under row planted maize. The result of this study is in line with other similar research results (Yilmaz, (2008); Ashenafi, (2016) and Belstie *et al*. (2016) who also found higher monetary advantage index for maize and legume intercropping systems.

Conclusion and Recommendations

The pooled means showed the highest significant land equivalent ratio, land equivalent coefficient, monetary advantage index, and total yield could be achieved through intercropping one and two common bean rows between two maize rows in moisture stress area of Yabelo, souther Oromia. Besides, crop intensification through intercropping of maize and common bean in moisture stress environments can reduce the down side risk of crop failure especially in short rain fall seasons. Therefore, from the two cropping season experimental results, intercropping one or two rows of common bean rows between two maize rows can be recommended for increased total yield per unit area, land use efficiencies and monetary advantages.

Table 1. The effect of different proportion of intercropping common bean in to maize on grain yields of maize and common bean across cropping seasons

Treatment	2012			2011		
	Grain Yields (t ha^{-1})			Grain Yields (t ha^{-1})		
	Maize	Common bean	Total	Maize	Common bean	Total
Sole Maize	4.51	0.00	4.51	4.41	0.00	4.46
Sole Common bean (CB)	0.00	3.13	3.13	0.00	2.85	2.99
1 CB row between 2 maize rows	3.91	1.95	5.86	3.65	1.98	5.73
2 CB rows between 2 maize rows	3.38	2.50	5.88	3.17	2.29	5.67
3 CB rows between 2 maize rows	3.11	2.03	5.14	2.93	2.16	5.12
Maize in row and CB broadcasted	3.38	2.30	5.68	3.17	1.95	5.40
Both Maize and CB broadcasted	2.39	2.11	4.5	2.19	1.91	4.30

CB=common bean

Table 2. Combined mean yield and yield components of maize as affected by different proportion of intercropping common bean in to maize (pooled data of two years)

Treatments	ED (cm)	EH (cm)	EL (cm)	PH (cm)	TSW (g)	Total yields (t ha^{-1})
Sole maize	4.55a	47.51a	13.76a	130.250a	283.05a	4.46b
1 CB row between 2 maize rows	4.25bc	47.10a	11.52b	122.39ab	291.08a	2.99c
2 CB rows between 2 maize rows	4.03c	52.10a	10.62bc	118.37ab	279.41a	5.73a
3 CB rows between 2 maize rows	4.32b	50.78a	13.390a	124.68ab	281.84a	5.67a
Maize in row and CB broadcasted	3.75d	46.73ab	10.79bc	119.60ab	290.74a	5.1ab
Both Maize and CB broadcasted	3.8cd	38.430b	9.64c	105.32b	281.10a	5.4ab
Mean	4.13	47.11	11.62	116.64	284.53	4.81
LSD	***	**	***	***	ns	***

*Means with the same letters within a column are not significantly different. Ns = non-significant and ** significant at p<0.05, DF=degree of freedom, EL=Ear ength, EH=ear height, ED=Ear diameter, PH=Plant height, and TSW=Thousand seed weight; CB=Common bean*

Table 3. The effects of intercropping different proportion of common bean in to maize on productivity and benefit of maize and common bean production

Treatments	Cropping Seasons 2012 Grain Yields (t/ha)			Cropping Seasons 2011 Grain Yields (t/ha)			Cropping Seasons 2012			Cropping Seasons 2011			Pooled mean		
	Maize	Common bean	Total	Maize	Common bean	Total	LER (Maize)	LER (CB)	LER (Total)	LER (Maize)	LER (CB)	LER (Total)	LER	MAI	LEC
Maize sole	4.51	0	4.51	4.41	0	4.46	-	-	-	-	-	-	-	26760	-
Sole Common bean (CB)	0	3.13	3.13	0	2.85	2.99	-	-	-	-	-	-	-	29900	-
1 CB row between 2 maize rows	3.91	1.95	5.86	3.65	1.98	5.73	0.86	0.62	1.48	0.82	0.69	1.51	1.495	42330	0.56
2 CB rows between 2 maize rows	3.38	2.5	5.88	3.17	2.29	5.67	0.74	0.79	1.53	0.71	0.80	1.51	1.520	43600	0.59
3 CB rows between 2 maize rows	3.11	2.03	5.14	2.93	2.16	5.115	0.68	0.64	1.32	0.66	0.75	1.41	1.365	39070	0.48
Maize in row and CB broadcasted	3.38	2.3	5.68	3.17	1.95	5.4	0.74	0.73	1.47	0.71	0.68	1.39	1.430	40900	0.52
Both Maize and CB broadcasted	2.39	2.11	4.5	2.19	1.91	4.3	0.52	0.67	1.19	0.49	0.67	1.16	1.175	33840	0.35

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Yield Improvement of Finger Millet due to Blended Fertilizers at Bako and Gute

[1]*Fufa Anbessa, Dagnachew Lule,Magarsa Kebede,Zarihun Ababe,Magarsa Dabala, Gudeta Badada, Kebede Desalagn,Girma Chemeda,Chamada B. and Hailu F.*

[1]Bako Agricultural Research Center, P.O.Box -West Shoa, Ethiopia.

E-mail:

Abstract

Finger millet (Eleusine coracana (L.) is an important crop in Ethiopia and other African countries due to its drought tolerance and nutritive value. It is widely cultivated and used in Ethiopia in dry land areas of the country that may be its origin and diversity. A field experiment was conducted to determine optimum nutrient requirement of finger millet for maximum economic yield. It was on sandy loam soils at Bako Research Center on station and Gute Sub-station for two years in 2015 and 2016. One finger millet variety (Adis-01) was used as test variety. Three types of fertilizer (NPS, Urea, DAP) were applied at different rates where Borax was uniformly applied across the plots. The result indicates that there is significant difference among the treatments in yield and plant height. At Bako, the highest yield (3801kg/ha) was recorded when the blend of 70kg Urea, 100kg NPS and 6kg borax is applied per hectare. Similarly,at Gute, the highest yield (3642kg/ha) was recorded when the blend of 90kg Urea, 100kg NPS and 6kg borax is applied per hectare. The economic analysis shows the feasibility of the two treatments hence they are recommended for use in these area and similar agro ecologies.

Introduction

Finger millet (*Eleusine coracana (L.*) is an important crop in dry land of Africa including Ethiopia. It is drought tolerant and high nutritive value crop (Apoorva,K.B. *et al*.). The crop is also important due to its superior nutritive value and excellent feed in dry lands of East African countries and some parts of Asian countries (Wekha N. *et al* 2016). It is widely cultivated and extremely adapted in dry lands of Ethiopia and wide range of environment for its efficient nutrition and storage quality (Birhanu Ayalew 2015, Dagnchew *et al*. 2012). Its origin is considered to be Ethiopia and the highlands of Uganda (Asfaw A. et al, 2011; Dagnachew L. 2012). The crop is also important for its durability in a traditional storage due to small size of its grain that can't be damaged by storage insects. It is also tolerant to soil nutrient deficiency and can give some yield in degraded soil (Wekha N. *et al* 2016).This does not mean there is no need of nutrients application for good yield of finger millet. It needs good soil fertility for its growth and development. Bekele A. *et al* 2016 reported good yield in fertile soils and in the farm treated with chemical and organic nutrients. Leaching of fertilizer in high rain fall areas is the main problem hence nutrients are insufficient for the plant. Therefore, application of fertilizer for the crop will be a must (Patil S.*et al* 2015). Even though it is an important crop in Africa with multiple advantages, it is still a lost crop of the continent concerning its management and consumption (Kumarnaik,A.H. *et al*. 2016). In Africa finger millet growers do not apply fertilizers in their field. The growers in Asia, Sub-Saharan Africa and India grow the crop on marginal land with low nutrient application hence low yield (Patro & Madhuri, 2014). Nutrients are important for the crop even though it is tolerant to nutrient deficiency compared to the other cereal crops. In Ethiopia, its yield is limited bellow 3700kg/ha due to poor crop management such as low or no nutrient application, improved variety, disease management & other pests (CHRISPU O.A. ODUORI 2008).The study was conducted with the objective to determine optimum blended fertilizer rate for finger millet in high rain fall areas of western Oromia.

Materials and Methods

The field experiment was conducted at Bako Agricultural Research Center (on station) and Gute sub site located 250km and 310 km respectively, west of Addis Ababa in East wellega zone. The soils of study areas were sandy loam with texture suitable for finger millet. The experiment was conducted for two years 2015 and 2016 cropping seasons on the two sites. The field experiment was laid in Randomized Complete Block Design in factorial arrangement in three replications. The number of treatments were 18 including one control and the DAP (100kg/ha) that was used before in the area for purpose of comparison. The rest treatments were four levels of NPS combined with four levels of Urea. Borax fertilizer was mixed with both NPS and Urea as a source of Boron for the crop. The rate of Borax was 6kg/100kg of NPS to avoid plant toxicity.

The total number of plot was 54 with four harvestable rows of 5m length in each plot. The distance between rows was 20cm and seeds were drilled across the rows. Urea was applied in split (½ at planting time and the rest after first weeding). The recently released variety (Adis-01) was used for the experiment. All yield and yield components data such as plant height, number of tiller, number of finger per plant, length of finger, grain yield and straw yields were collected and the data was analyzed using Genstate statistical software.

Result and Discussion

Effect of fertilizer on grain yield: The statistical analysis showed that the plot that received 90 kg Urea, 150 kg NPS and 6kg Borax produced highest average yield (3642kgha^{-1}) at Gute while the mixture of 70kg Urea, 100kg NPS and 6kg Borax at Bako produced the highest yield (3801kgha^{-1}). The lowest grain yield was recorded in untreated plot. There was significant yield difference among the treatments at both sites. The plots that received 90kg Urea &100kg NPS,50kg Urea & 150kg NPS,70kg Urea & 150 NPS and 50kg Urea & 75kg NPS with mixing of 6kg Borax fertilizer produced the grain yield of 2954kg,2833kg,2755kg & 2562kg per hectare at Gute and 3676, 3581& 3635 at Bako respectively (Table 1).

Plant Height: The statistical analysis showed that there is a highly significant difference among treatments at both sites. The plot that received 65kg Urea & 100kgDAP showed highest plant height (73.67cm) followed by the plot that received 70kg Urea & 125kgNPS at Gute (Table 1). The plot that received 90kg Urea 125kg NPS with the mix of 6kg Borax fertilizer showed highest plant height (87.7cm) among treatments followed by 50kg Urea & 100kg NPS at Bako.

Above Ground Biomass: Thestatistical analysis showed that there is highly significant difference among treatments. The plot that received 90kg Urea & 125kg NPS blended with 6kgha^{-1} Borax produced 9009kg ha^{-1} above ground biomass followed by 65kg Urea & 100kg DAP at Gute (Table 1). The plot that received fertilizer 70kg Urea & 100kg NPS blended with 6kg ha^{-1} Borax produced 24068kgha^{-1} above ground biomass followed by 30kg Urea & 125kg NPS, at Bako (Table 1). Generally, the study showed that there was highly significant difference among treatments the two fertilizers Urea and NPS blended with the fertilizer Borax. In the study economic analysis was done for the interaction of the treatments. Therefore, the miture of 90kg Urea with 100kg NPS at Gute and 70kg Urea with 100kg NPS at Bako blended with 6kgha^{-1} Borax are economically feasible.

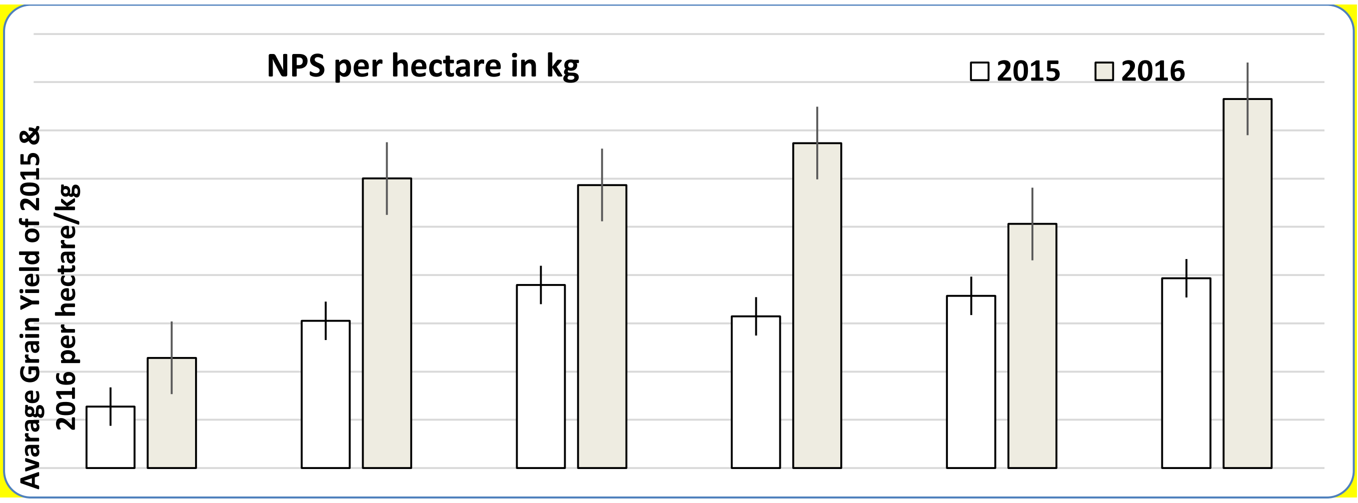

Fig.3:-Effect of NPS on yield of finger millet at Gute on station 2015 & 2016 cropping season

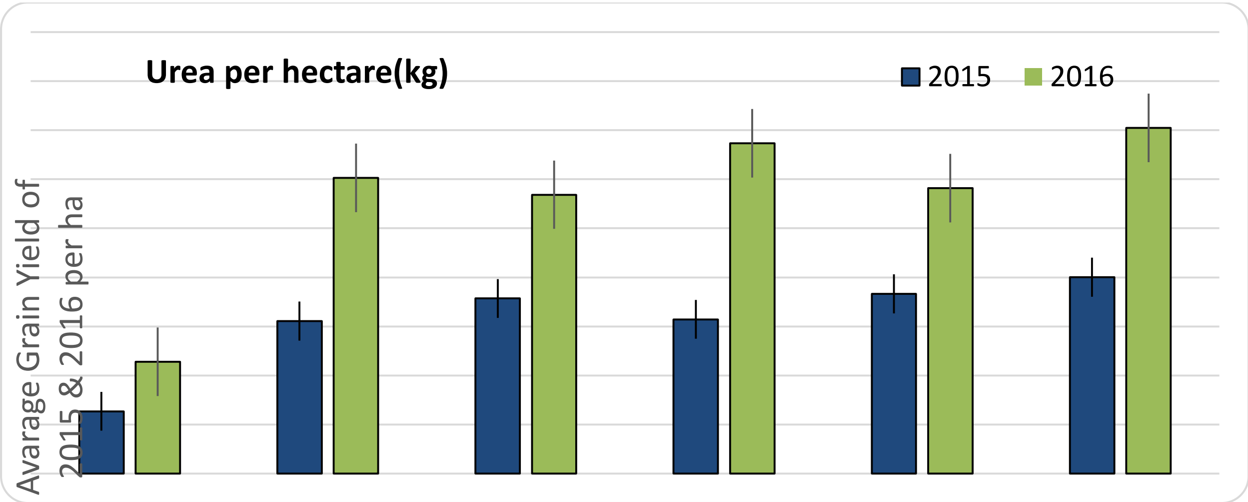

Fig.4:-Effect of Urea on yield of finger millet at Gute on station in cropping season of 2015 and 2015

Table1:-Mean of treatments interaction effect grain yield, plant height and above ground biomass at Gute and Bako

No	Treatment		Treatment mean/ha(kg)					
	Urea/ha(kg)	NPS/ha(kg)	Gute			Bako		
			G/yield	AGBM	PH	G/yield	AGBM	PH
1	90	150	3642a	8224bcd	66.55bcde	3676ab	21885bc	80.5bcdef
2	90	100	2954b	6667fg	63.28efg	3109def	16875h	79.93cdef
3	50	150	2833b	8068bcd	70.82abc	3136de	18455fg	78.4fgh
4	70	150	2755bc	8010bcd	71.08abc	3161de	18911fg	79.73bcdef
5	50	75	2562cd	7628de	60.42g	3057def	19807ef	82.63bcd
6	65	100	2470de	8580ab	73.67a	3581b	21854bc	82.08bcde
7	30	150	2357def	8404abc	67.41bcde	3073def	21635bcd	79def
8	90	125	2339ef	9009a	69.37abcd	3176de	21818bc	87.7a
9	30	125	2334ef	7217ef	63.92efg	3635ab	22562b	77.3fgh
10	70	125	2276efg	8179bcd	71.78ab	2532h	18328g	78.7efg
11	30	100	2275efg	6602fgh	69.83abcd	3039ef	20547de	75.22ghi
12	70	100	2252fg	7505de	60.7fg	3801a	24068a	78.67efg
13	70	75	2204fg	7978bcd	66.47bcde	3235cd	18995fg	78.75efg
14	50	100	2183fg	7824cde	67.79bcde	2935fg	19391fg	84.13ab
15	30	75	2171fg	5949ghi	60.63g	3370c	19922ef	73.4i
16	90	75	2117g	5870hi	64.57defg	2798g	19417fg	74.77hi
17	50	125	1678h	5394i	66.03cdef	3396c	20833cde	82.68bc
18	0	0	889i	2717	45.87h	1201i	9010i	52.97j
Cv(%)			7.6	9.1	7.1	5.4	4.9	7.1
Lsd			206.3	752.1	5.4	179.9	1112.1	3.7
F-prob			**	**	**	**	**	**

Table2:-Economic analysis of the treatments at Gute

No	Urea/NPSB/ (kg/ha)	Cost (ETB)	Grain/ha (kg)	Gross Benefit (Birr)	Net Benefit (birr.)	Dominance	MRR
1	0/0	0	889	7112	7112	--------	------
2	30/75	1620	2171	17368	15748		5.3
3	50/75	1900	2562	20496	18596		10.17
4	30/100	2020	2275	18200	16180	D	
5	70/75	2180	2204	17632	15452	D	
6	50/100	2300	2183	17464	15164	D	
7	30/125	2420	2334	18672	16252		0.13
8	90/75	2460	2117	16936	14476	D	
9	70/100	2580	2252	18016	15436	D	
10	65/100 DAP	2590	2470	19760	17170		1.61
11	50/125	2700	1678	13424	10724	D	
12	30/150	2820	2357	18856	16036	D	
13	90/100	2860	2954	23632	20772		13.34
14	70/125	2980	2276	18208	15228	D	
15	50/150	3100	2833	22664	19564	D	
16	90/125	3260	2339	18712	15452	D	
17	70/150	3380	2755	2204	18660	D	
18	90/150	3660	3642	29136	25476		5.88

Table2:-Economic analysis of the treatments at Bako

No	Urea/NPSB (kg/ha)	Cost (ETB)	Grain/ha (kg)	Gross Benefit (Birr)	Net Benefit (birr.)	Dominance	MRR
1	0/0	0	1201		9608		
2	30/75	1620	3370	26960	25340		9.7
3	50/75	1900	3057	24456	22556	D	
4	30/100	2020	3039	24312	22292	D	
5	70/75	2180	3235	25880	23700	D	
6	50/100	2300	2935	23480	21180	D	
7	30/125	2420	3635	29080	26660		1.65
8	90/75	2460	2798	22384	1992	D	
9	70/100	2580	3801	30408	27828		7.3
10	65/100 DAP	2590	3581	28648	26058	D	
11	50/125	2700	3396	27168	24468	D	
12	30/150	2820	3073	24584	21764	D	
13	90/100	2860	3109	24872	22012	D	
14	70/125	2980	2532	20256	17276	D	
15	50/150	3100	3136	25088	21988	D	
16	90/125	3260	3176	25408	22148	D	
17	70/150	3380	3161	25288	21908	D	
18	90/150	3660	3676	29408	25748	D	

Conclusion and Recommendation

Fertilizer level influences the yield of finger millet at bako and Gute and the optimum fertilizer rate at Gute is 100kg NPS/ha and 90kg Urea/ha. The optimum fertilizer rate at Bako is 70kg Urea/ha and 100kg NPS/ha that produces highest yield and economically feasible. The bio-mass and plant height of the crop also increased by the above level of fertilizer. Therefore, the farmers and investors of the area and policy makers are advised to use this optimum fertilizer rate to get economically feasible high yield.

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Experiences and the Challenges in Soybean Production Management and Promotions Supported by N_2Africa Project in Six Selected Districts of Western Oromia

[1]Zerihun Abebe, [1]Adane Arega, [1]Tadesse Birhanu, [1]Kifle Degefa, [1]Chala Dabala, [1]Alemayo Dabasa, [1]Getachew Birru, [1]Meseret Tola and [1]Solomon Bekele

[1]Bako Agricultural Research Center/ Oromia Agricultural Research Institute

P.O.box 03, Bako West Shoa

Corresponding author: baatiree@gmail.com

Abstract

Soybean is often described as a miracle golden bean due to its multi advantages, but its benefits are not well exploited in Ethiopian smallholder farmers. Some of the main problems that may limit its potential exploitation are lack or limited access to inputs (improved seed and quality inoculants), inappropriate and non-specific recommendations, lack of labor-saving farm tools and poor market linkage across soybean value chains. Many efforts have been made by National and Regional Agricultural Research Institutes in developing or adapting improved varieties with some agronomic managements since 1950, but the production rates are still low when compared to other crops. Recently, many international non-government organizations are very interested toinvestin soybean production technologies in order to boost the benefit of smallholder farmers of Ethiopia. N_2Africa project is one of the international projects that mainly focuses on legume value chains with the aim to putting nitrogen fixation to work for smallholder farmers in Africa. The project focuses on soybean value chain in six districts of Western Oromia under 'Chewaka' cluster. Some of the project's outputs in thetargetedareas resulted in 24-70% yield increase over the control when 50 kg ha^{-1}phosphorus fertilizer (+P) with Rhizobiuminculcation (+R) was applied. Similarly, the highest dry biomass yield (-how much?-)(both hulm and husk dry weight), which is a potential for animal feed, was obtained when both +P+R were applied while the lowest dry weight (how much?) was recorded from the control plot. Not all farmers benefitted to the same extent from the application of P and/or R. Even though more than 90% of the farmers saw a positive response to the application of P and R, around 10% of the farmers saw negative yield response. This requires further invesigation for nonresponsiveness of the soil. On the other hand, less than 50% of the farmers saw negative yield response when either of the two fertilizer sources was applied, indicating the combined application of P and R is very crucial. In Addition to field experiment, the project also engaged in farmers capacity building, demonstration, dissemination, input delivery and output market access with the aim to address more smallholder farmers to be benefited from the soybean technologies. More than 7500 farmers (30% women) were trained in soybean agronomic management and soybean recipe preparation and utilization in six districts. More than 2500 farmers directly benefited from distribution of all soybean inputs since 2013 in the targeted districts. Around 4000 farmers got awareness about soybean technologies through evaluation and field day events.These achievements were possible due to collaboration with local partners/stakeholders (e.g Self-help Africa, CHAI, SIMLESA, MfM, BOA and Primary cooperatives etc). Even though the project made many efforts on the promotion of soybean technologies, the benefit for the farmers is still very low due to many limiting factors that need immediate attention by the stakeholders. Some of the main challenges are lack of access to inputs (seeds, quality inoculants and pre-emergence herbicide), the issue of nonresponsive soils, lack of labor-saving tools (planter, thresher, soy grinder and soymilk processor) and poor market linkage across soybean value chains.

Keywords: Soybean, Inoculant, Capacity building, Diagnosis, Demonstration, Adaptation/pre-scaling up, Input supply and Market Access

Introduction

Soybean is one of the food crops which is native to China but well commercialized in America. About 55% of the USA edible oil consumption source is from soybean (Goldsmith, 2017). The world-leading producer of soybean is still the USA and followed by Brazil and Argentina in Latin America, and China in Asia (Spicer, 2017). Nigeria is the highest Africa's soybean producer (39%), closely followed by South Africa (35%) while Uganda is the third highest African producer (14%) (Spicer, 2017). Soybean is often described as the miracle golden bean, the meat that grows on vines, the protein hope of the future and the salvation crop among others. These attributions are mainly due to the relatively high protein content (about 40%) contained in soybean seeds (Adelodun, 2011). It is one of the least expensive sources of protein when compared to eggs, milk, beef, and cowpea. It also contains approximately 20% unsaturated and non-cholesterol fatty acid, oleic and linoleic acids, and it is suitable for reducing heart ailment which may be caused or aggravated by excessive intake of cholesterol from animal fat (Adelodun, 2011). Moreover, many studies showed that mature soybean seed contains vitamins such as thiamine, niacin, riboflavin, choline, vitamins E and K, which are necessary for normal body growth and development(Adelodun, 2011; Keyser and Li, 1992).

Soybean is a pulse crop with multiple food and economic advantages for small-scale farmers. It is used as food for home consumption, raw materials for local factories and feed for dairy animals or fattening farms (Abebe, 2017; Sisay Bekele, 2017). Many types of soybean recipes can be prepared with cereal and vegetable crops. Most of the smallholder farmers who are currently producing soybean in Chewaka area use the soybean products as parts of their staple food. Its by-products (soybean cake and soybean residues) are the main sources of animal feeds since it has good crude protein sources. Soybean has 45-50% crude protein content when compared with either wheat bran or noug cake (Sisay Bekele, 2017). In addition, soybean residues (both hulm and husk) have higher nutrient contents compared to other crop residue sources. In addition, soybean has the capacity to fix atmospheric nitrogen from the air through symbiosis with Rhizobium bacteria and thus contributes to improved soil fertility when grown in rotation with cereals (Ronner et al., 2016; Vugt et al., 2017). As a result, it has an additional advantage of reducing N fertilizer requirement for subsequent crops in a rotation(Abebe and Haile, 2017). Therefore, it can be grown in rotation with cereals like maize, finger millet, and sorghum.

Many efforts have been made in soybean variety development and/or adaptation with different agronomic and other management options since 1950 in Ethiopian agricultural production systems (Addisu et.al, 2016). Recently, different non-government organizations and projects like N_2Africa project, soybean innovation lab and Clinton Access Initiatives, are working on soybean value chain particularly in areas where soybean has a good potential for grain production. Among them, The N_2Africa project worked on soybean value chains, mainly focusing on research managed agronomy, capacity building in soybean production and utilization, demonstration and promotion of best bet soybean technologies and market linkages. Therefore, the objective of this paper is to summarize the experiences in achievements and the challenges in undertaking these activities in some districts of Western Oromia for the last five years (2013-2017) during the implementation of the project.

Material and Methods

The N_2 Africa project started in 2013 as bridging year focusing on major legume crops, particularly soybean value chains in Western parts of Oromia Region. The project mainly focused on four pillars; (1) Research managed agronomy, (2) Stakeholders' capacity building on improved soybean technologies, agribusiness, soybean recipe preparations and other value additions, (3) Input distributions (seeds, inoculants and others), (4) demonstration and adaptations or pre-scaling up of best bet soybean technologies and (5) access to market for soybean producers.

The project was implemented by IQQO-BARC supported by N_2 Africa in six districts of Western Oromia. The selected districts are Bako Tibe, Ilu Galan, and Dano from West Shoa, Gobu Sayo and Wayu Tuka from East Wollega and Ilu-Harar (Chewaka) are from Buno Badelle Zones. In 2013 cropping season, mother and baby trial for participatory variety selection and one input trial (50 kg DAP/ha & Inoculants (+P+R), 50 kg DAP/ha & no inoculants (+P-R), only inoculants (-P+R) and the control (-P-R)) were conducted to select best bet varieties along with good agronomic practices. Six released soybean varieties were evaluated under farmers' condition for participatory variety selection while Didessa variety was used to evaluate the effect of different inputs (+P+R, +P-R,-P+R,-P-R).

In 2014 cropping season, the response of fertilizer sources (+P+R, +P-R,-P+R,-P-R) under diagnosis trial was also conducted on 26 farmers' plots in Gobu Sayo district. At the same time, both demonstration and adaptation/pre-scaling up have been conducted to show and demonstrate the best bet performed varieties along with the inoculants. Therefore, both seeds for improved varieties and the inoculants were distributed in the selected districts. The inoculants were bought from Menagesha Biotech. Yield assessments for adaptation and demonstration trials were conducted in each district to evaluate the performance of the crop across locations. The yield for diagnosis trial from each farmer's plot was measured.

Training for different stakeholders (targeted farmers, DA, District experts, primary cooperatives and local NGOs) for capacity building was delivered since 2013. The training mainly focused on soybean production and management, post-harvest handling, soybean recipe preparations and utilization, agribusiness development and value additions, and means of access to market linkages. The training was conducted in collaboration with the identified local partners and/or stakeholders, such as Self Help Africa, Clinton Health Access Initiatives (CHAI), IFDC-2Scale, Menschen Fur Menschen (MfM), farmers union cooperatives, Agricultural experts of Districts, Development Agents (DA) and local agro-dealers.

Different farmers' forums were organized toevaluate soybean trials as a means of experience sharing among the farmers. The farmers evaluated the performances of the crop under the demonstration trials that received different input (+P+R, +P-R,-P+R,-P-R) using their own evaluation criteria. On the other hand, farmers' field day events as a means of technology promotion tools have been arranged in some farmers' fields since 2013. Both male and female farmers were engaged in both evaluation and field day events.

Finally, yield assessment on forty farmers' fields was done by harvesting from $100m^2$ in order to estimate the performance of the crop under farmers' management conditions and to assess the yield variability across the districts and/ or peasant associations.

Result and Discussion

Yield Response of soybean to fertilizer (P) and/or Rhizobium Inoculation (R): The response of soybean to Rhizobium inoculation and fertilizer rates showed significant differences across cropping seasons. The highest grain yield was obtained when both the inoculants and chemical fertilizer (50 kg DAP/ha) were applied across all cropping seasons. The result in Figure-1 showed that more than 70% (in 2014), 52% (in 2015) and 24% (in 2016) yield advantages were recorded when both the inoculants and 50kg DAP/ha were applied compared to the control plot receiving no fertilizer sources. However, yield performance of the crop in 2016 was not significantly different when both inoculants and the chemical fertilizer were applied compared to the independent application of only chemical fertilizer and Rhizobium inoculation or without fertilizer sources. The result of 2014 and 2015 confirm the results of other reports (Keyser and Li, 1992) who also found that application of only rhizobium inoculation to the crop significantly improved the yield of soybean over the control similar to the application of only chemical fertilizer (50 kg DAP/ha).

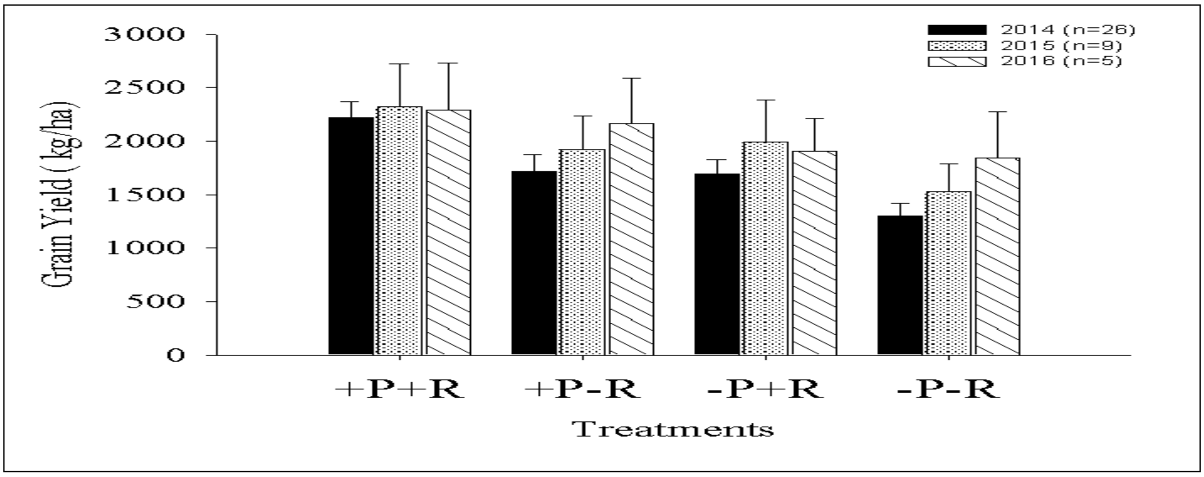

Figure-1: The Effect of Rhizobium Inoculation and Chemical Fertilizer rates (50 kg DAP/ha) on yield of soybean on Farmers' field

Soybean haulm and husk contain good amounts of crude protein (CP) which is important for animal feed, particularly for fattening. In addition to the increased dry weight of both hulm and husk, the improvement of CP content of soybean haulm was attained due to *Rhizobium*inoculations and chemical fertilizer applications (Sisay, 2017).The result in Figure-2 indicates that significantly more dry weight of hulm could be harvested compared to the husk dry weight. The highest hulm dry weight in 2016 was obtained when both Rhizobium inoculation and the chemical fertilizer were applied compared to the uses of either of the two fertilizer sources independently or no fertilizer sources. However, the total dry weight of husk was not significantly affected by treatment variations. In general, the highest total dry weight of biomass (both husk and hulm) could be harvested when both Rhizobium and chemical fertilizer were applied, and hence advisable and recommended.

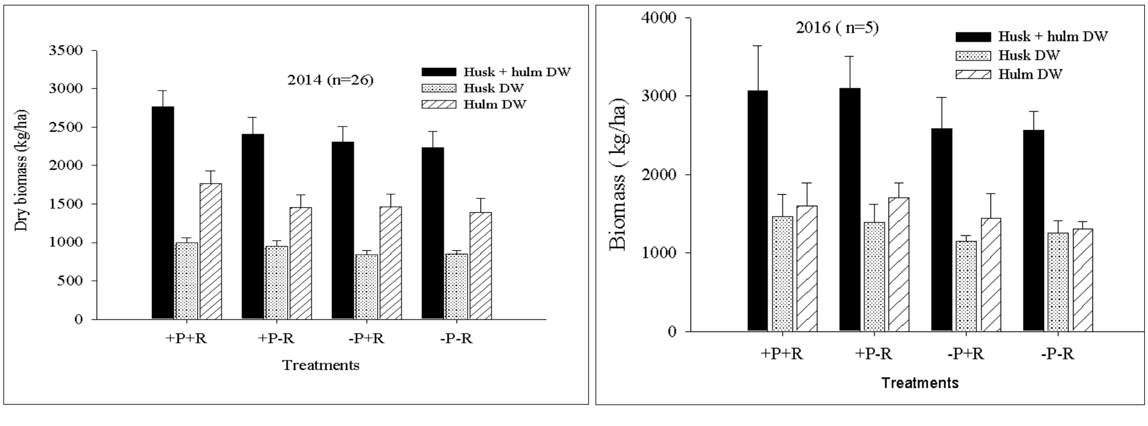

Figure-2: The Effect of Rhizobium Inoculation and Chemical Fertilizer rates (50 kg DAP/ha) on husk and hulm dry biomass of soybean on Farmers' field.

Yield Variability: Biomass and grain yield of soybean were significantly affected by the application of P and/or R, but the responses were not uniform across locations and farmers. This indicated that not all farmers benefitted uniformly from the application of P and/or R (Figure 3). The yield response to P and/or R across farmers' fields in 2014 cropping season indicated that the yield performance was varied from less than 500 kg ha^{-1} to more than 4300 kg ha^{-1} (Figure 3). The highest soybean yield (4319 kg ha^{-1}) was achieved on a farmer plot when both P and R were applied while the lowest yield under the same input application (949 kg ha^{-1}) was recorded on the other farmer plot, indicating that there are more than 3 tons ha^{-1} yield gaps between the two farmers. On the other hand, the crop did not respond to the application of P and/or R when compared to the control plot, and this might be due to the non-responsiveness of the soil which needs further research to identify the major limiting factors that determine the responsiveness of the treatments as also suggested by Ronner et al., 2016.

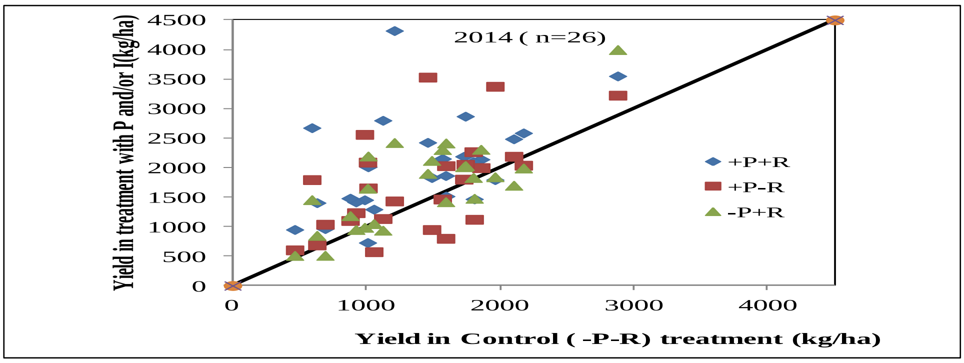

Figure 3: Soybean grain yields control (kg ha^{-1}) and the response to P, R and P + R for individual farms in Gobu Sayo District (2014). P = 50 kg P ha^{-1} applied as DAP fertilizer; R = seed inoculated with Bradyrhizobium japonicum.

The result indicated in figure-5 show that more than 90% of the farmers observed a positive response to the application of P and R compared to the control plots. Gains of more than 1400 kg ha^{-1} was achieved by about 15 and 13% of the farmers who applied P and R, and R or P respectively, compared to the control plot. Only 3% of the total farmers who applied P and/or R achieved yield gains of 2500 kg ha^{-1} compared to the control plot. A similar result was reported in Nigeria where all farmers did not gain yield advantage when P and/or R were used compared to the control plot (Ronner *et al.*, 2016). However, more than 50% of the total farmers observed a positive response to the application of either P or R compared to the control plot. In other words, less than 50% of the farmers came across negative yield response when either of the two fertilizer sources was applied independently. Only less than 10% of the farmers observed negative yield responses when both P and R were applied compared to the control plot. The 3% negative penalty was caused by inappropriate weed management, particularly at the early stage. Some farmers start weeding other plots two weeks after either P or R applied plots are weeded. In other words, weed management was not uniformly applied across all farmers' plots. However, more than 30-35% of the farmers did not see yield gain when either P or R was applied compared to the control. This may indicate that sole application of chemical fertilizer as P sources and Rhizobium inoculation did not significantly increase yield since both have complementary effect on nutrient utilization efficiencies (Abebe Zerihun, 2015). In general, the negative yield gains might be due to other factors, particularly no weed management at an early stage of the crop, or lack of integrated application of P and R that might hamper the response of the crop.

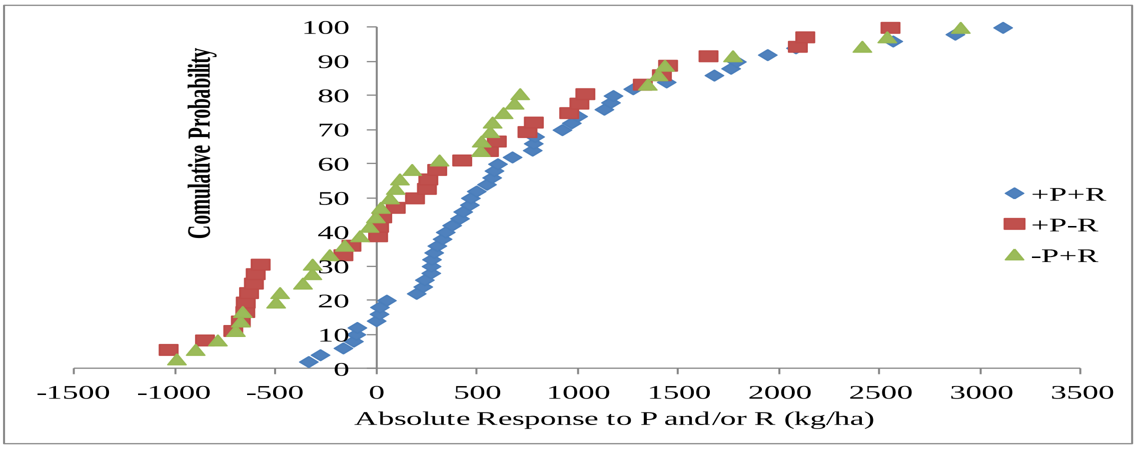

Figure 5: Cumulative probability of estimated absolute yield response (kg ha^{-1}; yield of P and/or R minus control yield). P =50 kg P ha^{-1} applied as DAP fertilizer; R = seed inoculated with Bradyrhizobium japonicum.

Achievements on Capacity Building, Input Distribution, and other Promotion Approaches

Capacity Building: One of the main targets of this project was to equip the farmers with soybean production technologies starting from land preparation to post-harvesthandling and soybean recipe preparation and utilization. Both general training and training of trainers (ToT) were given in each targeted district across all cropping seasons. More than 7500 farmers, of which 30% were women, and technical personnel (development agents, Primary cooperative unions, NGOs, experts, woreda Agricultural Offices management bodies) have attended the general training on soybean production and management and soybean recipe preparation and utilization (for women) in the last four years. The training was conducted not only by N_2Africa project, but also in collaboration with different stakeholders in different districts, namely Selfhelp Africa (in Bako Tibe district), IFDC-2Scale (in Ilu- Harar district), Menshun fur Menshin (in Dano District), Clinton Access Initiative (CHAI) in more than 10 districts of East Wollega and West Shoa zones, SIMLESA project (Wayu Tuka, Gobu Sayo, Bako Tibe and Ilu Galan districts). These organizations and projects contributed a lot in promotion of soybean production technologies through different approaches (training, demonstration, adaptation/pre-scaling up, evaluation events and field days)

Direct Benefits to the farmers: Both soybean seeds and inoculants were distributed to the farmers directly in addition to the demonstration and/or diagnostic trials conducted on their farm plots. In all six targeted districts, more than 2500 farmers were directly benefited through the delivery of improved soybean seeds and inoculants and through hosting demonstration trials at least on $400m^2$ areas (Table 1). More than 85% of the direct beneficiaries have got seed and inoculants to plant an area of 0.25 ha of land.

In addition to capacity building offered to the targeted farmers, more than 4000 farmers were exposed to awareness on soybean production technologies through evaluation events on demonstration trials and field days organized on adaptation trials hosted by the target farmers in all the locations (Table 1).

Table 1: Number of farmers and technical staff participated on soybean technologies promotion in six districts (Bako Tibe, WayuTuka, Gobu Sayo, Ilu Galan, Dano, Ilu Harar) in 2013-2017

Dissemination approaches	Cropping Seasons					
	2013	2014	2015	2016	2017	Total
General training for farmers	0	1198	1548	1511	1150	5407
Training for TOT (training for trainee)	0	53	199	140	50	442
Training on recipe soybean preparation	0	384	685	78	540	1687
Diagnosis	0	30	0	0	0	30
Demonstration	45	150	23	16	14	248
Adaptation/pre-scaling up	0	680	640	491	450	2261
Number of participants on evaluation events	0	0	621	0	0	621
Number of participants on field day events	570	382	648	2064	0	3664
Total	615	2877	4364	4300	2204	14360

In general, more than 14,000 farmers got the awareness on the general knowledge and skill of soybean production technologies directly or indirectly and hence are capable of producing the crop though they still need technical support from the development agents and other local technical personnel.

Input Distribution and Training Materials preparation: Both soybean seeds of four varieties (Didessa, Ethio-Yugosilavia, Ketta, and Korme) were distributed in six targeted districts in the last five years (Table 2). Bako Agricultural Research Center (BARC) has played a key role in distributing both the seeds and inoculants in five districts (Bako Tibe, Ilu Galan, Gobu Sayo, Wayu Tuka and Ilu Harar) while MfM distributed more than 3.5 tons in five kebeles of Dano district in 2016 and 2017 cropping seasons. A total of 19 tons of soybean seeds and 5000 sachets of bio-fertilizers (inoculants) were distributed to the direct beneficiaries.

Moreover, leaflets explaining about soybean production and management technologies, and soybean recipe preparation methodologies were prepared in the local language (Afan Oromo) and distributed to the farmers, DAs, and other local NGOs and GO experts during training, evaluation forum and field day events. More than 3000 copies of the leaflets were printed and distributed in each targeted district for the five years duration (Table 2). On the other hand, 4000 copies of a technical manual prepared in the local language in collaboration with IFDC-2Scale and Selfhelp Africa projects were printed and distributed to the farmers.

Table 2: Amounts of inputs (soybean seeds and inoculants) and training materials (leaflet and technical manual) distributed in the last five years (2013-2017)

Input distributed	Cropping Systems					
	2013	2014	2015	2016	2017	Total
Soybean seeds (tons)	0.5	3.2	2.6	6.9	5.8	19.0
Inoculants (sachets)	120	330	300	250	4000	5000
Number of training materials distributed						
Leaflets	640	580	1250	1300	0	3770
Soybean training manual	0	0	0	4000	0	4000

Lessons from on-farm yield assessments: The yield assessment was done on forty farmers' plots by collecting representative samples from direct beneficiaries who have accessed all the inputs (soybean seeds, inoculants, and chemical fertilizer) in 2016 cropping season in five targeted districts. The result of this assessment indicated that there is huge variability of yield performances across the districts and/or peasant associations (PA). The analysis of the collected samples indicated that more than 33, 27, 26, and 24% yield increases were observed in Dano district compared to Bako Tibe, Wayu Tuka, Gobu Sayo and Ilu Galan districts, respectively. The maximum average yield (2284 kg ha^{-1}) was recorded in Dano Roge PA of Dano District while the minimum average yield (1565 kg ha^{-1}) was observed in Seden Kite PA of Bako Tibe District (Figure 6). This result confirms that soybean has a potential yield performance to be grown in all the districts although yield variability might be related to the variation in soil fertility, inappropriate uses of the inputs (both inoculants and chemical fertilizers), inappropriate time and frequency of weeding, differences in pre and post-harvest handlings as well as poor close supervision of the development agents.

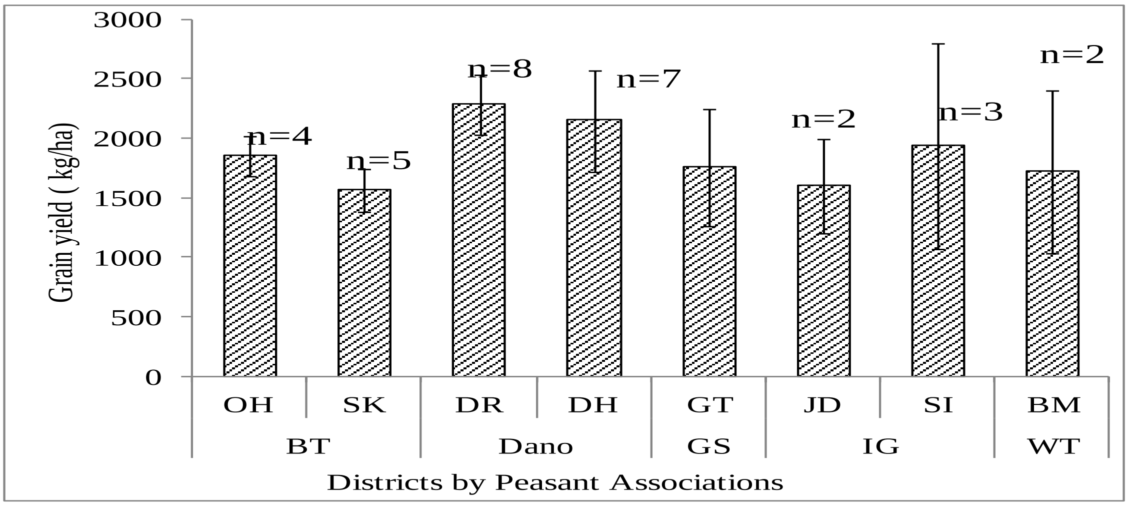

Figure 6: Soybean yield performances under farmers' management in each PA of five districts in 2016 cropping season. (PA= Peasant Associations; n= number of sample in each PA; BT= Bako Tibe (OH= Oda Haro and SK=Seden Kite PA); Dano district (DR= Danno Roge and DH=Dirre Harrayu PA); GS= Gobu Sayo district (GT=Gambela Tarre PA); IG= Ilu Galan district (JD= Jato Dirki and SI=Seden Ilu PA) and WT= Wayu Tuka district (BM=Boneya Molo))

Lessons and experiences, of farmers in Dano District where more than 54% of the farmers produced a minimum of 2000 kg ha^{-1} and 33% of the farmers achieved a yield of not less than 2500 kg ha^{-1} should be adopted. On the other hand, only 20% of the farmers have got soybean yield of fewer than 1500 kg^{-1} and the lowest yield recorded was 1000 kg^{-1} (Figure 7). On average, soybean yields of more 2200 and 2100 kg ha^{-1} were recorded in Dano Roge and Dirre Harayu PAs, respectively. These good achievements were due to close supervision of the development agents (MfM staff members) and MfM expert staffs who provided regular technical backup, particularly at the time of planting to ensure optimum plant populations, an appropriate fertilization and inoculation placements, appropriate time and frequencies of weed control and technically supporting the farmers on pre and post-harvest handing methods. Excellent lessons can be lernt from Farmer 1 and Farmer 3 in Dano Roge and Dirre Harrayu PAs who achieved about 3600 kg ha^{-1} soybean yields. However, there are soybean yields as low as 1900 and 2600 kg ha^{-1} in Dano Roge and Dirre Harrayu, respectively compared to the minimum producers in respective PAs, indicating that there are still huge yield gaps among the farmers. The low yields produced might have been due to soil fertility variations, the non-responsiveness of the soils to the applied inputs, inappropriate management practices from the time of planting to post-harvest handling. Therefore, these results clearly indicated that many efforts are required from DA and district experts, research organization and other stakeholders to minimize these yield gaps and hence increase the productivity.

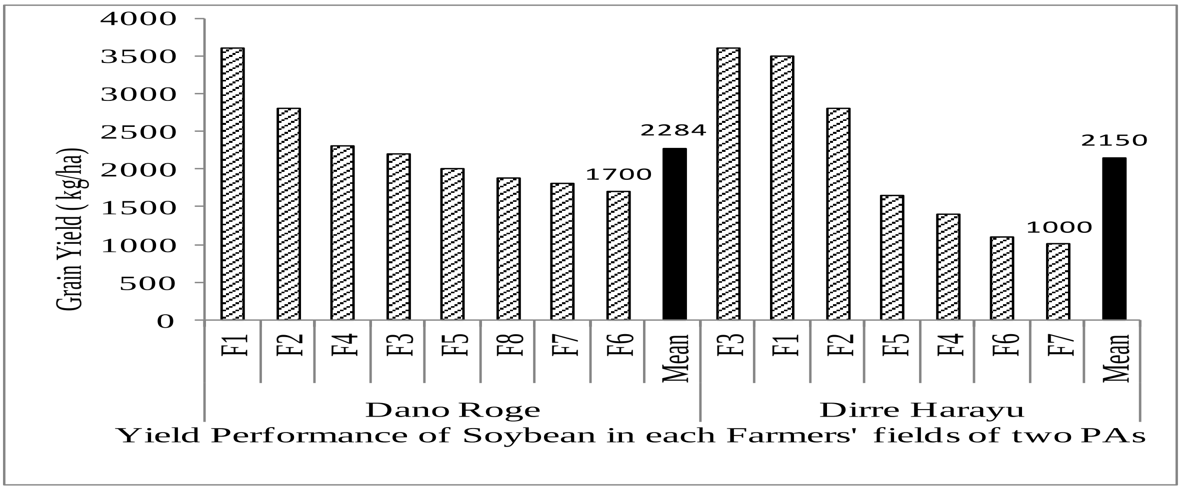

Figure 7: Soybean Yield performances under farmer's management in Dano Roge and Dirre Harrayu District in 2016 cropping season. F_{1-n}= represent the sampled farmers in each PA

Challenges and Possible Solutions

Poor Quality of the inoculants: Menagesha Biotech is one of the popular private share companies that are currently producing many biofertilizers for different legume crops, namely common bean, soybean, field pea, chickpea and etc. The demand for the inoculants are increasing from time to time as the popularization of the technology is widely addressed by different GO and NGOs. As evidence, not more than 10,000 sackets of the biofertilizers for different legume crops were distributed in 2011 while more than 70,000 sackets of different strains were nationally distributed in 2016 cropping season. Currently, the problem of poor quality of strain is emerging, particularly on soybean inoculants that are suitable for the acid soil areas of Western Oromia. For instance, more than 250 sackets of LEGUME-FIX biofertilizer were purchased from Menagesha Biotech in the 2016 cropping season by the project for Bako Agricultural Research Center. However, these strains did not respond, hence the crops suffered nitrogen deficiency andfinally, considerable yield loss occurred on almost all of the hosting farmers' plots. A lesson has been learned that there is a need to bring inoculant quality control system in the soybean production value chain with the increasing popularity and demand of the inoculants. Therefore, due attention should be given by government bodies and policymakers about the quality control and certification issue.

Non-responsive soils: The result of the analysis of diagnosis and demonstration plots indicated not all farmers benefited from the production technologies of soybean. Although all hosting farmers were supplied with the same soybean technologies (improved seeds, inoculants, and chemical fertilizers) some of the farmers achieved lower yields compared to the control plot, indicating that soils of these farmers' plots are not responding to the applied inputs. This needs further research. Even though N_2Africa project gave attention to solve the problem of non-responsive soils, additional efforts should be made by different research organizations to address the problem.

Weed Control Problem: The only and most practiced weed control method in soybean crop is hand weeding. But, farmers are seriously demanding pre-emergence herbicide in the local market. Almost all farmers have adopted the use of different pre- and post-emergence herbicides to control weeds in maize and want to have similar options for soybean production. Bako Agricultural Research Center has conducted two years evaluation trials on pre-emergence herbicide (Dual gold) for soybean weed control, and the result indicated that application of this pre-emergence chemical plus one time hand weeding, 30-40 days after planting can effectively control weeds and significantly increase the yield of soybean. However, the chemical is not locally and/or nationally available for the end users. Currently, the area of soybean production in targeted areas has been increasing as a result of the wide popularization and pre-scaling up activities done by different NGO (CHAI) and thus needs for alternative weed control methods. Therefore, the availability of pre-emergence and/or post-emergence (if any) herbicides at the local market are crucial. It is critical for soybean technology adoption as a package hence the responsible bodies have to take appropriate measure sooner than later.

Lack of soybean planter and thresher: While the area for soybean production is increasing from time to time, the demand for labor-saving tools such as planters and threshers are emerging issues, particularly for soybean seed producers and local investors where there is ashortage and /or high competition for labor at critical production time. Soybean planter is now a major problem particularly for private soybean seed producers as labor requirement at planting is very high and costly. For instance, Ano Agro Industry P.L.C has been producing soybean seeds mainly using human labor. However, planting soybean seeds using human labor leads to overpopulation of the plant as the seeds were simply drilled into the prepared rows and hence reduce the quality of the seed besides requiring high labor cost. Lack of soybean thresher is another problem. The current practice of threshing with human labor causes seed breakage resulting into low seed quality. Therefore, it is suggested that making these labor-saving tools locally available is an important issue. All concerned bodies like IQQO's agricultural Engineering research centers should consider the development and production of these tools locally in their future plans at lower cost. These centers should take the lead to produce small-scale planters and threshers for smallholder soybean producing farmers to make labor-saving tools locally available.

Lack of women labor saving tools: It is obvious that soymilk can be prepared from soybean seed through developedprocedures though it needs more human labor when prepared using locally available materials at the household level (soya grinder prepared from flat stone). Many efforts have been made by BARC teams in delivering training on how to prepare soybean meals, food recipe preparation, and utilization, particularly for women who directly or indirectly participated in the N_2Africa project. However, the women and other participants were strongly complaining that grinding using local grinder is labor intensive, resulting in poor soymilk quality, color and flavor. Soybean seed ground using local grinder produces low-qualitydough and many other defects have also been observed. The remaining soymilk preparation procedure after grinding is still labor intensive and may lead to poor milk quality products. However, one of the main objectives of N_2Africa project is to empower women in value addition of legume products, like on soymilk production as an enterprise and networking, to increase the benefits from legume (soybean) production. In absence of locally available women labor-saving tools, it is difficult to plan women economic empowerment on legume value chains through value additions like soymilk production at an intended enterprise level. Therefore, it is kindly suggested that the availability of modified soybeangrinder andsoymilk processors locally ensure business opportunities to soybean processing soymilk enterprises and other value-added soybean products producers. The good and adaptable experience from Ghana indicates that soya dairy business sustainably improves nutrition and economic development as labor-saving tools like soybean seed grinder and soymilk processors are locally available for the end users (http://soybeaninnovationlab.illinois.edu).

Poor Market linkage and absence of local collectors: While the area of soybean production is increasing from time to time, the problem of the local market for soybean bulk product is an emerging issue. One of the main bottlenecks in soybean marketing is that there are no local soybean bulk collectors as the market linkage from the bottom to the final grain buyers are very weak and/or never been there in some areas. Farmers are continuouslycomplaining at different forums (during training, evaluation and field day events) about lack of market. However, there is no excess product available in order to satisfy the amount of grain required by the local collectors, particularly in areas where soybean productions are currently underway.

On the other hand, the demand for soybean bulk production at the national level is very high. For instance, Gut-Agro Industry needs more than 5000 metric tons per annum of legume seeds including soybean grain for the production of blended soymilk flour (Wolde-meskel, 2017). Similarly, Alema Koudijs Feed Factory (AKF) has been producing poultry feeds from soybean seeds and its annual demand for the seed is very high. Moreover, the government of Ethiopia has made an agreement for the production of up to 39000 metric tons of corn-soybean blend (CDB) with eight different local manufacturers, namely Guts Agro Industry PLC, FAFA food share company, Healthcare food manufacture company, Nourish Business Group PLC, Bekana PLC, Abbay International PLC and Kidan PLC (Francom and Counselor, 2016). Currently, CHAI (Clinton Health Access Initiatives) is also widely popularizing soybean production and processing technologies through capacity development, conducting demonstration trials and field day organization to meet their annual demand of the soybean grain product of more 18000 metric tons only from Oromia regions. This indicates the demand of soybean grain bulk at the national level is very high while the linkage among local producers and the final grain buyers is very weak. Therefore, many efforts are needed to sustainably make market linkage among the producers and the final grain buyers.

Potential Opportunities: Different local NGOs, such as Self Help Africa (Bako Tibe), CHAI (Bako Tibe, Ilu galan, Dano, Wayu Tuka) and CASCAPE (Wayu Tuka), MfM (Dano) have been attracted for soybean wide dissemination in areas where the crop has potential for production. In addition, formally organized women groups have been identified in three peasant associations in Dano District. For instance, MfM has formally organized them and provided initial capital to inter into agribusiness, like animal fattening, poultry production, and soya dairy business. This good opportunity help to establish women led agribusiness in soybean value chain (soybean value addition like preparation of Baltina, soya milk processing and animal fattening using legume residue, grain/seed cleaning and grading). Bore-Bako union (Bako area) and other local farmers cooperatives are willing to supply inputs required for the production of soybean-based on the farmers demand. The governmentis also interested to break the problem of mono-cropping practices which is an important initiative to strategize legume technology dissemination widely and rapidly. Finally, local seed producers such as Ano Agro-Industry and farmers' cooperative unions (community-based seed production systems) are also potential to avail demand based quality legume seeds for the farmers while Bako Agricultural Research Center can provide basic seed for the certified seed producers.

Summary

There are good opportunities in terms of environmental suitability for soybean production in Western Parts of Oromia. But most of the smallholder farmers are not benefited from it. Some of the main reasons that hinder or limit the potential benefits of soybean are limited or unavailability of improved technologies (specific agronomic recommendations), limited access to inputs and skill/knowledge about production and management practices, lack of pre-emergence herbicides, lack of labor-saving tools (soybean planter, threshers, grinder and soymilk processors) and the lack or limited access to market and market linkage between the producers and the final grain buyers.

Many efforts have been made by the support of N_2Africa project in collaboration with different local partners and stakeholders to solve the main challenges that limit the potential benefits of soybean for the smallholder farmers. The project intervention started with addressing capacity building (from production up to utilization of soybean) for the targeted farmers in six districts of Western Oromia region. Many research managed agronomy, demonstration and adaptation trials have been directly conducted on farmers' field and a lot of best-bet practices have bee generated and recommended. Moreover, evaluation and field day events at different crop stages have been organized to further promote and popularize the technologies. More than 14,000 farmers and other stakeholders have been directly and indirectly addressed in the targete districts.

However, the area of soybean production has not been increased as expected due to unsolved production and processing problems that still remain the main challenges. Some of these challenges that need to be addressed immediately are the problem of inoculants quality, unavailability of pre-emergence herbicides (Dualgold) and postemergence (if any) herbicides, lack of labor-saving tools (planter, thresher, soybean grinder and soymilk processors) and weak market linkage across soybean value chain. Therefore, the role of different partners is very crucial to solving such problems so that the farmers' benefits more from soybean while in turn the problem of maize monocropping practices can also be addressed.

Acknowledgment

In the first place, the authors greatly acknowledge N_2Africa projects for the financial support. The role of Bako Agricultural Research Center played in managerial aspects is also very appreciated. Moreover, the authors sincerely acknowledge all partners and/or stakeholders such as SIMLESA, Self-help Africa, IFDC-2Scale, MfM, CHAI, BOA, Cooperative Unions contributing in different angles for the success of the activities. Finally, it is our pleasure to acknowledge all staff members of Pulse and Oil Crops Research Team of BARC for planting, supervising and collecting all required data since the start of the project in 2013.

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Effect of Fertilizer Rate on the Yield and Yield Component of Sesame (SesamumindicumL.) in Moisture Stress environments of east Harerghe Zone

Adugna Hunduma[1 *] *and Habte Birhanu*[1]

Fedis Agricultural Research Center P.O. Box, 904 Harar, Ethiopia.

*Corresponding author Email address: adgnhund@gmail.com

Abstract

Field experiments were conducted with the objective of identifying and recommending optimum combined phosphorus and nitrogen fertilizer rates for sesame production at Fadis Boke and Errer sub-sites in 2014 and 2015 cropping seasons. Four different phosphorus rates (0, 40, 60, and 80 kg ha^{-1}) in the form of P_2O_5 and four nitrogen nutrient rates (0, 10, 20,and 30 kg N ha^{-1}) were combined and used as treatments using sesame variety "Tate". The experiment was laid out in RCBD with three replications. Data were collected and analyzed for sesame seed yield, number of sesame branches and pods per plant, and number of seeds per pod under the different combinations of the fertilizers rates. The results of the study showed analysis of over location and season of the different NP fertilizer rates combination significantly ($p<0.05$) affected the yield components and seed yield of sesame. The highest sesame seed yield (891), number branches per plant (28.71)) and number of pods per plant (68.67) were obtained from sesame crops received 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} NP integrations of the fertilizers rates. The yield of sesame seed achieved from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} NP fertilizer rates was 35.7 and 72% greater than the average yields of all the rest fertilizer combinations and the no fertilizer application, respectively. Similarly, the highest number of sesame branches per plant obtained from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} NP fertilizer rates was 66.4 and 43.6% greater than the average number of branches per plant of all the rest fertilizer combinations and the no fertilizer application, respectively. Furthermore, the combined mean number of sesame pods per plant recorded from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} NP fertilizer rates was 42.4% greater than the no fertilizer application treatment. Therefore, to sesame growing farmers in Haraghe zone application of the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizer rates can be recommended for improved sesame production and productivity particularly to at Fedis, Errer and other similar environments of the area.

Keywords: Nitrogen, Phosphorus, Sesame seed yield, number of branches, pods

Introduction

Sesame (*Sesamumindicum)* is grown in areas with annual rainfall of 625to1100mm and temperature of greater than 27 degree Celsius . The crop is tolerant to drought, but not to water logging and excessive rainfall. Sesame is well adapted to a wide range of soils, but requires deep, well-drained, fertile sandy loams. Oromia National State is a major producer of sesame crop next to Tigray and Amhara National Regional States of Ethiopia. Sesame contributes to more than 80% of the export earning of oil seeds and become the second foreign currency earning crop after coffee in the country. Ethiopian sesame seed market covers quiet a wide range of countries all over the world. The growing demand in the world market and the available capacity to expand sesame production could contribute to the economic growth of Ethiopia (Haile Abera, 2009). At present, the Ethiopian government devotes considerable resources to research and extension in view of encouraging small scale farmers to increase their oil seed, particularly sesame, productivity for international high market demand of the crop to increase export earnings of the country. The oilseeds sector is one of Ethiopia's fastest growing and important sectors, both in terms of its foreign exchange earnings and as a main source of income for over three million Ethiopians. Study reports indicate that Ethiopia is among the six producers of sesame seed, linseed and Niger seed in the world (Wijnands*et al*., 2009). The major sesame seed producing regions are situated in the North West and South West Ethiopian in Humera, north Gondar and Wollega (Wijnands*et al*., 2007; CSA, 2013). For instance, the main source of farmers' income in western Tigray is sesame sales.Sesame is deep rooted and scavenges for fertility below the wheat root zone, but that only works once. The sesame strips lower nutrient reserve, and the fertility will not be available for future sesame crops. Research results have shown that nitrogen and phosphorus (NP) fertilizersare critical for high sesame seed yields, particularly in acidic soils. The major constraints in sesame production worldwide are lack of wider adapting cultivars, shattering of pods at maturity, nonsynchronous maturity, poor stand establishment, lack of fertilizer responses, profuse branching, and low harvest index (Ashri, 1994). Similarly, besides unavailability of improved sesame varieties with good production traits, lack recommendations of NP fertilizers rates in Hararghe in general and in Fedis sesame growing environments is limiting the production and productivity of the crop. Thusan experiment initiated with the objective of identifying NP fertilizers rate combinations that can increase the productivity of sesame in growing environments of east Hararghe.

Materials and Methods

Description of Experimental Site

The study was conducted under rain fed conditions at two location (Fadis; Boke site) and Errer sub-site. The sub-site is geographically located at the latitude of 9^o 07'N and longitude of 42^o 04'E at an altitude of 1702 meters above sea level. The area is situated at a distance of 24 km north of Harar city. The soil of the experimental site is black with surface soil texture of sand clay loam that contains 8.2% organic matter, 0.13% total nitrogen, 4.99ppm available phosphorus, $1.68C_{mol}{}^{(+)}$ kg^{-1} soil exchangeable potassium and a pH value of 8.26. It received mean annual rainfall of 860.4mm in the last five years. The area is characterized by a bimodal rainfall distribution pattern and maximum rain received from April to June while irregular and erratic rains are received from August to October. The mean maximum and minimum annual temperatures of the area are 27.7 and $11.3^o{}_C$, respectively, for the past five years (Fadis Agriculture Research Center Metrological Station, 2015 unpublished).

The second experimental area of our experiment Errer Sub-site is located at Errer valley of Babiledistrict, located at 34km east of Harar cit. The area receives an average annual rainfall of 400 to 600mm and suited at an altitude range of 950 to 2000 meters above sea level. The environment is characterized as extremely lowland suitable for the production of sesame.

Experimental Materials, Treatments and Designs

This experiment were planted at Fadis, Boke station and Errer experimental sub-site with the objectives of evaluating,identifying and, recommending the best combination of NP fertilizers ratesthatcan maximizesesame yield and it components in lowland and mid-altitude environments of Eastern Harerghe sesame producing areas. The treatments consisted of a combinations of four nitrogen fertilizer rates (0, 10, 20 and $30kgNha^{-1}$) in the form of UREA and four phosphorus levels (0, 40, 60 and $80kgP_2O_5ha^{-1}$) in the form Di-Ammonium Phosphate (DAP). Sesame variety "Tate" was used for the experiment. Sixteen (16) factorialcombinations of NP fertilizers rates were arranged in a Randomized complete block design (RCBD) with three replications. The experimental field was ploughed, harrowed and ridged 40 cm apart. A mixture of one part of sesame seed and two parts of course river sand were sown manually at depth about 1cm depth at and the emerged plants were later thinned at 10cm intra-row spacing of plant per stand two weeks after sowing to keep crop population densities of 250,000 plants per hectare. All Phosphorus fertilizer rates were applied at planting to all the plots and all the nitrogen fertilizer rates were divided in to two equal amounts and applied at two and six weeks after sowing. All other cultural and agronomic practices were applied uniformly to all the experimental plots.

Data Collection

Data were collected for number of branches per plant, number of pods per plant, number of seed per pod,and seed yield per hectare (kg/ha)for analysis and interpretations.

Data Management and Statistical Analysis

Analysis of variance (ANOVA) was computed for all collected data using GenStat 15th edition. Treatment means were separated using Duncanleast significant difference method (LSD) at 5% probability level for all statistically different means.

Results and Discussion

Response of sesame seed yield and its components to the combination of different NP fertilizers rates.The analysis of variance for 2014 cropping season revealed that the interaction of phosphorus and nitrogen fertilizers rate resulted in statistically significant differences ($p<0.05$) for sesame seed yield and number of branches per plant at Boko and Errer experimental sub-sites. These interactions also significantly ($p<0.05$) affected the number of pods per plant at Errer sub-site but did not at Boke sub-site. Number of seeds per pod was not affected by the interaction effect of the fertilizers at both experimental sub-sites (Table 1). In contrary, except the number of seeds per pods at Errer sub-site, all the seed yield of sesame, number of branches and pods per plant and seed per pod were significantly affect by the interaction effects of the fertilizers during 2015 cropping season(Table 2)Accordingly, in 2014, the highest mean seed yield (867.8) and number of branches per plant (23.33) were recorded for sesame crops that received the combination of 60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1} and 40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1} phosphorus and nitrogen fertilizers rates, respectively at Boke experimental sub-site while fertilizer combination of 60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1} resulted in the highest mean values of sesame seed yield and number of branches at Errer sub-site (Table 1). This maximum yield achieved at Boke from the combination of 60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1} was superior to yields obtained when all the nitrogen fertilizer rates are applied without phosphorus, combination of 40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}, and 80 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1} while the maximum number of branches per plant obtained at the same sub-site from the combination of fertilizer rates at 40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1} was significantly higher than all the rest fertilizer combinations except for 0 P_2O_5 kg ha^{-1} and 10, 20, 30 N kg ha^{-1}, 60 P_2O_5 kg ha^{-1} and 10 and 30 N kg ha^{-1} phosphorus and nitrogen fertilizer combinations (Table 1). Significantly the highest maximum sesame seed yield (912.5) was obtained at Errer experimental sub-site from the combination of 60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1} phosphorus and nitrogen rates which was superior to all the rest fertilizer combination rates. At Error, again significantly a maximum number of branches per plant (22.33) was achieved from combining 60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1} rates of phosphorus and nitrogen fertilizers which was superior to the number of branches obtained from no fertilizer treatment, 0 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}, 40 P_2O_5 kg ha^{-1} and 0 and 10 N kg ha^{-1}, 40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}, 60 P_2O_5 kg ha^{-1} and 0 to 20 N kg ha^{-1}, and 80 P_2O_5 kg ha^{-1} and 0 to 30 N kg ha^{-1} combinations of the fertilizers. The number of pods per plant (67.33 and 67.00) of sesame was highest at Errer sub-site from the combination of 40 and 80P_2O_5 kg ha^{-1} and 0 N kg ha^{-1} rates of the fertilizers and these were only superior to the number of sesame pods per plat achieved by the combination of 0P_2O_5 kg ha^{-1} and 30N kg ha^{-1}, and 80 P_2O_5 kg ha^{-1} and 20 and 30N kg ha^{-1} phosphorus and nitrogen fertilizers rates (Table 1). Similar to 2014, in 2015 cropping season 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1}combination of the fertilizers resulted in the highest maximum sesame seed yields (964.2 and 897.2), and number of branches and pods per plant (15.17 and 9.6; and 96.43 and 74.67), respectively at Boke and Errer experimental sub-sites and these numbers were a superior to all the rest fertilizer combination treatments (Table 2) The results obtained from the study on sesame yield differences at different combinations of NP fertilizer rates is in agreement with the results of Siddik*etal*. (2016) who reported increased and significant sesame seed yields when varying rates of NP fertilizers were combined for different environments. Similarly, (Reddy, 2004) reported that integrationof nitrogen and phosphorus fertilizers of different rates showed variations in number of pods and branches per plant.

Over cropping season and location effects of NP fertilizers rate combinations on sesame seed yield

Combined analysis of variance over location and cropping seasons showed statistically significant differences ($p<0.05$) for sesame seed yields due to combination of the different rates of phosphorus and nitrogen fertilizers (Table 3). The maximum and superior sesame seed yield (891) to all the rest of NP fertilizer combination rates was obtained from the integration of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizers. This sesame seed yield achieved from the combination of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 35.7 and 72% greater than the average yields of all the rest fertilizer combinations and the no fertilizer application, respectively. This result confirms the finding of (Shiferaw*et al.*, 2012) who reported 35% sesame seed yield increment due to application of 38/29 kg ha^{-1} NP_2O_5 fertilizers at planting. Similarly, Hossein*et al*. (2007) recorded the highest sesame seed yield with the application of 60 kg N ha^{-1} and Okpara*et al*. (2007) found that application of 75 kg N ha^{-1} and 26 kg P ha^{-1} significantly increased sesame seed yield per hectare.

Over cropping season and location effects of NP fertilizers rate combinations on sesame number of branches per plant

Combined analysis of variance over location and cropping seasons showed statistically significant differences ($p<0.05$) for sesame number of branches per plant as a result of combining different rates of phosphorus and nitrogen fertilizers (Table 3). The maximum and superior number of branches per plant(28.71) to all the rest of NP fertilizer combination rates was obtained from the integration of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizers. This highest sesame number of branches per plant achieved from the combination of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 66.4 and 43.6% greater than the average number of branches per plant of all the rest fertilizer combinations and the no fertilizer application, respectively. This result confirms the finding of Olowe and Busari (2000) who found that application of 60 kg N ha^{-1} and 13kg P ha^{-1} produced significantly the highest number of branches per plant.

Over cropping season and location effects of NP fertilizer rate combinations on sesame number of pods per plant and seeds per pod

Combined analysis of variance over location and cropping seasons showed statistically significant differences ($p<0.05$) for sesame number of pods per plant as a result of combining different rates of phosphorus and nitrogen fertilizers, however, the interaction did not affect the number of seeds per pod (Table 3). The maximum number of pods per plant (68.67) was obtained from the integration of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizers. This combined mean number of sesame pods per plant achieved from the combination of $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 42.4% greater than the no fertilizer application treatment. This result confirms the finding of Olowe and Busari (2000) who found that application of 60 kg N ha^{-1} and 13kg P ha^{-1} produced significantly the highest number of sesame capsules/pods per plant.

Conclusion and Recommendations

The results of these experimental researches from both locations across the experimental years indicated that sesame seed yield, and number of branches and pods per plant were significantly influenced by the combination of different phosphorus and nitrogen fertilizer rates across locations and experimental seasons. Sesame plantsreceived $60P_2O_5$ kg ha^{-1} and 30N kg ha^{-1}NP integrations of the fertilizers rates resulted in significantly the highest combined means of sesame seed yield (891), number of branches per plant (28.71) and number of pods per plant (68.67) compared to crops treated with most of the fertilizer combinations and the no fertilizer control plots. The yield of sesame seed achieved from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 35.7 and 72% greater than the average yields of all the rest fertilizer combinations and the no fertilizer application, respectively. Similarly, the highest number of sesame branches per plant obtained from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 66.4 and 43.6% greater than the average number of branches per plant of all the rest fertilizer combinations and the no fertilizer application, respectively. Furthermore, the combined mean number of sesame pods per plant recorded from the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1}NP fertilizer rates was 42.4% greater than the no fertilizer application treatment. Therefore, to sesame growing farmers in Haraghe zone application of the combination of 60P_2O_5 kg ha^{-1} and 30N kg ha^{-1} phosphorus and nitrogen fertilizer rates can be recommended for improved sesame production and productivity particularly to at Fedis, Errer and other similar environments of the area.

Table.1 Yield and some yield parameters of sesame as affected by the interaction of different NP fertilizer rate combinations at Boke and Errer experimental sub-sites (2014)

Fertilizer Combinations	Sesame seed yield and yield component, at Fadis (Boke)				Sesame seed yield and yield component, at Errer			
	Seed yield (kg ha^{-1})	Number of Branches per plant	Number of Pod per plant	Number of Seeds per pod	Seed yield (kg/ha)	Number of Branches per plant	Number of Pod per plant	Number of Seeds per pod
0P_2O_5 kg ha^{-1} and 0N kg ha^{-1}	525.0c	14.33cd	57.67	31.67	616.7c	15.00bc	56.33ab	28.67
0P_2O_5 kg ha^{-1} and 10kg N ha^{-1}	680.6bc	17.67abc	66.33	34	720.8bc	21.67ab	55.67ab	31
0P_2O_5 kg ha^{-1} and 20 kg N ha^{-1}	628.9bc	18.33ab	47.33	33	763.9bc	19.33ab	44.67b	30
0P_2O_5 kg ha^{-1} and 30 kg N ha^{-1}	522.2c	16.67abc	57	32.33	648.6c	20.67ab	6.00ab	29.33
40 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	759.7ab	12.67cd	58	33.33	754.2bc	16.67bc	67.33a	30.33
40 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	754.4ab	11.33cd	56.67	31.67	697.2bc	15.33bc	55.67ab	28.67
40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	731.9abc	23.33a	56.67	32.67	847.2b	20.00abc	55.67ab	29.67
40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	641.7bc	11.67cd	57	33	625.0c	15.67bc	56.33ab	30
60 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	709.4abc	8.67d	67	32.33	679.2bc	16.67bc	56.00ab	29.33
60 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	794.2ab	18.33ab	57	32	630.6c	18.33bc	56.67ab	29
60 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	759.7ab	12.67cd	56.67	33	675.0bc	16.67bc	55.67ab	30
60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	867.8a	18.33ab	67.33	31.67	912.5a	22.33a	56.00ab	28.67
80 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	610.8bc	13.33cd	67.33	32.67	673.6bc	17.33bc	67.00a	29.67
80 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	686.1abc	12.33cd	56.67	32.67	683.3bc	16.33bc	56.00ab	29.67
80 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	697.2abc	9.00d	57	32.67	691.7bc	13c	44.67b	29.67
80 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	818.1ab	8.00d	57	33.67	677.8bc	12c	55.67ab	30.67
CV (%)	15.4	11.4	12.3	4.4	18.8	10.9	19.9	4.9
LSD (5%)	*	*	NS	NS	*	*	*	NS

NS=Not significant, Means with the same letters in a column are non-significant at 5% probability level.

Table.2 Yield and some yield parameters of sesame as affected by the interaction of different NP fertilizer rate combinations at Boke and Errer experimental sub-sites (2015)

Fertilizer Combinations	Sesame seed yield and yield components at Fadis (Boke)				Sesame seed yield and yield components at Errer			
	Seed yield (kg ha^{-1})	Number of Branches per plant	Number of Pod per plant	Number of Seeds per pod	Seed yield (kg ha^{-1})	Number of Branches per plant	Number of Pod per plant	Number of Seeds per pod
$0P_2O_5$ kg ha^{-1} and 0N kg ha^{-1}	598.6b	7.47bc	65.5bc	44.33b	652.5d	5.67c	69.67ab	46
$0P_2O_5$ kg ha^{-1} and 10kg N ha^{-1}	664.4b	6.00c	56.00c	53.00ab	746.1c	6.33c	64.33ab	42
$0P_2O_5$ kg ha^{-1} and 20 kg N ha^{-1}	715ab	6.33c	56.33c	44.00b	772.2bc	6.33c	62.33ab	45.33
$0P_2O_5$ kg ha^{-1} and 30 kg N ha^{-1}	650.8b	4.33c	49.33c	54.00ab	702.8c	6.00c	61.00ab	44
40 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	700.6b	5.83bc	59.83bc	55.67ab	756.9c	7.67b	73.67ab	44.67
40 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	886.7ab	6.5bc	87.17ab	53.67ab	748.9c	7.00b	72.00ab	44.67
40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	865.3ab	7.53b	89.83ab	57.00ab	807.5ab	7.33b	71.33ab	46.67
40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	804.2ab	6.83c	56.83c	44.33b	799.7b	6.67b	62.67ab	44
60 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	723.6b	5.17bc	67.67abc	59.33a	727.8b	6.33c	62.33ab	44.67
60 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	938.9a	6.33bc	60.33bc	55.67ab	760.6c	9.00a	69.00ab	46.67
60 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	741.1ab	12.43ab	59.17bc	49.33ab	780.0b	7.67b	59.67b	44
60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	964.2a	15.17a	96.43a	61.00ab	897.2a	9.67a	74.67a	44
80 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	898.6ab	5.33c	50.33c	53.67ab	653.6d	6.67b	64.67ab	46
80 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	672.5ab	7.00bc	75.00abc	48.33ab	643.9d	5.67c	59.67b	44
80 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	891.4ab	5.17c	52.17c	49.67ab	774.2bc	6.00c	66.00ab	45.33
80 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	842.8ab	6.50bc	65.50bc	47.00ab	646.1d	7.33b	74.33a	43.33
CV (%)	19.1	25.8	25.8	13.1	16.7	7.3	7.3	6.4
LSD (5%)	269.7	7.6	27.6	11.42	170.68	1.33	11.7	NS

NS=Not significant, Means with the same letters in a column are non-significant at 5% probability level.

Table.3 The overall mean interaction of sesame yield of the two locations (Erer and Fadis) in 2014 & 2015

Fertilizer Combinations	Seed yield (kg ha^{-1})	Number of Branches per plant	Number of Pods Pod per plant	Number of Seeds per pod
$0P_2O_5$ kg ha^{-1} and 0N kg ha^{-1}	518.10d	20.00b	48.21b	41.58
$0P_2O_5$ kg ha^{-1} and 10kg N ha^{-1}	703.00bc	17.42b	58.21ab	40.00
$0P_2O_5$ kg ha^{-1} and 20 kg N ha^{-1}	670.0bc	17.33b	57.50ab	38.08
$0P_2O_5$ kg ha^{-1} and 30 kg N ha^{-1}	651.6bc	19.42b	57.75ab	39.92
40 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	692.8bc	15.71b	57.83ab	41.00
40 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	696.9bc	19.21b	57.46ab	39.67
40 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	763b.00	23.62b	57.04b	41.50
40 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	617.6cd	14.21c	57.67ab	37.83
60 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	617.7cd	15.02c	58.00ab	41.42
60 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	652.2bc	20.00b	58.58ab	40.83
60 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	639.00c	14.54c	58.21ab	39.08
60 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	891.00a	28.71a	68.67a	38.83
80 P_2O_5 kg ha^{-1} and 0 N kg ha^{-1}	659.2bc	18.92b	58.54ab	40.50
80 P_2O_5 kg ha^{-1} and 10 N kg ha^{-1}	614.0cd	13.33c	58.33ab	38.67
80 P_2O_5 kg ha^{-1} and 20 N kg ha^{-1}	663.6bc	17.54b	57.58ab	39.33
80 P_2O_5 kg ha^{-1} and 30 N kg ha^{-1}	693.7bc	12.46c	58.17ab	38.67
CV (%)	18.3	13.6	19.8	9.6
LSD (5%)	126	3.62	11.28	NS

NS = Non-significant; Means with the same letters in column are non-significant at 5% probability level.

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System Productivity as Influenced by Double Cropping of Maize as Green Cob Intercropped with Haricot Bean followed by Sorghum Intercropped with Groundnut in Fedis District

Fuad Abduselam[1*], Alemayehu Biri[1] and Zeleke Lagesse[1]

[1] Fedis Agricultural Research Center, P.O. Box, 904 Harar, Ethiopia

*Corresponding author: abduselamfuad@gmail.com

Abstract

Double cropping system is one of the main agronomic practices that can copeup with variable climate changes and/or erratic rainfall distribution and amount.Such types of practices can hamper total crop failure due to erratic rainfall distribution, which is also true for Fadis and similar agro-ecological areas.Therefore, thee study was conducted at Fedis Agricultural Research station duringf 2015 and 2016 cropping seasons. The experiment had two components: the first preceding component crops were early types of four maize varieties (Melkasa-2, Melkasa-3, Melkasa-4 and Melkasa-6) intercropped with a haricot bean variety (Awash melka) as wel as sole cropping and planted in 'Belg' rainy season whereas the second component of the succeeding component crops in which four early types of sorghum (Gambela 1107, Birhan, Gubiye and Hormat) varieties were intercropped with groundnut as well as sole cropping were planted in the main seasons (meher season). The experiment was laid out using RCBD with three replications. The result revealed that the highest grain yield of haricot bean was obtained from sole Awash melka (2344 kg ha^{-1}) whereas the highest effective ear of maize in 2016 year were obtained from Melkasa-2 intercropped with Awash melka, and Melkasa-6 intercropped with Awash melka variety of haricot bean. On the other hand, the highest grain yield of sorghum in succeeding cropping system was obtained from Gambella 1107 under sole and intercropped with groundnut and the next highest yield was obtained from sole Hormat variety. The highest monetary value were obtained when Melkasa-2 ((85998 ETB ha^{-1}) intercropped with Awash melka and as sole (74286 ETB ha^{-1}) as preceding component crops. On the other hand, the monetary value from the succeeding component crops were obtained from intercropping Gambella 1107 variety with groundnut variety (29809 Birr ha^{-1}) followed by Hormat intercropped with groundnut (29794 Birr ha^{-1}). Therefore, early planting of Melkasa-2 as intercropping with early types of haricot bean as preceding crops during the 'Belg' seasons and use of Gambella 1107 variety of sorghum as main crop intercropped with the early types of groundnut as second crops can also be used as the succeeding crops in double cropping practices in Fadis and similar agro-ecology areas receiving bi-modal rainfall distribution.

Keywords: double cropping, Maize, Haricot bean, Sorghum, Groundnut and Intercropping

Introduction

Double-cropping (also known as sequential cropping) is the practice of planting a second crop immediately following the harvest of a first crop, thus harvesting two crops from the same field in one year. This is a case of multiple cropping, which requires a season long enough and crops that mature quickly enough to allow two harvests in one year. Intercropping, the simultaneous growing of two or more crops in space and time on the same land is an important feature of cropping systems in the tropics (Francis, 1986; Connolly *et al*., 2001). In many parts of Ethiopia sorghum is usually grown mixed with crops, especially legumes. Intercropping is one of the cropping systems covering about 20% of the total sorghum production in the country (Yilma 1977). The most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available growth resources using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops (references). Moreover, intercropping improves soil fertility through biological nitrogen fixation with the use of legumes, increases soil conservation. Intercrops often reduce pest incidence and improve forage quality by increasing crude protein yield of forage (references). Intercropping provides insurance against crop failure or against unstable market prices for a given commodity, especially in areas subject to extreme weather conditions such as frost, drought, and flood (references). Thus, it offers greater financial stability than sole cropping, which makes the system particularly suitable for labor-intensive small farms. Besides, intercropping allows lower inputs through reduced fertilizer and pesticide requirements, thus minimizing environmental impacts of agriculture.

However, farmers in Fedis district were accustomed to sow the local varieties and even striga resistant varieties at the middle of April. This is because farmers are not volunteer to leave their land idle until the right planting time (from middle of June to the beginning of July) of the early maturing striga resistant varieties. As a result, these improved varieties were matured before the local varieties and became susceptible to the high bird infestation prevailed in the area. So, this resulted in complete crop failure. To alleviate this problem it is important to accomplish participatory action research which helps the farmer to compare his already accustomed and untimely planting practice with double cropping of improved, adapted and early maturing with his active involvement in management and evaluation of the crops.. With this background, this study was done to assess the effect of double cropping on yield, and yield components of the component crops and to compare the productivity of the double cropping system with the single cropping system.

Materials and Methods

Description of the study area

The experiment was conducted at Fedis Agricultural Research Center in Fedis district and. Fedis district is found at latitude between 8°22' and 9°14' North and longitude between 42°02' and 42°19' East, in middle and low land areas and the altitude range is from 1200-1600m.a.s.l with a prevalence of low lands. The district receives average annual rainfall of 400-804 mm; the minimum and maximum air temperature of 20–25^{o}c and 30–35^{o}c, respectively.

The experiment was conducted during the main cropping season of 2015 and 2016 under rain fed conditions. Boko is 24km far from Harar town in the South direction. Commonly sorghum is the staple crop cultivated by farmers, in the vicinity of the site. *Vertisols* and *Afilsols* soil type are common to the area (Fedis Woreda Profile, 2011). Soil is loam in texture with pH of 7.4 (FARC, 2012). As in the most of the Horn of Africa, two rainy seasons characterize Fedis woreda's climate. The first named 'Belg' is the shortest one and takes place between March and May, while the second and the most important is 'Meher' between July and October. The rainfall distribution during the year is bi-modal, with a dry-spell period during the months of June and July which, depending on its duration, may affect crop growth.

Description of the Experimental Materials

The experimental materials used for this study were divided into two, which were used as preceding and succeeding crops. The crops used as preceding crops (early types of maize and haricot bean) were selected on the basis of their current and potential importance and mainly for their early maturity. The succeeding crop used was sorghum and ground nut. Field trials were arranged in randomized complete blocks design in three replications using nine treatment combinations. Plot size used was 3.5 m x 3 m for each treatment during both seasons. The trial was started with sole planting and intercropping of 4 early maturing OPV maize varieties namely: Melkasa-2, Melkasa-3, Melkasa-4 and Melkasa-6 and were intercropped with one early maturing haricot bean, Awash melka variety as precursor crops. The Maize was harvested at green cob stage which is locally known as "Ashita". As succeeding treatment, four sorghum varieties (Gambela 1107, Birhan, Gubiye and Hormat) were planted with one early maturing Groundnut variety (worer 98).

The first sowing was planted at sowing time of local sorghum varieties (in the middle of April at the onset of the first rain). Then all the necessary management was accomplished according to the recommendation. Farmers from different PAs in the vicinity were invited to see the performance of the different crops and their perception regarding the performance of the varieties. At green cob stage, the maize was harvested and the haricot bean was harvested at maturity. After the preceding crops were harvested, the succeeding crops (both sorghum and groundnut) were planted on the plots, and four early maturing OPV sorghum varieties were planted as sole and intercropped with groundnut. . At sowing, all plots received a basal application of Di Ammonium Phosphate (DAP, 18% N, 20% P) at the rate of 50 kg ha^{-1}. At knee height growth stage of maize and sorghum, N in the form of urea (46% N) was applied at the rate of 100 kg ha^{-1} to all plots. Hand weeding and frequent hoeing were done for weeds.

Table 1: Treatments used as preceding and succeeding for the experiment

No	Preceding treatments	Succeeding treatments
1	Melkasa 2 + Awash melka	Birhan + Groundnut (Werer 98)
2	Melkasa 3 + Awash melka	Hormat + Groudnut (Werer 98)
3	Melkasa 4 + Awash melka	Gubiye + Groundnut (Werer 98)
4	Melkasa 6 + Awash melka	Gambela 1107 +Groundnut(Werer 98)
5	Sole Melkasa 2	Sole Birhan
6	Sole Melkasa 3	Sole Hormat
7	Sole Melkasa 4	Sole Gambela 1107
8	Sole Melkasa 6	sole gambela 1107
9	Sole Haricotbean	sole GN

AM= Haricot bean variety Awash melka, GN= Ground nut variety werer 98

Data collection

Data collected for Maize was number of effective ear harvested were counted and converted into kg ha^{-1} since the economic part considered for this activity were at green cob stage "Ashita" and data collected for haricot bean and ground nut were grain yield while data collected for sorghum were days to flowering, days to maturity, plant height and grain yield.

Gross Monetary Value (GMV): GMV was determined to evaluate the economic advantage of the cropping system as compared to sole cropping. It was calculated from the yield of preceding and succeeding treatment combinations in order to measure the profitability of double cropping as compared to sole cropping of the component crops. Gross monetary value was calculated by multiplying yields of the component crops by their respective market price as stated by Willey (1979). During July 2016, the price for haricot bean and Maize "Ashita" were 12 and 2 Ethiopian Birr (ETB) per kg and per ear respectively, and10 ETB kg^{-1} for haricot bean in 2015 and the price for sorghum grain and groundnut was 8 and 27 ETB kg^{-1}. While during December 2016, 7 and 22 ETB per kg for sorghum grain and groundnut yield respectively, at Harar grain market. Thus, this price was used to calculate the monetary value of the treatments used in this experiment.

Data Analysis

Analysis of variance for the design was carried out using Genstat 15th edition software for the parameters studied following the standard procedures outlined by Gomez and Gomez (1984). When the treatment effects were found to be significant, the means were separated using the least significant difference (LSD) test at 5% level of probability.

Result and Discussion

Preceding treatments

Comparison of crops that have different economic part, growth patterns and yield components is so difficult. However, since one of the objectives was to select the best sequential combination for 'Belg' season to be followed by sorghum which is considered as major crop and grown during 'Meher'. One of the characteristics that are required to be fulfilled is its earliness before time of planting for sorghum for *'Meher'* from end of June up to mid-July. Thus, the majorly considered data for the preceding crops were earliness of targeted economic part. Maize green cob called "Ashita" were considered as economic part of which only effective ears were considered to be eaten after roasting in this experiment.

In 2015 cropping season, maize has failed to bear any ear due to drought while in 2016 cropping season, effective ears had showed highly significant difference (at $P < 0.01$) and haricot bean variety had showed non-significant difference in 2015 and while highly significant difference (at $P< 0.01$) were observed in 2016 on haricot bean yield (kg ha^{-1}) during the study (Table 1). The result also showed that yield of haricot in 2015 was very low compared to 2016 which were due to stress happened in the growing season of 2016 (Table 2).

Table 2: Mean performance of effective ear of maize and haricot bean yield for preceding treatments at Fedis during 2016 and 2017 cropping season

	2015		2016	
Treatment	Effective ear (No.)	HB yield (kg ha^{-1})	Effective ear (No.)	HB yield (kg ha^{-1})
M-2 x AM	-	633	38095^{b}	1743^{b}
M-3 x AM	-	717	24762de	1292^{bc}
M-4 x AM	-	660	22540^{e}	1285^{bc}
M-6 x AM	-	575	32063^{c}	954^{c}
Sole M-2	-	-	41270^{a}	-
Sole M-6	-	-	27302^{d}	-
Sole M-4	-	-	25079de	-
Sole M-3	-	-	26349^{d}	-
Sole AM	-	1057	-	2344^{a}
LSD		421.5	2762.8	507.1
CV		30.7	5.3	17.7
P (0.05)		NS	**	**

In 2016 cropping season, the highest effective ear of maize were obtained from the treatment of sole M-2 (41270 cobs ha^{-1}), M-2 x AM (38095 cobs ha^{-1}) and M-6 x AM (cobs ha^{-1}) while the lowest effective ear number were obtained from M-4 x AM (22540 cobs ha^{-1}) and M-3 x AM (24762). In the same cropping seson, the highest grain yield of haricot bean were obtained from sole AM (2344 kg ha^{-1}) followed by M-2 x AM (1743 kg ha^{-1}) and M-3 x AM (1292 kg ha^{-1}). Similar research findings in the study area revealed that same variety of haricot bean yielded up to 1519 kg ha^{-1} (Fuad et al., 2017). In another study conducted by Fadis Agricultural Research Center (FARC), 2013 it has been reported that on double cropping of common bean varieties followed by main season early maturing *striga* resistant sorghum varieties at Boko, common bean variety Awash Melka was recorded highest yield of 1862.8 $kgha^{-1}$ (FARC, 2013).

Succeeding treatments : The treatments used during succeeding period were four sole sorghum, one sole ground nut and intercropping of the four sorghum varieties with ground nut variety (Werer 98). Sorghum had shown significant difference ($P < 0.05$) on days to flowering and highly significant difference ($P < 0.01$) on days to maturity and plant height in 2016. On the other hand, non-significant difference were observed on days to flowering and days to maturity while plant height was showed highly significant variations ($P < 0.01$) in 2015 main season. (Table 3). The variation observed among the varieties was due to varietal difference.

The latest days to flowering were observed by Gambella 1107 variety in both cases of sole and intercropping taking 74 days after planting followed by Gubiye X GN (74 days), Sole Hormat (73 days) and Hormat intercropped with groundnut (72 days) which are all statistically at par during 2016 cropping season (Table 3). However, the earliest days to flowering were observed by Birhan variety under both sole and intercropping taking 68 and 70 days, respectively. Fuad et al. (2015) has reported that Gambella 1107 showed the earliest days to flower at Fedis (71 days after planting) and Erer (69 days after planting) which is in agreement with the current research finding.. The same authors in the same locations revealed that Gubiye variety of sorghum took 59-68 days after planting to flower (Fuad et al., 2017; Samuel et al., 2013).

Table 3: Mean performance of growth parameters of succeeding treatments of sorghum at Fedis during 2015-2016 cropping seasons

Treatment	2015			2016		
	DF (Days)	DM (Days)	PH (cm)	DF (Days)	DM (Days)	PH (cm)
Gambella 1107 + GN	73.33	129.67	166.8[a]	74.33[a]	131.70[a]	152.40[a]
Sole Gambella 1107	74.33	133.00	173.3[a]	74.33[a]	130.70[a]	149.30[a]
Gubiye + GN	75.33	131.67	113.2[c]	73.67[ab]	119.30[bc]	100.90[e]
sole Hormat	73.33	132.00	132.7[b]	73.33[ab]	131.00[a]	127.00[b]
Hormat + GN	72.33	129.67	123.2[bc]	72.00[abc]	129.70[a]	120.00[bc]
sole Gubiye	72.00	128.33	129.00[b]	71.67[abc]	115.30[c]	102.30[e]
Birhan + GN	67.67	124.00	133.40[b]	70.00[bc]	122.70[b]	102.70[de]
sole Birhan	69.67	127.00	125.50[bc]	68.33[c]	120.70[b]	112.40[cd]
LSD	5.16	6.62	14.05	3.87	4.57	9.92
CV	4.10	2.90	5.90	3.10	2.10	4.70
P (0.05)	NS	NS	**	*	**	**

DF= Days to flowering, DM= Days to maturity, PH= Plant height, GN= Ground nut

Earliest days to maturity in 2016 year were observed by sole Gubiye (115 days) followed by Gubiye intercropped with Groundnut (119 days) and sole Birhan (121 days). However, the latest day to maturity recorded were 132, 131 and 131 days to mature for Gambella 1107 intercropped with Groundnut, sole Hormat and sole Gambella 1107 respectively (Table 3). Days to maturing of 117 and 113 days at Fedis and erer respectively. Similar results were also reported in the same study areas for the same varieties (Fuad et al., 2015; Tekle and Zemach, 2014).

Yield of succeeding sole and intercropped sorghum and ground nut

Analysis of variance revealed that highly significant differences ($P < 0.01$) on sorghum yield (kg ha^{-1}) were observed during 2015 and 2016 cropping seasons. On the other hand, significant difference on yield performance of groundnut either in sole or intercropping was observed only in 2015 cropping season.. Overall, significantly higher yield was observed in sole cropping for each variety as compared to yield obtained under intercropping within each variety for sorghum except for Birhan and Gubiye in 2015. The highest grain yield of sorghum were obtained from sole and intercropped of Gambella 1107 variety and sole Hormat in both cropping seasons.. However, the lowest yield were obtained from sole Birhan (2111 kg ha^{-1}) and sole Gubiye (2625 kg ha^{-1}) in 2015 and sole Gubiye (2006 kg ha^{-1}) and Gubiye intercropped with groundnut variety in 2016. The yield obtained during 2016 season for sorghum was low compared to previous seasons and the potential of the varieties. Similarly, ground nut yield was very low compared to potential of the variety which was due to weather condition of the season confounded with the climate change hampering/affecting crop production in the study area and in the country in general.

Table 4: Mean performance of yield of sorghum and ground nut at Fedis during 2015-2016 cropping seasons

Treatment	2015		2016	
	Sorghum yield (Kg ha^{-1})	GN yield (Kg ha^{-1})	Sorghum yield (Kg ha^{-1})	GN yield (Kg ha^{-1})
Gambella 1107 + GN	4340^{a}	222.5^{b}	2410^{a}	360
Hormat + GN	3584^{abc}	420.6^{a}	2368^{ab}	382
Birhan + GN	2816^{bcd}	299.0^{b}	2290^{abc}	383
Gubiye + GN	2511^{cd}	296.2^{b}	1916^{c}	342
Sole Gambella 1107	4951^{a}	-	2603^{a}	-
sole Hormat	4051^{ab}	-	2378^{ab}	-
sole Gubiye	2625^{cd}	-	2006^{bc}	-
sole Birhan	2111^{d}	-	2397^{ab}	-
Sole GN	-	260.0^{b}	-	552
LSD	1408.2	115.2	396.8	172.4
CV	23.8	20.4	9.9	22.7
P (0.05)	**	*	*	NS

GN= Ground nut

Monetary Value of the Cropping System

Monetary value of preceding treatments

Analysis of Monetary value of effective ear of maize, haricot bean and combination of preceding treatments revealed highly significant difference ($P < 0.01$) in 2016, but not significant 2015 year.. The price used to calculate monetary value was obtained from Harar local market which was 10 and 12

Ethiopian Birr (ETB) for haricot bean in 2015 and 2016 respectively and 2 ETB for maize per Ear (Table 5).

Table 5: Monetary value (ETB ha^{-1}) of different cropping sequence grown in double cropping system during preceding time at Fedis in 2015 and 2016.

Treatment	2015			2016		
	MVM	MVHB	MVPT	MVM	MVHB	MVPT
M-2 x AM	-	6333	6333	68571[b]	17427[b]	85998[a]
M-3 x AM	-	7175	7175	44571[de]	12923[bc]	57495[d]
M-4 x AM	-	6603	6603	40571[e]	12847[bc]	53419[de]
M-6 x AM	-	5746	5746	57714[c]	9537[c]	67251[c]
Sole M-2	-	-	-	74286[a]	-	74286[b]
Sole M-6	-	-	-	49143[d]	-	49143[ef]
Sole M-4	-	-	-	45143[de]	-	45143[f]
Sole M-3	-	-	-	47429[d]	-	47429[f]
Sole AM	-	10571	10571	-	23439[a]	23439[g]
LSD	-	4214.7	4214.7	4973	5071.4	5924.8
CV (%)	-	30.7	30.7	5.3	17.7	6.1
P (0.05)	-	NS	NS	**	**	**

M= Melkasa, AM= Awash melka, MVM= Monetary value from maize, MVHB= Monetary value from Haricot bean, MVPT= Monetary value from preceding treatment combinations.

The higher total monetary value of maize (74286ETB ha^{-1}) and haricot bean (23439 ETB ha^{-1}) was gained from sole Melkasa-2 and sole Awash melka, respectively. However, the highest monetary value were obtained when intercropping of Melkasa-2 with Awash melka (85998 ETB ha^{-1}) and sole Melkasa-2 (74286 ETB ha^{-1}) during preceding time (Table 5). The highest monetary value obtained from treatments consisting of Melkasa-2 due to its earliness the the higher number effective ears were harvested. (Table 5) .Overall, total monetary value obtained was low in 2015 due to maize failure. However, diversifying farm products have such an advantage in which at least some income can be generated from the haricot bean remaining.

Monetary value of succeeding treatments : The result of monetary value of the succeeding component crops revealed that the highest total monetary value (29809 Birr ha^{-1}) was gained from intercropping Gambella 1107 variety of sorghum with groundnut (werer 98)followed by Hormat intercropped with groundnut (29794 Birr ha^{-1}) (Table 6). The highest monetary value in this treatment of intercropping might be because of diversified options although the yields obtained from groundnut were low (Table 6).

Table 6: Monetary value (ETB ha^{-1}) of sorghum-Groundnut intercropping as succeeding in double cropping system at Fedis in 2015 and 2016 cropping seasons.

Treatment	2008			2009		
	MVS	MVGN	MVST	MVS	MVGN	MVST
Gambela 1107 X GN	30378[a]	4896[b]	35274[a]	20076[a]	9733	29809[a]
Hormat X GN	25089[abc]	9254[a]	34343[a]	19479[a]	10315	29794[a]
Birhan X GN	19711[bcd]	6579[b]	26290[abc]	18857[a]	10342	29199[a]
Gubiye X GN	17578[cd]	6516[b]	24094[bcd]	15327[b]	9226	24553[b]
Sole Gambela 1107	34656[a]	-	34656[a]	20825[a]	-	20825[c]
sole Hormat	28356[ab]	-	28356[ab]	19022[a]	-	19022[cd]
sole Gubiye	18378[cd]	-	18378[cd]	16051[b]	-	16051[de]
sole Birhan	14778[d]	-	14778[de]	19708[a]	-	19708[c]
Sole GN	-	5720[b]	5720[e]	-	14907	14907[e]
LSD	9857.5	2533.9	9647.1	2505.4	4653.9	3597.9
CV (%)	23.8	20.4	22.6	7.7	22.7	9.2
P (0.05)	**	*	**	**	NS	**

Conclusion and Recommendation

Multiple cropping in a given season can be an insurance against total crop failure, by diversifying farm product one could guarantee his family for self sufficiency and increase his income. Overall, during preceding time in 2015 maize has failed to bear any ear due to drought and in 2016 effective ear has showed highly significant difference ($P < 0.01$) and haricot bean variety has showed non-significant difference in 2015 while highly significant differences on haricot bean yield ($P< 0.01$) were observed in 2016 cropping season. The highest grain yield of haricot bean was obtained from sole Awash melka (2344 kg ha^{-1}) whereas the highest effective ear of maize in 2016 year were obtained from the treatment of sole and intercropping of Melkasa-2 with Awash melka, and Melkasa-6 intercropped with Awash melka variety of haricot bean. On the other hand, the highest grain yield of sorghum was obtained from Gambella 1107 under sole and intercropped with groundnut and the next highest yield was obtained from sole Hormat variety. The highest monetary value were obtained when Melkasa-2 ((85998 ETB ha^{-1}) intercropped with Awash melka and as sole (74286 ETB ha^{-1}) as preceding component crops. On the other hand, the monetary value from the succeeding component crops were obtained from intercropping Gambella 1107 variety with groundnut variety (29809 Birr ha^{-1}) followed by Hormat intercropped with groundnut (29794 Birr ha^{-1}). Therefore, early planting of Melkasa-2 as intercropping with early types of haricot bean as preceding crops during the 'Belg' seasons and use ofGambella 1107 variety of sorghum as main crop intercropped with the early types of groundnut as second crops can also be used as the succeeding crops in double cropping practices in Fadis and similar agro-ecology areas receiving bi-modal rainfall distribution.

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PEST MANAGEMENT (PATHOLOGY, ENTOMOLOGY AND WEED)

The Impact of Planting Time on Sorghum Stalk Borer Infestation and Damage In West Hararghe, Oromia

Abdela Usmae[1]*, Abubaker Terbush[1], Gabayo Chala[1] and Kinde Lemesa[1]

Mechara Agricultural Research Center; Cereal Research Team; P.O.Box: 19, Mechara, Ethiopia

*Corresponding author: abdelausmael@gmail.com

Abstract

Sorghum is the first most important cereal crop in West Hararghe. However, national figure of grain production still remains below the world average grain production per unit area due to different biotic and a biotic factor. Among the biotic factors, stalk borer is considered to be the most important insect pests of sorghum and maize in all areas of the country. As a management option, different scholars recommended sowing date. But there was conflicting report on the relationship between sowing time and borer infestation and damage. Even though sorghum is susceptible to stem borer in the area, there is no recommended sowing date that has been done so far. Therefore, it is very crucial to identify the better days of sowing in the zone to reduce pest infestation and increase yield of the crop. Thus, this experiment was designed to evaluate the effect of sowing date on infestation of sorghum stalk borer. Chiro variety was used for experimentation and sown at seven days interval for six weeks starting from 1st onset of rainfall. The treatments were arranged in RCBD with three replications. Each treatment had a control plot that was treated with two insecticides, carbaryle powders and Alpha cypermethrine. Based on combined analysis, mean percent infestation did not show significant variation ($P<0.05$) over location but it was highly significant at ($P< 0.01$) over years. The percent stalk borer incidence on untreated plot was highly significant at ($P< 0.01$) on both over years and over location. These variations also were shown significant at ($P< 0.05$) on percent stem tunnel length on untreated experimental plot over location while not significant on treated experimental plot.Length of the feeding tunnel and exit holes in sorghum stem and leaves were significantly higher in earlier planted crop than delayed sorghum. In general, chemicals treatment with early planting double the grain yield at Hirna sub site but, based on pest infestation status late planting was recommended at both location (Mechara and Hirna) to reduce pest infestation and damage

Keywords: Sorghum (*Sorghum bicolor* L), Chiro, Sowing date, *B. fusca* and *C. partellus*

Introduction

Sorghum is the fourth primary staple food crop in Ethiopia after teff, maize, and wheat, both in area coverage, and production (CSA, 2012). In the country cereals comprise 78.23% (8.8 million ha) of the field crops of which sorghum accounts for 14.41%. In Ethiopia sorghum is grown in almost all regions occupying an estimated total land area of 1.6 million ha (CSA, 2012). The productivity of sorghum in

Ethiopia is low when compared to other African countries (FAOSTAT, 2006). Ethiopia's average productivity of sorghum is <1.35 tons ha-1, ranking it fifth in Africa. It is a multipurpose crop, being utilized in different forms where the grain is used for making "Injera" (large round pancake made from fermented dough) and "Tella" (local beverage drinks). It is also consumed in boiled and roasted forms. Sorghum is also essential source of feed for livestock where the stalk is used to feed animals in dry season. Moreover, its stalk is used as firewood and construction material.

The national average sorghum productivity in Ethiopia is 2.0 tons/ha (CSA, 2012) which is far below the global average of 3.2 tons/ha (FAO, 2005). This is because of a number of factors. Several production constraints were identified as hindrance for sorghum production and productivity enhancement. The major constraints include drought, striga, insect pests (Stalk borer, midge and shoot fly), disease (grain mold, anthracnose and smut) and others. Among insect pests, stalk borers are considered to be the most important insect pests of sorghum and maize in all areas of the country (Jepson, 1954). Economically important species include the maize stalk borer (*Bussoela fusca*), the spotted stalk borer (*Chilo partellus*), and the pink stalk borer (*Sesamia calamistis*). *Bussoela* is important at higher altitudes (1700 meter above sea level and higher) whereas *Chilo* and *Sesamia* are important in the mid-altitudes (below 1700 m) (Sharma &Gautam, 2010). Contrary to these reports, *B. fusca* does occur in the lower altitudes in East Africa and it feeds on only a few host plant species (Addis, 2016). Yield loss due to stem borers in Africa vary from 0-100% among ecological zones, regions and seasons. In Sub Saharan Africa, they can cause 20-40% losses during cultivation and 30-90% losses postharvest and during storage (Nyukuri *et al*., 2014).

In Ethiopia, both B. *fusca* and *C. partellus* are considered to be the most damaging insect pests, with reported yield losses of 0 to 100, 39 to 100, 10 to 19 and 2 to 27% from South, North, East and Western Ethiopia, respectively (Melaku and Gashawbeza, 1993; Melaku *et al*., 2006). The average yield loss of maize caused by cereal stem borers in Ethiopia can be estimated between 20 - 50% (Boeke *et al*., 2004). The severity and nature of stem borer damage depends upon the borer species, the plant growth stage, the number of larvae feeding on the plant and the plant's reaction to the borer feeding. Feeding by borer larvae on sorghum and maize plants usually results in crop losses as a consequence of death of the growing point (dead heart), early leaf senescence, reduced translocation, lodging and direct damage to the ears (Nyukuri *et al*., 2014).

Management options for control of stem borers are manipulation of sowing dates, inter-cropping, natural enemies of stem borers, chemical control, botanical, host-plant resistance and genetically modified maize. In Ethiopia, a number of experiments on sowing date effects on stem borer damage were conducted. However, the results obtained were variable. Contrary to what was known in the past, early planting in Ethiopia averted stem borer damage maleku *et al* (2006) reported decreasing borer population damage with delays in planting in Addis Zemen areas of Amhara region. This indicated that in northern Ethiopia where there was one effective rainy season and long dry season, the borer incidence behaved differently from regions receiving bimodal rain fall in the country such as Hawasa, Ziway, Adama, and Sirinka. Such a situation could also arise from current climate change. Therefore, early planting or late planting can be recommended in different areas. Even the term early is relative as it is linked to the onset of rainfall. For example, early sowing for Hawasa and Arsi Nagele is in mid to the end of April, while sowing for Ziway, Melkassa and Meiso is in mid to end of June. Identification of proper time of sowing has long been recommended for various pest and disease problems. However, there are conflicting reports on the relationship between sowing time and borer infestation and damage. In general, most authors recommended early planting while a few of them recommended late planting which suggests the need for optimizing sowing dates based on location (Melaku *et al*, 2006). Even though sorghum is susceptible for stem borer in the area, there was no recommended sowing date that had been done so far. Therefore, it is very crucial to identify the better sowing period in the study area to reduce pest infestation and increase yield of the crop. Therefore, this study was designed to evaluate the effect of sowing date on infestation of sorghum stalk borer.

Materials and Methods

A field experiment was conducted to study the appropriate time of sowing that reduce the infestation of sorghum stem borer in one sorghum variety (Chiro) at Hirna (Haramaya University research sub site) and Mechara Agricultural Research center. The crop was sown at seven days interval six times starting from the onset of rainfall within the range of sorghum sowing in the area. This had been done starting from 1st weeks of April in the first year (2014/15) and 1st week of May in the second year (2015/16)because of rainfall problem. The plot size was 3.75 m x 4.5 m =16.88m^2 with75cm and 25cm row and b/n plant spacing, respectively.

The design used was RCBD in three replications. Each treatment has a control plot and replicated three times. In protected condition carbaryle powder was applied at the time of sowing and whole application of carbaryle powder was done at 12 days after sowing to manage soil inhabitant insect pest. One spray with Alpha cypermethrin was also done on 35th day after sowing, in order to protect the crop from stem borer and shoot fly. Observations were taken at regular intervals starting from fifteenth day of emergence of the crop for various pests. For stem borer incidence the observations on leaf scraping and pinhole damage was made at 35 DAE of the crop. The observations were made by counting the number of plants showing the symptoms and dividing to the total number of plants emerged per plot, then it was converted into percent leaf damage. Identification of the stem borer was carried out with reference to the key developed by Overholt *et al*. (2001).

Data collected

The data of percentage of infestation, Incidence, Stem tunnel length (cm) and adjusted grain yield (ku/ha) were collected using the following methods:

$$\%\text{age of infestation} = \frac{\text{No. of larvae per plant}}{\text{Total no. of larvae per each sampled plot}} \text{X } 100$$

$$\%\ \text{Incidence} = \frac{\text{No. of leaf scraped or exit holed plant per plot (infected plant)}}{\text{Total no. of plant sampled per plot}} \text{X } 100$$

$$\%\ \text{tunneling} = \frac{\text{Stem tunneled (cm)}}{\text{Total length of the plant sampled}} \text{X } 100$$

Yield Difference (ku/ha) =TMY-UMY

Where: TMY=Treated mean yield; UMY=Untreated mean yield

For exit hole and tunnel length measurement, five plants from each date of planting were collected. Plant damage percentage was assessed during the vegetative stage just before butting stage visually by counting healthy and damaged plants. However, the exit holes made by stem borer from the five sampled plants were counted visually after removing the intact leaves on stem, and then proceed for tunnel length measurement. The mean length of tunneling was taken from five randomly selected plants at harvest. Thereafter, the sampled plants were dissected longitudinally, and then the groove made by stem borer was measured by using simple measuring scale in centimeter.

Data analysis: All data were transformed before analysis, using the square-root transformation formula √(x+0.5). GenStat Statistical package 15th edition was used for the data analysis. LSD at 5% was used to separate the means.

Results and Discussion : Over year mean percentage of stem borer infestation and Tunneling were not significant at (P<0.05) while percent incidence showed significant difference on untreated plot at Mechara (Table 1). At Hirna, all parameters under consideration (Infestation, Incidence and Tunneling %) on both treated and untreated plots were not significant at (P< 0.05) (Table 2). Even if it was not significant in all parameters in all location, the mean percentage of the first three (1-4) weeks sown sorghum crop were recorded higher than the last two (5 and 6) weeks cropped sorghum.

Table 1. Over year mean percentage of Infestation, Incidence and tunneling by stem borers at Mechara

Sowing date	% Infestation		% Incidence		% Tunneling	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
1st week	8.2	19.70	2.22	6.95a	24.62	33.68
2nd week	6.4	23.10	0.77	6.93a	18.67	26.07
3rd week	11.1	21.83	1.99	5.11ab	11.73	25.50
4th week	7.9	20.15	2.64	3.37ab	12.15	22.32
5th week	13.0	0.67	1.88	1.62b	12.97	23.73
6th week	0.0	0.33	0.81	0.95b	11.92	14.60
Mean	7.8	14.3	1.72	4.16	15.3	24.3
LSD (5%)	Ns	Ns	Ns	4.07	Ns	Ns
S.E.	5.88	18.71	2.25	3.44	13.84	3.95

Note: 1 week (Mechara 4/10/2014, 10/5/2015); 2 week (Mechara 4/17/2014, 17/5/2015); 3 week (Mechara 4/24/2014, 24/5/2015); 4 week (Mechara 5/1/2014, 31/5/2015); 5 week (Mechara 5/8/2014,6/6/2015); 6 week (Mechara 5/15/2014, 13/6/2015); Ns= not significant, LSD- Least significant Difference; S.E.= Standard Errors

Table 2. Over year mean percentage of (Infestation, Incidence and tunneling by stem borers at Hirna

Sowing date	% infestation		%incidence		% Tunneling	
	Treated	Untreated	Treated	Untreated	Treated	Untreated
1 week	3.95	14.13	6.58	10.60	44.33	40.33
2 week	9.50	18.31	7.87	10.15	25.33	41.50
3 week	6.12	14.68	3.35	6.63	26.17	39.33
4 week	11.33	13.97	3.10	10.03	32.50	40.33
5 week	9.18	11.62	6.28	3.55	34.33	41.33
6 week	10.55	13.67	6.95	5.92	25.00	37.17
Mean	8.4	14.4	5.7	7.81	31.3	40.0
LSD (5%)	Ns	Ns	Ns	Ns	Ns	Ns
S.E.	11.29	13.78	2.00	5.44	35.09	2.46

Note: 1 week (Hirna 4/16/2014, 11/5/15); 2 week (Hirna 4/23/2014, 18/5/2015); 3 week (Hirna 4/30/2014, 25/5/2015); 4 week (Hirna 5/7/2014, 1/6/2015); 5 week (Hirna 5/14/2014, 8/6/2015); 6 week (Hirna 5/21/2014, 15/6/2015); Ns = not significant, LSD=Least significant Difference , S.E. = Standard Errors

Based on combined analysis, mean percent infestation did not show significant variation (P<0.05) over location but highly significant at (P< 0.01) over years. The percent stalk borer incidence on untreated plot was highly significant at (P< 0.01) on both over years and over location. These variations were also significant at (P< 0.05) on percent stem tunnel length in untreated plot over location but not significant in treated plot (Table 3). The highest score of combined mean of untreated plot was observed on the sorghum plants sown at the first fourth (1-4) weeks after the onset of rainfall.

Table 3. Combined analysis of percent infestation, incidence and tunneling, and grain yield over years and over location

Sowing date		% Infestation		% Incidence		% Tunneling		Grain Yield (ku/ha)	
		Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated
1 week		6.1	16.9	4.4	8.8a	6.2	20.0ab	22.3a	16.9a
2 week		7.9	20.7	4.3	8.5a	3.5	22.7a	16.4abc	17.4a
3 week		8.6	18.3	2.6	5.8ab	3.3	19.5ab	17.4ab	13.1ab
4 week		9.6	17.0	2.8	6.7ab	6.5	15.0ab	19.0ab	11.7ab
5 week		11.1	6.1	4.1	2.6b	4.8	12.8ab	9.1bc	6.9b
6 week		5.3	7.0	3.9	3.4b	5.0	9.1b	7.4c	8.2b
Mean		8.1	12.4	3.7	5.98	4.9		15.2	12.4*
LSD		Ns	Ns	Ns	3.9**	Ns	10.0*	9.1*	7.4
(5%)	Location	Ns	7.8*	2.4**	2.3**	Ns	5.7*	Ns	Ns
	Year	5.5**	6.4**	Ns	2.4*	Ns	Ns	4.7***	3.9***
CV%		29.3	24.9	25.5	21.1	18.2	26.2	9.9	8.2

*Note: 1 week (Hirna 4/16/2014, 11/5/15, Mechara 4/10/2014, 10/5/2015), 2 week (Hirna 4/23/2014, 18/5/2015, Mechara 4/17/2014 , 17/5/2015) 3 week(Hirna 4/30/2014, 25/5/2015, Mechara 4/24/2014, 24/5/2015), 4 week (Hirna 5/7/2014,1/6/2015, Mechara 5/1/2014, 31/5/2015) 5 week(Hirna 5/14/2014, 8/6/2015, Mechara 5/8/2014,6/6/2015) 6 week(Hirna 5/21/2014, 8/6/2015, Mechara5/15/2014, 6/13/2015), ***-very highly significant,** - highly significant, *-significant, Ns –not significant, LSD- Least significant Difference , CV-Coefficient of variation, Trt- Treatment*

Statistically, grain yield was highly significant at ($p<0.01$) on untreated plot while significant at ($p< 0.05$) on the treated plots at Hirna. But There was no significant variation on both treated and untreated plots at Mechara. Even though there was no significant variation between the treatments, but there was variation between treatments mean. The highest positive yield difference of (10.66) was recorded on the 4 weeks sown sorghum crop at Hirna experimental site. While the negative yield difference of (-4.57) were recorded on the 6 week cropped sorghum at Mechara (Table 4).

Table 4. Over year mean grain yield difference from cypermethrine treated and untreated treatment at both Hirna and Mechara

Sowing date	Grain Yield (ku/ha) by location					
	Mechara			Hirna		
	Treated	Untreated	Difference	Treated	Untreated	Difference
1 week	17.75	16.03	1.72	26.74a*	17.91a**	8.83
2 week	18.36	18.28	0.08	14.35ab	16.56a**	-2.21
3 week	19.37	13.23	6.14	15.44ab	12.96ab	2.48
4 week	17.09	17.06	0.03	20.93ab	10.27abc	10.66
5 week	8.78	7.72	1.06	9.40b	6.86bc	2.54
6 week	7.26	11.83	-4.57	7.48b	4.50c	2.98
Mean	14.8	14.0	0.74	15.7	11.5	4.21
LSD (5%)	Ns	Ns		12.92*	7.22**	
CV%	9.7	9		8.7	8.7	

Note: 1 week (Hirna 4/16/2014, 11/5/15, Mechara 4/10/2014 ,10/5/2015), 2 week (Hirna 4/23/2014, 18/5/2015, Mechara 4/17/2014 , 17/5/2015) 3 week (Hirna 4/30/2014, 25/5/2015, Mechara 4/24/2014, 24/5/2015), 4 week (Hirna 5/7/2014,1/6/2015, Mechara 5/1/2014,31/5/2015) 5 week(Hirna 5/14/2014, 8/6/2015, Mechara 5/8/2014,6/6/2015) 6 week(Hirna 5/21/2014, 8/6/2015, Mechara5/15/2014, 6/13/2015), ***-very highly significant,** - highly significant, * significant, Ns –not significant, LSD- Least significant Difference , CV-Coefficient of variation

Combined mean percent (infestation, incidence and stem tunnel) on treated and untreated plots screened for stem borers damage is shown in Table 3. The result shows that the highest mean percent (infestation, incidence and stem tunnel) were scouted on the sorghum planted at the first fourth (1-4) weeks on the onset of rainfall. In this case sorghum crop sown some weeks later after the first and second rain was less infected than immediately sown sorghum crop in both location and years. ISU, (2012) reported that later sown maize is less affected by stem borer larvae than earlier sowing as it disrupts their seasonal cycle. It is thought that at the start of the rainy season, borer populations arising from diapausing-generation larvae will still be building up and cause heavy damage to the crop. In addition, Maleku *et al* (2006) reported decreasing borer population damage with delays in planting. The highest numbers of larvae (Figure 1c), exit hole and stem tunnel length by stalk borer (Figure 1A & B) were recorded on earlier than late planted sorghum. During late planting there were enough alternate preferable grassy weeds and other cereal crop than earlier planted sorghum that made adult insects to distribute over and reduce population density of ovipositor adults and minimize the damage of the main crop.The African maize stalk borer is primarily a pest of maize and sorghum; other hosts include pearl millet, finger millet, sugarcane and many wild grasses including Johnson grass (*Sorghum halepense*), elephant grass, wild Sudan grass and Guinea grass comparably preferred for ovipositor. Because of this stalk borer infestation was reduced by half in such area. Buddhi *et al*. (2015) also states that as adult population in the field fluctuates in response to ambient condition, the degree of damage by larvae may also be fluctuated.

The highest positive yield difference of (10.27) was observed on the fourth week planted sorghum crop at Hirna. While the large negative yield difference of (-4.57) scored on the sixth weeks planted sorghum crop at Mechara. Weeks with (+ve) yield difference record means insecticide is important for the area for sorghum production whereas (-ve) yield difference record shows no need of wasting the chemical for control. These yield difference mightn't only due to stem borer but also other factors such as recommended plant density (determined by the yield potential of an area), bird pest and rainfall distribution had a major influence on harvests (Table 1).

Symptoms of stem borer damage were first observed on the leaves and stalk in all treatments, and the differences between their combine means were significant on both over years and location. Damage is caused by the larvae which at first feed on the young leaves but soon tunnel into the stems and produce about22.7% tunnel length.In addition to this, Songa *et al*. (2001) observed that stem borers damage greatly reduced maize yield with tunnel lengths greater than 20 cm causing a 40% potential yield loss. During the early stages of crop growth, larvae may kill the growing points, resulting in the production of 'dead hearts' with a consequent loss of crop stand.At later stages of growth, extensive tunneling inside the stems weakens the plant but the crop can tolerate than the earlier growth stage. Similarly, Walker (1960) reported that in East-Africa infestation at an early stage of plant growth will reduce the yield up to 36 kg grain per ha for every 1% plant infestation in high potential plantings. An infestation at a later stage is less injurious. A 33% yield loss was found in plants with more than one stem borers exit hole (Songa *et al*., 2001).

Conclusion and Recommendation

The combined analyzed results of this study confirm that the percent infestation was not significant ($P<0.05$) over location but highly significant ($P< 0.01$) over years. Grain yield was highly significant ($p<0.01$) on untreated check at Hirna while non significant at Mechara. It shows that manipulation of sowing date has variable in the reduction of stalk borer infestation and damages from one location to another. As a result, the sorghum crop which had been sown at 5 week (Hirna 5/14/2014, 8/6/2015, Mechara 5/8/2014,6/6/2015), and 6 week (Hirna 5/21/2014, 8/6/2015, Mechara5/15/2014, 6/13/2015) were less infected than earlier planted at (1 week (Hirna 4/16/2014, 11/5/15, Mechara 4/10/2014,10/5/2015), 2 week (Hirna 4/23/2014, 18/5/2015, Mechara 4/17/2014 , 17/5/2015) and 3 week (Hirna 4/30/2014, 25/5/2015, Mechara 4/24/2014, 24/5/2015)) planting date. The highest numbers of larvae and exit hole were recorded on earlier than late planted sorghum. This study, therefore, showed that the leave and stems of sorghum planted at the 1- 4 weeks more damaged than the 5 – 6 weeks cropped. Yield was also influenced by plant stand, bird pest and rainfall distribution in the study area. As recommendation, late planting was recommended for both location (Mechara and Hirna) to reduce pest infestations and damage if there is enough rainfall. Based on the yield difference for Hirna area 1 and 4 weeks sowing with cypermethrin treatment doubled the yield of sorghum grain. While for Mechara area 2, 4 and 6 weeks sowing without chemical treatment were recommended starting from the onset of rainfall.

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Powdery mildew (*Odium lini*) and Pasmo (*Septoria lincola*) combined effect on yield, yield components and oil content of linseed (*Linum usitatissimum* L.)

Ermias Teshome

Sinana Agricultural Research Center, P.O.Box 208, Bale-Robe, Ethiopia.

E-mail: ermiastafa@gmail.com

Abstract

Linseed (Linum usitatissimum L.) is a traditional oil crop and is the third most important oilseeds in the higher altitudes of Ethiopia. It is the first most important oilseed crop in the highlands of Bale both in productivity and area of production. The experiment was conducted for the last three years during 2013/14, 2014/15 and 2015/16 main cropping season at Sinana on-station and welte'i berisa. The trial was laid out in RCBD with 3 replications. Local linseed variety and "Dibene" were used in the experiment. To create a disease gradient a fungicide Odeon was used with a rate 2.5 kg/ha in different spray interval. At welte'i berisa; ANOVA for pasmo disease depicted significant difference ($P\leq0.05$) between treatments. The highest and the lowest pasmo disease severity of 58.03% and 23.46 % was recorded from local landrace with no spray and Dibene variety sprayed at 7days interval, respectively. For Powdery mildew, ANOVA showed significant statistical variation ($P\leq0.05$) between treatments. The highest powdery mildew severity (64.20%) was recorded from local linseed landrace without fungicide spray, while the lowest severity (30.86%) was recorded in Dibene variety sprayed at 7 days interval. Similarly, Analysis of Variance for pasmo (Septoria licola) showed that there was significant difference ($P<0.05$) between treatments at Sinana on-staion. The highest pasmo disease severity (23.46%) was recorded from the local landrace with no fungicide spray,while the lowest severity (12.96%) was recorded from Dibene variety sprayed at 7 days interval. Likewise, there is statistically significant difference ($P<0.05$) between treatments for powdery mildew. The highest powdery mildew severity (46.3%) was recorded from non-sprayed local variety; while the lowest (22.84%) was recorded from Dibene variety sprayed at 7 days interval. There was significant difference for most of the agronomic parameters considered. The highest (2859.3 kg/ha) and the lowest (2316.8 kg/ha) grain yield was recorded from Dibene variety sprayed at 14 days interval and non sprayed local landrace, respectively. Therefore, application of a fungicide Odeon at 14 days interval for the management of pasmo and Powdery mildew diseases is recommended .

Key words: ANOVA, Yield loss, Pasmo, Powdery mildew and Grain yield

Introduction

Linseed (*Linum usitatissimum* L.) has been traditional oil crop of Ethiopia and it is the third most important oilseeds in the higher altitudes, whereas the first in Bale highlands in its area of production and productivity (CSA, 2008/09). Ethiopia is the fifth producer of linseed in the world with a total share of about 5% of the world production. It is usually grown in rotation with wheat; barley and teff. Oromia is the first producer of linseed with total share of 75% of domestic production in Ethiopia (Wijnands *et al.*, 2009). Regardless of the potential for linseed production in Bale, biotic stresses, particularly diseases are the major yield limiting factors. Among diseases associated with linseed production, Pasmo *(Septoria lincola)* and powdery mildew *(Odium lini)* are the most important. But diseases like Alternaria, botrytis grey mold and wilt are common across the world where linseed is produced (Perryman *et al.,* 1998). Despite the disease presure and importance of the crop, pathological studies are lacking in Bale highlands hence management methods are not yet developed. Yield loss assessment was not conducted for major linseed diseaes in Bale highlands. Therefore, this work is intended to fill the gaps regarding managing of major diseases of linseed in Bale highlands. This trial was initiated in order to investigate the combined effect of Powdery mildew (*Odium lini*) and Pasmo (*Septoria lincola*) on yield, yield components and oil content of linseed.

Materials and Methods

The field experiment was conducted during 2013/14, 2014/15 and 2015/16 bona cropping season at SARC on-station experimental field and welte'i berisa farmer's field. The trial was laid out in RCB Design in 3 replications. 'Dibene' and local linseed verities were used in this study. The disease severity gradient was created by spraying the fungicide Odeon (Chlorothalonil) at a rate of 2.5kg/ha at different spray interval. The fungicide was sprayed at intervals and frequency was arranged the way it can create disease infection gradient to assess the effect of the diseases on linseed yield and yield components. The first spray was applied immediately after the diseases occurrence. The plot size was 1.2m x 3m with 0.2m, 1m and 1.5m row, plot and block spacings were, respectively. All other agronomic practices were properly applied as per the agronomic recommendation for the crop. The disease development was rated using 1-9 scoring scale (Bernier *et al.,* 1993). The disease severity rated in scoring scale was converted into percentage disease severity (DS) for analysis (Wheeler, 1969).

Result and Discussion

Out of the evaluated eight (8) treatments, most of them were found effective against linseed Pasmo and Powdery mildew management.

Sinana On-station

Analysis of variance (ANOVA) for Pasmo (*Septoria lincola*) depicted that there is significant difference ($P<0.05$) between treatments. The highest Pasmo disease severity of 23.46% was recorded in local linseed variety without fungicide spray, while the lowest severity of 12.96% was recorded from Dibene variety sprayed every 7 (seven) days. In the third year, there was high powdery mildew disease pressure that showed statistically significant variation ($P<0.05$) between treatments. The highest powdery mildew disease severity (46.30%) was recorded from a plot with local linseed variety without fungicide spray, while the lowest powdery mildew disease severity (22.84%) was recorded from Dibene variety sprayed every 7 (seven) days (Table 2). There was no statistically significant difference in number of boll per plant, date of flowering and biomass yield between treatments. ANOVA for seed per boll showed significantly different ($P<0.05$) variations between treatments. The maximum number of seed per boll (9.56) was counted from Local variety sprayed every seven (7) and fourteen (14) days. Whereas the lowest seed per boll (7.78) was counted from local linseed landrace sprayed every twenty one (21) days.

Table 2: Effect of Powdery mildew (*Odium lini*) and Pasmo (*Septoria lincola*) diseases on yield and yield components of linseed at Sinana On-station

	*Parameters										
*Trt.	Pa	PM	Tlr/plnt	Branch/plnt	Boll/plnt	Sd/boll	Plntht	%stnd	BM	1000SW	Yld kg/ha
D0	19.14	31.48	5.56	28.11	86.22	8.11	112.67	81.67	2750.0	6.53	2699.0
D7	12.96	22.84	5.00	23.89	70.44	9.44	108.22	88.33	2783.3	6.53	2802.9
D14	14.82	25.31	4.33	22.11	68.67	9.33	108.33	88.33	2816.7	6.27	2859.3
D21	15.43	27.16	4.33	20.89	73.33	9.11	103.33	88.33	2716.7	6.73	2693.1
L0	23.46	46.30	5.22	30.33	81.78	8.67	102.78	80.00	2583.3	6.07	2316.8
L7	17.28	40.74	5.89	29.11	87.44	9.56	101.11	76.67	2700.0	6.13	2555.8
L14	20.37	36.42	5.00	30.89	97.89	9.56	102.22	76.67	2416.7	6.27	2612.8
L21	21.61	38.27	4.00	27.33	83.89	7.78	99.44	80.00	2700.0	6.13	2498.3
CV (%)	14.74	15.19	14.97	13.55	21.27	9.50	2.52	5.25	13.14	2.03	10.21
$LSD_{0.05}$	4.63	8.83	1.27	6.23	NS	1.47	4.56	7.50	NS	0.22	464.72

**D0-Dibene variety with no fungicide, D7-Dibene variety sprayed every seven days, D14-Dibene variety sprayed every fourteen days, D21-Dibene variety sprayed every twenty one days, L0-Local linseed landrace with no fungicide spray, L7-Local linseed landrace sprayed every seven days, L14-Local linseed landrace sprayed every fourteen days, L21-Local linseed landrace sprayed every twenty one days, Pa-Pasmo Disease severity, PM-Powdery mildew disease severity*

Percent plant stand (%stand) was one of the parameters influenced by the fungicide application; ANOVA for this parameter also indicated that there is significant variation among the treatments. The highest stand percentage (88.33) was recorded from Dibene variety sprayed every seven (7), fourteen (14) and twenty one (21) days and the lowest stand percent (76.67) was recorded from local linseed variety sprayed seven (7) and fourteen (14) days. Thousand seed weight (TSW) was also among the parameters influenced by fungicide application. The maximum thousand seed weight of 6.73g was recorded from Dibene variety sprayed every twenty one (21) days; whereas the minimum thousand seed weight of 6.07g was recorded from local linseed variety without fungicide spray. Grain yield was significantly differenent ($P<0.05$) between treatments. The highest grain yield (2859.30kg/ha) was obtained from Dibene variety sprayed every fourteen days (14) days while the lowest grain yield (2316.8kg/ha) was recorded from local linseed variety without fungicide spray.

Welte'i Bersia

Analysis of variance (ANOVA) for Pasmo (*Septoria lincola*) showed significant difference ($P<0.05$) between treatments. The highest Pasmo disease severity (58.03%) was recorded from a plot with local linseed landrace without fungicide spray while the lowest severity (23.46%) was recorded from Dibene variety sprayed every 7 (seven) days. There was high powdery mildew disease pressure that resulted in statistically significant variation ($P<0.05$) between treatments. The highest severity (64.20%) was recorded from a plot with local linseed variety without fungicide spray while the lowest severity (30.86%) was recorded from Dibene variety sprayed every 7(seven) days (Table 3). ANOVA for seed per boll showed significantly different ($P<0.05$) variations between treatments. The maximum number of seed per boll (9.56) was counted from Local variety sprayed every seven (7) days. Whereas the lowest seed per boll (7.89) was counted from local linseed landrace sprayed every fourteen (14) days. Percent plant stand (%stand) was one of the parameters influenced by the fungicide application; ANOVA for this parameter also indicated significant variation among the treatments.

Table 3: Effect of Powdery mildew (*Odium lini*) and Pasmo (*Septoria lincola*) diseases on yield and yield components of linseed at Welte'i Berisa

	*Parameters										
Trt.	Pa	PM	Tlr/plnt	Branch/plnt	Boll/plnt	Sd/boll	Plntht	%stnd	BM	1000SW	Yld kg/ha
D0	38.27	48.15	3.33	18.56	30.00	8.89	98.89	90.00	2216.7	5.80	1161.3
D7	23.46	30.86	2.56	15.22	32.33	9.00	97.22	86.67	2166.7	5.70	1704.8
D14	30.86	37.04	2.11	10.44	26.89	8.56	87.22	78.33	1983.3	5.80	1733.6
D21	30.86	43.21	2.56	13.00	27.44	9.00	87.22	88.33	2000.0	5.87	1309.0
L0	58.03	64.20	2.44	14.89	30.89	9.44	84.44	86.67	1783.3	5.27	1045.6
L7	45.68	50.62	2.89	18.56	35.89	9.56	91.11	83.33	2100.0	5.30	1646.3
L14	38.27	46.91	2.44	11.22	18.44	7.89	71.67	75.00	1083.3	5.53	1745.2
L21	46.91	56.79	4.11	24.78	33.33	9.11	88.89	75.00	1450.0	5.30	1315.0
CV (%)	18.27	20.38	40.58	31.14	29.76	6.73	11.69	9.92	35.04	3.17	18.21
$LSD_{0.05}$	12.35	16.66	1.97	8.53	15.14	1.04	17.88	14.24	1120.8	0.31	459.51

*D0-Dibene variety with no fungicide, D7-Dibene variety sprayed every seven days, D14-Dibene variety sprayed every fourteen days, D21-Dibene variety sprayed every twenty one days, L0-Local linseed landrace with no fungicide spray, L7-Local linseed landrace sprayed every seven days, L14-Local linseed landrace sprayed every fourteen days, L21-Local linseed landrace sprayed every twenty one days, Pa-Pasmo Disease severity, PM-Powdery mildew disease severity.

The highest stand percentage (90.0%) was recorded from Dibene variety without fungicide spray and the lowest stand percent (75.00%) was recorded from local linseed variety sprayed every fourteen (14) and twenty one (21) days. Thousand seed weight (TSW) was also among the parameters influenced by fungicide application. The maximum thousand seed weight (5.87g) was recorded from Dibene variety sprayed every twenty one (21) days; whereas the minimum thousand seed weight (5.27g) was recorded from local linseed variety without fungicide spray. In case of grain yield, ANOVA showed statistically significant differences ($P<0.05$) between treatments. The highes grain yield of 1733.6kg/ha was obtained from Dibene variety sprayed every fourteen days (14) days and the lowest grain yield of 1045.6kg/ha was recorded from local linseed variety without fungicide spray.

Conclusion and Recommendation

Although this is a one year result, a fungicide Odeon (Chlorothalonil) application a fungicide Odeon (Chlorothalonil) is very crucial in linseed production package. From this study it can be recommended that the application of Odeon (Chlorothalonil) at fourteen (14) days interval is important. As seen from the data in the table 2 and 3; most of the essential parameters have positively responded for the fungicide application. As we compare the unsprayed plots with the sprayed plots, there was a significant difference for most of the parameters in test. The grain yield from the highest yielding plot exceeds the lowest yielding plot by 542.5 kg/ha at Sinana on-station and 688.0 kg/ha at welte'i berisaa due to the control of pasmo and powdery mildew diseases over unsprayed plots. This dictates that the use of fungicide for linseed production is one of the most important and crucial component of linseed production packages. Therefore, a fungicide Odeon (Chlorothalonil) is recommended for farmers (both small scale and large scale producers) against major diseases of linseed (Powdery mildew and Pasmo). Based on the current data, Dibene variety sprayed every fourteen (14) days with this fungicide is found to be most important against infection by the two major diseases (Powdery mildew and Pasmo) of linseed. Therefore, based on biological data and cost-benefit analysis result Dibene variety sprayed twice at fourteen (14) days interval is recommended for both small and large scale producers of the crop

Cost-Benefit Analysis

Table 5: Total variable cost of fungicide application and costs associated with it for protected plots at Sinana in 2013/14, 2014/15 and 2015/16 GC main cropping season

No.	Treatment	List of items and activities as a source of costs (Ethiopian Birr)								
		Fungicide			Sprayer rent	Labor cost to spray	Labor cost for water supply	Cleaning equipment	Cost for water	Total variable cost
		Rate (kgha^{-1})	Frequency	Cost (ETH Birr)						
1	D0	0	0	0	0	0	0	0	0	0
2	D7	2.5	3	2250	60	105	45	15	24	2499
3	D14	2.5	2	1500	40	70	30	10	16	1666
4	D21	2.5	2	1500	40	70	30	10	16	1666
5	L0	2.5	0	0	0	0	0	0	0	0
6	L7	2.5	3	2250	60	105	45	15	24	2499
7	L14	2.5	2	1500	40	70	30	10	16	1666
8	L21	2.5	2	1500	40	70	30	10	16	1666

Note: D0-Dibene variety with no fungicide, D7-Dibene variety sprayed every seven days, D14-Dibene variety sprayed every fourteen days, D21-Dibene variety sprayed every twenty one days, L0-Local linseed landrace with no fungicide spray, L7-Local linseed landrace sprayed every seven days, L14-Local linseed landrace sprayed every fourteen days, L21-Local linseed landrace sprayed every twenty one days.

Table 6: Cost-benefit assessment of fungicide application frequency against Chocolate spot of Faba bean at Sinana in 2013/14, 2014/15 and 2015/16 GC main cropping season

No.	Treatment	Fungicide (kgha^{-1})	Yield kgha^{-1}	SR (ETB ha^{-1})	MC (ETB ha^{-1})	MB (ETB ha^{-1})	MRR (%)
1	D0	0	1930.15	34742.7	0	34742.7	0.00
2	D7	7.5	2253.85	40569.3	2499	38070.3	312.47
3	D14	5	2296.45	41336.1	1666	39670.1	564.74
4	D21	5	2001.05	36018.9	1666	34352.9	245.58
5	L0	0	1681.2	30261.6	0	30261.6	0.00
6	L7	7.5	2101.05	37818.9	2499	35319.9	202.41
7	L14	5	2179	39222	1666	37556	437.84
8	L21	5	1906.65	34319.7	1666	32653.7	143.58

SR = Sale revenue; MC = Marginal cost; MB = Marginal benefit; MRR = marginal rate of return

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Chocolate spot (*Botrytis fabae* Sard.) management on Faba bean (*Vicia faba* L.) through application of fungicide at critical susceptible stage of the crop in Bale highlands, Southeastern Oromia

Ermias Teshome*[1]

[1]Sinana Agricultural Research Center, P.O.Box 208, Bale-Robe, Ethiopia.

*Corresponding author: ermiastafa@gmail.com

Abstract

Due to its high nutritive value, Faba bean (Vicia faba L.) is one of the most important food legumes in the world and in Bale-highlands as well. An experiment was conducted for three years (2013/14, 2014/15 and 2015/16) at Sinana Agricultural Research Center with the objectives of identifying the critical growth stage of faba bean susceptible to chocolate spot infection and to determine the right stage of fungicide spray for Chocolate spot management. The trial was arranged in RCBD with three replications. Disease severity was scored on 20 randomly pre- tagged plants from the central four rows. Area under the disease progress curve (AUDPC) and disease progress rate (r) were derived from percent disease severity index. Logistic model (ln[y/ (1-y)]) was employed to estimate the disease progression and data were analyzed using SAS procedure. The association of disease parameters with yield and yield related traits were assessed using Correlation and Regression analysis. The partial budget analysis was done to see the financial profitability of fungicide application for the management of chocolate spot on Faba bean. ANOVA for disease severity, AUDPC and r have shown statistically significant difference ($p\leq0.0001$) between treatments. The highest Chocolate spot disease severity of 48.95% and the lowest (19.75%) were recorded from a plot without fungicide treatment and from a plot treated three times at flowering stage, respectively. Similarly, the highest AUDPC (2534.3%-days) and r (0.029554 units^{-1}) and the lowest AUDPC (978.7%-days) and r (-0.006925units^{-1}) were calculated from a plot without fungicide spray and a plot sprayed with a fungicide three times at flowering stage, respectively. Regarding yield and yield related traits; ANOVA have shown significant variations ($P\leq0.05$) between treatments for number of pods per plant, seeds per pod, TKW and grain yield. The highest number of pods per plant (29.66), seeds per pod (3.25), TKW (575.07g) and grain yield (3515.4kg/ha) were recorded from plots sprayed three times at flowering stage; while the lowest number of pods per plant (14.01), seeds per pod (2.08),TKW (485.57g) and grain yield (2347.1 kg/ha) were recorded from check. Simple linear regression of grain yield with Chocolate spot severity index and AUDPC have revealed significant difference ($P\leq0.0001$) between treatments; the estimated slope of the regression line obtained for Chocolate spot severity index was -47.80 and for AUDPC was-1.00. *The Correlation of grain yield with Chocolate spot severity index and AUDPC shows that Chocolate spot severity index and AUDPC have significant negative correlation* *with grain yield (r= -0.52938, P≤0.0001) and (r= -0.64815, P≤0.0001), respectively. In partial budget analysis, the highest marginal benefit (30669.60 ha^{-1} ETB) was obtained from Mancozeb 80% WP sprayed plot (three times at weekly interval during flowering stage). However, the maximum marginal rate of return (MRR) of 2307.43% was obtained from a plot sprayed with Mancozeb 80% WP once at flowering stage. Therefore, foliar application of 2.5 kg/ha Mancozeb 80% WP once at flowering stage is recommended for the management of Faba bean chocolate spot.*

Key words: Faba bean, Chocolate spot, Botrytis fabae Sard. Disease severity index, AUDPC, and Disease progress curve

Introduction

Faba bean *(Vicia faba* L.*)* is one of the earliest domesticated food legumes in the world, probably in the late Neolithic period (Metayer, 2004). It is used as human food in developing and as an animal feed in developed countries. Food value of faba bean is high and this legume has been considered as a substitute of meat due to its high protein content (24-41 %) and provides the much needed protein supplement to the diet of rural households (Crépona *et al*., 2010).

From the economic point of view, faba bean is a source of cash to the farmers and foreign currency to the country. Nowadays, Ethiopian farmers are getting awareness on the role of legumes in general and faba bean in particular in improving soil fertility and soil health; there by widely using Faba bean in rotation with cereals (Sahile *et al*., 2008a). The crop occupies the largest area in Ethiopia among other pulses and currently the total area under cultivation is increasing dramatically which is estimated to be about 521,000 ha from which 6,886,670 quintals are produced (MoARD, 2008).

The crop is grown in several regions of the country receiving annual rainfall of 700-1000 mm (ICARDA, 2006). Despite the availability of high yielding varieties in Ethiopia, the average yield of Faba bean under small-holder farmers is not more than 1.8 t ha^{-1} (CSA, 2014 and MoA, 2011). This low productivity is attributed to its susceptibility to biotic stresses mainly diseases (Sahile *et al*., 2008a; Mussa *et al*., 2008; Nigussie *et al*.,2008 and Berhanu *et al*., 2003). The most important yield limiting diseases are chocolate spot (*Botrytis fabae*), rust (*Uromyces vicia-fabae*), black root rot (*Fusarium solani*) and Aschochyta blight (*Ascochyta fabae*) (Mussa *et al*., 2008; Ahmed *et al*., 2010). Different Experiments have conducted so far on the management of Chocolate spot.

However, all of them were focusing on the frequency of the fungicides to be applied and crop growth stage was not considered. Furthermore, the development and rate of progress of the disease in relation to the host growth stage are important epidemiological factors determining the level of crop damage (Ermias *et al*., 2013). Therefore, this study was initiated with the objective of evaluating the effect of Faba bean growth stage and fungicide frequency on the management of chocolate spot.

Materials and Methods

Description of Experimental Site

The experiment was conducted for three consecutive years; 2013/14, 2014/15 and 2015/16 during the main cropping season of Bale highlands at Sinana Agricultural Research Center (SARC), southeast Ethiopia. The location represents the highlands of Bale which is the major Faba bean production area. It is high rainfall area and is expected to be suitable environment (hot spot) for the development of chocolate spot disease. SARC is located at 7^{o}7' N (latitude) and 40^{o}10' E (longitude) at about 2400 m.a.s.l and receives 750–1000 mm mean annual rain fall. Its mean annual temperature is 9–21 ºC (Nefo *et al*., 2008). The dominant soil type is pellic vertisol and slightly acidic (Dagne *et al.*, 2016).

Treatments and Design

The experiment was arranged in three replications in RCB Design. An improved Faba bean variety ‘Shallo’ was evaluated on a plot size of 3m x 2.4 m with a total of 6 seeding rows. The spacing between row, plot and replication were 0.4m, 2m and 2m, respectively. Disease infection gradient was created by spraying a fungicide Mancozeb 80% WP at a rate of 2.5 kg/ha. A fungicide sprays were made at different crop growth stages and frequencies (Table 1).

Table 1: Treatment Arrangement

Treatment No.	Beginning of spray	Frequency of spray
1	At flower initiation (FI1)	1
2	At flower initiation (FI2)	2
3	At flower initiation (FI3)	3
4	At flowering (F1)	1
5	At flowering (F2)	2
6	At flowering (F3)	3
7	At pod initiation (PI1)	1
8	At pod initiation (PI2)	2
9	At pod initiation (PI3)	3
10	At 50% pod set stage (PS1)	1
11	At 50% pod set stage (PS2)	2
12	At 50% pod set stage (PS3)	3
13	Un treated check (UC)	0

Untreated check (UC) which was not receiving a fungicide spray was included as negative control for treatment comparison. Fungicide application started immediately after the development of the first observable diseases symptom and then the spray were made at a regular interval. Seed rate, fertilizer rate, weeding and other all agronomic packages are applied as per the recommendation for the crop.

Data Management and Statistical Analysis

Logistic, [ln [(Y/1-Y)], (Vander Plank 1963) and Gompertz, -ln[-ln(Y)], (Berger, 1981) models were compared for estimation of disease parameters in each treatment. Goodness of the fit of the models was tested using coefficient of determination (R^2) and Logistic model was found to fit best. Therefore, Independent variables for field experiment data under different treatments were analyzed using logistic model, ln[y/ (1-y)] with the SAS Procedure (SAS Institute, 1998). The slope of the regression line estimated the disease progress rate in different treatments. Disease scoring was conducted in a 1-9 diseases scoring scale (Bernier *et al.*, 1993). The data was converted to percentage severity index (PSI) according to Wheeler (1969). Mean separation was made based on LSD technique at 5% probability level.AUDPC values were calculated for each plot using the formula developed by (Shaner and Finney, 1977). ANOVA was performed for disease severity index (Wheeler, 1969), AUDPC (Shaner and Finney, 1977), and rate of disease progress (r).The association of disease parameters with yield and yield related parameters was assessed using Correlation and regression analysis.

$PSI = \frac{\text{Sum of Numerical Ratings X 100}}{\text{Number of Plants Scored X Maximum Score on Scale}}$……………1 (Wheeler, 1969)

$AUDPC = \sum_{i-1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_i)$……………………..2 (Shaner and Finney, 1977)

Where, X_i= the PSI of disease at the i^{th} assessment

t_i= is the time of the i^{th} assessment in days from the first assessment date

n= total number of disease assessments

Cost-Benefit Analysis

The cost of production and benefit of each treatment was analyzed using partial budget analysis. Marginal rate of return (MRR) was computed by considering the total variable costs incurred in each treatment. In this experiment the sum cost of fungicide, water, Sprayer rent, labor for spraying, Labor of water supply and Labor for cleaning equipments were considered as total variable cost. The yield and economic data were collected to compare the advantage of fungicide application on different crop growth stage and frequency for the management of Chocolate spot disease. The MRR was used as major criteria which measures the effect of additional investment on net returns (CIMMYT, 1988). MRR provides the benefit value obtained as a function of the additional investment or cost incurred for the management of Chocolate spot in percentage.

$$\mathrm{MRR} = \frac{\mathrm{DNI}}{\mathrm{DIC}} \times 100$$

Where: - MRR- Marginal Rate of Return, DNI-Difference in Net Income compared with control, DIC-Difference in Input Cost compared with control.

The total income from each treatment was obtained as sale revenue (SR) from the product (grain of Faba bean) and the marginal cost (MC) is computed as a sum of all production costs that varied and marginal benefit (MB) is calculated as a difference of sale revenue and marginal cost

Results and Discussion

The combined Analysis of variance over years have shown that there was statistically significant difference between treatments for disease parameters (severity (%), Area Under Disease Progress Curve (AUDPC) (%-days) and Disease Progress Rate (r) (units day^{-1})) and for yield and yield components (No. of Tillers per plant, No. of Pods per Plant, No. of Seeds per Pod, Biomass yield (kg/ha), Thousand Kernel Weight (TKW (g)) and Grain yield (kg/ha)) (Table 2 and Table 3). Statistically significant difference (*P<0.0001*) was observed for disease severity. The highest severity (48.95 %) was recorded from a plot without fungicide treatment (untreated check), while the lowest disease severity (19.75 %) was recorded from a plot sprayed three times at flowering stage (Figure 1 and Table 2). This finding is comparable with Sahile *et al*. (2008c) who have reported mean disease severity index ranging from 25 to 46.6% in sprayed plots, in comparison with 56.7% in unsprayed plots.

Table 2. Effect of Fungicide application Timing and Frequency on Chocolate spot Disease parameters

Treatment	Severity (%)	AUDPC (%-days)	r (units-day^{-1})
Spraying at flower initiation (FI1)	40.59	2138.90	0.014666
Spraying at flower initiation (FI2)	34.29	1801.80	0.010758
Spraying at flower initiation (FI3)	30.45	1575.00	0.006384
Spraying at flowering (F1)	32.20	1685.20	0.002545
Spraying at flowering (F2)	26.72	1361.10	-0.004055
Spraying at flowering (F3)	19.75	978.70	-0.006925
Spraying at pod initiation (PI1)	34.75	1827.80	0.009291
Spraying at pod initiation (PI2)	32.36	1691.70	0.005777
Spraying at pod initiation (PI3)	27.83	1445.40	0.001928
Spraying at 50% pod set stage (PS1)	33.95	1782.40	0.006685
Spraying at 50% pod set stage (PS2)	34.57	1821.30	0.008845
Spraying at 50% pod set stage (PS3)	33.54	1763.00	0.009205
Untreated check (UC)	48.95	2534.30	0.029554
CV (%)	15.82	21.09	159.82
$LSD_{(p<0.05)}$	5.79	401.77	0.0105

Note: LSD-Least Significant Difference, CV-Coefficient of variation

Similar result was also reported by Ermias and Addisu, (2013) and El-Sayed *et al.*, (2011) when they found the highest chocolate spot severity from non treated plot and the reverse from controlled plot. In general, the disease severity has shown a decreasing trend as the spray frequency increases from one to three times (Figure 2 and Table 2).

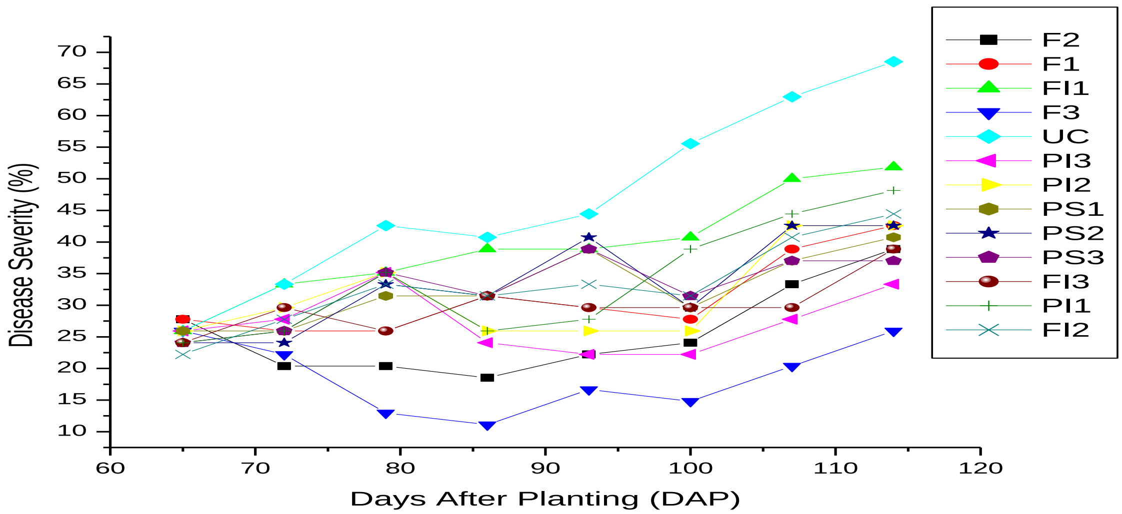


Figure 1: Chocolate spot progress curve as affected by the combination of Faba bean growth stage and fungicide spray frequency on "shalo" variety at Sinana.

In the same way, statistically very highly significant difference (*P<0.0001*) was observed for AUDPC and disease progress rate (r). The highest AUDPC of 2534.3 %-days and the lowest AUDPC (978.7 %-days) were obtained from untreated plot and a plot sprayed three times at flowering crop growth stage, respectively (Table 2). Similarly Dagne *et al.*, (2016) and El-Sayed *et al.*, (2011)have reported the highest and the lowest AUDPC from non protected and fully protected plots, respectively. The highest and the lowest chocolate spot disease progress rate (r) of 0.029554 units-day^{-1} and -0.006925 units-day^{-1}, respectively were observed in unreated plot and a plot sprayed three times at flowering stage, respectively.

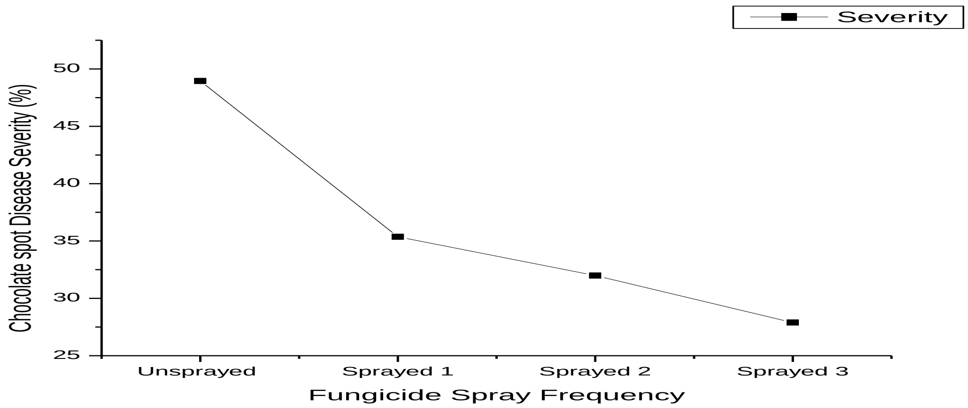


Figure 2: Effect of Fungicide Spray Frequency on Development and Progress of Chocolate spot Disease Severity on Variety Shalo at Sinana.

Similar result was reported by El-Sayed *et al.*, (2011) and Dagne *et al.*, (2016). In general, all of the chocolate spot disease severity, AUDPC and disease progress rate (r) have shown an increasing trend as the days after planting (DAP) progresses ((Figure 1 and Table 2). On the other hand, combinations of Faba bean growth stage and fungicide spray frequency have shown an effect on chocolate spot development, progression and severity (Figure 3 and Table 2).

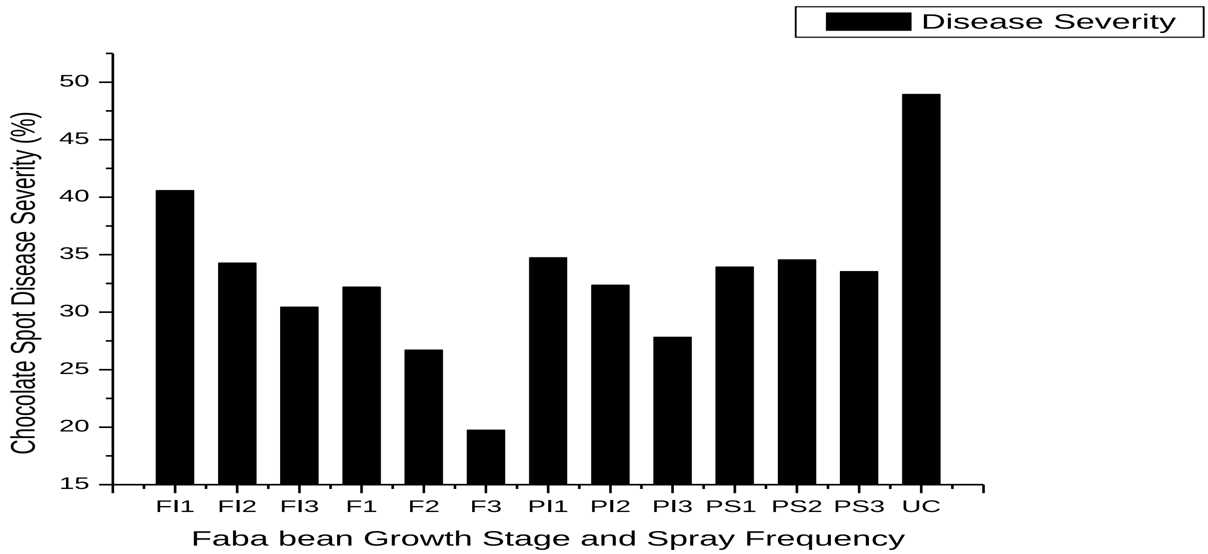


Figure 3: Effect of growth stages and fungicide spray frequencies on Chocolate spot severity

The maximum number of tillers per plant (3.21) and pods per plant (29.66) were recorded from the plots sprayed three times at flowering stage; while the smallest tillers per plant (2.02) and pods per plant (14.01) were recorded from unsprayed plots (Table 3). Ermias and Addisu, (2013) reported similar result from their study on integrated management of faba bean chocolate spot. Similarly, the highest number of seeds per pod (3.25), plant height (169.46 cm) and the biomass yield (2510.4 kg/ha) were recorded from plots sprayed three times at flowering stage while the lowest for all were recorded from unsprayed plots (Table 3). (El-Sayed *et al.*, 2011; Ermias and Addisu, 2013 and Dagne *et al.*, 2016) reported that the high disease severity and the highest AUDPC are directly aligned with the lowest yield components in agreement with the finding of this study.

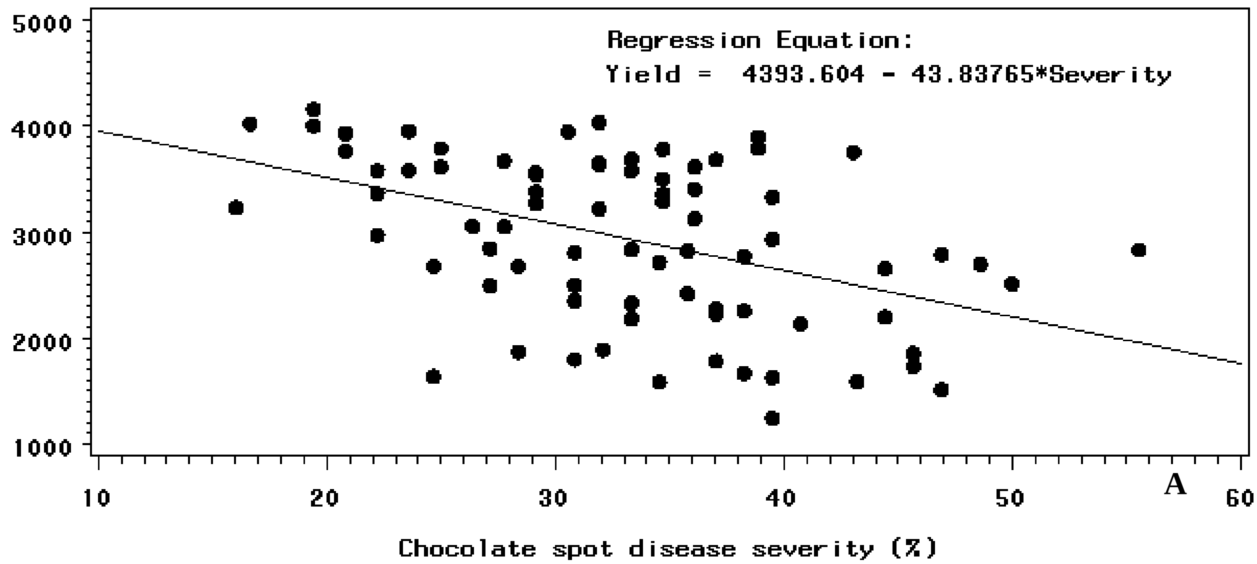
Simple linear regression model was employed to assess the relationship between chocolate spot severity index and grain yield. This showed significant difference ($P \leq 0.0001$) between treatments. The estimated slope of the regression line obtained for disease severity index was -43.84. This estimate shows that for each unit increase in percent severity index of chocolate spot, there was a Faba bean grain yield loss of 43.84 kg/ha (Figure 4). Based on the coefficient of determination (R^2) values calculated, the equations explained that about 57.94% of losses in Faba bean grain yield occurred due to chocolate spot disease. F-statistics calculated have shown very high significance ($P \leq 0.0001$) of the over all probability of the equation (Figure 4a). Similarly, the simple linear regression analysis between grain yield and AUDPC has resulted significant difference ($P \leq 0.0001$) between treatments. The estimated slope of the regression line obtained for AUDPC was -0.96 This estimate shows that for each unit increase in AUDPC, there was a Faba bean grain yield loss of 960 g/ha (Figure 4b).

Likewise, pair wise Pearson correlation analysis was employed to assess the relationship between chocolate spot disease parameters and yield and yield related traits of Faba bean. Chocolate spot disease severity index have significant negative correlation with number of pods per plant (r= -0.77268, $P<0.0001$). Number of seed per pod and Biomass (kg) have similarly significant negative correlation with chocolate spot severity (r= -0.52578, $P\leq 0.0001$ andr= -0.67263, $P\leq 0.0001$, respectively). Likewise, chocolate spot disease severity was found to be negatively significantly correlated with TKW (g) and Faba bean grain yield (r= -0.63994, $P\leq 0.0001$ and r= -0.52938, $P\leq 0.0001$, respectively) (Table 4). On the same way, significant negative correlation (r= -0.77723, $P\leq 0.0001$; r= -0.53576, $P\leq 0.0001$ and r= -0.68662, $P\leq 0.0001$) were found between AUDPC and number of pods per plant, number of seeds per pod and biomass (kg), respectively.

Table 3. Yield and Yield Components of Faba bean as Influenced by the Fungicide Application Timing and Frequency against Chocolate spot

Treatment	No. Tiller/plant	No. of Pod/plant	No. of Seed/pod	Plant height (cm)	BM (kg/ha)	TKW (gm)	Grain yield (kg/ha)
Spraying at flower initiation (FI1)	2.28	16.98	2.35	153.79	2049.0	534.45	2708.8
Spraying at flower initiation (FI2)	2.32	19.29	2.51	159.06	2093.8	546.92	2713.2
Spraying at flower initiation (FI3)	2.48	23.64	2.60	160.06	2140.6	559.80	2953.0
Spraying at flowering (F1)	2.59	22.14	2.63	161.76	2156.3	554.47	3211.1
Spraying at flowering (F2)	2.66	25.01	2.83	162.11	2296.9	561.27	3051.0
Spraying at flowering (F3)	3.21	29.66	3.25	169.46	2510.4	575.07	3515.4
Spraying at pod initiation (PI1)	2.26	21.58	2.46	161.03	1968.8	523.80	2974.7
Spraying at pod initiation (PI2)	2.34	21.90	2.61	164.13	2053.1	525.43	3124.2
Spraying at pod initiation (PI3)	2.33	25.08	2.67	160.00	2192.7	533.77	3000.1
Spraying at 50% pod set stage (PS1)	2.23	19.26	2.44	160.82	2041.7	526.18	2690.9
Spraying at 50% pod set stage (PS2)	2.27	19.62	2.54	164.77	2041.7	548.43	2806.4
Spraying at 50% pod set stage (PS3)	2.34	20.14	2.77	162.17	2119.8	563.07	3173.7
Un treated check (UC)	2.02	14.01	2.08	143.33	1825.0	485.57	2347.1
CV (%)	16.60	16.57	17.78	4.99	11.06	5.74	26.35
$LSD_{(p \leq 0.05)}$	0.47	4.32	0.53	9.30	275.75	35.99	915.93

Note: LSD-Least Significant Difference, CV-Coefficient of variation and TKW-Thousand Kernel Weight. BM-Biomass



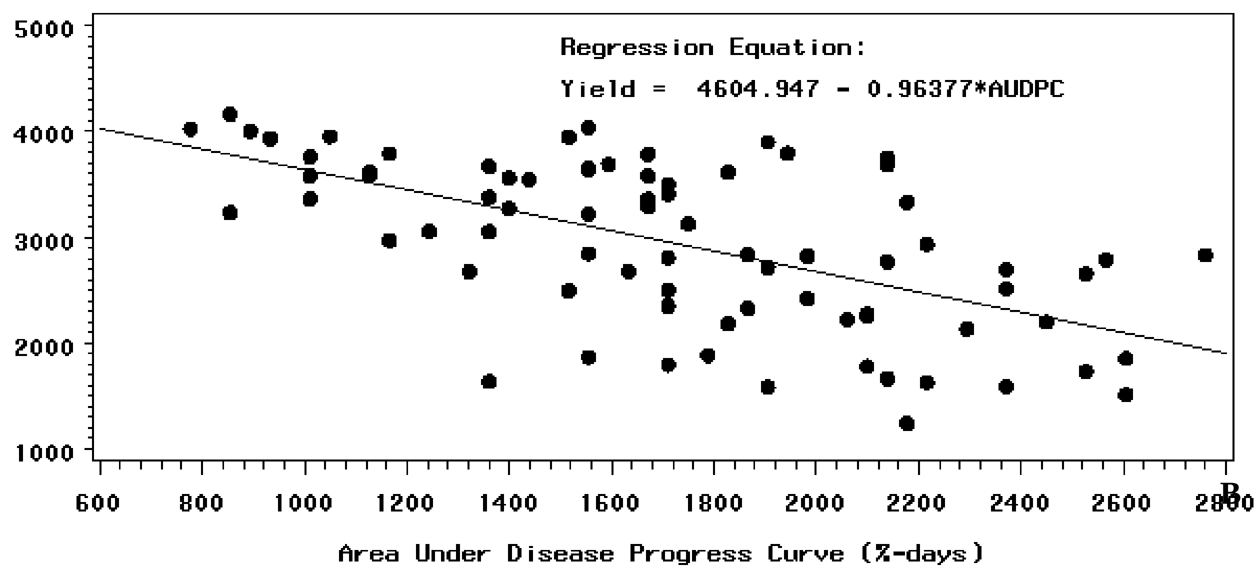


Figure 4: Estimated relationship between losses in Faba bean grain yield and Chocolate spot severity index (A) and AUDPC (B) at Sinana

Similarly, AUDPC have strong negative correlation (r= -0.71781, $P \leq 0.0001$ and r= -0.64815, $P<0.0001$) with TKW and grain yield, respectively. It was observed that, disease progress rate (r) have significant negative correlation with number of pods per plant (r= -0.67737, $P \leq 0.0001$), number of seeds per pod(r= -0.44209, $P \leq 0.0001$) and Biomass yield (r= -0.52945, $P<0.0001$), respectively. And also TKW (r= -0.59177, $P \leq 0.0001$) and grain yield (r= -0.45336, $P \leq 0.001$), respectively have significant negative correlation with disease progress rate (Table 4).

Table 4: Pair wise Pearson correlation coefficients among disease parameters, yield and yield Components of Faba bean

	Ch. spot	AUDPC	r	No. pod/plant	No. seed/pod	BM	TKW	Grain yield
Ch. Spot		0.97386***	0.86460***	-0.77268***	-0.52578***	-0.67263***	-0.63994***	-0.52938***
AUDPC	0.97386***		0.86161***	-0.77723***	-0.53576***	-0.68662***	-0.71781***	-0.64815***
R	0.86460***	0.86161***		-0.67737***	-0.44209***	-0.52945***	-0.59177***	-0.45336***
No. pod/plant	-0.77268***	-0.77723***	-0.67737***		0.64125***	0.68230***	0.53496***	0.53494***
No. seed/pod	-0.52578***	-0.53576***	-0.44209***	0.64125***		0.57535***	0.43676***	0.44245***
BM	-0.67263***	-0.68662***	-0.52945***	0.68230***	0.57535***		0.60126***	0.63634***
TKW	-0.63994***	-0.71781***	-0.59177***	0.53496***	0.43676***	0.60126***		0.77309***
Grain yield	-0.52938***	-0.64815***	-0.45336***	0.53494***	0.44245***	0.63634***	0.77309***	

Table 5:Total variable cost of fungicide application and costs associated with it at Sinana.

No.	Treatment	List of items and activities as a source of costs (Ethiopian Birr)								
		Fungicide			Sprayer rent	Labor cost to spray	Labor cost for water supply	Cleaning equipment	Cost for water	Total variable cost
		Rate (kgha^{-1})	Frequency	Cost (ETH Birr)						
1	Un treated check	0	0	0	0	0	0	0	0	0.00
2	Spraying at flower initiation	2.5	1	240	20	35	15	5	8	323.00
3	Spraying at flower initiation	2.5	2	480	40	70	30	10	16	646.00
4	Spraying at flower initiation	2.5	3	720	60	105	45	15	24	969.00
5	Spraying at flowering	2.5	1	240	20	35	15	5	8	323.00
6	Spraying at flowering	2.5	2	480	40	70	30	10	16	646.00
7	Spraying at flowering	2.5	3	720	60	105	45	15	24	969.00
8	Spraying at pod initiation	2.5	1	240	20	35	15	5	8	323.00
9	Spraying at pod initiation	2.5	2	480	40	70	30	10	16	646.00
10	Spraying at pod initiation	2.5	3	720	60	105	45	15	24	969.00
11	Spraying at 50% pod set stage	2.5	1	240	20	35	15	5	8	323.00
12	Spraying at 50% pod set stage	2.5	2	480	40	70	30	10	16	646.00
13	Spraying at 50% pod set stage	2.5	3	720	60	105	45	15	24	969.00

Cost-Benefit Analysis

The Partial budget analysis shows that the highest marginal benefit (30669.60 ha^{-1} ETB) was obtained from a plot sprayed with Mancozeb 80% WP three times at weekly interval at flowering stage followed by a plot sprayed once at flowering stage (ETB 28576.90ha^{-1}). The lowest (ETB 21123.90ha^{-1}) was obtained from unsprayed check (Table 6).The highest marginal rate of return (ETB 2307.43 %) was obtained from a treatment sprayed once at flowering stage. Accordingly, for every ETB 1.00 invested in Mancozeb 80% WP sprayed once at flowering stage, there was a gain of about ETB 23.07 (Table 6). The highest Faba bean grain yield (3515.4 $kgha^{-1}$) and the highest marginal benefit (30669.6 ETB^{-1}) were obtained from the three times sprayed plot during the flowering stage, followed by a plot sprayed once at flowering. Its yield was 3211.1 $kgha^{-1}$ with a marginal benefit of 28576.9 ETB^{-1}.

Therefore, from the economic profitability point of view, production of moderately resistant Faba bean variety Shalo sprayed once with Mancozeb 80% WP at flowering stage is the most profitable business under small holder farmers' condition at the current Faba bean price.

Table 6: Cost-benefit analysis of fungicide application frequency against Chocolate spot of Faba bean at Sinana in 2013/14, 2014/15 and 2015/16 GC

No.	Treatment	Fungicide (kgha^{-1})	Yield kgha^{-1}	SR (ETB ha^{-1})	MC (ETB ha^{-1})	MB (ETB ha^{-1})	MRR (%)
1	Un treated check	0.0	2347.1	21123.90	0.00	21123.90	0
2	Spraying at flower initiation 1	2.5	2708.8	24379.20	323.00	24056.20	907.83
3	Spraying at flower initiation 2	2.5	2713.2	24418.80	646.00	23772.80	410.05
4	Spraying at flower initiation 3	2.5	2953.0	26577.00	969.00	25608.00	462.76
5	Spraying at flowering 1	2.5	3211.1	28899.90	323.00	28576.90	2307.43
6	Spraying at flowering 2	2.5	3051.0	27459.00	646.00	26813.00	880.67
7	Spraying at flowering 3	2.5	3515.4	31638.60	969.00	30669.60	985.11
8	Spraying at pod initiation 1	2.5	2974.7	26772.30	323.00	26449.30	1648.73
9	Spraying at pod initiation 2	2.5	3124.2	28117.80	646.00	27471.80	982.65
10	Spraying at pod initiation 3	2.5	3000.1	27000.90	969.00	26031.90	506.50
11	Spraying at 50% pod set stage 1	2.5	2690.9	24218.10	323.00	23895.10	857.96
12	Spraying at 50% pod set stage 2	2.5	2806.4	25257.60	646.00	24611.60	539.89
13	Spraying at 50% pod set stage 3	2.5	3173.7	28563.30	969.00	27594.30	667.74

SR = Sale revenue; MC = Marginal cost; MB = Marginal benefit; MRR = marginal rate of return

Conclusion and Recommendation

Chocolate spot epidemic frequently occurs and causes high yield losses in the highlands of Bale as farmers are growing local cultivar. Therefore, this study was initiated with the objective of investigating the effect of Mancozeb 80% WP spray frequency at different growth stages of Faba bean on chocolate spot disease progress and yield and yield components. The result indicated that application of Mancozeb 80% WP fungicide once at flowering stage of the crop is found to be the right frequency and stage for optimum yield (3211.1kg ha^{-1}) and profitability. Flowering period is found to be the most susceptible stage to chocolate spot infection. This can be observed from the lowest severity and other disease data recorded when fungicide is applied at this stage. Hence, flowering is the right stage to apply disease management measures. Maximum marginal benefit (MB) of 30669.60 ETB ha^{-1} was recorded from a plot sprayed three times at flowering stage. The highest marginal rate of return (2307.43%) was obtained from a plot sprayed once at flowering stage.

Therefore, based on the biological yield and cost-benefit analysis (MRR), one time spray of Mancozeb 80% WP at flowering stage at a rate of 2.5kgha^{-1} is recommended for the management of Faba bean Chocolate spot and optimum yield. Sustainable productivity with minimum effect on environment can be achieved by the use of integrated management options. In this particular case to, it is highly recommended to use moderately resistant varieties in combination with the fungicide and recommended agronomic practices.

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Weed Management Practices and their effect on Weeds and Yield of Barley (*Hordeum vulgare* L.) at Shambo and Gedo, Western Oromia

Megersa Kebede*[1], Tigist Bidira[2], Geleta Gerama[1], Girma Chemeda[1], Kasa Mamo[1], Megersa Debela[1] and Hailu Feyisa[1],

[1] Oromia Agricultural Research Institute, Bako Agricultural Research Center

[2] Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, P.O.BOX 192, Jima, Ethiopia

*Corresponding Authors' email: - magarsaa430@gmail.com

Abstract

A field experiment on weed control in barley was conducted during the main season of 2015/2016. Different weed management practices were evaluated with the hand weeding and weedy check, for weed competition and grain yield of barley. The trial was laid out in randomized complete block design in three replications. Results of the experiment revealed that significantly lowest total weed density (13.3m^{-2}) and (29.7 m^{-2}) and maximum grain yield of (4312.5 and 4382.6 kg ha^{-1}) with (50.7 and 54.4 %) harvest index were recorded in two times hand weeded plot at Shambo and Gedo sites, respectively. The lowest total weed dry weight (20.3 m^{-2})and (17.8g m^{-2}) with highest control efficiency (81.7 and 72.4 %) were recorded from two times hand weeded plots followed byDical 720 gm/lt SL + Fenoxaprop-P-Ethyl 69 gm/lt at these respective locations. The highest weed density (49.5m^{-2}) and (102.0 m^{-2}), and lowest grain yield (2525.7 kg ha^{-1}) and (2776.9 kg ha^{-1}) was obtained from weedy check at Shambo and Gedo, respectively. Economic analysis shows that the maximum rate of return (36.4162 and 35.91566) was obtained from Dical followed by Fenoxaprop-P-Ethyl 69 gm/lt + Dical 720 gm/lt SL (4.080275 and 6.5375) at Shambo and Gedo, respectively. It can be concluded that integration of Fenoxaprop-P-Ethyl 69 gm/lt with Dical 720 gm/lt SL or one time hand weeding was quite effective to control major broad and grass weed species observed in barley fields.

Key words: - Integrated practices, Barley, weed reduction, Grain yield.

Introduction

Ethiopia is the second largest barley (*Hordeum vulgare* L.) producer in Africa, next to Morocco, accounting for about 25 percent of the total barley production in the continent (FAO, 2014). It is grown mainly in the highlands of the country and represents approximately 11% share of the total area where grain is cropped (CACC, 2003). It is predominantly grown at altitudes ranging from 2000 to 3000 m.a.s.l in various regions of the country. It is also preferred by subsistence farmers because of its ability to grow on marginal farms, unlike other cereals. Barley has a wide range of uses. Its grain is used as a staple food, for malting and for making local drinks, and is sold for cash. The grain is rich in Zinc, iron and soluble fibers and higher in contents of vitamin A and E than other cereals. Its straw and stem stubs are used for animal feed and thatching. The annual average national yield of the crop is only 1200 kg/ha (CSA, 2005). The low national average yield, which is far below the world average, could be partially attributed to poor weed management, which results in high competition from weeds. Yield gains from weed control, on the other hand, ranges from 14-60 percent depending on the location and type of weed (Negewo *et al*., 2011; Negewo *et al*., 2006). Weeds are important constraint in agricultural production systems, acting at same tropic level as the crop; weeds capture a part of the available resources that are essential for plant growth (Oerke, 2006; Ryan *et al*., 2009; Smith *et al*., 2010). Weeds compete with crop plants for various resources such as water and nutrients, resulting in low yields (Jarwar *et al.,* 2005). By competing for light, water, space and nutrients, weeds can reduce crop yield and quality and can lead to billions of dollars in global crop losses annually (Das, 2008; Srinivasrao *et al*., 2014).

Weed control plays an important role in raising barley grain yield, since weeds cause great losses in yield that reaches 48.9 % (Metwally *et al*., 2000). Effective weed management is critical to maintaining agricultural productivity (Ahmed *et al*., 2010; Verma, 2014). Weeds can be controlled through different management practices in barley fields. These include cultural, physical, chemical and integrated methods. Hand weeding is the most practiced weed control option in barley. Manual weed control is labour intensive and therefore limits the production area (Verma et al., 2008; Dubey, 2014). Chemical control is the most common, efficient and economical method of control (Dalley *et al.,* 2006; Marwat *et al.,* 2008). In many barley producing areas, barley fields are mostly treated with broadleaf herbicides. The herbicide 2, 4 dichlorophenoxy acetic acid (Dical) was the first to be introduced in rain-fed areas for the control of broadleaved weeds (Goetze 1976, Qasim 1982). Under partial weed management, it is common to observe barley fields infested with grass weeds, causing yield losses of up to 60% in some barley growing areas of Ethiopia (Alemu Hailye *et al.*, 1999). El-Bawab and Kholousy (2003) reported that controlling weeds by herbicidal treatments increased grain yield by about 40.3 and 13.6%, compared with unweeded and hand weeding treatments, respectively. Several herbicides are available to control barley weeds. Metosulam and sulfamoylurea herbicides were introduced as new selective herbicides for controlling broadleaved weeds in cereals (El-Metwally, 2002). Fenoxaprop-p-ethyl and clodinafop-propargyl are two selective herbicides for control of grass weeds in wheat and barley (Nassar, 2008). El- Metwally and El-Rokiek (2007) also found that the two herbicides provided control of narrow leaf weeds (97.7% reduction in dry weight after 90 DFS). Several combinations of herbicides are there that can provide good control of broad and narrow leaved weeds and cause significant reduction in their density and increase yield attributes(Chaudhry *et al.*, 2008; Bostrom & Fogelfors, 2002; Khan & Rashid, 1994). Integrated weed management relies on weed management principles that are proved to be suitable for long term weed management by combining the use of cultural, mechanical, thermal, biological and chemical means based on ecological approaches (Singh, 2014; Kewat, 2014).

Despite suitable environmental condition of Western Oromia highlands and importance of barley as food, malting and cash crop for farmers, both broad and grass weeds infestation has been a major constraint to barley production in these areas. Few investigations indicated that most broadleaf weeds are effectively controlled by hand weeding because they are easier to identify and can also be controlled using cheaply available 2, 4-D herbicide. However, no effective and applicable technology has yet been adopted to control grass weed species in barley in these areas. Hand weeding failed to control most grasses, especially wild oat, which resembles the crop and cause higher damage as they compete with the crop throughout the growing season. Hence, the introduction of any revised weed management technology which is economically and agronomical feasible, such as combination of herbicides and/or with hand weeding should be investigated for western Oromia barley growing areas. Thus, the objective of this study was to identify and develop effective weed management option/s in Barley (*Hordeum vulgare* L.) in Western Oromia.

Materials and Methods

Description of Study Areas: The experiments were conducted at Shambo and Gedo on farmers' field for one year (2015/16) during the main cropping season. Gedo site is found in Western Showa zone about 60 km North West of Ambo, the capital town of the zone. It is located at 09º012' 84" N latitude, 37º 26' 23.9" E longitude and altitude of 2438 masl. The soil is clay loam in texture. Shambo site is found in Horo-Guduru Wolega zone about 4 km northwest of Shambo, the capital town of the zone. It is located on geographic coordinates of 09^{o}037'23.0'' N latitude, 370 40' 33.2''E longitudes and altitude of 2609masl.

Treatments, Experimental Design and Crop Husbandry: The experiment contains seven treatments arranged in Randomized Complete Block Design (RCBD) in three replications on 4m x 5m plot size. Treatments comprised of post-emergence application of Fenoxaprop-P-Ethyl 69 gm/lt, Dical, Fenoxaprop-P-Ethyl 69 gm/lt + Dical 720 gm/lt SL, Fenoxaprop-P-Ethyl 69 gm/lt + One times hand weeding at 40 DAS, Dical 720 gm/lt SL + One times hand weeding at 40 DAS, Two times hand weeding at 25 and 40 DAS, and weedy check. Improved Food barley variety "HB-1307" with seed rate of 85 kg ha^{-1} was used in the experiment. The herbicides were applied at 30 days after sowing or (between 2-4 crop leaves stage) using Knapsack sprayer fitted with flat fan nozzle by mixing 200 liters of water per hectare. Dical 720 gm/lt SL and Fenoxaprop-P-Ethyl 69 gm/lt were applied at the rates of 1 L and 1.25 L ha^{-1}, respectively.

Table 1. Trade and Common Name of Herbicides and Rates

Trade Name	Common Name	Rates per hectare
Dical	Dical 720 gm/lt SL	1 L
Ralon Super EW 144	Fenoxaprop-P-Ethyl 69 gm/lt	5

Data collection and Analysis

All agronomic practices were applied as per recommendation and necessary data were collected from both weed and barley crop. Weed infestation was assessed and scored by number and species by throwing quadrate with 50cm x 50cm area three times per plot as per method described by Cruz *et al.* (1986). Percentage of weed inhibition (PWI) was calculated by the formula:

$$Percentage\ of\ weed\ inhibition\ (PWI) = \left(NWC - \frac{NWT}{NWC}\right) * 100 \ldots\ldots\ldots\ldots\ldots\ldots.(Eqn.1)$$

Where, NWC &NWT are number of weeds (m^{-2}) in weedy check and any particular treatment, respectively.

Weeds within quadrant were harvested and dried in oven dry. The dry weight of each species was taken by an electrical balance and expressed in g m^{-2}. Weed control efficiency (WCE) was calculated using the following formula developed by Sawant and Jadhav (1985),

$$Weed\ control\ efficacy\ (WCE) = \left(\mathrm{WDC} - \frac{\mathrm{WDT}}{\mathrm{WDC}}\right) * 100 \ldots\ldots\ldots\ldots\ldots\ldots..(Eqn.2)$$

Where, WDC & WDT are weed dry weight (g m^{-2}) in weedy check and any particular treatment, respectively.

The collected data were subjected to analysis of variance (ANOVA) using SAS the statistical software (SAS, 2008) (version 9.2). The mean separation, in cases where there were significant differences among treatments, was done using LSD (0.05) to facilitate the comparison of all pairs of treatment means (Montgomery, 2001).Data of weed parameters were transformed in square root for statistical analysis √ x+0.5 (Panse and Sukhamet 1967).

Results and Discusion

Weed Flora Composition: Various weeds species were observed in the experimental fields. They can be categorized under broad and grass weed species. A total of 18 weed species (11 broadleaf and 7 grass species) belonging to 10 families were recorded (Table 2). Among grass weed species, *Avena fatua, Phalaris paradoxa, Oplismus hetilatus and setaria pumila* were the major ones. On the other hand, *Guizotia scarba, Spergula Arvensis, Raphanus raphanustrum, Galium sporium, and Polygnom nepalensis* were the major broad leaf weed species observed in the trial fields across locations.

Table 2. Scientific names, family, life form and categories of weeds in experimental field

Scientific name	Family	Life form(Category)
Achyranthes aspera	Acanthaceae	Annual(Broadleaved)
Avena fatua	Graminaea	Annual(Grass)
Caylusea abyssinica	Resedaceae	Annual(Broadleaved)
Commolina latifolia	Commelinaceae	Annual(Broadleaved)
Corrigoila capensis	Caryophyllaceae	Annual(Broadleaved)
Digitaria ternate	Graminaea	Annual(Grass)
Galinsoga Parviflora	Asteraceae	Annual(Broadleaved)
Galium sporium	Rubiaceae	Annual(broadleaved)
Guizotia scarab	Asteraceae	Annual(Broadleaved)
Oplismus hertilatus	Graminaea	Annual(Grass)
Phalaris paradoxa	Graminaea	Annual(Grass)
Poa Annua	Graminaea	Annual(Grass)
Polygonum nepalense.	Polygnonaceae	Annual(Broadleaved)
Rhaphanus raphanistrum	Brassicaceae	Annual(Broadleaved)
Setaria pumila	Graminaea	Annual(Grass)
Snodonia Polystachia	Graminaea	Annual(Grass)
Spergula arvensis	Caryophyllaceae	Annual(Broadleaved)
Stachys arvensis	Labiatae	Annual(Broadleaved)

Weed Density (m^{-2}) and Percentage Weed Reduction: Results of the experiment revealed that all weed management practices reduced weed density significantly as compared to weedy check (Table 3). But the level of reduction varies based on the type of practices. This is in analogy with findings of Rekha *et al*., (2002) who reported that weed density was lower in all weeding practices compared to the un-weeded control plot. Among the weed management practices, the minimum total weed density (13.3m^{-2} and 29.7 m^{-2}) was recorded in two times hand weeded plots followed by Fenoxaprop-P-Ethyl 69 gm/lt + One times hand weeding (16.0m^{-2} and 30.3m^{-2}) at Shambo and Gedo, respectively. The lower number of weed density shows the effectiveness of management practices in weed suppression compared to the maximum total weed density (49.5m^{-2} and 102.0 m^{-2}) observed in weedy check plots at Shambo and Gedo, respectively. This result is supported by the reports of Singh and Pillai (1993).

From post-emergence herbicides, plots treated with Fenoxaprop-P-Ethyl 69 gm/lt alone shown the minimum number of grass weed species at both study locations and scored higher number of broad leaved weed species. Nassar (2008) reported that Fenoxaprop-p-ethyl and clodinafop-propargyl are the two herbicides effective against grass weeds. In contrast, application of Dical 720 gm/lt SL alone at thirty days after sowing (30 DAS) scored the minimum number of broad leaf weed species. These variations are due to the selective nature of those herbicides. This result was in line with the finding of Nano *et al.* (2012) who reported 2, 4-DEE to be ineffective in reducing the population of grassy weeds but effectively controlled broad leaved weed species. Thus, Dical 720 gm/lt SL can be a better option for broadleaf weed infested fields in the periods of labor shortage. These results are also in accordance with those of Salarzai *et al*. (1999) and Nati (1994) who concluded that herbicides significantly affected the weed population per unit area.

Combination of herbicides (Dical 720 gm/lt SL + Fenoxaprop-P-Ethyl 69 gm/lt) effectively controlled both broad and narrow leaved weed species. Herbicides mixtures that are effective against target weed species can show synergetic effect and result in sufficient management.

This result is in analogy with the findings of (Chaudhry *et al.,* 2008; Bostrom &Fogelfors, 2002; Khan & Rashid, 1994) where several combinations ofherbicides provided good control ofbroad and narrow leaved weeds and caused significantreduction in their density and

increase yield attributes ascompared to check plots. Percentage weed reductions of all the treatments were different (Table 3). The maximum percentage of weed reduction (72.9 and 70.8 %) was recorded from two times hand weeded plot followed by Fenoxaprop-P-Ethyl 69 gm/lt + One times hand weeded plots (66.0 and 70.2%) at Shambo and Gedo, respectively. Results had shown variation across location for weed density that could be mainly due environmental factors.

Weed dry weight (g m^{-2}) and weed control efficiency (WCE %): Results of the experiments regarding weed dry weight (g m^{-2}) and weed control efficiency (WCE %) depicted that both of these parameters were significantly affected by weed management practices (Table 4). All treatments significantly reduced weed dry weight (g m^{-2}) as compared to weedy check. This is in analogy with the finding of Sharma *et al.* (1998) and Saini, (2000) who reported significant reduction in weed dry matter accumulation with weed control treatments. Statistically significant difference was observed among treatments for total weed dry weight (g m^{-2}) at both study areas. The maximum total weed dry weights (111 and 65.5g m^{-2}) were recorded from un-treated plots at Shambo and Gedo, respectively. Singh and Kumar (1999) also reported that the maximum weed dry weight was recorded in the un-weeded control which was significantly higher compared to other weed control practices. The minimum total weed dry weights (20.3 and 17.8g m^{-2}) were observed in two times hand weeded plots at Shambo and Gedo, respectively.

Table 3. Effect of weed management practices on weed density(m^{-2}) at study areas

	Weed Density (m^{-2}) at 80 DAS				Weed Density (m-2) at 80DAS			
	Shambo				Gedo			
Treatments	Broad (m^{-2})	Grass (m^{-2})	Total(m^{-2})	PWR (%)	Broad(m^{-2})	Grass(m^{-2})	Total(m^{-2})	PWR (%)
Dical	9.7±3.1b	10.7±3.2ba	20.3±4.5bc	58.6 7.6b	12.7±3.6c	30.7±5.5a	43.3±6.6b	57.3±7.7b
Dical+Fenox	9.5±3.1b	7.8±2.8b	17.3±4.2bc	64.5±8.0ba	25.3±5b	12.7±3.5b	38.0±6.1cbd	62.8±7.9ba
Fenox	12.5±3.5b	7.1±2.6bc	19.5±4.4bc	60.5±7.8ba	26.0±5.1b	15.3±3.9b	41.3±6.4bc	59.3±7.7b
Fenox+HW(1x)	7.1±2.6b	9.7±3.1b	16.7±4.1bc	66.0±8.1ba	14.0±3.7c	16.3±3.9b	30.3±5.5d	70.2±8.3a
Dical+HW(1x)	10.5±3.2b	10.7±3.3ba	21.1±4.7b	57.4±7.6b	19.3±4.4bc	11.3±3.4b	30.7±5.6cd	69.9a±8.4
HW(2X)	10.2±3.1b	3.1±1.7c	13.3±3.7c	72.9±8.5a	17.0±4.1bc	12.7±3.5b	29.7±5.4d	70.8±8.4a
UN WD	35.3±5.9a	14.2±3.8a	49.5±7.0a	0C	73.3±8.6a	28.7±5.4a	102.0±10.1a	0c
LSD(0.05)	5.7	4.4	7.2	12.6	9.8	8	10.7	10.2
CV (%)	12.68	15.69	10.79	6.51	11.2	12.3	7.7	5.1
F-test	**	**	**	**	**	**	**	**

Note: - Means followed by the same letter within columns has statistically no difference. LSD= list signifance difference, CV (%) = Coefficient of variation, F-test= probability signifance difference & highly *signifance difference*, respectively, PWR(%) = Percentage wee *WD = weedy check, Fenox = Fenoxaprop-P-Ethyl 69 gm/lt, Dical + HW(1x) = Dical 720 g weeding, Fenox+ Dical= Fenoxaprop-P-Ethyl 69 gm/lt + Dical 720 gm/lt SL, HW(2x)= weeded, Fenox + HW(1x) =Fenoxaprop-P-Ethyl 69 gm/lt + One times hand weeding*

Application of Dical 720 gm/lt SL and Fenoxaprop-P-Ethyl 69 gm/lt alone and in integration significantly reduced the total weed dry weight as compared with un-treated plots. The reduction in weed dry weight might be due to the inhibition effect of herbicide treatments on growth and development of weeds. These results are generally in agreement with the reports of Turk *et al* (2003); Nassar (2008) and EL-Metwally and Soudy (2009). Combination of these chemicals with one times hand weeding also resulted insignificantreduction of weed dry weight. Treatments had shown different weed control efficacy. Twice hand weeding provided maximum weed control efficacy (81.7 and 72.4 %) followed by Dical 720 gm/lt SL + Fenoxaprop-P-Ethyl 69 gm/lt (77.8 and 68.6 %) treated plots at Shambo and Gedo, respectively. These results are in accordance with the findings of Shah and Koul (1990) and Thakur (1994), who observed higher WCE under twice hand weeding carried out at 20 and 40 days after sowing in maize crop.

Table 4. Effect of weed management practices on weed dry matter(g m $^{-2}$) at Shambo and Gedo

	Weed Dry weight(g m $^{-2}$) at 80 days after sowing							
	Shambo				Gedo			
Treatments	Broad(g m $^{-2}$)	Grass(g m $^{-2}$)	Total(g m $^{-2}$)	WCE (%)	Broad(g m $^{-2}$)	Grass (g m $^{-2}$)	Total (g m $^{-2}$)	WCE(%)
Dical	22.0b±4.7bc	23.0±4.6a	43.7±6.5 b	60.7±7.7d	16.5±4.0bc	16.7±4.0a	33.1±5.7b	50.1±7.0c
Dical+Fenox	16.3±4.0cd	8.3±2.9b	24.7 ±+5.0 cde	77.8 ±8.8bac	10.7±3.2c	9.5±3.1b	20.2± 4.5cd	68.6±8.3ba
Fenox	26.0±5.1b	9.3±3b	35.3±5.9bcd	68.2± 8.2bad	21.7±4.6b	8.4±2.9b	30.1±5.5bc	53.9±7.3bc
Fenox+HW	14.0±3.6c	7.3±2.7b	21.3 ± 4.6 de	75.1±9.0ba	15.3±3.9bc	8±2.8b	23.3±4.8cbd	64.8±8.0bac
Dical+HW	25 ± 5.0b	12.0±3.4bb	37.0 ±6.1bc	66.7±8.2 dc	12±3.5c	10.2±3.2b	22.2±4.7cd	65.8±8.1ba
HW(2X)	13.3 ± 3.6d	7.0±2.6b	20.3±4.5e	81.7±9.0a	9.8±3.1c	8.0±2.8b	17.8±4.2d	72.4±8.5a
UN WD	82a±13.03a	29.0 ± 5.4a	111±10.5a	0e	48.0±6.9a	17.5±4.2a	65.5±8.1a	
LSD	7.1	10.8	14.8	13.3	7.7	6.1	10.8	14.8
CV (%)	10.1	18.3	11.2	6.6	11.8	15.4	10.3	8.5
F-test	**	**	**	**	**	*	**	**

*Note: - Means followed by the same letter within columns has statistically no difference.LSD= list signifance difference, CV (%) = Coefficient of variation, F-test= probability value, *,** = signifance difference* & highly *signifance difference*, respectively, WCE(%) = *weed control efficacy ,UN WD = weedy check, Fenox= Fenoxaprop-P-Ethyl 69 gm/lt, Dical + HW(1x) = Dical 720 gm/lt SL +One times hand weeding, Fenox + Dical= Fenoxaprop-P-Ethyl 69 gm/lt + Dical 720 gm/lt SL, HW(2x)= two times hand weeded, Fenox + HW(1x) =Fenoxaprop-P-Ethyl 69 gm/lt + One times hand weeding*

Yield and yield related parameters of barley: Analysis of variance revealed that there is statistically significant difference observed among treatments in yield and yield components like plant height, number of tillers m^{-2}, spike length and thousand kernel weight (Table 5 & 6).

Number of tillers: All treatments were superior over un-weeded (weedy) check across locations in number of tillers they produced. Maximum number of tillers were obtained from two times hand weeded (199.7 and 215.6 m^{-2}) plots. However, the minimum number of tillers(154.7 and 183.4 m^{-2}) were observed in un-weeded plots at Shambo and Gedo, respectively. The combinations of treatments significantly increased the number of tillers compared to other treatments except two times hand weeding. This maximum number of tillers wasprimarily due to the better crop growth as a result of less competition with weeds. This is in agreement with the findings of Ijaz *et al.* (2008) who reported that better weed control increased the nutrients availability to the crop which ultimately increased the spike bearing tillers. Application of herbicides alone resulted in lower number of tillers, while doses of herbicides when supplemented with one hand weeding resulted in better tiller numbers.

Plant height: Among the treatments the highest plant heights (115.3 and 116 cm) were measured from two times hand weeded plots followed by Dical 720 gm/lt SL + one times hand weeded at (40 DAS), having (109 and 115.4 cm) at Shambo and Gedo, respectively while the minimum plant height (100 and 103 cm) were scored in weedy check plot in similar order. The maximum plant height scored is due to efficient weed control provided by these treatments. The minimum plant height is attributed to adverse crop affect caused by heavy weed competition for resource which in turn suppressed crop growth. This result is in analogy with (Oerke, 2006; Ryan et al., 2009; Smith et al., 2010).

Panicle length: Analysis of variance revealed that panicle length was statistically significantly affected by weed management practices ($p \leq 0.05$) at Shambo, while no statistically significance difference was observed for panicle length at Gedo site (Table 5). But, numerical difference was observed. Plots treated with combination of Dical 720 gm/lt SL and Fenoxaprop-P-Ethyl 69 gm/lt scored the highest panicle length (7.2 and 6.9 cm) where the lowest (6.3 and 6.0 cm) was observed in un-weeded plot at Shambo and Gedo, respectively.

Number of grain per spike: Number of grain per spike is one of the basic parameters in studying weed management practices to assess its impact on crop and weeds. Results showed that there is significant difference among treatments in of number of grain per spike. All treatments showed superiority over un-weeded plots. The maximum number of grain per spike (48.5) was obtained from the plots treated with hand weeding + Fenoxaprop-P-Ethyl 69 gm/lt followed by two times hand weeding (46.9) at Shambo site, whereas maximum (51.1) grain per spike was found in Dical 720 gm/lt SL + Fenoxaprop-P-Ethyl 69 gm/lt followed by hand weeding + Fenoxaprop-P-Ethyl 69 gm/lt (50.9) at Gedo site. The minimum number of grain per spike (42.2 and 46.0) was obtained from un-weeded plots at Shambo and Gedo, respectively. Significantly higher number of grains is the result of easily accessible growth factors (nutrient, moisture and light) for individual plant that retained more flowers and higher net assimilation rate in the absence of competition from weeds. Also the development of more and vigorous leaves under low weed infestation might have helped to improve the photosynthetic efficiency of the crop and supported higher number of grains. Similar result was reported by (Chaudhry et al., 2008; Bostrom & Fogelfors, 2002; Khan & Rashid, 1994).

Grain yield as affected by weed management practices: Grain yield was affected significantly by weed management practices. The maximum grain yield (4312.5 and 4382.6 kg ha^{-1}) was recorded in two times hand weeded plot. This maximum yield is due to effective weed management achieved by hand weeding without possible adverse effect. The minimum yield (2525.7 and 2776.9 kg ha^{-1}) was recorded in weedy check at Shambo and Gedo, respectively, attributed to maximum weed infestation that can heavily compete for resource. This is in analogy with the reports of Jarwar *et al., (*2005) which suggests weeds compete with crop plants for various resources such as water and nutrients, resulting in low yields. Chaudhary *et al*., 2008; Dalley *et al., (*2006) also reported that high weeds intensity and more competition time with crop plants cause more reduction in crop yield. Post-emergence application of Fenoxaprop-P-Ethyl 69 gm/lt alone showed the least (3532.2 and 3533.5 kg) grain yield as compared with any other treatments except un-treated check at Shambo and Gedo, respectively.

Combination of management practices provided better yield as compared with single management practices. This performance might be due to synergistic effect in weed control provided by integration of management options. This is in conformity with Singh (2014); Kewat, (2014). Integration of the two herbicides, Fenoxaprop-P-Ethyl 69 gm/lt at the rate of 1.25 L and Dical 720 gm/lt SL 1 L per hectare gave the maximum yields (4166.7 and 4303.5 kg) next to two times hand weeding at Shambo and Gedo, respectively. This is due to the fact thatcombination of herbicides resulted in broad spectrum effect that achieved effective management for almost all weed species which in turn leads to increase in grain yield. It is in analogy with the findings of Chaudhry *et al.*, 2008; Bostrom & Fogelfors, 2002; Khan & Rashid, 1994 who reported combinations of herbicides can provide good control of broad and narrow leaved weeds and cause significant reduction in their density and increase yield attributes as compared to check. The combination of herbicides with hand weeding also showed better yield compared to herbicidal application alone and un-weeded check

Harvest index as influenced by weed management ractices: Harvest index of the crop was significantly affected by treatments. There was highly significant difference among weed management practices at both study sites (Table 5 & 6). The variation in harvest index under different treatments is due to variation in the grain yield and yield related parameters. Two times hand weeding produced significantly maximum harvest index (50.7 and 54.4 %) followed by Fenoxaprop-P-Ethyl 69 gm/lt + one times hand weeding (47.3 and 53.0 %) at Shambo and Gedo, respectively. Whereas the minimum (22.0 and 27.6 %) was obtained from weedy check plots at those respective locations. In agreement with this result, Nano (2012) reported that twice hand weeding showed the highest harvest index (46%) than other treatments on the same variety.

Table 5. Effect of weed management practices on Yield related parameters of barley at Shambo

Treatments	Plant height(cm)	Panicle length(cm)	No. of grain spike-1	TKW(gm)	No. tiller (m-2)	Yield ha-1(Kg)	Harvest Index (%)
Dical	102.7bc	7.1a	43.8ba	31.7c	178.0ba	3766.7b	43.2ba
Dical+Fenox	108.0bac	7.1a	45.3ba	38.3ba	187.0ba	4166.7a	47.2ba
Fenox	105.3bc	6.9ba	45.2ba	36.7bac	182.7ba	3532.2b	40.2b
Fenox+HW(1x)	108.3bac	7.6a	48.5a	41.7a	184.3ba	4133.3a	44.2ba
Dical+HW(1x)	109.0ba	6.9ba	45.7ba	40.0a	195.0a	4116.7a	40.3b
HW(2X)	115.3a	7.2a	46.9ba	43.3a	199.7a	4312.5a	50.7a
UN WD	100.0c	6.3b	42.2b	30.0c	154.7b	2525.7c	22.0c
LSD(0.05)	8.9	0.71	5.97	7.56	35.372	249.97	9.42
CV (%)	4.7	5.7	7.39	11.367	10.86	3.704	12.876
F-test	*	**	*	**	*	**	**

*Note: - Means followed by the same letter within columns has statistically no difference. LSD= list signifance difference, CV (%)= Coefficient of variation, F-test= probability value, *,** = signifance difference* & highly *signifance difference*, respectively, *UN WD = weedy check, Fenox = Fenoxaprop-P-Ethyl 69 gm/lt, Dical + HW(1x) = Dical 720 gm/lt SL +One times hand weeding, Fenox + Dical= Fenoxaprop-P-Ethyl 69 gm/lt + Dical 720 gm/lt SL, HW(2x)= two times weeded, Fenox + HW(1x) =Fenoxaprop-P-Ethyl 69 gm/lt + One times hand weeding*

Table 6. Effect of weed management practices on Yield related parameters of barley at Gedo, Western Oromia

Treatments	Plant height(cm)	Panicle length(cm)	No. grain spike-1	TKW	No. tiller(m-2)	Yield ha-1(Kg)	Harvest Index (%)
Dical	107.9dc	6.7a	50.3a	43.3bac	202.2ba	4001.3b	51.5ba
Dical+Fenox	114.0bac	6.9a	51.1a	50.0a	206.6ba	4303.5ba	53.0ba
Fenox	109.1bdc	6.3a	49.8a	38.3dc	193.4ba	3533.5c	46.6c
Fenox+HW	110.9bac	6.7a	50.9a	46.7ba	200.0ba	4181.2ba	50.8bac
Dical+HW	115.4ba	6.6a	47.6a	41.7bdc	204.0ba	4269.8ba	46.4bc
HW(2X)	116.0a	6.8a	49.5a	48.3ba	215.6a	4382.6a	54.4a
UN WD	103.0d	6.0a	46.0a	35.0d	183.4b	2776.9d	27.6d
LSD(0.05)	6.69	0.91	6.88	7.04	14.33	313.16	6.92
Cv (%)	3.40	7.80	7.84	9.13	8.02	4.49	8.30
F-test	**	Ns	ns	**	*	**	**

Partial budget analysis

Economic analysis of different weed control treatments revealed different economic return compared to no weeding (Table 7&8). The maximum net benefit (20124.38 and 20547.08) was recorded from two times hand weeded plotat shambo and Gedo, respectively. Application of Dical 720 gm/lt SL herbicide alone at the rate of 1L ha^{-1} fetched the highest marginal rate of return (36.4162 and 35.91566%) followed by integration of Dical 720 gm/lt SL with Fenoxaprop-P-Ethyl 69 gm/lt at the rate of 1L $ha^{-1}$with 6.5375 and 4.080275%MRR at both respective locations. Thus, it was concluded that use of Dical 720 gm/lt SL alone is more economical than hand weeding and any other treatments. Some treatments were dominated due to higher costs involved.

Table 7. Partial budget analysis for weed management practices at Shambo, Western Oromia.

Treatments	Yield(kg/ha)	AdY(kg/ha)	GI(Birr)	V.cost(Birr)	Tot.cost	N.Benefit (%)	MRR (%)
UN WD	2525.7	2273.13	15229.97	0	5000	10229.97	0
Dical	3766.7	3390.03	22713.2	200	5200	17513.2	36.4162
Fenox	3532.2	3178.98	21299.17	480	5480	15819.17	D
Dical + HW(1x)	4116.7	3705.03	24823.7	640	5640	19183.7	3.79659
Fenox+ Dical	4166.7	3750.03	25125.2	680	5680	19445.2	6.5375
HW(2x)	4312.5	3881.25	26004.38	880	5880	20124.38	3.39587
Fenox+ HW(1x)	4133.3	3719.97	24923.8	920	5920	19003.8	D

Note:- Yied(kg/ha)= Grain yield per hectare, Ady =Adjusted yield, GI(Birr)=Gross income by birr, Tot.cost = Total cost N.Benefit = Net benefit, MRR(%)= Marginal rate of return, UN WD= weedy check, Fenox = Fenoxaprop-P-Ethyl 69 gm/lt, Dical + HW(1x)= Dical 720 gm/lt SL + One times hand weeding, Fenox + Dical= Fenoxaprop-P-Ethyl 69 gm/lt + Dical 720 gm/lt SL, HW(2x)= two times hand weeded

Table8. Partial budget analysis for weed management practices at Gedo, Western Oromia.

Treatments	Yield(kg/ha)	AdY(kg/ha)	GI(Birr)	V.cost(Birr)	Tot. cost	N.Benefit (%)	MRR (%)
UN WD	2776.9	2499.21	16744.71	0	5000	11744.71	0
Dical	4001.3	3601.17	24127.84	200	5200	18927.84	35.91566
Fenox	3533.5	3180.15	21307.01	480	5480	15827.01	D
Dical + HW(1x)	4269.8	3842.82	25746.89	640	5640	20106.89	2.67967
Fenox+ Dical	4303.5	3873.15	25950.11	680	5680	20270.11	4.080275
HW(2x)	4382.6	3944.34	26427.08	880	5880	20547.08	1.384865
Fenox+ HW(1x)	4181.2	3763.08	25212.64	920	5920	19292.64	D

Note:- Yied(kg/ha)= Grain yield per hectare, Ady =Adjusted yield, GI(Birr)=Gross income by birr,Tot.cost = Total cost N.Benefit = Net benefit, MRR(%)= Marginal rate of return, UN WD= weedy check, Fenox = Fenoxaprop-P-Ethyl 69 gm/lt, Dical + HW(1x)= Dical 720 gm/lt SL + One times hand weeding, Fenox + Dical= Fenoxaprop-P-Ethyl 69 gm/lt + Dical 720 gm/lt SL, HW(2x)= two times hand weeded

Conclusion and Recommendation

Weeds in general and grass weed species in particular are the major constraint in barley production in western part of our country and its control is too important to increase barley production and productivity. From the result of this experiment, it can be concluded that integration of Fenoxaprop-P-Ethyl 69 gm/lt with Dical 720 gm/lt SL or one times hand weeding was quite effective to control major broad and grass weed species observed in barley fields. From economic analysis, the highest net returns obtained from two times hand weeded plots. The maximum rate of return was obtained from the plot sprayed with Dical 720 gm/lt SL alone followed by its integration with Fenoxaprop-P-Ethyl 69 gm/lt. Thus, Dical 720 gm/lt SL post-emergence herbicide is economically feasible.

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Survey and Identification of Major Highland and Lowland Pulse Crops Diseases in Bale, Ethiopia

[1*]Ermias Teshome, [2]Addisu Tegegn and [1]Dagne Kora

[1]Sinana Agricultural Research Center, P.O.Box 208, Bale-Robe, Ethiopia.

[2]Oromia Agricultural Research Inistitute, P.O.Box 81265, Finfine, Ethiopia

[*]Corresponding author: ermiastafa@gmail.com

Abstract

*Ethiopia is one of the major producer countries of the major food legumes (Faba bean, Field pea, Lentil, Common bean and Chick pea). The nutritive value, the highest social value and an immediate cash source value of pulse crops made it very popular crops in the country. The surveys were conducted in different survey routes of highlands, mid-altitudes and low-land districts of Bale Zone for two years in 2015/16 EC and 2016/17 EC during 'Bona' and 'Gena' cropping seasons. Pulse crops farms were assessed within 5-10 km in the survey routes of the districts Sinana, Goba, Dinsho, Agarfa, Gassera, Goro, Ginir, Gololcha, Sewena & Delo-mena. The disease incidence and severity were rated based on 1-9 scoring scale and disease prevalence was calculated according to the procedure. During the 2015/16 and 2016/17 GC surveys a total of 285 pulse crops fields were visited out of which 250 farms were during the main "Bona" season. With 55% of total assessed farms Faba bean was the most predominant crop during the survey time. Among the sites visited, Ginir and Agarfa were the most visited sites covering 23% and 22% of the districts considered, respectively. The diseases intensity (Incidence, Severity and Prevalence) was assessed based on the standard method for the crops. Rust (*Uromyces fabae*) was the foremost important Faba bean disease during the survey period. Whereas, Ascochyta blight* (Ascochyta fabae) *and Chocolate spot (*Botrytis fabae*) were recorded as the second and the third important Faba bean diseases. Rust, Ascochyta blight and Chocolate spot diseases with incidence values 99.13 %, 92.56% and 93.57% and severity of 3.99, 3.87 and 2.96, respectively was the most important diseases. Whereas, prevalence of Rust, Ascochyta blight and Chocolate spot diseases were found to be 98.57%, 100%, and 93.81%, respectively which shows the dispersion of the diseases over location. On the other hand, Black root rot* (Fusarium solani) *is becoming the newly emerging important Faba bean disease in recent years. During this survey, black root rot incidence as high as 100% was recorded in Sinana district. Viral diseases were also recorded in most of the districts as another emerging faba bean disease with as high as up to about 22% incidence. In case of chick pea, Ascochyta blight was the most important disease however root rot as high as up to 31% incidence was recorded as emerging important disease.*

Key words: Survey, diseases, incidence, severity and prevalence

Introduction

Ethiopia is one of the major producer countries of food legumes such as Faba bean, Field pea, Lentil and Chick pea and Bale is among the major producing zones of these pulse crops in Ethiopia. However, the total area coverage of these crops and the average productivity is extremely low less than 0.8 t/ha. Among a number of factors for low productivity, diseases are the most important constraints. A survey conducted before 10 years to identify the major diseases of pulse in the highlands of Bale indicated several pathogens affecting these crops. Powdery mildew caused by *Erysiphae Polygoni*, Downy mildew caused by *Peronospora pisi*, Ascochyta disease complex caused by *Microspherella pinodes*, *Ascochyta pisi*, and *Phoma medicaginis* var. pinodella are the most important diseases of Field pea in Bale highlands (SARC, 2003). Diseases like chocolate spot, Ascochyta blight and rust are among the production constraints of faba bean. According to the research results from Holeta and Debre Zeyit ARC, chocolate spot and rust caused, yield loss of 34.1% and 14-21% respectively (Asfaw, *et al*., 1994). Rust caused by *Uromyces fabae* pers de bery is the most economically important disease in the highlands of Bale.

The disease can cause a complete crop failure even though yield loss on plot basis varies form 30-60%. Another experiment also has confirmed that it can cause heavy losses when it occurs before flowering/podding stage and susceptible varieties can be killed under sever epidemics (Geletu and Yadeta, 1993). Although, survey of crops diseases has to be conducted at least every 5 years, survey of pulse crops diseases has been conducted 10 years ago. Recently there are some reports and also observations of some diseases occurrence in Bale area. Therefore, this activity is proposed to check the status of pulse crops diseases.

Materials and Methods

The surveys were conducted in different survey routes of highlands, mid-altitudes and low-land districts of Bale Zone in 2015/16 EC and 2016/17 EC during ‘Bona’ and ‘Gena’ cropping seasons. A representative pulse crops farms available within every five to ten (5-10) km in the survey routes of both the highland and mid-altitude Woredas (Sinana, Goba, Dinsho, Agarfa, Gassera, Goro, Ginir, Gololcha, Sewena & Delo-mena) (Figure 1). The farms were visited by walking diagonally across the field and samples were collected where necessary. The disease severity and Incidence was rated based on the diseases scoring standard scale 1-9 scoring scales (Bernier *et al*., 1993). Most of the diseases were identified in the field and some diseases samples were identified in the SARC plant pathology laboratory.

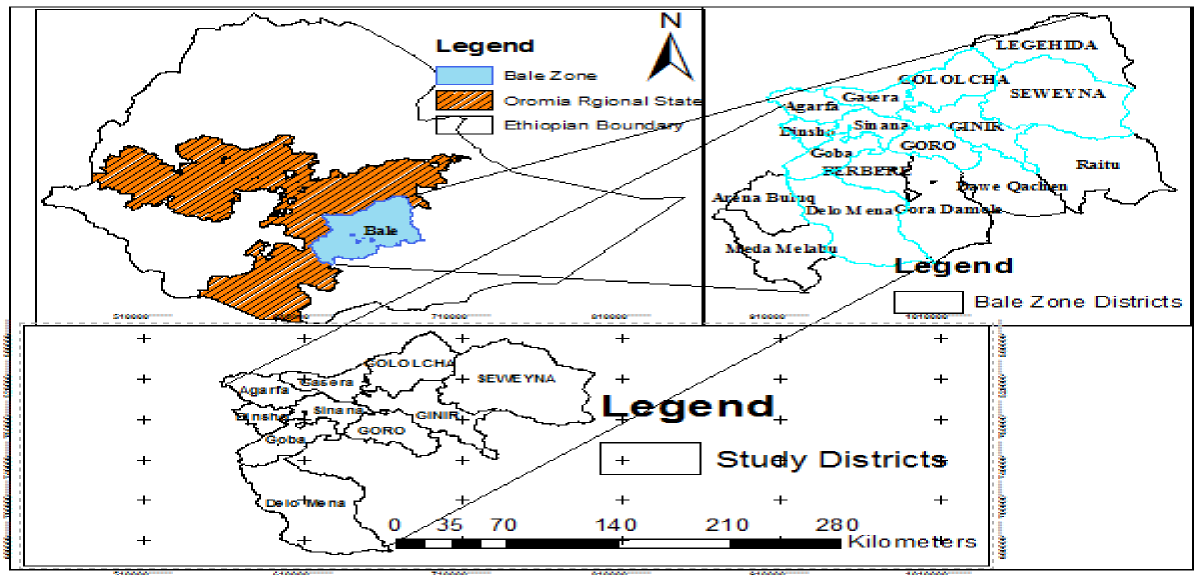

Figure 1: A map showing districts covered during the survey in 2015/16 GC and 2016/17 GC

Results

Surveys of highland and lowland pulse crops diseases were conducted during the main cropping season 'Bona' and the second season "Gena" of 2015/16 and 2016/17 GC in the highland, mid-altitude and lowland districts of Bale zone. The survey districts were highlands (Agarfa, Dinsho, Gassera, Goba and Sinana), mid-altitude (Gololcha and Ginir) and lowlands (Goro, Delo-mena and Sewena). In all the districts as much as possible the representative farms were visited and as much as necessary specimens were collected. Most of the diseases were identified on spot (on the field) and some were identified in SARC plant pathology laboratory.

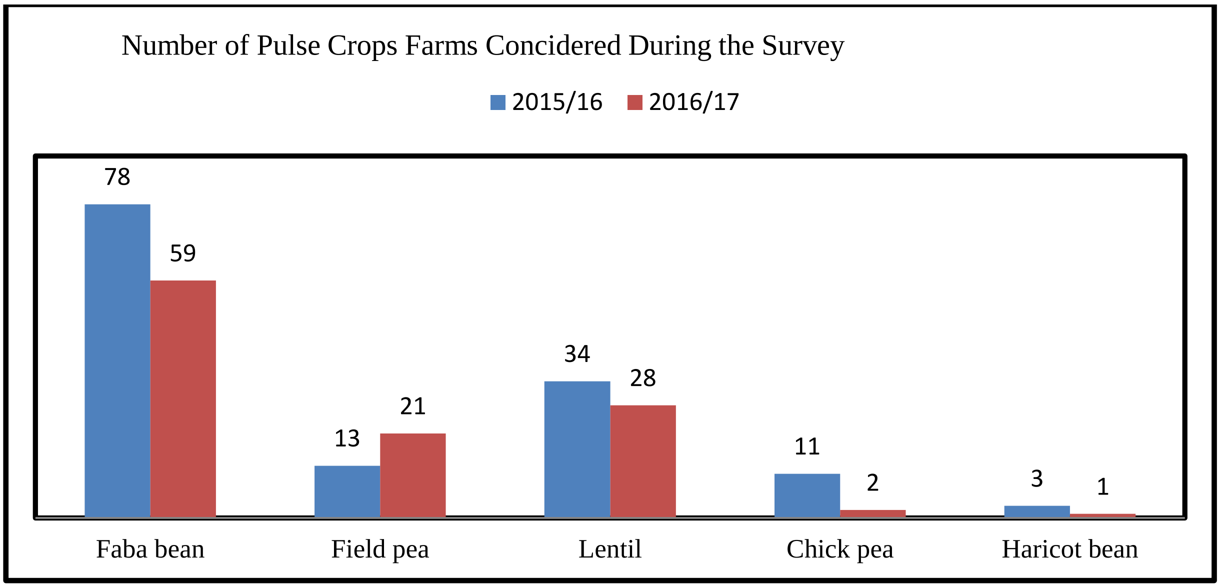

Figure 2: Pulse crops farms frequency during the 2015/16 and 2016/17 GC pulse crops diseases survey in 'Bona' Season

During the survey, a total of 285 pulse crops fields were visited in all over the districts out of which 250 farms were during 'Bona' and 35 farms were assessed during 'Gena' season. Diseases of 5 pulse crops (Faba bean, Lentil, Field pea, Chick pea and Haricot bean) were assessed (Figure 2, Figure 3, Table 1 and Table 2).

Among the pulse crops farms visited, Faba bean was the most predominant pulse crop recorded (137 farms) which accounts for about 55% the total assessed farms and common bean (4 farms) is the least recorded pulse crop in all the survey districts which accounts for 1.7% of the total surveyed farms during the main 'Bona' cropping season (Figure 2 and Table 1).

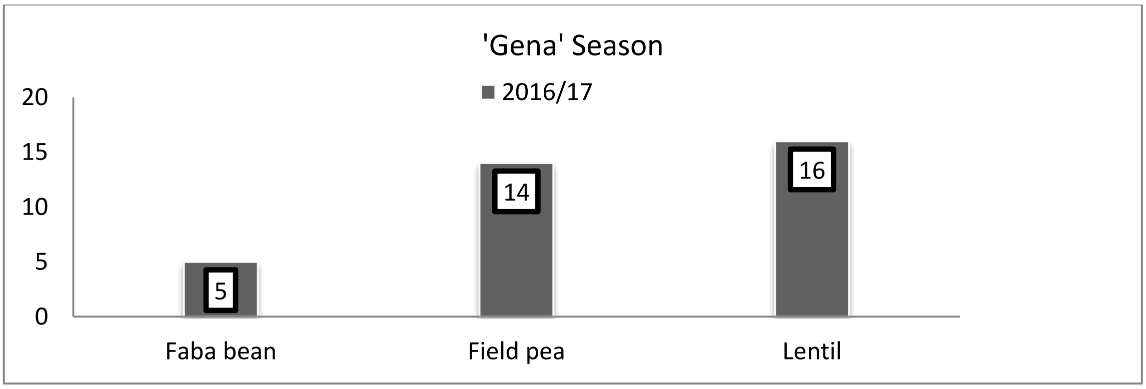

Figure 3: Pulse crops farms frequency during the 2016/17 GC pulse crops diseases survey in 'Gena' Season

Whereas, during the second cropping season 'Gena' lentil was the most predominant crop assessed for disease intensity (16 farms) which about 45.71% of the total surveyed farms and followed by field pea (14 farms) which is 40% and with 5 farms assessed Faba bean was the least crop visited. Out of the districts assessed, Ginir was the most frequent district in which 58 farms (which accounts for about 23 % of the total farms assessed) of different pulse crops were assessed and Gololcha (1.6 % of the farms) is the least assessed district with only 4 (four) assessed pulse crops fields ((Figure 4, Figure 5, Table 1 and Table 2).

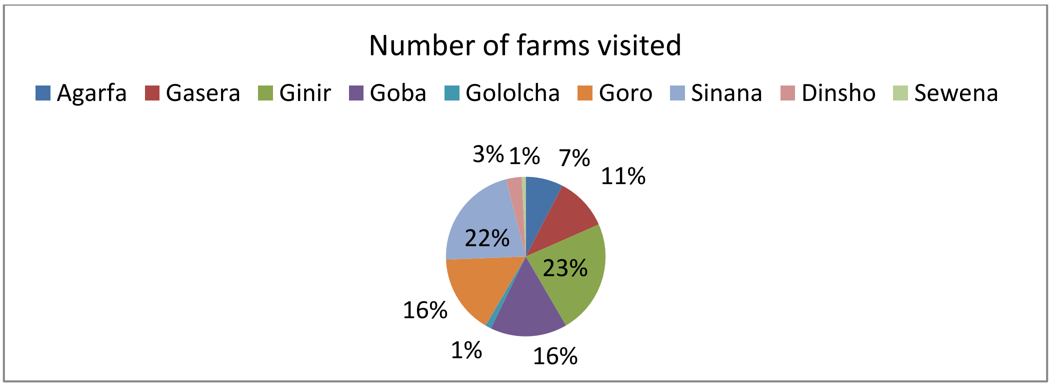

Figure 4: Districts surveyed and percent of farms addressed per district by the survey in 2015/16 GC and 2016/17 GC during 'Bona' Season

During the main cropping season, among the districts, the highest frequency of Faba bean farms were assessed from Sinana district in which 38 Faba bean farms were assessed which account for about 15 % of the total Faba bean farms and the least frequency of Faba bean farms (0 and 2) were assessed from Sewena and Gololch, respectively (Table 1); which accounts for 0% and 0.8%, respectively. On the other way, the largest frequencies of Lentil farms (31) were recorded in Ginir district which accounts for about 12% of the total lentil farms.

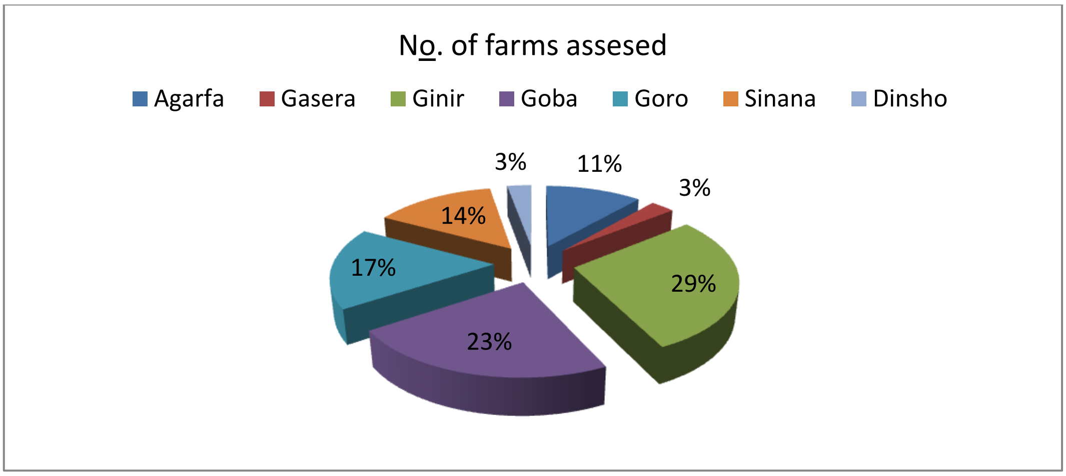

Figure 5: Districts surveyed and percent of farms addressed per district by the survey in 2015/16 GC and 2016/17 GC during 'Bona' Season

Whereas, Sewena and Gololch are districts with the least (1 and 0, respectively) frequency of lentil farms assessed which is about 0.4% and 0% of total lentil farms (Table 1). During 'Gena' season the most assessed district district was Ginir, where 7 farms of lentil and 3 farms of Field pea were visited which accounts for about 28.57% of the total assessed farms while the list assessed district was Dinsho and Gassera where only one farms each was assessed (Table 2).

The diseases intensity (Incidence, Severity and Prevalence) was assessed based on the standard method according to (Bernier, 1993). From main cropping season 'Bona' survey unlike from the previous' information we have; from the current survey result it was recorded that Rust (*Uromyces fabae*) was found to be the foremost important Faba bean disease during 'Bona' season with high incidence and severity value of the disease (Table 3). Whereas, Ascochyta blight (*Ascochyta fabae*) and Chocolate spot (*Botrytis fabae*) were recorded as the second and the third important Faba bean diseases (Table 3).

Although from previous information Chocolate spot was the foremost important disease of Faba bean, the current survey resulted that Rust and Ascochyta blight diseases come to be the most important diseases of Faba bean however this diseases appear at the stage that does not damage the crop as chocolate spot. This might be due to the reason that the survey was conducted late in the season at the time when chocolate spot was hidden by maturity and natural wilting.

Table 1: Frequency of Pulse Crops Farms per district and Districts covered by the survey during 2015/16 G.C and 2016/17 GC survey in 'Bona' season

Districts	Faba bean	Field pea	Lentil	Chick pea	Haricot bean	Total
Agarfa	12	1	1	2	0	16
Dinsho	11	0	0	0	0	11
Gassera	20	6	1	0	0	27
Sinana	38	7	8	1	0	54
Goba	33	5	1	0	0	39
Goro	11	2	19	7	1	40
Ginir	10	12	31	3	2	58
Sewena	0	0	1	0	1	2
Gololcha	2	1	0	0	0	3
Total	137	34	62	13	4	250

Table 2: Frequency of Pulse Crops Farms per district and Districts covered by the survey during the 2016/17 GC survey in 'Gena' season

Districts	Faba bean	Field pea	Lentil	Chick pea	Haricot bean	Total
Agarfa	-	3	1	-	-	4
Dinsho	1	-	-	-	-	1
Gassera	-	1	-	-	-	1
Sinana	1	2	2	-	-	5
Goba	1	4	3	-	-	8
Goro	2	1	3	-	-	6
Ginir	-	3	7	-	-	10
Total	5	14	16	-	-	35

On the other hand, Black root rot (*Fusarium solani*) is becoming the newly emerging important Faba bean disease in recent years. During this survey, black root rot incidence as high as 100% was recorded in Sinana district (Hisu). Viral diseases were also recorded in most of the districts as another emerging faba bean disease with as high as up to about 22% incidence. In case of chick pea, Ascochyta blight was the most important disease however root rot as high as up to 31% incidence was recorded as emerging important disease. Similarly other diseases of pulse crops were assessed and summarized in Table 3 below. During 2016/17 GC 'Gena' season survey, Rust was found to be the foremost important disease of Faba bean with high incidence (100%) and Severity (3.3) values.

Table 3: Percent Diseases Incidence, Severity and Prevalence of pulse crops diseases in 2015/16 GC and 2017/18 GC during 'Bona' Season Survey

Diseases	Faba bean			Field pea			Lentil			Chick pea			Common bean		
	Inc.	Sev.	Pre.	Inc.	Sev.	Pre.	Inc.	Sev.	Pre.	Inc.	Sev.	Pre.	Inc.	Sev.	Pre.
Chocolate spot	93.57	2.96	93.81	-	-	-	-	-	-	-	-	-	-	-	-
Rust	99.13	3.99	98.57	-	-	-	28.33	1.00	20.42	-	-	-	95.00	4.25	100
Ascochyta blight	92.56	3.87	100.00	98.22	4.03	100.00	50.60	1.08	41.10	44.25	1.75	75.00	-	-	-
Black Root rot	11.93	-	63.49	-	-	-	-	-	-	-	-	-	-	-	-
Pow M.D	100.00	3.00	20.00	78.17	4.00	58.06	25.75	2.09	12.41	-	-	-	-	-	-
Downy mildew	-	-	-	97.00	3.85	38.43	-	-	-	-	-	-	-	-	-
Root rot	-	-	-	-	-	-	5.00	-	36.25	31.07	-	57.92	-	-	-
Stemp.leaf blight	38.13	1.75	22.38	-	-	-	-	-	-	-	-	-	-	-	-
Anthracnose	-	-	-	-	-	-	-	-	-	-	-	-	28.75	1.00	50
Leaf blight	-	-	-	-	-	-	-	-	-	-	-	-	50.00	1.67	50
Virus1	21.98	-	18.28	-	-	-	-	-	-	-	-	-	-	-	-
Virus 2	1.50	-	6.25	-	-	-	-	-	-	-	-	-	-	-	-

- The crops has not the specified disease

And the second important disease was Ascochyta blight disease with incidence (100%) and severity (3) values where chocolate spot had incidence (20%) and severity (2) values far below the above two diseases (Table 4). Similarly, important diseases of pulse crops during 'Gena' season are summarized in Table 4 below.

Table 4: Percent Diseases Incidence, Severity and Prevalence of pulse crops diseases in 2016/17 GC during 'Gena' Season Survey

Diseases	Faba bean			Field pea			Lentil		
	Inc.	Sev.	Pre.	Inc.	Sev.	Pre.	Inc.	Sev.	Pre.
Chocolate spot	100.0	2.0	20.0	-	-	-	-	-	-
Rust	100.0	3.3	60.0	-	-	-	50.0	4.0	3.13
Ascochyta blight	100.0	3.0	100.0	100.00	3.29	100.00	100.0	1.8	37.50
Black Root rot	15.0	15.0	6.0	-	-	-	5.0	5.0	0.31
Powdery mildew	-	-	-	83.16	3.50	47.50	100.0	2.0	6.25
Downy mildew	-	-	-	100.00	4.00	7.14	-	-	-

Summary and Conclusion

Ethiopia is one of the major producer countries of food legumes such as Faba bean, Field pea, Lentil and Chick pea. Similarly, Bale is among the major producing zones of these pulse crops in Ethiopia. However, pulse crops are threatening by a number of biotic and abaiotic constraints. Among which, diseases are the most important constraint. Survey conducted before 10 years to identify the major diseases of pulse in the highlands of Bale indicated several pathogens affecting these crops. Powdery mildew caused by *Erysiphae Polygoni*, Downy mildew caused by *Peronospora pisi*, Ascochyta disease complex caused by *Microspherella pinodes*, *Ascochyta pisi*, and *Phoma medicaginis* var. pinodella are the most important diseases of Field pea in Bale highlands (SARC, 2003). To identify the status of pulse crops diseases in the highlands of Bale, a survey was conducted during 2015/16 and 2016/17 GC in both main season 'Bona' and short season 'Gean'. The survey was covered all districts of the zone where pulse crops are grown and as much as possible farms were assessed. From the result of the current survey we have observed that there are a number of dynamisms in the pulse crops disease. Chocolate spot has been the foremost important disease of Faba bean for a long years in the southeastern part of the country and everywhere Faba bean is grown. However, at this time the trend is on the way to change where Rust and Ascochyta blight were found the most important diseases of the crop during this survey. On the other way, some viral diseases and black root rot of faba bean is becoming an emerging disease of the crop in most areas where the crop is under production.

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Evaluation and Demonstration of Different Post-emergence Herbicides for Controlling Wild oat (*Avena fatua* L.) and Other Grass Weeds in Wheat (*Triticum spp*) at Bore, Ethiopia

Yared Tesfaye[1], Kebna Assefa[1], Girma Teshome[1] and Obsa Cimdesa[1]

[1]BoreAgriculturalResearchCentre, P.O.Box21,Guji-Bore,Ethiopia

Abstract

In the high lands of Ethiopia, weed causes considerable yield losses on wheat production due to absence of better management options for the producers. This also true, in the highlands of Guji Zone, Southern Oromia. Field experiment was conducted to study the effect of different post-emergence herbicides to control wild oat and other grass weeds in wheat (Triticum aestivum L.) at Bore Agricultural Research Center on station and Ana Sora district on farm during 2015/16 cropping season to identify the most effective herbicide for the control of the targeted weeds thereby improving wheat production of the area. The experiment was laid out in randomized complete block design using three replications. Pallas 45OD, Current 8EC, Ralon super144, hand weeding at tillering and weedy check were used as treatments. The combined analyzed data showed that significant variation among treatments for all parameters tested. Among herbicides, Pallas 45OD showed better control of wild oat and other grass weeds. In other cases, hand weeding and hoeing at tillering resulted in lowest weed density. Highest grain yield (4210.7 kg ha^{-1}) was recorded in Pallas 45OD followed by Current 8EC (4000.3 kg ha^{-1}). Partial budget analysis revealed that ,applying Pallas 45OD had the highest net field benefit (30591.9 ET birr) followed by Current 8EC(29512.3ET birr ha^{-1} compared to Ralon Super 144(26265.1ET birr ha^{-1}),Three times hand weeding (22911.6 ET birr ha^{-1}) and weedy check (22919.4ET birr ha^{-1}).However, Current 8EC had showed maximum economic profitability than Pallas 45OD and other types with marginal rate of return(MRR) of 6494.4%. Therefore, Current 8EC at rate of 1itre ha^{-1} is the best herbicide for the effective control of wild oat and other grass weeds in wheat under proper cultural practices and there by improve yield production of wheat up to 25.1% at high lands of Guji Zone, Southern Oromia.

Key words: Herbicide, Weed, Economic profitability or MRR (%)

Introduction

Wheat (*Triticum aestivum* L.) is the most important cereal crop cultivated worldwide and there by sustaining the livelihood of the world hungrier. Wheat serves as staple food for more than 40% of the world population (Peng *et al*., 2011). Of the total cereal crop in Ethiopia, wheat ranked fourth next to sorghum both in terms of area (1.66 million hectare) and production (42.19 million qt) (CSA, 2016). The national average yield of the crop is about 2.5 t ha^{-1} (CSA, 2016). This is by far below the global average which is about 3.5 t ha^{-1}. Multifaceted biotic and biotic factor are responsible for this low yield. cultivation of unimproved low yield varieties, insufficient and erratic rainfall, poor agronomic practices, disease and insect pests are among the most important constraints to wheat production in Ethiopia (Hailu,1991; Dereje and Yaynu, 2000).

Weeds are one of the major factors reducing crop yield, deteriorate quality of crops and reduce farmers' income. Weed infestation is a very serious and less attended issue in the country. It has been estimated that delaying in weed causes up 35 % yield loses in wheat annually (Kebede Desta, 2000). They compete with crop plants for light, nutrient, moisture and space which they could be either of broad leaf or grasses (Arnon 1972). The major weeds compete with wheat are: Wild oat *(avena fatua), Phalaris minor, Cirsium arvense, Convolvulus arvensis, Ammi visnaga, Chenopodium album, Carthamus oxycantha* and*Euphorbia helioscopiais* are grassy weeds which have now became a threat to the nutritional requirement of mankind.

Wild oat *(Avena fatua)* has increased tremendously in rain fed areas in the country. It is an annual grass and difficult to eradicate because the seeds shatter before crop maturation and many of the seeds are plowed into the soil where they lie dormant for one to many years and germinated when they are turned up near the surface (Arnon 1972).

Weed control is a major component in the production system of wheat whether it may manually, mechanically or physically. The use of herbicide is considered to be the most viable option for controlling weeds in wheat production. However, the existence of many grass weeds, specially, wild oat (*avena fatua*) create obstacle to increase production and productivity of wheat.

Despite of development of high yielder, insect pest resistance varieties and other agronomic packages production of wheat in Southern Oromia is challenged with several grass weed infestation. They are more problematic in wheat production than broadleaf species because of the selective nature of available herbicides and the difficulties of distinguishing between species while hand weeding. Hence many weed management practices such as, two times hand weeding, Mecoprop, 2,4-D, Brittox and the ready tank mixture of Mecoprop and 2,4-D, all at respective manufacturer recommendation rates can be a best management option in wheat production, control only broad leaves species while grass weeds, especially, wild oat(*Avena fatua)* compete with crop and causes significant yield losses in southern Oromia farming community.

Therefore, the present study was conducted to address the following objectives:

- To evaluate the efficacy of different herbicides on wild oat and other grass weeds
- To identify and recommend economically visible herbicides for wheat production to the study area

Materials and Methods

Description of the study area: The experiment was conducted at Bore Agricultural Research center on station and Ana Sora district on farm during 2015 and 2016 the main cropping season. Bore is located at about 387 km from the capital, Fifine to South while Ana Sora is about 25 km from Bore which is 402 km from Finfine to similar direction. Both locations represented high land agro-ecologies of Guji Zone having an altitude range of 2200-2780 M.a.s.l. Both locations receive an annual rain fall of 1200-1750 mm per annum. Maize, barley and wheat are majorly produced cereal crops in the area.

For this experiment, two types of weed management practices (cultural and chemical) involving five treatments were used. Pallas 45OD, Current 8EC, Ralon super144, hand weeding at tillering and weedy check were the utilized treatments. Improved bread wheat variety (Senate) was used as seed source. Twenty liter capacity manual knapsack sprayer was used for applying the herbicide. Quadrant having a size of 2.5m^2 was used to score weed population.

Experimental design and treatment application

The trial was arranged in Randomized Complete Block Design (RCBD) with three replications on 5 m x 5 m plot size. 1 m and 1.5 m were used between the plots and the blocks respectively. All inputs and agronomic practices were applied as per of its recommendation for wheat production. All herbicides were emulsified in water at recommended rate and applied once time at 30 days or (between 2-4 crop leaves stage) after sowing using manual knapsack sprayer and weed infestation was assessed and scored by number and species by throwing quadrate with 50 cm x 50 cm area three times per plot.

Data collection and analysis: Data was collected on various parameters including tillers per plant, plant height, number of grains per spike, thousand kernel weights, grain yield and straw yield. Four harvestable rows were used for yield and other agronomic data source. Adjusted data was subjected to analysis of variance (ANOVA) as suggested by Gomez and Gomez (1984) using SAS soft ware (version 2009). Least significant difference at 5% probability level was used to test the mean separation.

Harvest index (%) was calculated by the following formula;

$$HI = \frac{\text{Grain yield}}{\text{Total above ground dry biomass}} * 100$$

Economic data were collected to compare the economic advantage of each herbicide in different treatments. These included variable input costs and costs for the herbicides and labour during the execution of the experiment. Costs of herbicides were obtained from pesticide companies and local distributing agencies. Based on the data obtained from both locations, economic analysis was computed using partial budget analyses and Marginal Rate of Return (MRR) (CIMMIT, 1988). The following formulas were used to compute partial budget and marginal rate of return (MRR) analysis, respectively.

Net field benefits (NBs) = Gross field benefits (GB) - Total Variable costs (TVC) MRR = DNI/DIC

Where: MRR = the marginal rate of return;

DNI = difference in net income compared with control; and

DIC = difference in input cost compared with control.

Results and Discussion

Analysis of variance: Combined analyzed data of two locations revealed that, all the utilized treatments showed statistically significant variations (P<0.05) for all the parameters tested except spike length that showed highly significant variation (P<0.01). Similarly, highly significant effect of the herbicides was observed across the locations (Table 1).

Table1. Mean squares of different parameters of bread wheat as affected by herbicide and location at Bore and Ana-Sora during 2016/17 cropping season

Source of variation	DF	NT	NFT	PH(cm)	PL(cm)	SL(cm)	BIM	TKW(g)	GY/P
Herbicide	4	2.82*	2.8*	72.27*	0.68 *	259.22**	45.97*	386.67 *	1322.33 *
Replication	2	0.14ns	0.28 ns	36.44 ns	0.006 ns	2.53ns	5.02 ns	120 ns	266.57 ns
Location	1	121.97**	158.33**	2815.14**	12.58**	288.3**	630.73**	653.33 *	8672.56 **
Error	10	0.88	0.77	11.69	0.36	28.42	16.07	120	336.39

**, **, Significant at p<0.05, P<0.01, LSD= Least significance difference (P<0.05), NT= Number of tillers, NFT= Number of fertile tiller, PH= Plant height (cm), PL=Peduncle length (cm), SL= Spike length (cm), GPS= Grain /spike, TKW=Thousand kernel weight, GY/ha=Grain yield per hectare (Kg)*

Plant height: Highly significant variation was observed across location among herbicides treatment plants for plant height (Table 2). Similar result was also reported by Zahara Mohammed and Shugute Addisu, 2016 who also found highly significant variation among different herbicides for plant height over the locations tested. However, non-significant variation among the tested herbicides was reported by Sareta *et al.,* 2016. Analysis of the data indicated significantly heights (97.22 cm) plant height observed from plot treated with Pallas 45 OD followed by Current 8EC (92.99 cm) and Ralon Super 92.78 cm. Whereas, significantly lowest plant height was depicted by hand weeding (89.51cm) followed by weedy check (88.36 cm).

Peduncle length: Analysis of variance showed highly significant differences peduncle length was observed due to herbicide (Table 2). Means for peduncle length of the treatments was ranged from 6.70 to 7.59 cm with the mean value of 7.12 cm (Table 2). Among the treatments, the maximum peduncle length (7.59 cm) was recorded from Pallas 45OD followed by Current 8EC (7.31cm) and Ralon Super 144 (7.02 cm); while the minimum peduncle length (6.70 cm) was recorded by weedy check (6.15 cm) followed by hand weeding (6.99 cm).

Spike length: Height of spike is an important part of plant growth parameter for cereal crops that could determines the grain holding capacity of a particular variety. Thus, in current study significant effect was observed on spike length due to weed management and locations. According to analysis of the data, maximum spike length was obtained from plots treated with Pallas 45OD (52 cm) followed by Current 8 EC (51.83 cm). But, short spike length was scored from un-treated plots or weedy check (39 cm) followed by hand weeding (39.83cm).

Table 2.Mean effect of different weed management practices on different parameters of Bread wheat at Bore and Ana Sora during 2015/16 cropping season

Treatments	NT	NFT	PH	PL	SL	GPS	TKW	GYLD	HI (%)
Pallas 45OD	5.75[a]	5.42[a]	97.22[a]	7.59[a]	52.00[a]	31.57[a]	53.33[a]	4210.7[a]	35.98a
Current 8EC	5.54[a]	5.33[a]	92.99[b]	7.31[ab]	51.83[a]	29.21[ab]	46.67[ab]	4000.3[a]	35.01a
Ralon Super 144	5.0[ab]	4.67[ab]	92.78[b]	7.02[ab]	41.17[b]	26.74[b]	40.0[bc]	3569.3[ab]	33.83a
Hand weeding	4.9[ab]	4.61[ab]	89.51[bc]	6.99[ab]	39.83[b]	26.19[b]	36.67[bc]	3544.0[ab]	33.62a
Weedy check	3.99[b]	3.72[b]	88.36[c]	6.70[b]	39.0[b]	24.50[b]	33.33[c]	2996.0[b]	28.39b
Mean	5.04	4.75	92.17	7.12	44.77	27.64	42.00	3664.07	33.37
CV (%)	18.63	18.51	3.71	8.42	11.92	14.50	26.08	15.83	10.53

LSD= least significant difference, CV=coefficient of variation, NT= Number of tillers, NFT= Number of fertile tiller, PH= Plant height (cm), PL=Peduncle length (cm), SL= Spike length (cm), GPS= Grain /spike, TKW=Thousand kernel weight, HI (%) = harvest index. GY/ha=Grain yield per hectare (Kg)

Yield and yield components: According to the result of the analysed data, all the treatments had showed significant ($P<0.05$) effect on number of tillers at both locations. Number of tillers per plant was scored in a range of 3.99 to 5.75 with the mean value of 5.04. Maximum number of tillers per plant was scored from plots treated with Pallas 45OD (5.75) followed by current 8 EC (5.54) and Ralon Super 144(5). However, minimum number of tillers per plant was scored from weedy check (3.99). Similar research report was reported by Sareta *et al.,* 2016, where he found significant effect of different herbicides on number of tillers.

Grain per spike was significant affected by herbicides treatments ($P<0.05$). The highest grain per spike was recorded from Pallas 45OD (31.57) treated plot. The lowest grain per spike was recorded from un-treated plot (24.5) followed by plot treated by hand weeding (26.19) and Ralon super (26.74) (Table 2).As it is revealed by the study result, applying recommended rate of Pallas 45OD at effective stage of weed emergence would significantly affect weed population and improve number of wheat grain development through proper utilization of available nutrients without any competition

Thousand kernel weight: The combined analysis over locations was showed significant variation of thousand kernel weight comparing herbicide and weedy check. However, there was no significant variation between herbicides. The mean value of thousand kernel weight (TKW) due to herbicide application was ranged from 33.33 to 53.33(Table 2).The maximum TKW was obtained from the plot treated by Pallas 45OD (53.33) followed by Current 8EC(46.67).The lowest number of TKW was obtained from un-weeded or weedy plots (33.33).

Harvest index: Combined analysis of the study revealed that, statistically non-significant difference was observed on harvest index of bread wheat due to the application of different herbicides and hand weeding except weedy check. The mean value range of 28.39% to 35.98% of harvest index with mean value of 33.35% was obtained from the study. High harvest index was obtained from plot treated by Pallas 45OD followed by the rest of herbicides and hand weeding. Lowest value of harvest index (28.39%) was obtained from un-treated plot.

Grain yield: According to the combined analysis of this study, statistically significant variation of grain yield was observed among the herbicides with the range of 2996 kg ha^{-1} to 4210 kg ha^{-1} with mean value of 3664.07 kg ha^{-1}(Table 2). The highest grain yield was recorded from Pallas 45OD (4210 kg ha^{-1}) followed by current 8 EC (4000kg ha^{-1}). The lowest grain yield was recorded from weedy check treatment (2996kg ha^{-1}).This result is concord with the result of Sareta *et al.*, 2016 who found high grain yield per hectare from herbicide treatment and low yield from weedy check treatment.

Weed control efficiency

Effect of different herbicides on weed control was observed (Table 3).The highest weed control efficacy (82.95%) was recorded from hand weeding followed by Pallas 45 OD (74.01 %) during early stage of wheat growth, while the lowest (48%) control efficiency observed from weedy check and Ralon super EW 144. Similarly the highest weed control efficiency was observed from plot treated with Pallas 45OD and hand weeding during head emergence and dough stage. Interestingly, as stage of crop development increase there was decrement in weed control efficiency and Pallas 45 OD application was better than all applied herbicides at both sites against both grassy and broadleaved weeds. These finding are in accordance with (Ashiq and Noor, 2007) who reported that herbicides with broad spectrum provided better weed control efficiency than control treatment.

Table 3. Weed control efficacy of different herbicides at different growth stage of wheat at Bore and Ana-Sora during 2016/17 cropping season

Treatments	Weed control efficiency (%)		
	Early jointing stage	Head emergence stage	Dough stage
Pallas 45 OD	74.0	66.8	47.5
Current 8 EC	48.1	42.0	25.9
Ralon super EW 144	48.0	36.0	27.5
Hand weeding	83.0	67.9	46.3
Weedy check	-	-	-

Weed density: Major weed density in bread wheat was significantly (P<0.05%) affected by weed management options. Among the weed management options the minimum weeds density (2.61 m^{-2}) was recorded in hand weeding followed by Pallas 45 OD (3.05 m^{-2}) , Current 8 EC (4.03 m^{-2}) and Ralon Super EW 144 while the maximum total weed density (6.53 m^{-2}) was in weedy check (Table 4). These finding are in accordance with result of (Ashiq and Noor Ahmad, 2007) who stated that weed population is lower in herbicides treated plot than control plot.

Table 4. Effect of different herbicides on weed density (m^{-2}) at different crop growth stages of bread wheat at Bore and Ana Sora during 2016/17 cropping season

	Weed density (m^{-2})		
Treatments	Jointing stage	Ear head emergence stage	dough stage
Pallas 45OD	0.63(15.83)	0.60(14.96)	0.77(19.20)
Current 8EC	1.20(30.00)	1.30(32.54)	1.76(43.95)
Ralon super EW 14	1.19(29.65)	1.20(30.22)	2.03(50.83)
Hand weeding	0.21(5.25)	0.44(10.89)	0.74(18.42)
Weedy check	1.83(45.74)	2.66(66.55)	3.62(90.48)

Value in breaks are transformed

Weed species: As part of the study, identification of weed species which were observed in quadrant was also conducted. Because it is imperative to know the nature of the existing weeds species per unit area towards seeking effective management practice. Accordingly, about 11 weed species which have different families, life cycle and life category were identified from both trial sites. Out of these species 63.63% were categorized under grass weeds and 36.36 were broad leaved species. However, all of the identified weed species from both sites have annual life cycle (Table 4).

Table 4. Major weed species identified from the experimental sites (Bore and Ana Sora) during 2016/17 growing season

Scientific name	Family	Life form category
Avena fatua L.	*Poaceae*	Grasse weeds
Bromus pectinatus, (Pilg *)*	*Poaceae*	Grass weeds
*Snowdenia Polystachya(*Fresen.)	*Poaceae*	Grass weeds
Phalaris paradoxa L.	*Poaceae*	Grass weeds
Galinsonga parviflora Cav.	*Asteraceae*	Broad leaved
Bidens pilosaL	*Asteraceae*	Broad leaved
Chenopodium album L.	*Chenopodiaceae*	Broad leaved
Guizotiascabra(Vis)Chiov	*Asteraceae*	Broad leaved
PolygonumnepalenseL.	*Polygonaceae*	Broad leaved
Galium	*Rubiaceae*	Broad leaved
Tagetes minuta L.	*Asteraceae*	Broad leaved

Partial budget analysis

Yield and economic data were collected to compare the economic advantage of each herbicide with control treatment. Accordingly, cost of each herbicides were estimated based on the season price which was 1100 ET birr for 0.5 litre Pallas 45OD, 570 birr for 1 litre Current 8EC,and 520 birr for 0.5litre Ralon super 144. Labour cost for three times hand weeding was calculated as 35 birr/person/day*40*3 which was = 4200. The average grain price of wheat was 850 birr per 100 kg in 2016/17 season. Average daily labourer cost and rent for knapsack sprayer for herbicide application was 520 birr ha^{-1}. To minimise un-necessary exaggerations of grain yield, productivity of the location mean grain yield obtained was adjusted by 10%. Labour costs for three times hand weeding were determined by man-days and it was 4200 ha^{-1} indicating that application of Pallas 45OD had the highest net field benefits. But, the marginal rate of return (MRR) analysis revealed that Current 8EC was more profitable for farmers, and resulted in a MRR of 6494.4% (Table 5).

Table 5: Partials budget analysis of different herbicides for control of weeds at Bore and Ana Sora, Southern Oromia

Treatments	Rate of herbicide L ha^{-1}	Net benefit in birr	Total variable cost in birr	MRR (%)
Weedy check	0.00	22919.40	0.00	0.00
Ralon Super 144	0.50	26265.10	1040.00	321.70
Current 8EC	1.00	29512.30	1090	6494.40
Pallas 45OD	0.50	30591.90	1620	203.70
Hand weeding (3x)	0.00	22911.60	4200	D

Conclusions

In the present study different herbicides had showed significant effect on different characters of bread wheat variety as affected by weed management efficiency. Highest grain yield was obtained from plot treated with Pallas 45 OD (4201 kg ha^{-1}) followed by current 8 EC (4000kg ha^{-1}). Partial budge analysis indicated that applying Pallas 45OD had the highest net field benefit (30591.9 ET birr) followed by Current 8EC (29512.3ET birr ha^{-1}). However, Current 8EC had showed maximum economic profitability than Pallas 45OD and other types with marginal rate of return (MRR) of 6494.4%.

Therefore, Current 8 EC at rate of 1itre ha^{-1} is profitable herbicide for the effective control of wild oat and other grass weeds in wheat and there by improve yield production of wheat up to 25.1% under proper land management during the season market price of wheat and herbicide at high lands of Guji Zone, Southern Oromia.

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Evaluation of Fungicides against Bread Wheat Rusts at Guji Zone, Southern Oromia

Yared Tesfaye[1], Girm Teshome[1], Obsa Cimdesa[1] and Kebna Asefa[1]

[1]BoreAgriculturalResearchCentre, P.O.Box21, Guji-Bore,Ethiopia

Abstract

Wheat is one of the most important cereal crops in terms of the area coverage, volume of production and the number of farmers engaged in its production. However, the production and productivity of wheat is affected by various biotic and abiotic stresses. Among the biotic stresses, the three rusts (yellow rust, stem rust and leaf rust) caused by Puccinia striiformis f.sp. tritici, Puccinia graminis f.sp. tritici, and P.triticina *respectively were the most destructivediseaseofwheat (TriticumaestivumL.). Field experiment was conducted to evaluate the efficacy of fungicides against wheat rusts at Guji zone on Bore on-station and Yirba on-farm in 2016 main cropping season. Four different fungicides including un-sprayed plot were used as a treatment. The experiment was laid out in RCBD with three replications at both locations. Theeffectsoffungicideon wheat rust and yieldof susceptible breadwheat (Kubsa) werestudiedinbothmajorwheatgrowing districts (Bore and Yirba) of Guji Zone. Disease onset was vary from early to late, strip rust was start from tillering, leaf rust was observed at jointing and stem rust was occur late after head emergency atbothlocations. Fungicide spray treatments significantly reduced both yellow rust and stem rust diseases severity to the lowest level possible over the un-sprayed check. Further, there was statistically significant difference (p = 5%) between the test fungicides and un-sprayed check in reducing wheat rust (yellow rust, stem rust and leaf rust) severity. There is significant difference (p = 5%) in plant height, panicle length, total number of tiller, number of fertile tiller, seed per spike, grain yield and thousand kernel weight between fungicide treatments and un-treated. The disease resulted in relative grain yield losses of up to 72.05% at Boreand 72.25% atYirbaonun-sprayedplots.Generally, commercial fungicides like Rex Duo and Tilt gave nearlycompleteprotection onthe susceptible bread wheatvarieties. However, Tilt had maximum economic profitability than Rex Duo with the marginal rate of return (MRR) of 6494.4%.*

Keywords:Puccinia striformis, Puccinia graminis f.sp. tritici, P.triticina,Triticum aestivum, and Fungicide.

Introduction

Bread wheat (*Triticum aestivum* L.) is one of the most widely grown and most consumed food crops all over the world. It is the most important crop among the cereals by area coverage and followed by maize (*Zea mays* L.), barley (*Hordeum vulgare* L.) and sorghum (*Sorghum bicolor* L.) in its economic importance (FAO, 2009). Annually, wheat is produced on 224.53 million hectares of land and 672.2 million metric tons of wheat is produced in the world (USDA, 2010). According to this report the world average wheat production is 2.99 tons /ha. Wheat ranks fourth in area production next to tef, maize and sorghum. About 4.6 million farmers produce 4.2 million tons of wheat across 1.6 million hectares of land with average productivity of 2.45 tons/ha (CSA, 2014). However, the production and productivity of wheat is curtailed by various biotic and abiotic factors. Among the biotic factors, wheat rust diseases are the most series and wheat production bottlenecks. Wheat rust (stripe rust, leaf rust, stem rust) caused by *P.striformis*, *P.graminis* f.sp *tritici*, *P.triticina* respectively are highly destructive disease of wheat (*Triticum aestivum* L.). Under favorable conditions, stem rust can cause yield losses of up to 100% in susceptiblevarieties (Roelfs, 1985; Leonardand Szabo, 2005). Whereas, yield loss of up to 71% was recorded in bread wheat due to yellow rust in Bale highlands (Bekele, 2003; Dereje, 2003). However, in severe cases 100% yield loss was recorded on the highly susceptible varieties due to yellow rust (CIMMYT, 2010). Through the widespread use of resistant varieties, however, stem and yellow rust are currently largely under control worldwide except in eastern Africa.Forreasonsthatdue to either introduction of exotic races or evolvement of new local races and changes in environmental factors (Wubishet and Chemeda, 2016).

Trials were conducted during 2016 in different areas of Ethiopia showed that wheat rust has been increasing. The major strategy for the management of wheat rust in Ethiopia would remain focused on the development of resistant varieties and chemical options.To come up with this; several fungicides have been evaluated against rusts and are being used in wheat production. Hence, evaluation of new fungicides against wheat rust is important to sustain wheat production and productivity. Thus, the objective of this study is to evaluate the efficacy of fungicides against wheat rust diseases and evaluate and promote economic and agronomic feasibility of fungicide against wheat rust control at Guji highlands.

Materialsandmethods

Field experiments were executed at Gujihighlands of Ethiopia under rain fed conditions during 2016and 2017main croppingseasons at Bore Research Center on station and Yirba farmer'sfield. Bore located at 06°24.000'N,038°35'.019 Eandat 2450 meters above sealevel (m.a.s.l).The monthl meanminimum and maximum temperatures are 9.3 and 20.9 °C, respectively. Yirba experimental site was located at 06°13.36'N,38°42.367'E and 2584 m.a.s.l.Both locations receive an annual rain fall of 1200-1750 mm per annum.The minimum and maximum temperatures of Yirba are 7.3 and 22.8°C, respectively. Both locations represent major wheat-growing and wheat rust prone areas.They are also characterized by bimodal rainfall, the short rainy season extending from March to July and the main season from July to December. Four types of fungicides (Tilt250 E.C., Rex Duo, Natura 250 EW, and BayletonWP25) and un-sprayed plots (check) a total of five treatments were used. Treated plots received sprays of every 20days in which the first spray was done at first appearance of yellow rust. Susceptible bread wheat variety 'Kubsa' was used from original seed source. Fungicides were manually sprayed with the help of twenty liters capacity knapsack sprayer. During fungicide sprays, plastic sheets were used to separate the plot being sprayed from the adjacent plots. The trial was arranged in randomized complete Block Design (RCBD) with three replications on 5 m x 5 m plot size. 1.5 m and 2 m were used between the plots and the blocks respectively. All inputs and agronomic practices were applied as per of its recommendation for wheat production.

Data collection and analysis

Data was collected on various parameters including (leaf rust, yellow rust and stem rust) infestation. Severity was assessed and recorded using the modified Cobb's scale (Peterson *et al*., 1948), by assessing 46 randomly pre-tagged plants. Agronomic parameters like plant height, spike length, tillers per plant (fertile tillers), plant height, number of grains per spike, thousand kernel weights and grain yield and other parameters were assessed. During disease assessment,the growth stage of the crop was recorded based on Zadoks*etal*.(1974) to observe onset and progress of the disease in relation to wheat phenology.

Disease assessment:-severity of yellow, stem and leafrust was estimated as proportion of the leaf and head infectionof a plant affected by the disease. Disease assessment was made at weekly interval from the time of symptom appearance to physiological maturity of the crop. Severity was recorded using the modified Cobb's scale (Peterson*etal*., 1948),by assessing 23 randomly pre-tagged plants.

Crop yield and thousand-kernelweight:- grain yield was harvested from the middle rows and adjusted to 12.5% moisture content . The weight of thousand kernels was sampled at random from the total grains harvested from each experimental plot counted and measured at the same moisture level. The collected data was subjected to analysis of variance (ANOVA) as suggested by Gomez and Gomez (1984) using SAS soft ware (version 2009). Least significant difference at 5% probability level was used to test the mean separation.

Relative yieldlossestimation:-The relative losses in yield and yield component of each treatment were determined as a percentage of that of the protected plots (treated) as compared to un-protected (un-treated) plots.

$$RL(\%) = \frac{(Y1-Y2)}{Y1} X100$$

Where, RL (%) = percent of relative yield loss, Y1= mean of the respective parameter on protected plots (plots with maximum protection) and Y2= mean of the respective parameter in unprotected plots (i.e. unsprayed plots or spraye plots with varying level of disease).

Result and Discussion

Wheat rust epidemics, severity and reaction were significantly varied due to fungicide application (Table 1). The combined analysis over locations were significant (P<0.05) varied among the fungicides in levels of severity of yellow rust, with the exception of Rex Duo and Tilt. Lower levels of yellow rust severity were observed on Rex Duo (4.99) and Tilt (5.83). Highest yellow rust severities were recorded on un-sprayed plots (61.67). The disease resulted in relative grain yield losses of up to 71.06% average at both locations.

Table1.Combined analysis result of terminal wheat rust severity levels on bread wheat with different fungicide spray at Bore andYirba, Southern Oromia, 2016

Fungicide	Terminalwheatrustseverity(%)		
	Yellow rust	Stem rust	Leaf rust
Rex Duo	4.99[a]	2.66[a]	0.00[a]
Tilt 250 EC	5.83[a]	4.50[a]	0.00[a]
Natura 250 EW	11.67[ab]	8.99[a]	6.50[c]
Bayletone WP25	19.99[b]	11.66[a]	4.00b
Unsprayed	61.67[c]	29.16[b]	14.16[d]
LSD (0.05%)	9.36	15.00	1.77
CV (%)	16.19	47.41	12.96

Effect on grain yield and yield component: Grain yield was significantly (P < 0.05) increased by fungicide applications (Table 2) at both locations. Further, Rex Dou provide significant yield increase over the other at both locations. Relative yield losses due to wheat rust reached 72.25 % and 71.86% on un-sprayed check at Bore and Yirba respectively. The thousand kernel weight (TKW) was also significantly increased by fungicide application at both locations. The maximum TKT of 60 gram was recorded from both locations.

Table2: Grainyieldandthousandkernelweightofbreadwheatand relative yield lossesdueto wheat rustunderdifferentfungicidesprayatBoreand Yirba in 2016.

Fungicides	Location					
	Bore			Yirba		
	Yield (kgha-1)	Loss (%)	TKW(g)	Yield (kgha-1)	Loss (%)	TKW (g)
Rex Duo	3484[a]	00.00	60.00[a]	3880[a]	0.00	60.00[a]
Tilt250EC	3093[b]	11.20	60.00[a]	3286[b]	15.31	60.00[a]
Natura250EW	2169[c]	37.70	53.00[b]	2423[c]	37.54	46.60[b]
BayletonWP25	2266[c]	34.94	53.00[b]	2301[c]	40.69	46.60[b]
Unsprayed	967[d]	72.25	24.00[c]	100.[d]	71.86	23.30[c]
LSD (0.05%)	2.24		8.64	2.17		18.63
CV (%)	7.52		13.88	4.79		21.11

There is significant difference in plant height between fungicide treatments and un-sprayed plot (Table 3). However, there is no significant difference among Rex Duo and Tilt 250EC. Even though there was no statistical variation of plant height among fungicides treated plots, relatively better plant height (70.72 cm) was obtained from Rex Duo. The shortest plant height (64.22 cm) was obtained from non-treated plots.

Effects of fungicides on number of tillers were also significant. The highest (2.72) number of tillers was recorded from treated plots whereas the lowest number of tiller (1.44) was recorded from un sprayed checks. Effect of fungicide treatments on grains per spike was also significant. Significantly highest (47.50) number of grains per spike was recorded from plot treated with Rex Duo followed by Tilt250EC whereas the lowest (15.20) was recorded from un-sprayed check. This result is in accordance with the work of (Hailu and Fininsa, 2007) who found relationship between stripe rust (*Puccinia striiformis*) and grain quality of bread wheat (*Triticumaestivum*) in the highlands of Bale, southeastern Ethiopia.

Table 3: Combined effect of fungicide application on wheat hieght, panicle length and seed per spike as affected by three rust at Bore and Yirba of Guji high lands in 2016.

Fungicides	Plant hieght (cm)	Pancle length (cm)	Nunber of effective tilleers	Seed/spike
Rex Duo	70.72a	7.27a	2.72a	47.50a
Tilt250 E.C	70.33a	6.88a	2.72a	36.70b
Natura250EW	66.27ab	6.88a	2.55a	27.83c
Bayleton WP25	66.52ab	6.72a	2.67a	25.50c
Control	64.22b	6.05b	1.44b	15.20d
LSD (0.05%)	4.78	0.57	0.43	3.40
CV (%)	5.91	7.10	15.10	9.32

Fungicide efficacy is based on proper application timing to achieve optimum effectiveness of the fungicide. Differences in efficacy among fungicide products were determined by direct comparisons among products in field tests and highly influenced by environment if we based on a single application of the company labeled rate (Kiersten Wise, 2016). All the current commercial wheat cultivars in East Africa are susceptible to the new wheat rust races and it is not possible to grow a profitable crop without the application of fungicides (Wanyera *et al*., 2009). Fungicide tests in Ethiopia showed up to1334.30kg/ha higher yield advantage in the treated versus the un-treated plots (Wubishet and Tamene, 2016). Ordish and Dufour (1969) noted the popularity of spraying fungicides to control crop diseases, returns of up to three times the cost involved often were realized from fungicide application.

Partial Budget Analysis

Partial budget analysis was done to identify the rewarding treatments. Yield from experimental plots was adjusted downward by 10% for management difference for to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment (Getachew and Taye, 2005). Three years average market grain price of wheat (Ethiopian Birr of 13.5 per kg of wheat) at farm-gate and price of Rex Duo, Tilt, Natura and Bayletone was at 1ltier ha $^{-1}$ spraying labor of 40 ETB per person day were used. Labor for wheat field management was 5 person- days per hectare. The result of the partial budget analysis is given in (Table 4). The partial budget analysis revealed that the highest net benefit of (birr 27217.3 ha) was obtained from the application of Rex Duo fungicide, where as the control treatment (nil application of fungicide) gave the lowest net benefit (birr 5075.67 ha^{-1}).

Table 4: Partial budget analysis of fungicide application for wheat rust management at Guji high lands, 2016

Treatments	Yield kg/ha	Adjusted Yield (kg/ha)	Gross benefit (Birr/ha)	Costs that vary (ETB /ha			Net benefit (Birr/ha)	CTC	CINB	MRR (%)
				Fungicide	Labour	T. cost				
Control	1029.5	926.55	8750.75	--	0	0	5075.67	0.0	00.0	00.
Bayleton	2283.5	2055.15	19409.75	500	200	700	16768.35	7000	11692	1670
Natura	2296.0	2066.40	19516.00	530	200	730	16834.40	30	66	220
Tilt 250EC	3189.5	2870.55	27110.75	650	200	862	23537.25	132	6702	5078
Rex Duo	3682.0	3313.80	31297.00	750	200	950	27217.30	88	3680	4181

The partial budget analysis further revealed that the application of Tilt at 1liter ha^{-1} provided the highest marginal rate of the return (MRR) of 5077.9% (Table 4) suggesting for each birr invested in wheat production, the producer would collect birr 5.077 after recovering his cost. Since the MRR assumed in this study was 100%, the treatment with application of Tilt fungicide gave an acceptable MRR. Therefore, Tilt fungicide application would be economical to be recommended on wheat to control wheat rust at Guji highlands of Ethiopia

Conclusion and Recommendations

Although wheat rust appears early to late during the crop season,it could develop to severe epidemic levels and could be an important factor limiting bread wheat production in Guji highlands of Ethiopia. Location variations in severity of the disease are may be related to differences in weather conditions. Despite variations among fungicides effectiveness, bread wheat was severely attacked by wheat rust in the absence of fungicide application.There is an urgent need for developing resistant varieties to the existing wheat rust pathotypes.

Fungicides were found to be effective in reducing wheat rust severityand improving crop yield. Partial budget analysis of the study revealed that, applying Rex Duo had the highest net field benefit (27217.3ET birr) followed by Tilt (23537.25ET birr ha^{-1} compared to Natura, (16834 birr ha^{-1}), Bayletone (16768.3 birr ha^{-1}) and unsprayed check (5075.67 birr ha^{-1}). However, Tilt 250 E.C had showed maximum economic profitability than Rex Duo and other fungicides with marginal rate of return (MRR) of 6494.4%. Therefore, application of Tilt 250 EC at rate of 0.5 litre ha^{-1} was found to be economical foe bread wheat production and there by improve yield of susceptible bread wheat up to 25.1% under proper management and the current market price of Guji high lands, Southern Oromia.

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Survey on Distribution and Economic Importance of Weeds in Cereal Crops at Guji Zone, Southern Oromia

Siyoum A*[1]., Yared T[1]., Kebna A[1]. and Obsa Cimdesa[1]

[1]Bore Agricultural Research Centre, P.O.Box21,Guji-Bore,Ethiopia

*Corresponding author:seyum23@gmail.com

Abstract

A weed survey was carried out during 2014 and 2015 main cropping seasons with in three agro-ecologies of Guji zone of Southern Oromia. Objectives of the study were investigation distribution and exploring the most dominant weed flora in cereal crops. For this survey, data was collected from six agro-ecologically representative districts where two districts were purposively selected from each agro-ecology. From each districts four Peasant Associations were selected and totally, 220 fields were assessed. Collected data was analyzed using quantitative and descriptive tools. Accordingly, a total of 42 weed taxa belonging to 18 families were identified. Among these families, Gramineae, compositae, Polygonaceae and Rubiaceae were the most abundant families recorded during the investigation. Snowden polistachia, Avena fatua, Bromus pectinatus Thunb, Phalaris paradoxa L, Setaria pumila, Digitaria abyssinica, Galansoga Palviflora, Guizotia scabra, Tagetes minuta, Bidens pilosa, Bidense pachloma, Parthinium hystrophorus, Polygonum nepalense, Oxygonum sinuatum, Rumex abyssinica, Andropogon abyssinicus, Lauracaea cornuta, Galium sporium, Galansoga palviflora, were the most frequent species (68%) followed by Snowden Polistachia (51%).Furthermore, most of farmers(90%) in high land districts mentioned Snowden polistachia as important weeds whereas Galansoga palviflora was mentioned as the worst weed. Additionally, based on the collected data, these two weeds were found the most abundant, frequency and dominant weed species at highland agro-ecologies of Guji Zone. In other hand, Setaria verticillata and Setaria pumila were identified as the most abundant, frequency and dominant weed species of cereal crops at both Mid land and Low land agro-ecologies of Guji Zone. In general, this study would provide basic information regarding the situation of cereal crop weeds in different agro ecologies of Guji Zone that could serve as corner stone for future research on weed.

Key words: Cereal crops, weeds, dominance, frequency, abundance

Introduction

In Ethiopia, wheat production is majorly hindered by several biotic and a biotic factors. Among biotic factors, weed holds large portions. Weeds is a plant that interfere with the objective and requirements of man, cause great yield loss in cultivated crop by competing for the limited natural resource, including plant nutrient, soil moisture, light, space etc., particularly in areas where continuous monoculture is practiced. In addition to their direct effect on the crop, weed can harbor pathogen, insect pest, rodent and wild animals.

Weeds represent one of the greatest limiting factors to efficient crop production as they cause greater economic losses on agricultural lands than all other pests combined (Patil and Jadhav, 2013). Because, it has been estimated that weeds cause a yield loss of about 10% in the less developed countries and 25% in the least developed countries (Akobundu, 1987). Even if the amount of yield loss is not clearly estimated, it's observed that loss caused by this pest is likely to be high in most areas of Ethiopia where crops are dominantly grown. Likewise, the problem is very decisive at high land agro-ecologies of the country. This might be due to the occurrence of high rain fall throughout crop growing seasons. In such conditions, conducive environments will be created for the development as well as spreading out of different weed species to compete with the intended crops to be grown.

Thus, presence of each weed population in an arable field is usually the result of ecological reactions to previous management practices, soil characteristics of the site and the regional (Salonen, 1993; Andersson & Milberg, 1998). Weed management practices are varying with nature of weeds, time of weed emergence, cropping system etc. Thus, weed identification before adopting management strategies are necessary in particular crops (Himalaya Subedi, 2013). As a result, several weed species are found in different agro-ecological regions of the country. So, identifying important weed species found in specific locations is very essential.

Because, knowledge of the weed community structure is an important component of weed management, and is essential in setting priorities for both weed management and research. In view of this, the present survey was conducted to address the following objectives; (i) to identify agro-ecological distribution of weed species in cereal crops; (ii) to assess and identify cereal weeds dominancy, frequency and abundance. (iii) to assess the influence of some environmental factors and crop management practices on weed species composition and distribution in cereal crops in the study area.

Materials and methods

The survey was carried out at three agro-ecologies of high land, mid land and low lands of Guji Zone, Southern Oromia during 2014/15 main cropping season. Guji zone is located at an altitude of 600-2700 m.a.s.l. with a distance of 604 km from the capital Finfine (Addis Ababa) to the South. Geographically, the Zone is situated at 05 39’59’’.99 North latitude and 39 ^{0} 00’0’’.00 East longitude and bordered by SNNP in the North, Bale administrative Zone to South East, Somali Regional state in the South and Borena administrative Zone in the West. Guji Zone has structured by thirty rural districts and two urban districts with about 35,454 km^2 land coverage and above 1.6 million populations (Zonal data). About 68% of the Zone climatic condition is characterized as Kola, 19% Weina Dega and 13% Dega. The Zone receives an annual rain fall of 500-1750 mm with a maximum and minimum temperature of 30.5^{o}c and 10.5^{o}c respectively. Agriculture holds large portion of the Zone economic sector integrated with others.

Survey methodology: For this survey, districts were selected using a stratified sampling method based on altitudes; low altitude (<1600 m.a.s.l), medium altitude (1600±1900 m.a.s.l), high altitude (>1900 m.a.s.l). Accordingly, two districts were selected from each agro-ecology. Thus, Bore and Anna Sora were selected from high land districts, Adola and Shakiso from mid land while Hara-kelo and Liba were selected for low land. From the selected districts four PA's were purposively selected. Cereal crop fields were selected regardless of field size and on the grounds of accessibility or adjacent to road at every 5 km using vehicle speedo meter. In each field, three to five 0.5 m x 0.5m quadrants were used following an inverted W pattern (Thomas, 1985). Percentage cover (the ground area covered by the vertical projection of above-ground plant parts) was estimated visually for each of the weed species in each quadrant. Weed identification in the field was done based on weed identification guides (Terry and Michieka, 1987; Stroud and Parker, 1989).

Data on major environmental factors and crop management practices believed to influence the weed flora in general and cereal crop in particular in each field were collected by observation (soil type, topography, type of crop), measurement (altitude), interviewing farmers (number of ploughings before planting, month of planting, fertilizer use, number of weeding before the survey date) as well as from secondary sources (administrative zone, rainfall). Environmental and crop management variables of nominal type (administrative zone, soil type, topography, crop type, fertilizer use) were converted into binary dummy variables that take the value 1 if the field belongs to the category or 0 if it does not. Altitude, number of ploughings, month of planting, number of weeding and rainfall were quantitative variables and hence measured on an interval scale. Survey date was used as a co variable in the data analysis.

Farmers Interview: Farmers were requested to respond to 15 questions on weeds and weed control in general on cereal crop in particular. Because answers tended to be relatively consistent within each village, only a subset (n ˆ 148) of the farmers whose fields had been surveyed was interviewed.

Method of data analyses

The data on weed species were summarized using:

Frequency: The number of fields in which a species occurred expressed a percentage of the total number of fields surveyed; Abundance: A = ∑W/N, Where, A = abundance, W = number of individuals of a weed species, N = Sample number

Dominance: D = A/ ∑Ax100, Where, D = dominance, ∑A = total abundance of all species andField uniformity: the number of sampling quadrants in which a species. Occurred in a field expressed as percentage of the total number of samples.

Results

For this study, six districts which were clustered under three agro-ecologies and a total of twenty four Peasant associations were addressed. About, 220 fields from all PA's were assessed during the study (Table 1). A total of 42 weed species belonging to seven plant families were recorded from the three agro-ecologies of Guji zone. Among these families, *Gramineae* was identified as the most dominant weed family (43.86%) followed by *Compositae* (33.84) whereas *Rubiaceae (4.79%) & Polygonaceae (4.62%)* were the list abundant weed families.

However, different weed species were identified at each agro-ecology based on abundance, frequency and uniformity in the field. About 20 weed species having dominance range of 1.8-17.58, frequency 6-80, abundance 3-29.3 and field uniformity of 9-43 were identified from high land agro-ecology (Table 1). Accordingly, *Galisonga Palviflora, Snowden Polistachia, Avena fatua and Phalaris paradoxa* L were the most dominant, frequent and abundant weed species identified at high land agro-ecologies of Guji zone. During the survey, it was also observed that these all weeds are majorly affecting cereal crop production.

Interviewed farmers also suggested as these all weeds are significantly affecting yield and beyond their capacity to control due to the convalesce nature of the weed species towards management practices undertaken. Farmers described that, climatic conditions of the area were highly contributing for the development and poor management practices. Because, the area was known with continuous rain fall throughout the growing season as a result it's difficult for them to undertake land preparation on time and its management practices properly. In line with the farmers suggestion, it's observed that most of the assessed fields were not properly managed starting from land preparation to pests management.

Two types of weed management practiced were observed. Hand weeding was majorly practiced for weed management in most of the fields observed (85%) with different frequency. In most of the fields, 1-2 times of hand weeding practices was observed to be undertaken. In some cases, unweeding fields were also identified. However, less number of the assessed fields were attempted to manage using ineffective and recommended packages of herbicides (15%).

Tef, maize, wheat and barley are major cereal crops produced in mid land agro-ecology of Guji Zone. However, similar to the high land agro-ecology production of these crops were also significantly hindered by several weed species. During this study, about 17 weed species having dominance range of 0.14-13.3, frequency 24-88, abundance 0.2-19 and field uniformity of 12-51 were identified from Mid land agro-ecology (Table 2). Among, the identified species *Setaria Pumila*, *Setaria Verticillata* and *Digitaria abysinica* were showed dominance >10 and >75 frequency. Particularly,*Setaria Pumila* is a major grass weed species highly affecting cereal crops including tef, wheat and barley at mid land agro-ecology of Guji Zone.

Table 1: Major troublesome weed species of cereal crop fields in high lands of Guji Zone, Southern Oromia and their quantitative measures over two years (2015/2016) cropping season

Botanical name	Local name	Family name	Freq.	Abun-dance	Domi-nance	Field uniformity
1.Galansoga Palviflora	*Darachesa*	*Compositae*	80	29.30	17.58	43
2. Snowden Polistachia	*Muja*	*Gramineae*	67	28.00	16.79	42
3. Avena fatua,	*Jigda*	*Gramineae*	64	13.80	8.29	39
4. Phalaris paradoxa	*Asandabo*	*Gramineae*	61	10.70	6.42	37
5. Bromus pectinatus	*Gishe*	*Gramineae*	43	9.80	5.88	37
6. Polygonum Nepalense	*Abadabo*	*Polygonaceae*	60	9.70	5.82	28
7. Pennisetum polystachion	--	*Gramineae*	19	3.20	1.92	28
8. Pennisetum clandestinum	--	*Gramineae*	28	4.60	2.76	28
9. Guizotia Scabra (vis.) chiov	*Hada*	*Compositae*	39	7.70	4.62	27
10. Galium Sporium	*Matane*	*Rubiaceae*	52	8.00	4.79	23
11. Bidens pilosa	*Qaqabata*	*Compositae*	50	8.20	4.92	23
12. Erucastrum arabicum	*Zaroo*	*Cruciferae*	49	8.80	5.28	21
13. Rumex abyssinica	*Ababo*	*Polygonaceae*	20	4.40	2.64	18
14. Bidense pachloma	*birra*	*Compositae*	19	3.10	1.86	17
15. Cynodon dactylon	*Sardo*	--	19	3.60	2.16	17
16. Tagetes minuta	*Ajo*	*Compositae*	18	7.50	4.50	17
17. Oxygonum sinuatum	--	*Polygonaceae*	12	3.30	1.98	12
18.Lolium temulentum	--	*Gramineae*	6	3.00	1.80	9

Even though, Farmers were undertaking several management practices, it was observed that the weed is not effectively controlled. This could be due to several factors. Systematic nature of some problematic weed species towards any management practices is one of the major problem in controlling weeds in field. Most of the assessed fields in mid land were observed with *Setaria Pumila and Setaria Verticillata* weed species devastation. Farmers were also remarked that these weed species were majorly affecting their fields and beyond their control. Some of the observed fields were totally competed by weeds than the intended crops.

From this situation, it was suggested that proper land preparation (timely and frequency), using weed free planting materials (source of seeds used to control weed movement to unreached fields), absence of scheduled cereal crop rotation with other recommended crops (to inhabit source of the inoculums for the pest), untimely planting that might be creating active season for weed emergence and expansion. In proper management practices(time of undertaking weed management based on the appearance and weed species, methods of weed managements used for different types of weed species etc.) is also another factor observed in most of the fields assessed.

In general, absence of effective weed management practices in mid land agro-ecology of Guji Zone is majorly contributed for the occurrence and spreading out of several devastating weed species to the area. Except few farmers, most of them were managing their field manually (hand weeding) due to several reasons. Because, they perceived that use of herbicides in crop production was considered to be cost, negative effect both on environment and animals, even grain produced by herbicide is harmful to feed. So, in order to improve the production and productivity of cereal crops at mid land agro-ecology of Guji Zone, weed management practices need unlimited attention towards bringing attitudinal change to farmers on using recommended herbicides as well as supplying the herbicides as required.

Table 2. Major troublesome weed species of cereal crop fields identified from mid land agro-ecology of Guji Zone, during 2015/16 cropping seasons.

No	Botanical name	Local name	Family	Freq-uency	Abun-dance	Dom-inancy	Field uniformity
1	*Setaria pumila*	Asnadabo	Gramineae	88	19.0	13.30	51
2	*Setaria verticillata.*	Asnadabo	Gramineae	--	17.0	11.90	48
3	*Sorghum arundianaceum*	-	Gramineae	61	10.0	7.02	28
4	*Digitaria abyssinica*	Marga	Gramineae	78	18.3	12.80	47
5	*Cyperus rotundus*	-	Cyperaceae	36	8.6	4.77	22
6	*Galansoga palviflora*	Darachesa	Compositae	73	9.73	6.83	41
7	*Cynodon dactylon*	Sardo	Gramineae	71	5.6	3.93	33
8	*Guzotia scabra.*	Haadaa	Compositae	69	9.7	6.81	35
9	*Bidens pilosa*	Qaqabata	Compositae	79	7.3	5.12	37
10	*Commelina benghalensis*	Banji	Commelinaceae	42	3.5	2.46	11
11	*Tagetes minuta*	Ajoo	Compositae	57	6.4	4.53	27
12	*Datura stramonium*	Banji	Solanaceae	33	3.2	2.24	16
13	*Nicandra physalodes*	-	Solanaceae	43	0.6	0.42	18
14	*Galium Sporium*	Ashkit	Rubiaceae	55	13.8	9.68	27
15	*Erucastrum arabicum*	Zero	Cruciferae	47	4.3	3.04	22
16	*Xanthium spinosum*	Qoraatti	Compositae	32	5.2	3.65	17
17	*Xanthium strumarium*	Qoraatti	Compositae	24	0.2	0.14	12

Like that of mid land, tef, maize and wheat are major cereal crops produced at low land. Weed is a major pest affecting the production of these crops. From the survey collected data, about 9 weed species having dominance range of 5.93-20.78, frequency 30-76, abundance 8-28 and field uniformity of 9-44 were identified from low land agro-ecology (Table 2). Among the identified species, *Setaria verticillata* was the dominant weed species at low land (20.78) followed by *Parthenium hysterophorus* L. (14.84), *Xanthium spinosum* L. (12.84) and *Xanthium strumarium* L. (Table 3). Despite the fact that some weeds, such as *Argemone mexicana* and Xanthium spinosum, had low frequency they were considered to be problematic weeds by farmers. Thus, high frequency does not indicate the economic or sociological importance of a weed species, as some weeds have other uses, such as feed for livestock, which can be especially important in the lowlands.

Table 3 Major troublesome weed species of cereal crop fields identified from low land agro-ecology of Guji Zone, during 2015/16 cropping seasons.

	Botanical name	Local name	Family	Frequ-ency	Abun-dance	Dom-inancy	Field uniformity
1	Setaria verticillata	Migira saree	Gramineae	76	28.00	20.80	44
2	Setaria pumila	Migira saree	Gramineae	73	14.80	11.00	41
3	Amranthus hybridus	Raafuu	amaranthaceae	68	11.00	8.16	31
4	Amaranthus spinosus	Raafuu	amaranthaceae	63	8.00	5.93	27
5	Parthenium hysterophorus	Anemele	Compositae	63	19.00	14.10	39
6	Xanthium spinosum	Qoraattii	Asteraceae	56	17.30	12.80	21
7	Xanthium strumarium	Qoraattii	Asteraceae	48	13.50	9.65	16
8	Commelina latifolia	-	Commelinacea	31	10.60	7.86	9
9	Argemone Mexicana	Qoraatti	Paraveraceae	30	12.60	9.32	12

Conclusions

In crop production, weed management holds large portion. Particularly, cereal crops are majorly competent with different weed species. In order to provide effective weed management options to the producers, identification of the most problematic weed species in particular area is an important scheme for any intervention to be planned with regard to weed management. As a result, this study also conducted to identify the most problematic cereal weeds found at different agro-ecologies of Guji Zone using different quantitative parameters and factors contributing for their occurrence.

Through this survey study, the most abundant and troublesome weed species found in small scale farms of different agro-ecologies of Guji Zone were ranked. The differences were observed between soils, crop types and between locations in weed flora composition, in terms of frequency, abundance and dominance in the highlands, mid land and low land agro-ecologies. Accordingly, *Galansoga Palviflora* and *Snowden Polistachia* were identified as the most dominant weed species from high land agro ecology , while*Setaria verticillata* (L.) and *Setaria pumila* from mid land agro ecology whereas *Setaria Verticillata ,Xanthium strumarium L. ,Parthenium hysterophorus L. and Xanthium spinosum L* were identified as dominant weed species from low land agro-ecology of Guji zone. Poor land preparation(time and frequency),use of poor quality seeds, absence of crop rotation, lack of awareness on importance of weed management using recommended herbicides, method of sowing (broadcasting), in accessibility and incompatibility price of herbicides were identified as major factors contributing for the occurrence and spreading of weed species throughout the study area. Therefore, this study has provided preliminary information regarding weed taxonomy of Guji Zone and would serve as base line for any research as well as strategies to be implemented towards weed management options.

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COFFEE

Status of Coffee Insect Pests in major Coffee *(Coffea arabica L.)* growing areas of Eastern Oromia

Mohammedsani Amin[1*] and Hika Bersisa[1]

[1]Oromia Agricultural Research Institute, Mechara Research Center, Coffee research team

P.O.Box: 19, Mechara, West Hararghe, Ethiopia

*Corresponding author's E-mail: mamasaniamin@yahoo.com

Abstract

The yield and quality of coffee in the country had been significantly reduced by biotic factors (diseases, insects, weeds etc.) and abiotic factors (temperature, drought, and rain pattern). Hararghe coffee is among the specialty coffee which is vital to the economy of Ethiopia, as one of the major sources of foreign currency earnings. However, its production and productivity has been decreasing due to limiting factors that include major insect pest, such as antestia bug (AnB), bloch leaf miner (BLM) and green scale (GrS). Therefore in order to establish the effective management of the insect pest, there was a need to ascertain their current infestation and spread in Eastern Oromia coffee growing areas. To this end, extensive survey was conducted in August 2015. The study covered representative sites known for high production and high cup quality in the districts of West (Daro Labu, Habro, Boke) and East (Bedeno) Hararghe zones. Presence or absence and prevalence or volume of the insect pest was determined as infestation and severity, respectively. The infestation by Antestia bug was severe in all lowland PAs of all districts in which up to 15 Antestia bug per tree was recorded. The economic threshold level for the insect is three bugs per tree. Higher infestations of blotch leaf miner (18%) and green scale insect (36%) were recorded in D/labu and Boke districts respectively. 27% infestation by antestia bug was recorded in Habro. These three are identified as the major insect pests of coffee and are becoming a big threat for coffee production in the areas. Green leaf scale was severe on berry (19.48%) in Boke while high antestia bug severity (2.22%) was observed in Habro district. However, the severity of BLM in all studied areas was very low (0.81%). The current climate change may have favored the infestation by these pests. Generally, from the results of the study, there is a major shift in the status of coffee the pests in Hararghe, therefore, development and/or adoption of management options of the insect pests in region should get immediate attention.

Keywords: Insect pests; infestation; severity

Introduction

Coffee is the most important and valuable agricultural commodity in Ethiopia and in the world supporting the economic growth and providing job opportunity to millions of people. Ethiopia is Africa's largest coffee producer and the world's fifth largest exporter of Arabica coffee. In 2015/16 total production was 6.4 million 60 kg bags, of which 3.7 million were consumed in Ethiopia (ICO, 2015). Hararghe (located in Eastern Oromia, Ethiopia) is one of the areas known for quality coffee production where coffee is sun coffee and it is usually grown at an altitude range from 1600–2100 m, often near dwellings. On the eastern side of the Rift Valley, the Hararghe coffee zone usually receives far less total rainfall (800–1200 mm per year) than all other coffee growing areas. Thus farmers complain an increase in the frequency and severity of drought. , There is a gradual reduction in rainfall over several decades (Moat *et al.*, 2017). The crop is prone to a number of diseases and insect pests that attack fruits, leaves, stems and roots and reduce the yield and marketability (Aebissa, 2012). Thus, the yield and quality of coffee are significantly reduced by biotic factors (diseases, insects, weeds etc.) and abiotic factors (temperature, drought and rain pattern).

Coffee plants show climate-related stress through the increased occurrence, and intensity of pest attacks (Moat *et al*., 2017). The major coffee pests known to occur in Ethiopia are antestia bug, coffee berry & stem borer, leaf minor and scale insects. The problem of pests is higher in more intensively managed systems like home garden coffee of Hararghe. Hence, farmers sometimes might be obliged to consider uses of chemical pesticides (Tadesse, 2015). Insect pests are among the number of factors that limit coffee production both in quality and quantity (Million and Bayissa, 1986).

Globally, an estimated crop loss by insect pests is about 13%, but it can be higher up to 96% in Africa. The antestia bug is a major coffee pest that feeds on all vegetative and fruiting parts of the coffee tree leading to yield reduction and poor quality of coffee beans (Ahmed *et al*., 2016).White stem borer (*Anthores leuconatus)*, antestia bug (*Antestiopsis sp*.), coffee berry borer (*Hypothenemus hampei*and) and blotch leaf miner (*Leucoptera meyricki)* are the four major economically important pests observed in different coffee plantation. Other coffee pests cause low economic damage (Aebissa, 2012; Nahayol and Bayisenge, 2012). Antestia bug, blotch leaf miner and green scale are the three major insect pests in Hararghe area (MARC, 2010; 2015). A crop loss of 15-27% in total bean weight has been associated with infestation of 2-4 antestia bugs per tree.The density of Antestia bug ranged from 1-2 per tree is considered as the economic thresh hold level (Mugo *et al*, 2013). Antesia bug (C. alpinus De Lotto) causes the death of bearing branches (Million, 2000). Green scale is a common and serious problem in coffee which sucks the plant resulting in reduced growth and crop yield and requires constant attention particularly in dry areas. Blotch Leaf Miner (BLM) feeds on the palisade parenchyma cells of the leaves (Ramiro *et al*., 2004). In Ethiopia, cultural practices like shading and pruning are used for insect pest control. The problem of pests is higher in the more intensively managed systems like plantations and home gardens. This could be attributed to narrow genetic pool of the coffee stock, reduced shade and habitat complexity.

Therefore, as an essential prerequisite in the effective management of major coffee insect pests, there was a need to find out the current infestation level and spread of those insect pests. Hence, the survey was conducted to identify major coffee insect pests distribution, infestation and severity in major coffee growing areas of eastern Oromia.

Materials and methods

Description of the studied areas: Four major coffee producing districts (D/Labu, Habro, Boke and Bedeno) were purposively selected from West and East Hararghe zones. Each district was categorized in to highland, lowland and midland agro ecologies. From each agro-ecology 4 farmers farms were sampled in interval of 5 km.

Methods of insect pest assessment

Insect pest infestation: From each selected and sampled farms 50 trees were diagonally assessed for the presence or absence of antestia bug, green scale and blotch leaf miner (BLM). The infestation is calculated as a percentage of infected trees to the total assessed tree.

Insect pest severity: For severity of BLM and green scale assessment, a sample size of 10 trees with relatively uniform age was systematically selected at a distance of about 6-8 m within the sampling farm. Each tree was classified into top, middle and bottom branches strata. From each stratum, a pair of branches was selected for pest data recording. Pest damaged and healthy berries/leaves were counted and then percentages of infected berries/leaves over total counted berries/leaves were computed as pest severity as follows:

$$\text{Severity (\%)} = \frac{\text{Total infected berries/leaves}}{\text{Total ocounted berries/leaves}} \text{X } 100$$

For antestia bug (AnB) severity assessment, 10 trees were randomly selected with in farm, each sampled trees with muslin cloth underneath. A few minutes later the trees were shaken and number of Antestia bug (AnB) was counted. Alternatively, hand collection of antestia per sample trees was done to determine number of the insect per tree.

Data analysis

The collected data was subjected to Excel speared sheet and summarized. The mean percentage of pest infestation and severity were computed for each sample farm. Final data were analysed using SPSS 20 software package.

Results and Discussion

Status of insect pest across the districts

Infestation of antestia bug was observed in lowland PAs of all districts where up to 15 antestia bugs per tree was recorded (Figure 1). This is severe infestation where 1-2 bugs per tree is considered as economic threshold level. This requires immediate application of control measure. Similarly, the infestation of green scale insect (15%) and blotch leaf miner (9%) were recorded showing that these are major pests that are becoming a big threat for coffee production in the areas. High infestation (17.5%) of BLM is recorded in Daro Labu followed by Habro (9.5%) and the least 1.7% in Bedeno (Figure 1). While, the highest (36%) and the least (1%) infestation of green scale was recorded in Boke and Bedeno, respectively with over all mean infestation of 15% (Figure 1).

The overall mean infestation of BLM, GrS and AnB were 9, 15 and 11%, respectively (Figure 1). This may show the impact of environment on different insect pest. In agreement with this, Esayas *et al. (*2008) reported that, whether factors, host plants and natural enemies may attribute for distribution and seasonal changes in population of the insect.

The severity of all incest pests significantly varied between the districts. Accordingly, the highest green scale severity was recorded in Boke district and the lowest in Daro Labau and Bedeno with overall 9% severity mean (Table 1). However, the highest severity of green scale on berry (19.5%) and leaf (13%) was observed in Boke than all distracts with over location mean of 7.2% and 4.5 % (Table 1). Higher antestia bug severity was recorded in Habro followed by Boke and zero in Bedeno district with over all mean of 1.04% (Table 1). This shows the need to focus on different insect pests as a priority for management in different districts.

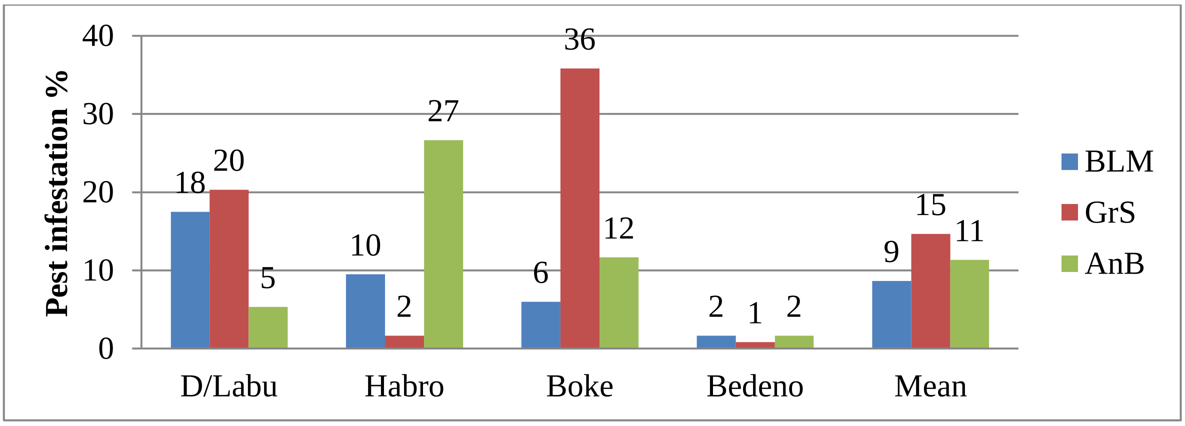

Figure 1. The occurrence/infestation of major insect pests in major coffee growing districts of Hararghe zones

Table 1. Mean severity of insect pests under different Hararghe coffee growing districts

District	Severity of Insect pests (%)			
	BLM	GrS on berry	GrS on leaf	AnB
Daro Labu	0.59	9.26	4.96	0.78
Habro	0.85	0.00	0.02	2.22
Boke	1.20	19.48	12.97	1.17
Bedeno	0.59	0.00	0.00	0.00
Mean	0.81	7.18	4.49	1.04
Range	0-4	0-91	0-62	0-12
Std. Dev.	1.11	20.05	13.22	2.65

Key: BLM = blotch leaf miner; GrS = green scale; AnB = Antestia bug

Status of insect pests under different coffee growing agro-ecology: In all studied agro-ecologies, the severity of green leaf scale was higher compared to the other insect pests. High mean infestation (33%) of GrS in midland and no AnB severity in highland area of Bedeno district (Table 2). The pests' distribution and dominancy in the agro ecological were different. The highest mean (19.20%) severity on berry due to AnB in midland and the least severity was recorded in the highland indicating the effect of Agro-ecology on distribution and infestation status of insect pests in coffee growing areas of Eastern and Western Hararghe (Table 2).

Table 2. Mean infestation and severity of insect pests under different coffee growing agro-ecology.

Coffee growing Agro-ecology	Infestation (%)			Severity (%			
	BLM	GrS	AnB	BLM	GrS berry	GrS leaf	AnB
Highland	6.00	4.38	1.25	0.81	0.91	0.45	0.00
Midland	7.13	33.13	0.63	0.4	19.2	11.97	0.13
Lowland	12.88	6.50	32.13	1.21	1.44	1.04	3.00
Mean	8.67	14.67	11.33	0.81	7.18	4.49	1.04
Range	0-70	0-100	0-100	0-4	0-91	0-62	0-12
Std. Dev.	13.31	29.13	26.75	1.11	20.05	13.22	2.65

Key: BLM=blotch leaf miner; GrS=Green scale; AnB=Antestia bug

Within the districts, there are differences on the infestation and severity of pests across agro ecologies. The highest infestation of 9, 15 and 5% of BLM, GrS and AnB were recorded under highland of D/Labu, Boke and Bedeno districts, respectively (Table 3). Whereas the highest; 85% of GrS, 13.5% of BLM and 2.5% of AnB was observed in the midland of Boke, Habro and D/Labu district, respectively (Table 3). In lowland of Habro district AnB infestation was high (80%) followed by Boke district, while the highest (33% BLM and 16% GrS) in lowland of Darolabu recorded (Table 3).

The high severity of GrS both on leaf and berry and BLM were observed in midland of Boke followed by D/Labu district and it was very low under highland of all districts (Table 3). In all highlands of all districts the severity of AnB was zero, but in lowland its severity was high (7% at Habro followed by Boke) (Table 3).

Table 3. Infestation and severity of the insect pests in districts and under different coffee growing agro-ecologies

District name	Infestation of the insects (%) per agro-ecology								
	Highland			Midland			Lowland		
	BLM	Green Scale	AnB	BLM	Green Scale	AnB	BLM	Green Scale	AnB
D/Labu	9.00	0.00	0.00	10.50	45.00	2.50	33.00	16.00	13.50
Habro	8.00	2.50	0.00	13.50	0.00	0.00	7.00	2.50	80.00
Boke	7.00	15.00	0.00	4.50	85.00	0.00	6.50	7.50	35.00
Bedeno	0.00	0.00	5.00	0.00	2.50	0.00	5.00	0.00	0.00
Mean	6.00	4.38	1.25	7.13	33.13	0.63	12.88	6.50	32.13

District name	Severity of the insects (%) per agro-ecology											
	Highland				Midland				Lowland			
	BLM	GrS on berry	GrS on leaf	AnB	BLM	GrS on berry	GrS on leaf	AnB	BLM	GrS on berry	GrS on leaf	AnB
D/Labu	0.86	0	0.37	0	0.53	23.81	11.20	0.5	0.37	3.98	3.31	1.85
Habro	0.98	0	0.05	0	0.71	0.00	0.00	0	0.86	0.00	0.00	6.65
Boke	1.41	3.66	1.38	0	0.35	53.01	36.69	0	1.83	1.77	0.85	3.50
Bedeno	0.00	0.00	0.00	0	0.00	0.00	0.00	0	1.77	0.00	0.00	0.00
Mean	0.81	0.91	0.45	0	0.4	19.20	11.97	0.13	1.21	1.44	1.04	3.00

Key: BLM=blotch leaf miner; GrS=Green scale; AnB=Antestia bug

Relationship between coffee shade tree status and occurrence of pests: High mean infestation (19%) of GrS and (16%) AnB were recorded in un-shaded coffee farms (Table 4). And, there was no AnB occurrence under fully shaded coffee in this area. This shows coffee tree shading limits AnB occurrence. The major coffee insect pests varied in their severity on coffee as a result of shade. According to Kimani *et al.* (2002), in some insect pests, shade depressed their severity while others were positively favored. Shade trees reduce excessive light, mulch the soil with their litter, create hostile conditions for pests and diseases, and harbor a variety of predatory animals (Beer *et al.*, 1998). Coffee shade tree can reduce antestia population by producing unfavorable temperature and humidity conditions to antestia bugs, which prefer dense foliage (Crowe and Tadasse ,1984). So this survey result also confirms previous findings.

Table 4. Effect of coffee shade on the occurrence of different pests in Hararghe.

Insect pest status	Shade status					
	Unshaded			Shaded		
	Mean	Range	Std. Dev.	Mean	Range	Std. Dev.
BLM infestation (%)	10	0-70	15.2	5.4	0-20	6.3
BLM severity (%)	0.8	0-4	1.04	0.8	0-4	1.3
GrS infestation (%)	19.2	0-100	33.0	3.6	0-4	10.8
GrS severity on berry (%)	9.7	0-91	23.3	1.1	0-15	3.9
GrS severity on leaf (%)	6.3	0-62	15.4	0.1	0-1	0.3
AnB infestation (%)	16.0	0-100	30.7	0.0	0.0	0.0
AnB severity (%)	1.5	0-12	3.1	0.0	0.0	0.0

Key: BLM=blotch leaf miner; GrS=Green scale; AnB=Antestia bug

Insect infestation across different environment varied depending on their shade status. In Bedeno AnB infestation was 5%under open un-shaded farms while there was infestation in shaded coffee farms. Similarly, the highest (35.83%) mean infestation of GrS was recorded in Boke under open un-shaded farm. In Daro Labu only BLM severity was higher under fully shaded than open un-shaded fields. But the other pests were less severe under fully shaded than open un-shaded farms. In Habro, high infestation and severity of BLM was recorded under fully shaded compared to un-shaded farms (Table 5). This might have been due to the coffee leaf insect pests more attracted to shady environment and/or might have been the interruption of the activity of natural enemy by the shade canopy as it is supported by Lan and Wintgens (2004) who recommended that the use of shade has a direct relationship with the behavior of the pests. Attacks have been found to be more severe where the coffee is grown under heavy shade or is closely planted and un-pruned or inadequately de-suckered. A single, very large, dense shade tree can cause a serious local infestation (Le Pelley, 1968; Jameson, 1970; Bardner, 1985). This result indicates the importance of proper coffee tree and shade management for the control of insect pests based on their behavior.

Table 5. Mean infestation and severity of insect pest under different coffee farm shade status and environments

District	Shade status	Infestation (%)			Severity (%)			
		BLM	GrS	AnB	BLM	GrS on berry	GrS on leaf	AnB
D/Labu	Unshaded	24.86	29.14	9.14	0.52	13.77	8.29	1.34
	Shaded	7.20	8.00	0.00	0.69	2.95	0.29	0.00
Habro	Unshaded	8.55	1.82	29.09	0.83	0.00	0.02	2.42
	Shaded	20.00	0.00	0.00	1.08	0.00	0.00	0.00
Boke	Unshaded	6.00	35.83	11.67	1.20	19.48	12.97	1.17
	Shaded	na	na	na	na	na	Na	na
Bedeno	Unshaded	0.00	0.00	5.00	0.00	0.00	0.00	0.00
	Shaded	2.50	1.25	0.00	0.88	0.00	0.00	0.00
Mean	Unshaded	9.85	16.70	13.73	0.64	8.31	5.32	1.23
	Shaded	9.90	3.08	0.00	0.88	0.98	0.10	0.00

Key: BLM=blotch leaf miner; GrS=Green scale; AnB=Antestia bug

Effect of agronomic practice on status of insect pests : Different agronomic practices showed different impact on the insect pests. As the result (Table 6) shows, except infestation of BLM (13%) all the other insect pests were less severe in slashing practice. 18% of GrS infestation is observed under cultivation practice. Slashing reduced the infestation and severity of insect pests compared to the rest activities except in GrS severity on berry (9%) across the surveyed districts.

Table 6. Effect of agronomic practices on the infestation and severity of insect pests

Agronomic practices	Infestation (%)			Severity (%)			
	BLM	GrS	AnB	BLM	GrS on berry	GrS on leaf	AnB
Slashing	13.33	3.33	3.33	0.04	0.00	0.00	0.00
Cultivation	6.73	18.18	4.91	0.41	9.16	4.39	0.67
Intercropping	8.45	15.61	15.16	1.09	7.88	5.39	1.37
Mean	8.67	14.67	11.33	0.81	7.18	4.49	1.04

In Bedeno, ploughing/cultivation activity was the best for insect pest control. In Boke, higher infestation and severity of insect pests were recorded in intercropping compared to cultivation. Similar result was observed in Habro district. This shows the harmful effect of intercropping coffee with other crops by favouring the occurrence of pests. Intercropping coffee with crops such as bananas is believed to favor higher pest infestations (Le Pelley, 1968; Jameson, 1970; Bardner, 1985).

Table 7. Agronomic effect on infestation and severity of insect pests in the districts.

District name	Agronomic practice	Infestation (%)			Severity (%)			
		BLM	GrS	AnB	BLM	GrS on berry	GrS on leaf	AnB
D/Labu	Intercropping	24.67	18.00	3.33	1.09	4.71	4.40	0.67
	Slashing	70.00	10.00	0.00	0.00	0.00	0.00	0.00
	Cultivation	8.25	22.50	6.75	0.47	12.13	5.79	0.93
Habro	Intercropping	10.40	2.00	32.00	1.00	0.00	0.02	2.66
	Slashing	10.00	0.00	0.00	0.21	0.00	0.00	0.00
	Cultivation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boke	Intercropping	5.82	37.27	12.73	1.23	20.91	13.98	1.27
	Cultivation	8.00	20.00	0.00	0.78	3.71	1.93	0.00
Bedeno	Intercropping	2.86	0.00	0.00	1.01	0.00	0.00	0.00
	Slashing	0.00	2.50	5.00	0.00	0.00	0.00	0.00
	Cultivation	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mean	Intercropping	10.94	14.32	12.02	1.08	6.41	4.60	1.15
	Slashing	26.67	4.17	1.67	0.07	0.00	0.00	0.00
	Cultivation	4.06	10.63	1.69	0.31	3.96	1.93	0.23

Conclusion and recommendation

Insect pests such as antestia bug, blotch leaf miner and green scale were assessed in major Hararghe coffee producing districts. The finding confirmed that currently they are critical problems, most often are not controlled by any insecticide since it is not affordable to the farmers. The insect pest infestation and severity varied among and within the districts depending on environmental conditions and management practices applied. Hararghe coffee is increasingly threatened by antestia bug, blotch leaf miner and green scale insects. The use of shade has direct relationship with reducing infestation and severity of insect pest. Agronomic practices like cultivation, slashing can be options in cultural control of the insect pests. A field experiment that leads to the development of integrated pest management strategy should be designed to confirm the results of this survey.Therefore, for sustainable, environmentally friendly organic coffee production that fetches premium price to farmers and the country at large, the integrated insect pest management of these major pests should be given attention. Research should be strengthened in coffee insect pest protection. Location specific insect pests resistant/tolerant cultivars should be developed as long-term solution. Ethiopia is believed to possess about 99.8% of the total Arabica coffee genetic diversity. These diverse genetic resources are vital in selecting coffee cultivars that are of high quality, resistant to diseases/insect pests, and adapt to climate extremes (drought/ temperature). Farmers purposely maintain diverse landraces on their farm to overcome environmental stresses like diseases, pests, and drought and also conserve varieties that have specific qualities and are high yielding. The research should focus on the integration of pest management options for the management of the insect pests.

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Status of Coffee Diseases in major Coffee *(Coffea arabica L.)* growing areas of Eastern Oromia

Mohammedsani Amin[1]* and Hika Bersisa[1]
[1]Mechara Research Center, Coffee Research Team , Mechara, West Hararghe, Ethiopia
*Corresponding author's E-mail: mamasaniamin@yahoo.com

Abstract

Hararghe coffee is among the specialty coffee which is vital to the economy of Ethiopia, as one of the major sources of foreign currency earnings. However, its production and productivity has been decreasing due to limiting factors that include major diseases, such as coffee leaf rust (CLR), coffee berry disease (CBD, branch dieback (BDB) and coffee wilt disease (CWD). In order to establish effective management of the diseases, there is a need to ascertain their current incidence and spread in Eastern Oromia coffee growing areas. To this end, extensive survey was conducted in August 2015. The survey was conducted in four major coffee producing districts, three of them (D/Labu, Habro & Boke) are located in West and one district (Bedeno) in East Hararghe zones. Presence or absence and volume of the diseases were determined as incidence and severity, respectively. The result indicates that CBD, CLR and BDB were highly affecting the coffee tree followed by BDB. However, CWD incidence was only observed in Daro Labu and Bedeno district at very low level to less than 3% with overall average of 0.92%. The mean severity of CBD was 29% with range of 0-89 and its highest (45%) severity in Bedeno followed by Boke (26%) district, while average CLR severity was 6.3% with the range of 0-19. Also, the mean severity of BDB is 25% with the range of 0-74 and highest (40%) in Boke followed by Habro (25%) district. The disease occurrence was very high across all study areas with an average incidence of 66%, 33% and 47% for CBD, CLR and BDB, respectively. Thus, currently CBD, CLR and BDB are economically important diseases which cause severe loss of yield. Generally, from the results of the study, there was the major shift in the status of coffee diseases in Hararghe. Therefore, the diseases in the region should get due attention immediately.

Keywords: major disease; Hararghe coffee; incidence; severity

Introduction

Coffee is one the most important commodities produced primarily for consumption as a beverage by more than one third of the world's population in more than 80 countries around the world. In Ethiopia, it is the single commodity that provides source of revenue for many millions of people (Rutherford and Phiri, 2006). The wide climatic and soil factors offer the country to birth place of Arabica coffee which accounts for 80% of the world coffee. Ethiopia is Africa's largest coffee producer and the world's 5th largest exporter of Arabica coffee (ICO, 2015). About 70% of Ethiopian coffee is produced in Oromia Regional State.

Despite the largest share in export and economic contribution, several constraints have been identified that affect the production and utilization of coffee. Of these constraints, perennial coffee diseases pressure are the most serious issue confronting Oromia's coffee production, and calls for immediate control measures. Climate change is believed to be playing its role where new diseases occur as an outbreak. The area known as Hararghe comprises the eastern most of the specialty coffee growing zones of Oromia (Ameyu, 2017). In Hararghe, an increase in temperature threatens the coffee at an alarming rate and become more conducive for disease prevalence (Iscaro, 2014). As climate change becomes increasingly severe, an assessment of the status of coffee disease could be especially valuable to those hoping to create adaptation strategies and policies (Battiste *et al*., 2016). Significant proportion of potential coffee yields is annually lost due to persistent disease problems. Previously, the major coffee diseases in Ethiopia were coffee berry disease (CBD) and coffee wilt disease (CWD), but nowadays, coffee leaf rust (CLR) and branch dieback (BDB) are common and economically important coffee problems particularly in Hararghe. Therefore in the area CBD, CLR, CWD and BDB became a big threat for Hararghe coffee production. Recent study (Mohammedsani, 2011) showed that up to 53-100% yield loss was observed due to above mentioned diseases in some individual Haraghe coffee producing farms. Mohammedsani, 2011 reported 54% and 74% occurrence of CBD and CLR respectively during 2010 in Hararghe zones with the highest incidence in Bedeno and Boke district. Extensive biological survey of major coffee diseases in major coffee growing areas of West & East Hararghe was conducted with the objective to document the incidence and severity of the major coffee diseases in different Hararghe coffee producing agro-ecologies there by recommend the possible intervention required.

Material and methods

Description of the study areas: The assessment covered the most important four major coffee growing districts of Hararghe zones in eastern Oromia. The selected districts were Daro Labu, Habro and Boke from West and Bedeno from East Hararghe zones. The assessment was conducted from August to September 2015 on several small-scale coffee farms. The areas are known for their high cup quality Harar coffee brand, which fetch premium price in the world market. The climate data of the study areas during 2015 is shown in Figure 1.

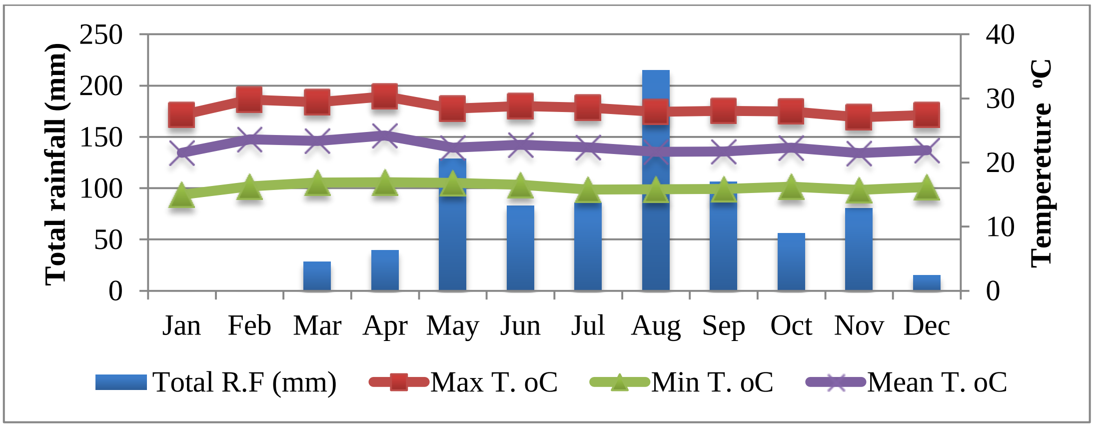


Figure 1. Monthly total rainfall and minimum, maximum and mean temperature of the study area during 2015 cropping season.

Methods of Assessment : Each district was categorized into three agro-ecology (highland, midland & lowland) based on their altitudinal variation (Table 1). From each agro-ecology four (4) representative coffee farms with approximately similar age coffee trees were selected as sample plots at the interval of 3-5 km. Forty eight 48 (12 per district) farm plots were assessed for the diseases and other required information were collected. At each farm, a questionnaire was administered and the owner was asked about the age of the tree, type of coffee species and disease history. The fields were observed for agronomic practice applied, weed control method, shade tree condition (shaded or non-shaded), slope of the land and other factors that contribute in occurrence, distribution and severity of the diseases. Geographical information such as altitude, longitude & latitude of each farm was recorded, using GPS at a central point per farm surveyed.

Table 1. The classification of each selected coffee growing agro-ecology based on altitudinal variation of each district

District name	Altitude variation per agro-ecology (m.a.s.l)		
	Lowland	Midland	Highland
Daro Labu	1669 - 1715	1729 - 1755	1795 - 1870
Habro	1731 - 1765	1801 -1875	1865 - 1925
Boke	1711 - 1760	1840 - 1875	1885 - 1940
Bedeno	1577 - 1618	1771 - 1937	2008 - 2061

Disease data collection procedures

Data was collected on incidence, severity and prevalence of major coffee diseases for each selected coffee mother trees following formula or procedures developed by different authors.

CBD, CWD and BDB incidence assessment

In each visited farm, fifty (50) trees were observed in a diagonal line across the farm for the presence or absence of symptoms of coffee berry disease (CBD), coffee wilt disease (CWD), branch dieback (BBD) and others. Total numbers of infected and healthy trees were counted. The incidences of the diseases were calculated as a ratio of infected number of mother trees over the total number of observed trees as follows:

$$\text{Incidence (\%)} = \frac{\text{Total infected tree}}{\text{Total observed tree}} \text{X } 100$$

CBD and BDB severity assessment: A sample size of 10 trees with relatively uniform age was systematically selected at a distance of about 6-8 m within the selected farm. Each tree classified into three strata of branches (top, middle and bottom). From each stratum two branches were selected to record disease severity. Disease damaged and healthy berries/branches were counted and then percentages of diseased berries/branches over total counted berries/branches were computed as severity as follows:

$$\text{Severity (\%)} = \frac{\text{Total infected berries/branches}}{\text{Total ocounted berries/branches}} \text{X } 100$$

CLR incidence, severity and SLD assessment: Ten (10) coffee trees were randomly selected from each farm. Three pairs of branches representing upper, middle and lower canopy layers of the tree were also selected for the assessment. Rust incidence expressed in percentage was determined as the number of diseased leaves per branch. Thus, total of 60 pairs of leaves were collected from each farm in plastic bags. Severity and sporulation density (SLD) were recorded. Finally rust severity was measured as the proportion of leaf area rusted using diagrammatic scale, 1, 3, 5, 7 & 10 indicates 1%, 3%, 5%, 7% and 10% of leaf area rusted, respectively. Any rust severity on the leaves was estimated by an average number of pustules per leaf making a cumulative count of each sporulation lesion area following the Kushalappa and Chaves (1980) procedure (Figure 2). At the same time, sporulation lesion density (SLD) was measured as number of sporulated lesions per infected leaves. Severity is total sum of leaf area rusted.

Data analysis

The data were summarized on excel spreadsheet software and the mean disease incidence, severity and SLD were computed for each coffee tree. Completed questionnaires were entered into Microsoft Excel spread sheets where variable codes assigned. Data were then analyzed using Statistical Package for Social Sciences (SPSS). Disease infections were also tested for agro ecological variation, agronomic practice, shade type and farm slope.

Results and Discussion

Incidence and severity of the disease: The result showed that, CBD was very severe problem at the high land of Bedeno followed by Boke district, where as CLR was sever at Boke followed by lowland of Bedeno (Table 2). CWD infection was observed only in Daro Labu district at very low level (less than 3% with overall average infection of 0.92% and ranges from 0-20%) (Table2). The incidences of CBD, CLR & BDB were very high across all study areas with a mean value of 66%, 33% and 47% respectively, (Table2). The significant variation on incidence and severity were observed among the agro-ecology (Table 2 and Figure 3-5). The mean incidence of CBD ranged between 35. 5% at Daro Labu and 79.67%at Bedeno where as the severity of the disease varied between 18.5 % and 44.7% at Daro Labu and Bedeno, respectively (Table 2). This shows an increase in disease pressure in comparison with 2010 in which mean incidence ranged between 33.75% at Daro Labu and 70.19% at Bedeno and the severity of the disease varied between 6.34% and 28.53% at Daro Labu and Bedeno, respectively (Mohammedsani, 2011). Similar trend can also be observed from the reports of Eshetu *et al*. (2000) where the average severity of CBD was 32 % in 1997. High incidence of CBD may be explained by the recurrent climate change with high/low rainfall in all study areas. Similarly, Cook (1975) explained that, in general, high rainfall, high humidity or wetness and relatively low temperature persisting for long period favors CBD development at high altitudes. Fluctuation of climate in the coffee growing area resulted in reduction in the yield and quality, increasing the outbreak of pests and diseases, increasing cost of production and reduced area of production.

Table 2. Mean incidence and severity of major disease across major coffee growing districts of Hararghe during 2015 cropping season

District name	Incidence (%)				Severity (%)	
	CBD	CLR	BDB	CWD	CBD	BDB
D/Labu	35.50	14.09	43.33	2.83	18.52	23.81
Habro	75.50	20.41	56.00	0.00	25.41	24.47
Boke	72.17	50.26	73.67	0.00	26.09	40.20
Bedeno	79.67	46.49	15.17	0.83	44.72	10.09
Mean	65.71	32.81	47.04	0.92	28.68	24.64
Range	0-100	0-75	0-100	0-20	0-89	0-74
Std. Dev.	27.52	25.23	29.66	3.74	18.27	19.19

The three diseases (CBD, CLR and BDB) occurred across all the districts in all the agro ecologies with variable ranges of incidences and severities (Table 2 and 3). This indicates that the diseases are very important in both lowland and highland coffee growing agro ecologies of Hararghe and may cause significant yield loss. Such disease occurrence may cause considerable yield losses in the study areas. According to Biratu (1995) yield losses due to CBD was 52.5 % and can be as high as 100% (total loss) in some individual farm plots in Habro district (West Haraghe). Similarly, Biratu (1998) reported that coffee cultivation has been hampered by CBD that decreased the annual coffee production by an average of 47%. As MCTD (1989) reported, the national coffee yield loss due to CBD was about 20%. According Silva *et al*., (2006) CLR may cause yield losses varying between 10-40% in different countries.

Table 2. Regional and ecological variation on the Severity of major coffee disease in Hararghe areas

District name	Severity of different diseases per agro-ecology (%)								
	Highland			Midland			Lowland		
	CBD	CLR	BDB	CBD	CLR	BDB	CBD	CLR	BDB
D/Labu	29.87	1.72	7.46	11.06	2.12	24.72	14.62	0.92	39.25
Habro	32.07	8.24	19.36	18.41	0.18	28.94	25.76	8.16	25.11
Boke	22.40	7.74	50.53	33.98	9.91	27.90	21.89	7.03	42.16
Bedeno	64.23	2.61	4.98	41.91	14.91	6.67	28.02	12.15	18.64
Mean	37.14	5.08	20.58	26.34	6.78	22.06	22.57	7.07	31.29
Range	0-86.8	0.02-17	0-56.5	0.23-65	0-19.3	0-48.2	0.2-35.97	0.25-18.8	3.37-74.1
Std. Dev.	24.14	5.01	19.64	15.81	6.91	15.15	9.52	5.98	21.60

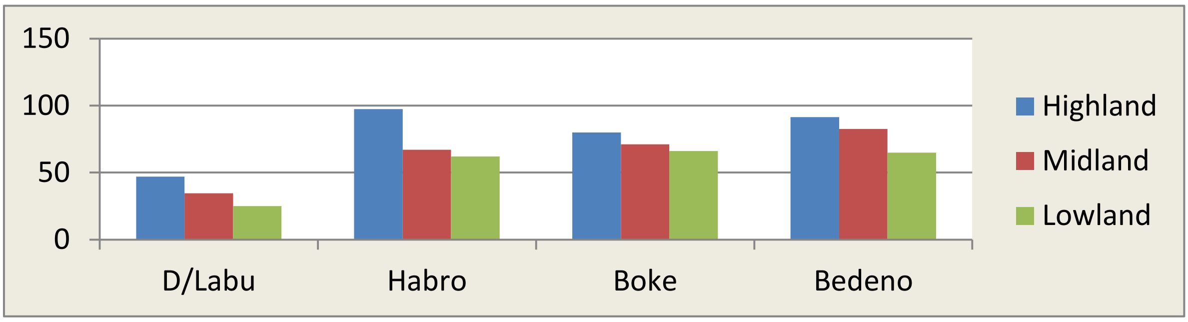


Figure 3. CBD incidence across each-agro ecology per district

CLR severity and sporulation density (SLD) was high at Bedeno followed by Boke district and the minimum values was recorded from D/Labu district with the overall mean of about 6% and 4% of severity and SLD (Figure 5).

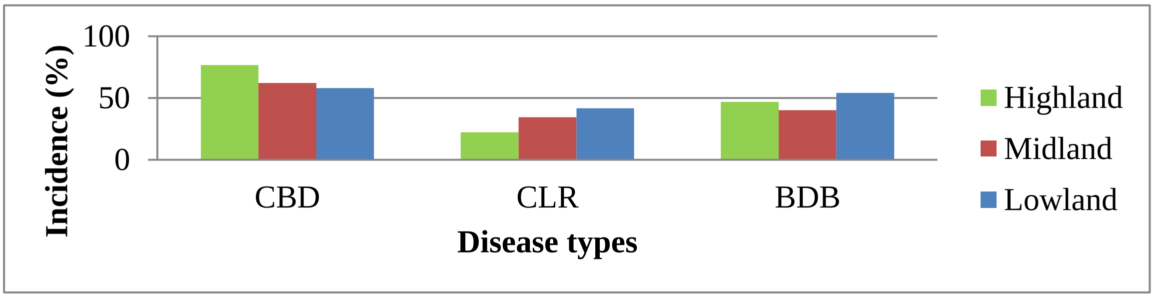
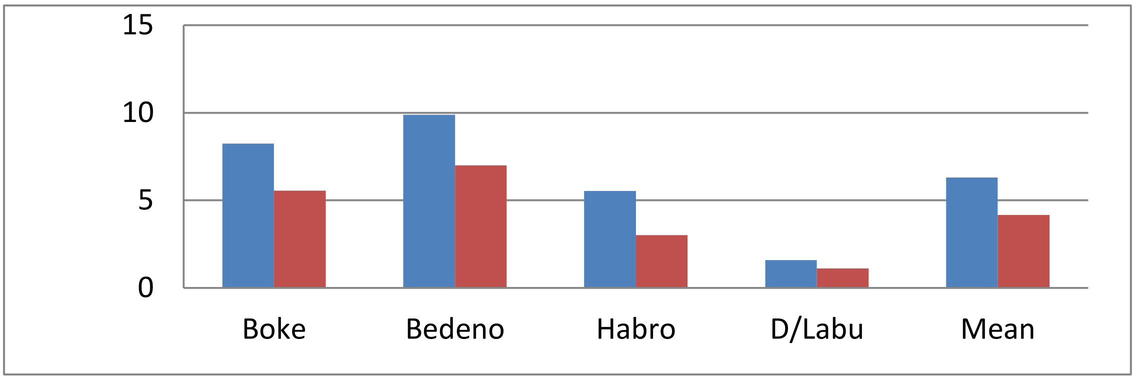


Figure 4. Incidence of CBD, CLR & BDB per coffee growing agro-ecology of Hararghe regions



un-shaded coffee farms (Table 4). Shade tree was best in reducing the incidence and severity of CBD and BDB. Although, CLR incidence was lower under shade, rust severity was higher compared to un-shaded coffee (Table 4). The shades may serve as a barrier for inoculum; hence reduced incidence. But the microclimate of the shade may favor growth and development of the pathogen once infection occurs hence higher severity. Similarly agronomic management practice shows different effects on the severity and incidence of the disease (Table 5). Accordingly, cultivation of coffee farm as practiced by most of Hararghe farmers can reduce more disease occurrence that all other management practice. Well managed pants are generally resistant and/or tolerant to diseases.

Table 4. Effect of coffee shade on the mean Incidence and severity of different coffee diseases

Shade type	Incidence (%)			Severity (%)			CLR sporulation density
	CBD	CLR	BDB	CBD	CLR	BDB	
Un-shaded	66.35	33.32	57.76	26.05	6.08	30.62	3.94
Shaded	64.14	31.57	21.00	35.07	6.85	10.12	4.72
Mean	65.71	32.81	47.04	28.68	6.31	24.64	4.17

Table 5. Effect of agronomic practices on the disease infestation

Agronomic practice	Incidence (%)			Severity (%)			CLR Sporulation density
	CBD	CLR	BDB	CBD	CLR	BDB	
Slashing	81.00	31.30	25.70	44.70	6.20	23.20	4.29
Cultivation	46.73	23.33	46.73	24.17	3.87	21.43	2.43
Intercropping	69.48	36.46	51.29	27.29	7.18	26.06	4.76
Mean	65.71	32.81	47.04	28.68	6.31	24.64	4.17

Farmers' Coffee varieties: Farmers in the study areas still depend on the heterogeneous local land race cultivars, which are known by different vernacular names. This shows that; farmers in the area have their own local names to distinguish the coffee types grown on their farms. There are six locally known agro-types, which have distinct difference in morphology, yield, resistant to the disease and agronomic characteristics (Table 6). The names are derived from the name of the first collector or introducer, the area of collection, or the agronomic characteristics of each coffee type. Farmers grow a minimum of two local varieties in their individual orchards based on their tolerance to moisture stress, resistance to disease and pests. Accordingly, for the low altitude, where CBD prevalence is low, but high temperature and shortage of moisture is problem, they grow more adapted land races, such as *Shumbure and Muyra*. However, although cultivars are known to be inferior in terms of their productivity, in the CBD prone areas, they grow less susceptible cultivars such as, *Shumbure*, *Charcharo and Wagare*. But, all the respondents are very interested to plant high-yielder, disease resistant and drought tolerant adaptable improved coffee varieties. Improving new cultivars resistant to pests and diseases, more productive, well adapted to the local climatic and soil conditions, and have acceptable and desired quality for the market is very important.

Table 6. Local coffee landraces growing by the farmers in the study areas.

No.	Local name	Frequency	Percentage
1	Shumbure	33	68.8
2	Cherchero	5	10.4
3	Shunkiyi	5	10.4
4	Abadir	2	4.2
5	Wagare	2	4.2
6	Muyra	1	2.1

Conclusion and recommendation

The finding indicates that four coffee diseases CBD, CLR, CWD and BDB are the major diseases in all the districts. Their incidence and severity varied among and within the areas based on the agro-ecological conditions and production system of coffee. All the areas are increasingly threatened by the diseases where there is considerable coffee berry, leaf and bearing branch losses, respectively across all location and agro ecology. However, the current study showed that even if CWD was reported in earlier times on coffee Arabica in Ethiopia, the survey result showed very low incidence across the coffee production areas as compared to higher incidence in plantation and garden coffee, attributed to variation in resistance among the coffee germplasm and low intensity cultural practices in the forest. Generally, coffee production potential of Harerghe areas has been highly decreasing & changing to khat due to the above all mentioned results.Therefore, for producing sustainable, environmentally friendly organic coffee fetching premium price to farmers, integrated management of diseases should be given attention. Research should be strengthened in coffee disease protection by developing disease resistant cultivars as long-term solution. Farmers' indigenous knowledge needs to be explored; and ultimately all practices integrated with research work. As a last and short term option research should also be focused on appropriate chemical efficacy test for disease control. This in turn could help to increase income generation of coffee producers in specific & to the country in general; thereby increase foreign currency eaernings.

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Determining the impact of mulching practices on the early survival and subsequent growth performances of newly transplanted coffee seedlings

Mohammedsani Amin[1], Abera Jaleta[1] and Hika Bersisa[1]*

[1]*Mechara Research Center, Coffee Research Team, Mechara, Eastern Ethiopia*

*Corresponding Author's email: mamasaniamin@yahoo.com

Abstract

The current global temperature has been increasing over the years due to recurrent climate change and variability, which directly or indirectly affects the agriculture sector. This has made the necessity for farmers to get the best out of the varying rainfall amount and distribution.Experiments were conducted with the objectives of identifying effective mulching materials and their optimum mulching thicknesses for newly transplanted coffee seedlings at Mechara Agricultural Research Center (MARC) on-station and Sakina on-farm during 2015 and 2016. Coffee seedlings of Mechara-1 variety and organic mulching materials of maize stover and vetiver grass at 5cm and 10cm mulching depths were compared with farmers' practices of using soil as mulching material and no mulch bare soils.The experiment was laid out in RCBD with three replications.Data were analyzed for seedling survival rate,soil moisture content, moisture stress score, weed density and subsequent early growth performance of the coffee seedlings under the different mulching treatments. The resultsshowed that there are statistically significant differences (p <0.05) among the treatments for most parameters studied at both locations and seasons. The highest seedling survival rate, soil moisture contentand different growth parameters, and the minimum moisture stress score were recorded for coffee seedlings treated with maize stover and vetiver grass mulches compared to the no-mulch bare soils and farmers' practices of using soil as a mulching material. However, vetiver grassmulches applied at 5cmmulching thickness resulted in the highest combined over location and season percentage of coffee seedling survival rate (94.6%),soil moisture content (16.5%), the lowest moisture stress score (1.5)and the highest mean values of the different early growth measurements of coffee seedlings. Weed species and their densities were lowest of all under coffee seedlings treated by maize stover mulches at 10cm mulching depth. Therefore, from these results, mulching newly transplanted coffee seedlings with vetiver grass at 5cm mulching depth can be recommended to farmers in Daro-Labu district and similar moisture stress areas of Haraghe as this practice conserved soil moisture resulting in better seedlings survival through increasing their tolerance to moisture deficits.

Keywords: Vtiver grass; maize stover; survival rate; soil moisture; moisture stress, coffee seedlings

Introduction

Coffee (*Coffee Arabica* L.) is a non-alcoholic stimulant beverage crop that belongs to the family *Rubiaceae* and genus *Coffea*(CFC, 2004). Growing coffee provides income for about 25% of Ethiopia's population and is the country's top export (NPR, 2017).The country is the largest African producer of Arabica coffee. The crop is the backbone of the country's economy in which more than 15 million Ethiopians depend on it for living (NPR, 2017). Coffee accounts for more than 25% of the GNP, 40% of the total export earnings, absorbing 25% of the employment opportunity for both rural and urban dwellers, and 10% of the total government revenue GDP (CFC, 2004).

Currently, the effects of climate change; higher temperatures and rainfall variability could take a toll on the country's ability to farm this treasured crop. And the frequency of droughts has increased in recent years, affecting coffee growing regions as well. Ethiopia could lose from 39 to 59% of its current coffee-growing areas to climate change by the end of the century, according to a new study published in Nature Plants (NPR, 2017).Despite the favorable climatic conditions, diversified genome and long history of its production in Ethiopia, coffee genetic erosion is increasing from time to time due to climate change.The traditional farmer depends entirely on rainfall as a source of moisture forcoffee productionin Ethiopia. But in the recent past, frequent droughts of varying degrees have been experienced in the tropics (Norman *et al*., 2011).According to the study, Ethiopia's coffee-growing areas could expand despite climate change, if farmers moved their farms to higher altitudes and adopted other mitigation strategies such as irrigating and mulching.

Currently, the most severe stress conditions (wilting and curling of leaves, loss of coffee crop, and plant death through drought) were recorded in the Hararghe coffee growingenvironments. In many Hararghe coffee gardens, cultivation appeared to be lacking suitable farming practices such as mulching and/ terracing or irrigation required for growing coffee in this area which, due to low rainfall, is not ideally suited to coffee production (Moat *et al*., 2017).One ofthe most important methods of moisture conservation is use of mulches. The use of mulch in coffee farms has been on the increase over the years especially during the first few years after transplanting seedling. Mulching is the covering of the soil with different materials (e.g. grass, compost, manure) not only helps to preserve soil moisture and decrease soil temperature (reducing evapotranspiration), but it can also increase soil fertility, suppress weeds, and improve rainfall penetration into the ground. Mulching has been used to good effect in Kenya, Tanzania and other countries in East Africa (Moat *et al*., 2017). Hararghe is one of the areas currently under influence of climate change. It is moisture deficit area. In addition the tradition of using different mulching materials such as grass, maize and sorghum stovers, banana leaves, wood barks, coffee husk and etc. is not well adapted by Hararghe coffee growing farmers. The mulching thickness of these materials is also not yet identified in the area. There is no any research output in the area for what type and how much to apply. As a result of these problems early survival of transplanted coffee seedling is becoming the most limiting factor for coffee production to the crop growing farmers of the area. Thus, scientific researchesare required to ascertain the precise outcomes and benefits of on-farm interventions for better coffee production and productivity in coffee growing environments of Hararghe. Therefore, field experiments were established with the objectives of identifying effective mulching materials and to determine their mulching thicknessesthat can improves the survival rate of transplanted coffee seedlings for increased productivity.

Materials and Methods

Description of the Study Area: Experimentswere conducted at Mechara Agricultural Research Center (MARC) on-station and Sakina on-farm during 2015 and 2016 cropping seasons.Geographically, Mechara is located 434 km east of Addis Ababa in Daro-Labu district of west Hararghe Zone of Oromia National Regional State. It has analtitude of 1760meters above sea level with annual average temperature and rainfall of 16^{0}_{C} and 963 mm, respectively. The major soil type of the center is sandy loam clay, which is reddish in color.Sakina is 22km away from Mechara, found at an elevation of 1711 meters above sea level. It is categorized as one of the low land environmentsin the Daro-Labu district.

Experimental Materials, Treatments and Designs

The experiments at both locations were made up of four mulching treatments of maize stover and vetiver grass with different mulching thicknesses. These treatments were compared with the usual soil mulching farmers' practices and no mulch treatments. The treatments were arranged in randomized complete block (RCB) design with three replications at both locations across the cropping seasons. Amongrecently released improved Hararghe coffee varieties, *Mechara-1*variety, which is recommended for the area, was used as a test material.

Experimental Procedures and Methods of Application: Seedlings of *Mechara-1*coffee variety were raised in polyethylene bag at MARC nursery site. After the seedlings grown and produced 8 true leaves, they were transplanted to the experimental fields in to already prepared planting holes in the month ofAugust 2014. The mulching treatment materials were applied at the end of September which is characterized by the termination of rainfall and start of dry season. The mulch treatments were kept under the seedlings until the commencement of early*belg*rain (end of March 2015 and 2016). All other agronomic and cultural practiceswere uniformly applied to the treatments as per recommendations. The mulching materials were applied by spreading under the transplanted coffee seedlings as per their mulching depths at 10cm distances away from the trunk of the seedlings/tree.

Data and Methods of Collections

Data for seedling survival rate, soil moisture content, moisture stress score, weed density and species, soil property, and growth performance of the seedlings were collected from each treatment at different time intervals. The methods of data collection were as follows:

Coffee seedling survival rate

The total number of survived and dead seedlings throughout the dry period from the time of mulchingat the end of September 2014to the beginning of rainy season (end of March 2015) were recorded for all the treatments at both experimental locations. The percentages of dead seedlings from the total number of seedling at early application of mulching materials per plot and treatmentswere calculated using the following formula.

$$Seedling\ Survivalrate\ (\%) = \frac{No.of diedseedlingsatendof dryperiod}{\text{Total seedlings at early application of mulching}} X\ 100$$

Soil moisture content

Soil sampleswere collectedat a depth of 40cm and fresh weight the soil samples were recorded using sensitive balance. These soil samples then were subjected to oven dry at $105^{o}{}_{C}$ for 72 hours. The dry weights of the oven dried soil samples were recordedto calculate the percentage of soil moisture content per plot and mulch treatments as follows:

$$Soil\text{moisture}\ (\%) = \frac{Freshweightofsoil(gm) - Dryweightofsoil\ (gm)}{Dryweightofsoil\ (gm)} X\ 100$$

The soil moisture content data wererecordedat 30 days interval throughoutthe dry period extending from end of September to March across the experimental years to determine the moisture conservation efficiency of each mulching treatment.

Moisture stress score (1-5 scale): Moisture stress scoreswere recorded from all plants per experimental plotstwice per day early in the morning and late at noon at monthly interval for four consecutive times along with soil sample collections for soil moisture content measurement immediately after application of the mulching materials lasting throughout the dry period of each experimental season.A scale of 1 to 5 was used to score the moisture stress where1=all leaves green and turgid; 2= most leaves still turgid but younger leaves show leaf folding; 3= all leaves wilt or fold; 4= leaves partially turning pale and partly shed showing severe wilting; and 5=leaves completely turning brown, dry and mostly dropping.

Weed species and density: The number of weeds and species emerged per plot was recorded twice before the application of mulching treatments and at the end of the dry period. This was done by listing the names and counting the number of emerged weeds per species under three sample coffee seedlings which covered an area of $2500cm^2$ per experimental plots.

Seedling growth performance: Coffee seedling growth performance data were recorded for total seedling height, stem diameter (girth), number of primary branches, and canopy diameter from five central representative seedlings/trees per plot.

Total height (TH): The length of the plant starting from the ground level to the tip of the tree on main stem was measured using tape meter.

Girth (mm): the girth (stem diameter) of coffee tree on main stem was measured using digital caliper at 10cm from the ground level.

Number of primarybranches *(NPB): T*otal number of primary branches was counted per tree.

Canopy diameter CD*:* averagelength of tree canopy was measured from east-west and north-south direction, from the widest portion of the tree canopy.

Data Analysis

Analysis of variance (ANOVA) was computed for all collected data using GenStat 15th edition. Treatment means were separated using fishery's protected least significant difference method (LSD) at 5% probability level for statistically differentmeans.

Results and Discussion

The effect of mulchingmaterials and mulching thicknesseson seedling survival rate: The analysis variance showed statistically significant different percentage of seedling survival across locations in 2016 while non-significant in 2015 cropping seasons. But, the combined analysis of variance across seasons and locations resulted in statistically different ($p<0.05$) for the measured percentage of seedling survival rates (Table 1). Accordingly the highest combined mean seedling survival rate (94.6%) was recorded bycoffee seedlings received vetiver grass at 5cm mulching thicknessacross the growing seasons followed by the same mulching material at 10cm mulching depth (Table 1). The least seedling survival rates were recorded from plots with no mulch followed by the farmers' practices of using soil mulch.The reason for the highest seedlings survival rates recorded under vetiver grass mulches at 5cm mulching thicknesscould be due to the fact that the mulches allowedseedling roots to extend, grow and establish deep in to the soil through conserving moisture compared to bare soils. The result of experiment is in line with that ofLinda (2007) who reported seedling root development and density were greatest under organic mulches compared to bare soil.

The effect of mulching materials and mulching thicknesses on soil moisture content: The analysis of variance for soil moisture content showed statistically significant differences ($p<0.05$) among the mulching treatments across seasons at Sakina on-farm while the 2015 results were statistically non-significant for MARC on-station (Table 2). The combined analysis of variance for soil moisture content, however, resulted in statistically significant differences across the cropping seasons and experimental locations (Table 2). Accordingly, statistically the maximum pooled mean percent (16.5%) of soil moisture content across locations and seasons was recorded for soils of coffee seedlings mulched with vetiver grass at 5cm mulching thickness. This result is supported by findings of different authors (Sinkevičienė*et al.*,2009; Taparauskienė and Miseckaitė, 2013; Bert and Cregg, 2009; Nkansah*et. al.*, 2003) who reported organic mulching increased soil moisture content compared tobare soils under transplanted seedlings.

Effects of mulching materials and mulching thicknesseson moisture stress score

The analysis of variance for moisture stress showed statistically significant differences ($p<0.05$) among the mulching treatments across the experimental seasons at Sakina on-farm while the 2015 results were statistically non-significant for MARC on-station (Table 2). However, the combined analysis of variance for moisture stress resulted in statistically significant differences across the cropping seasons and experimental locations (Table 3). Statistically the least pooled mean (1.5) score of moisture stress across locations and seasons was recorded from coffee seedlings mulched with vetiver grass at 5cm and 10cm mulching thicknesses.

Effects of mulching materials and mulching thicknesseson weed suppression : The analysis of variance for weed species and density for growing seasons and location showed statistically significant differences ($p<0.05$) among the mulching treatments (Table 4). Similarly, the combined analysis of variance for weed species and densities resulted in statistically significant differences across the cropping seasons and experimental locations (Table 4). Statistically the lowest mean number of weed species (2 and 2.3) and (0.3 and 1.6) were recorded in coffee seedlings mulched by maize stover at 10cm and 5cm mulching thicknesses, respectively at both locations. But weed densities were all low in coffee seedlings received either maize stover or vetiver grass at both mulching thicknesses compared to the farmers' practices of using soil as mulching material and the bare soil with no mulch (Table 4). Similarly, the pooled means of both the number of weed species and their densities were significantly reduced in coffee seedlings mulched with both maize stover and vetiver grass for both thicknesses compared to the control mulching treatments. The results of this study is in support of the findings achieved by (Salman *et al.*, 2015; Edyta, 2014; Linda, 2007; and Norman *et al.*, 2011)who also reported that organic mulching reduces weed infestation and enhances growth and yield of crops.

Effects of mulching materials and mulching thicknessesonearlygrowth performance of the seedlings: The analysis of variance for early seedling growth performances showed statistically significant differences ($p<0.05$) among the mulching treatments at Sakina on-farm across both cropping seasons (Table 5). Statistically the highest mean values for plant height, stem diameter (Girth) and seedling canopy diameter were achieved for coffee seedlings mulched by vetiver grass at 5cm mulching thicknesses in 2015and 2016 but the highest seedling canopy diameter was also recorded under vetiver grass mulches at 10cm mulching thickness in 2016 for the on-farm research experiment (Table 5). In contrast, statistically the highest mean number of primary branches were achieved by coffee seedlings treated with maize stover mulches at 5cm and 10cm mulching thicknesses in 2015 and mulching of maize stover at 10cm mulching thickness in 2016 for Sakina on-farm. However, most of the mulch treatments are statistically at par among each other but superior to the no mulch treatment control and farmers' practices of using soil as a mulching material for growth performance parameters.

The analysis of variance for early seedling growth performances showed statistically significant differences ($p<0.05$) among the mulching treatments in both 2015 and 2016 experimental seasons except for stem diameter (girth) in 2015 at MARC on-station (Table 6). All the mulching treatments showed statistically superior coffee seedling growth performances to the no mulch and farmers' practices with vetiver grass mulching at 5cm mulching thickness resulted in the highest measurements of the growth parameters (Table 6). The results of the study conducted at both experimental locations in 2015 and 2016 on the coffee seedling growth performances as affected by the mulching materials and thicknesses are in line with other similar studies (Linda, 2007; Manuel *et al.,* 2000; Thakur *et al.,* 2000; Norman *et al.,* 2002; Nkansah*et al.,* 2003; Gandhi and Bains, 2006; Moniruzzaman, 2006; Awodoyin, 2007; Ojeniyi*et al.,* 2007; Iftikhar*et al.,* 2011; Dauda, 2012; Norman *et al.,* 2011) who reported that mulching enhanced early growths of transplanted seedlings through improvingseedling survival and enhancing root establishment of the seedlings as mulches provide improved soil moisture conservation, reduced soil temperature, reduced weed infestation and nutrient availability as a result of reduced leaching of nutrients.

Conclusions and Recommendations

The results of these experimental researches from both locations across the experimental years indicated that soil moisture content, survival rates of transplanted coffee seedlings, early growth performances, moisture stress scores and weed suppression were significantly influenced by mulching materials and mulching thicknesses. Soilsreceivedvetiver grass mulch at 5cm mulching thickness retained significantly the highest percentage of seedling survival rates (94.6%) and soil moisture (16.5%) compared to soils under no and soil mulches treatments. This mulching practice also significantly reduced the impact of moisture stress to the transplanted coffee seedlings resulting in the lowest moisture stress score of 1.5.

The mulching treatments also significantly affected the early growth performances of transplanted coffee seedlingswherevetiver grass mulch at 5cm mulching thickness achievedvigor growths. Superior pooled means of plant height, stem diameter (girth), number of primary branch and seedling canopy diameter were recorded bytransplanted coffee seedlings treated with vetiver grass mulch at 5cm mulching thicknesses. In general, the studies confirmed mulching newly transplanted coffee seedlings by vetiver grass mulches at mulching thickness of 5cm exhibited highest seedling survival rates, improved soil moisture contents, reduced moisture stress effects, vigor seedling growth performances and reduced weed infestations. Therefore, coffee growing farmers in Haraghe zone where rainfall variability causes moisture stress the limiting factor for the production of the crop, the use of vetiver grass as mulching material at 5cm mulching thickness through spreading the grass within 30cm radius and 10cm away from the trunk of newly transplanted coffee seedlings/tree starting from end of September when rainfall terminates every growing season for increased production and productivity. Immediate on-farm demonstration and pre-scaling up activities should get due attention to take this result to the end users.

Table1. Effect of mulching materials and thicknesses on survival rate of newly transplanted coffee seedlings at MARC and Sakina

Treatment	Seedling Survival rate (%)						Combined means
	MARC on-station			Sakina on-farm			
	2015	2016	Means	2015	2016	Means	
Maize stover mulch 5cm thickness	100	93.30a	96.70a	85.0	66.7ab	75.8ab	86.3abc
Maize stover mulch 10cm thickness	100	88.3ab	94.3ab	83.3	66.7ab	75.0ab	84.6abc
Vetiver grass mulch 5cm thickness	100	96.70a	98.30a	95.0	86.7a	90.8a	94.600a
Vetiver grass mulch 10cm thickness	100	96.70a	98.30a	88.3	75.0ab	81.7ab	90.00ab
Soil mulch (farmer practice)	99.0	76.7bc	87.8bc	85.0	61.7ab	73.3ab	80.60bc
Without mulch (control)	96.7	74.00c	85.30c	85.0	48.0b	66.5b	75.009c
Mean	99.3	87.7	93.5	86.9	67.5	77.1	85.3
LSD (5%)	NS	13.4	6.4	13.7	32.1	21.2	12.3
CV%	1.9	8.4	3.8	8.6	26.2	15.1	7.9

Means with the same letters in a column are non-significant at 5% probability level. NS=Non-significant

Table 2. Soil moisture content as affected by mulching materials and thicknesses under newly transplanted coffee seedlings at MARC on-station and Sakina on-farm

Treatment	Soil moisture content (%) by location and year						Combined mean
	MARC on-station			Sakina on-farm			
	2015	2016	Mean	2015	2016	Mean	
Maize stover mulch 5cm thickness	11.1a	10.7c	11.0b	18.2ab	8.4bc	13.3b	12.1bc
Maize stover mulch 10cm thickness	11.1a	11.6bc	11.4b	22.1ab	8.4bc	15.5ab	13.3b
Vetiver grass mulch 5cm thickness	11.1a	17.4a	14.3a	26.1a	11.4a	18.7a	16.5a
Vetiver grass mulch 10cm thickness	11.1a	12.6b	11.9b	22.1ab	8.8b	15.9ab	13.7b
Soil mulch (farmer practice)	10.1a	8.73d	9.9c	14.9b	7.2cd	11.1b	10.8c
Without mulch (control)	7.3b	7.48d	7.3d	14.9b	6.4d	12.9b	9.8c
Mean	10.3	11.4	11.0	19.7	8.4	14.6	12.7
LSD (5%)	2.7	1.7	1.31	10.7	1.4	5.3	2.6
CV%	14.4	8.4	6.6	28.9	9.5	20.3	11.4

Means with the same letters in column are non-significant at 5% probability level.

Table 3. Effect of mulching materials and thicknesses on moisture stress tolerance for newly transplanted coffee seedlings at MARc on-station and Sakina on-farm

Treatment	MARC on-station			Sakina on-farm			Combined mean
	2015	2016	Mean	2015	2016	Mean	
Maize stover mulch 5cm thickness	1.2ab	2.4b	1.8bc	2.9bc	2.2b	2.6b	2.2b
Maize stover mulch 10cm thickness	1.0a	2.1ab	1.6ab	3.2c	2.2b	2.7b	2.2b
Vetiver grass mulch 5cm thickness	1.0a	1.6a	1.3a	1.5a	1.8a	1.6a	1.5a
Vetiver grass mulch 10cm thickness	1.0a	1.8a	1.4ab	1.6a	1.5a	1.5a	1.5a
Soil mulch (farmer practice)	1.5bc	2.0ab	1.8bc	3.2c	2.4bc	2.8b	2.3b
Without mulch (control)	1.8c	2.5b	2.2c	1.8ab	2.7c	2.3b	2.1b
Mean	1.27	1.98	1.66	2.08	2.22	2.17	1.74
LSD (5%)	0.4	0.5	0.4	1.1	0.4	0.6	0.4
C.V (%)	21.9	14.2	13.7	26.5	10.1	15.7	11.2

Means with the same letters in a column are non-significant at 5% probability level.

Table 4.Total weed density and weed species emerged as affected by different mulching materials and thicknesses

Treatments	Weed Species			Weed Densities		
	MARC on-station	Sakina on-farm	Mean	MARC on-station	Sakina on-farm	Mean
Maize stover mulch 5cm thickness	2.3a	1.6ab	2ab	5.3a	6.3a	5.8a
Maize stover mulch 10cm thickness	2.0a	0.3a	1.2a	3.0a	2.7a	2.8a
Vetiver grass mulch 5cm thickness	4.0ab	2.3ab	3.2bc	12.0a	4.0a	8.0a
Vetiver grass mulch 10cm thickness	5.7bc	3.0bc	4.3cd	15.3a	7.7ab	11.5a
Soil mulch (farmer practice)	6.7bc	5.0cd	5.8de	34.7b	19.3bc	27b
Without mulch (control)	7.0c	6.0d	6.5e	41.7b	21.3c	31.5b
Mean	4.6	3.0	3.8	18.7	10.2	14.4
LSD (5%)	2.9	2.1	1.8	17.6	12.1	10.3
CV%	34.4	37.6	26.2	51.8	37.0	39.5

Means with the same letters in column are non-significant at 5% probability level.

Table 5. Early growth performance of newly transplanted coffee seedling as affected by mulching materials and thicknesses at Sakina on-farm

Treatment	2015				2016			
	PH (cm)	Girth (mm)	NPB	CD (cm)	PH (cm)	Girth (mm)	NPB	CD (cm)
Maize stover mulch 5cm thickness	41.3ab	6.33b	9.40a	17.7b	80.7ab	19.1bc	20.3abc	75.4ab
Maize stover mulch 10cm thickness	38.6ab	6.27b	9.40a	19.5b	90.6a	18.3bc	23.9a	73.0ab
Vetiver grass mulch 5cm thickness	43.6a	8.33a	9.20ab	27.4a	90.4a	23.4a	21.4ab	84.4a
Vetiver grass mulch 10cm thickness	39.6ab	6.60b	8.93ab	19.9b	91.9a	19.6ab	21.1ab	85.9a
Soil mulch (farmer practice)	29.8bc	5.47b	8.13ab	18.3b	73.9b	15.4bc	18.5bc	66.7ab
Without mulch (control)	26.4c	5.73b	6.87b	19.3b	74.0b	14.9c	15.4c	60.6b
LSD (5%)	11.54	1.44	2.4	5.23	14.48	4.39	5.27	22.94
CV%	17.40	12.30	15.20	14.10	9.50	13.10	14.40	17.00

Means with the same letters in column are non-significant at 5% probability level; Key: PH=Plant height; NPB; number of primary branch; CD=Canopy diameter

Table 6. Early growth performance of newly transplanted coffee seedling as affected by mulching materials and thicknesses at MARC on-station

Treatment	2015				2016			
	PH (cm)	Girth (mm)	NPB	CD (cm)	PH(cm)	Girth (mm)	NPB	CD (cm)
Stalk of maize with 5cm thickness	48.7ab	9.6a	8.4ab	32.4a-c	80.7abc	19.1ab	20.3abc	75.4ab
Stalk of maize with 10cm thickness	42.7ab	8.9a	7.2bc	31.3a-c	91.9ab	18.3ab	23.9ab	73.0ab
Vetivar grass with 5cm thickness	52.1a	10.1a	9.2a	36.80a	97.1oa	21.10a	26.40a	91.10a
Vetivar grass with10cm thickness	52.6a	9.9a	7.8a-c	35.7ab	85.2a-c	19.6ab	21.1abc	79.3ab
Soil mulch (farmer practice)	40.9b	8.5a	7.0bc	28.1bc	77.2bc	17.1ab	18.5bc	66.7b
Without mulch (control)	39.3b	8.1a	6.4c	25.1c	70.7oc	14.90b	15.40c	57.3b
LSD (5%)	11.11	2.60	1.90	8.57	18.24	5.05	6.95	23.35
CV%	13.30	15.50	13.80	14.90	12.00	15.10	18.30	17.40

Means with the same letters in column are non-significant at 5% probability level. Key; PH=plant height; NPB; number of primary branch; CD=Canopy diameter

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