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Determination of Appropriate Seed Rate and Row Spacing of Bread Wheat for Highlands of Guji Zone

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Abstract

Wheat is one of the major staple crop in Ethiopia in terms of both production and consumption. Even though it is such an important cereal crop in Ethiopia, it gives low yield due to many production constraints such as lack of improved varieties, poor agronomic practice (inappropriate seeding rate and row spacing), diseases, weeds and low soil fertility in Ethiopia in general and in Guji zone in particular. Therefore, field experiment was conducted during the 2015-2017 main cropping season at Bore and Ana sora to assess the effect of seeding rate and row spacing on yield and yield components of bread wheat; and to determine appropriate seeding rates and row spacing for bread wheat. The experiment was laid out RCBD in a factorial arrangement with three replications using a wheat variety known as 'Huluka' as a test crop. The treatments consisted of four levels of seeding rate (100, 125, 150 and 175 kg ha^{-1}*) and four levels of row spacing (15, 20, 25 and 30 cm) making a total of 16 treatments. Analysis of the results revealed that all considered parameters were significantly (P<0.05) affected by the interaction of the factors (seeding rate x row spacing) as well as the main effects except date to 50% heading and plant height which did not significantly (P<0.05) affected. The highest grain yield (4239 kg/ha), was obtained from combination of 150 kg/ha seeding rate and 20cm row spacing. Therefore, use of 150 kg/ha and 20cm row spacing could be recommended for production of bread wheat for the study area (Bore and Ana Sora) and other areas with similar agro ecologies.*

Keywords: Interaction, Interaction effect, Main effect, Nutrient

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal crop in terms of area and production in the world. It was grown on more than 216 million hectare (ha) of land with a total production of 651 million tonnes of grain in 2010 (FAOSTAT, 2012). In Ethiopia, wheat covered an area of 1.653 million ha with a total production of 4 million metric tonnes and yield average of 22.11 t/ha during 2010. Despite its ranking third in area and fourth in production, it stands fourteenth in yield in Africa (FAOSTAT, 2012). Production of the crop is highly constrained, among others, by low soil fertility. Developing and using an improved variety alone is not enough to realize optimum production of the crop unless fertilizers are properly supplied (Tesfaye, 1987).Besides, regular nutrition of plants for achieving high yields and good quality, sowing time and planting density play an important role. Optimum plant densities vary greatly between areas, climatic conditions, soils, sowing time, and varieties. Since cultivars genetically differ for yield components, individual cultivars need to be tested at a wide range of seeding rates to determine their optimum seeding rate (Wiersma, 2002). Management practices play an important role in determining yield and end-use quality of wheat.

Numerous studies have documented on seeding rate, planting date, row spacing, and seeding depth that affect yield and yield components of wheat (Wajid *et al*., 2004; Guberac *et al*., 2005; Schillinger, 2005; Kristó *et al*., 2007; Maric *et al*., 2008; Otteson *et al*., 2008; Valério *et al*., 2009). Seeding rate affected virtually all of the agronomic variablesO'Donovan, Turkington, and Edney,2011). Using appropriate seeding rate which fits specific wheat genotypes is necessary to optimize grain yield and enhance grain protein content of the crop (Haile , 2013). Narrow row spacing causes higher leaf photosynthesis and suppresses weeds growth compared with wider row spacing. Narrow row spacing also produces high leaf area index (LAI), which results in more interception of photo synthetically active radiation (PAR) and dry matter accumulation (DMA) (Tollenaar, and Auguilera, 1992).

Southern Oromia in general, Guji zone in particular is one of the major wheat growing area; especially the highland parts. Even though it is such dominant crop in the zone, the yield obtained is very low which is less than national average .This problem is mainly due to poor agronomic practices such as row spacing, seeding rate, sowing date, weeding and lack of improved variety (personal observation). In addition to this, there was no research conducted concerning seeding rate and appropriate row spacing. As a result of this fact, the farmers rely on traditional practices (broad casting) and inappropriate seeding rate. Therefore, there is a need to study the effect of different seeding rates & row spacing on the yield and yield components of bread wheat and determine optimum seeding rate and row spacing for production and productivity of bread wheat at Bore and Ana Sora districts of Guji zone.

Materials and Methods: The experiment was conducted at Bore agricultural research center and Anna Sora district using Huluka variety as planting material. The treatments consisted of factorial combination of four levels of row-spacing (15, 20, 25, 30 cm) and four levels of seeding rate (100,125, 150, 175 kg ha^{-1}). The experiment wa laid out in a randomized complete block design (RCBD) with three replications in factorial arrangement of 4 x 4 making a total of 16 treatments. The gross size of each plot was 2.4 m × 2.5 m (6 m^2) consisting of 16, 12, 10 and 8 rows for 15,20,25 and 30cm row spacing respectively and the distance between adjacent plots and blocks were 0.5 m and 1 m apart, respectively.

The outermost one rows on both sides of each plots were considered as border plants and were not used for data collection to avoid border effects. Fertilizer used was 46/41 P_2O_5/N per hectare and Nitrogen fertilizer was splited, ½ at planting and ½ at peak tillering stage.

Data Collections and Measurements

Crop phenology and growth parameters

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

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

Plant height (cm): plant height was measured from the soil surface to the tip of the spike (awns excluded) of 10 randomly tagged plants from the net plot area at physiological maturity.

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

Yield components and yield

Number of tillers per plant: number of tillers per plant was determined from 10 tagged plants per net plot at physiological maturity by counting the number of tillers. **Number of productive tillers**: number of productive tillers was determined at maturity by counting all spikes bearing tillers from two rows of 0.5 m length per plot at physiological maturity.

Number of spikelet per spike: the mean number of spikelet per spike was computed as an average of 10 randomly tagged spikes from the net plot area.

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

Grain yield (kg ha^{-1}): grain yield was taken by harvesting and threshing the seed yield from net plot area. The yield was adjusted to 12.5% moisture content as:

$$\text{Adjusted grain yield} = \frac{(100 - \text{MC}) \times \text{unadjusted grain yield}}{100 - 12.5}$$

Where MC is the moisture content of bread wheat seeds at the time of measurement and 12.5 is the standard moisture content of bread wheat in percent. Finally, yield per plot was converted to yield per hectare basis and the yield was reported in kg ha^{-1}.

Statistical Data Analysis

All data collected were subjected to analysis of variance (ANOVA) using GenStat (18th edition) software (GenStat, 2012). Comparisons among treatment means with significant difference for measured characters were carried out using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

Results and Discussions

Crop phenology and growth parameters Days to 50% heading

The analysis of variance revealed that the interaction of the factors (spacing x seeding) and main effects did not significantly ($P < 0.05$) affect days to 50% heading of wheat (Table 1). Lack of significance might be due to the fact that heading of the crop is mainly controlled by the genetic makeup of a genotype.

Days to 90% physiological maturity

The analysis of variance revealed that the interaction of the factors (spacing x seeding) and the main effects were highly significantly ($P < 0.01$) affected days to 90% physiological maturity of wheat. The results showed that, increasing row spacing across seeding rate increased days to physiological maturity of wheat. The longest days to physiological maturity (147.1 days) was recorded at the combination of 150kg/ha seeding rate and 30cm spacing which is statistically at parity with 100kg seeding rate and 25cm spacing whereas the shortest days to physiological maturity (145.2 days) was obtained from 125kg/ha and 15cm spacing. The decrease in days to maturity of wheat at the lowest row spacing might be due to high competition at lower spacing resulting non vegetative growth.

Table 1. Interaction effect of seeding rate and row spacing on days to 50% heading

	Date to 50% heading				Date to 90% physiological maturity			
Row spacing (cm)	**Seeding rate(kg)**				**Seeding rate(kg)**			
	100	**125**	**150**	**175**	**100**	**125**	**150**	**175**
15	75.39	75.83	75.33	75.56	146^{cde}	145.2^{h}	146.4^{b}	145.4^{gh}
20	75.94	75.72	75.11	75.5	145.7^{efg}	146.8^{a}	145.6^{fgh}	146.3^{bc}
25	75.61	75.61	75.61	75.28	147.1^{a}	146^{cde}	146.1^{bcd}	145.6^{fgh}
30	75.89	75.17	75.39	75.61	145.4^{gh}	145.7^{efg}	147.1^{a}	145.8^{def}
Mean	75.71	75.58	75.36	75.49	146.06	145.93	146.27	145.78
LSD(0.05)	**NS**				**0.34**			
CV (%)	**0.5**				**0.1**			

Plant height

The analysis of variance revealed that the interaction of the factors (spacing x seeding) did not significantly ($P < 0.05$) affect plant height of wheat as well as the main effects. This might be due to the fact that plant height is mainly controlled by genetic make (Shahzad *et al*, 2007).

Table 2. Interaction effect of Row spacing and seeding rate on spike length and plant height of bread wheat

	Spike length				Plant height			
Row spacing(cm)	**Seeding rate(kg)**				**Seeding rate(kg)**			
	100	**125**	**150**	**175**	**100**	**125**	**150**	**175**
15	8.44^{ab}	8.70^{ab}	8.42^{ab}	6.37^{c}	85.81	86.71	89.4	86.43
20	8.49^{ab}	8.50^{ab}	8.81^{a}	8.19^{b}	86.25	84.81	88.59	86.62
25	8.58^{ab}	8.48^{ab}	8.54^{ab}	8.35^{ab}	87.22	86.94	88.32	89.39
30	8.617^{ab}	8.63^{ab}	8.61^{ab}	8.66^{ab}	86.51	85.81	88.81	87.55
Mean	8.53	8.58	8.59	7.89	86.45	86.07	88.78	87.49
LSD(0.05)	**0.55**				**NS**			
CV (%)	**3.9**				**2.0**			

Spike length

The analysis of variance revealed highly significant ($P < 0.01$) effect of the factors (spacing x seeding) as well as the main effect of seeding rate whereas the main effect of spacing significantly ($P<0.05$) influence this parameter.The longest spike (8.81 cm) was obtained at 150kg/ha seeding rate and 20cm row spacing whereas the shortest spike (6.37cm) was produced at 175kg/ha and 15cm row spacing (Table 2). This result disagree with the finding of Rahel and Fikadu (2016) who reported non significant effect of seeding rate and row spacing on spike length.

Yield Component and Yield

Number of tillers per plant

The interaction effect of the two factors (spacing x seeding) and the main effect of spacing were significant ($P < 0.05$) on tiller number produced per plant whereas the main effect seeding rate did not. The maximum number of tillers per plant (4.7) was obtained from plants treated with the combined application of the second seeding rate (125kg/ha) and row spacing (20cm whereas the minimum number of tillers per plant (3.36) was obtained at the highest seeding rate rates (175 kg/ha and the lowest row spacing (15cm). This might be due to the fact that plants such as wheat can increase root growth to enhance nutrient uptake and tiller, especially during early growth stage as seeding rate decrease and row spacing increase. In line with this result, Iqbal *et al.* (2010) reported significant effect of row spacing on the number of tiller per plant and the number of fertile tillers. But the current result did not agree with that of Rahel and Fikadu (2016) who reported non effect/interaction of seeding rate and row spacing on number of tiller of bread wheat.

Table 3. Interaction effect of spacing and seeding on number of tillers and productive tiller per plant of bread wheat

	Number of fertile tiller per plant				Number of tiller per plant			
Row spacing(cm)	Seeding rate(kg)				Seeding rate(kg)			
	100	125	150	175	100	125	150	175
15	4.06 ab	3.83 ab	3.49 b	2.42 c	4.531 a	4.44 ab	3.93 b	3.36 c
20	4.08 ab	3.66 ab	3.98 ab	4.15 ab	4.28 ab	4.70 a	4.53 a	4.61 a
25	3.94 ab	4.17 ab	4.15 ab	4.22 a	4.53 a	4.52 a	4.55a	4.63 a
30	4.08 ab	3.89ab	4.28 a	3.98 ab	4.47 ab	4.33 ab	4.66 a	4.45 ab
Mean	4.04	3.89	3.98	3.69	4.46	4.51	4.42	4.26
LSD(0.05)	0.72				0.54			
CV (%)	11.1				7.3			

Means with the same letter(s) in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, LSD= Least Significant Difference at 5% level

Number of productive tillers

The interaction effect of the factors (spacing x seeding) and main effect of spacing significantly ($P<0.05$) influenced the number of productive tillers of bread wheat except seeding rate.

Thus, significantly highest number of productive tillers (4.28) was produced at the third levels of the two factors whereas the lowest (2.42) was recorded at the highest seeding rate and the lowest row spacing (Table 3). The increase in the number of productive tiller produced in response to the increased row spacing and decreased seeding rate might be due to less inter plant competition for nutrients, space and light by the plant even though there were no consistency. This result agrees with the findings of Iqbal *et al* (2016) who reported that different number of productive tiller under different seeding rate. The current result was not inagreement with those of Rahel and Fikadu (2016) who reported no interaction effect of seeding rate and row spacing.

Thousand Kernels weight

The interaction effect of spacing and seeding rate, as well as the main effects significantly ($P< 0.05$) influenced thousand kernels weight of wheat. The highest thousand kernels weight

(44.82 g) was recorded from a combination of 125kg/ha seeding rate and 30cm row spacing. On the other hand, the minimum thousand kernel weight (34.75 g) was obtained from combination of 175kg/ha seed rate and 15cm row spacing. Thousand kernels weight obtained from the highest seeding rate and the lowest row spacing was significantly lower than thousand seed weight from the lowest seeding rate and highest row spacing. This might be due to the increment of seed size at higher spacing and lower seeding rate due to less competition. The current result was not in agreement with that of Rahel and Fikadu (2016) who reported non significant effect of seeding rate and row spacing on thousand seed weight.

Table 4. Interaction effect of row Spacing and seeding rate on thousand kernels weight of bread wheat.

Row spacing(cm)	Seeding rate(kg)			
	100	125	150	175
15	41.53^{abc}	44.62^{a}	41.99^{abc}	34.75^{d}
20	44.79^{a}	42.42^{abc}	44.2^{ab}	40.89^{abc}
25	42.56^{abc}	41.45^{abc}	39.5^{c}	40.04^{bc}
30	42.72^{abc}	44.82^{a}	41.57^{abc}	42.88^{abc}
Mean	42.9	43.3275	41.815	39.64
LSD(0.05)	4.56			
CV (%)	6.5			

Number of spikelet per spike

The interaction effect of the two factor (spacing x seeding rate) and seeding rate significantly ($P< 0.05$) influenced number of spikelet per spike whereas the main effect of spacing highly significantly($P< 0.01$) affected number of spikelet per spike. The maximum numbers of spikelet per spike (16.65) was produced at the combination of 100kg/ha seeding rate and 30cm row spacing which was statically at parity with all other combination except the minimum spacing and maximum seeding rate. But the minimum number of spikelet per spike (14.33) was obtained from 175kg/ha seeding rate and 15cm row spacing of the two factors. The lowest numbers of spikelet per spike at the narrow spacing might be due to increment of competition for light, nutrient and space at lower spacing. This result was not inagreement with that of Rahel and Fikadu (2016) who reported no interaction effect of seeding rate and row spacing.

Grain yield

The interaction effect of the two factors (spacing x seeding rate) and their main effects significantly ($P< 0.05$) influenced grain yield of bread wheat.Increasing row spacing across the levels of seeding rate significantly increased grain yield. Thus, the highest grain yield (4239 kg ha^{-1}) was obtained at combined rates of 150 kg ha^{-1} seeding rate and 20cm row spacing whereas the lowest grain yield (2737 kg ha^{-1}) was obtained at the combinations of 175kg/ha seeding rate and 15cm row spacing (Table 5). The highest grain yield at the medium row spacing and seeding rate might have resulted from improved root growth and increased uptake of nutrients and better tiller and growth favored due to less competition which enhances yield components and yield by decreasing inter plant competition for light, space and light.

Table 5. Interaction effect of row Spacing and seeding rate on Grain yield and number of spikelet per spike of bread wheat.

	Grain yield (kg/ha)				Number of spikelet per spike			
Row spacing (cm)	Seeding rate(kg)				Seeding rate(kg)			
	100	125	150	175	100	125	150	175
15	3577^{b-f}	3075^{fg}	3605^{b-e}	2737^{g}	16.08^{a}	16.5^{a}	16.02^{a}	14.3 ^{b}
20	3551^{b-f}	3603^{b-e}	4239^{a}	3356^{c-f}	16.17^{a}	16.36^{a}	16.49^{a}	16.36^{a}
25	3107^{efg}	3464^{c-f}	3818^{abc}	3624^{bcd}	16.59^{a}	16.09^{a}	16.51^{a}	16.58^{a}
30	3267^{def}	3547^{b-f}	4043^{ab}	3083^{fg}	16.65^{a}	16.58^{a}	16.57^{a}	16.48^{a}
Mean	3375.49	3422.2	3926.24	3200.09	16.37	16.3825	16.40	15.94
LSD(0.05)	505.24				0.78			
CV (%)	8.7				2.9			

In line with the result of this study, Iqbal *et al* (2010) reported maximum grain yield (4.120 t/ha and 3.92 t/ha) at 150 kg/ha seeding rate and 22.5 cm row spacing respectively for wheat. Similarly, Rahel and Fikadu (2016) also reported that increasing seeding rate increase grain yield of bread wheat where the application of 150 kg ha^{-1} gave more grain yield than others. But they reported non interaction effect of seeding rate and row spacing. Similarly to the above, Hameed *et al.* (2003) found that increasing seeding rate increased grain yield of bread wheat. Nazir et al (200) also reported maximum grain yield at 150kg/ha seeding rate.

Summary and Conclusions

Analysis of the results revealed that all parameters were significantly ($P<0.05$) affected by the interaction of the factors (seeding rate x row spacing) as well as the main effects except date to 50% heading and plant height which did not significantly ($P<0.05$) affected. The highest grain yield (4239 kg/ha), were obtained from combination of 150 kg/ha seeding rate and 20cm row spacing. Therefore, use of 150 kg/ha and 20cm row spacing can be recommended for production of bread wheat for the study area (Bore and Ana Sora) and other areas with similar agro ecologies.

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Adaptability study of improved food barley varieties at highland agro-ecology of Guji Zone, Southern Oromia

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Abstract

Barley is a majorly grown cereal crop at high land agro-ecology of Guji Zone, Southern Oromia. However, the production and productivity of the crop remains low due to several production constraints. Absence of improved barley variety for the area is a major one preceding other factors. As a result, the current study was conducted to address the gap through testing the adaptability of released improved food barley varieties and recommending the best performing varieties for production. The experiment was conducted at two districts (Bore and Ana Sora) at three different sites (Songo on site, Alayo and Irba Buliyo farmer's field). For this experiment, seven improved food barley varieties were collected and evaluated with previously recommended variety as standard check. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications at each location. Data were collected from a net plot of four rows and selected plants of the plot for agronomic traits. Collected data were subjected to analysis using appropriate software and Mean separation was carried out using Least Significant Difference (LSD) at 5 percent levels of significance. The analysis of variance (ANOVA) indicated a highly significant differences at ($P \leq 0.01$) among the evaluated food barley varieties for days to maturity and significant difference at ($P \leq 0.05$) for days to heading and grain yield. However, non-significant difference was observed among the varieties for other agronomic characters. Based on the study result, the longest day to heading was revealed by standard check and EH-1493 (90.22 days). However, early heading was recorded for varieties Dafo (80.22 days) followed by Robera (80.56 days) and others. In other cases, variety Dafo was early maturing variety (133.78 days) followed by Robera (134days), Dinsho (134.11 days) and Biftu (134.11 days). Among the tested varieties, standard check was late maturing variety with 140.33 days followed by CROOS41/98(139.56 days).The highest grain yield (25.12 qt/ha) was obtained from standard check followed by Abdane (20qt/ha). But, low yield of 16.34qt/ha was obtained from variety Dafo. As a result, it is recommended for the farmers of the study area to use the previously recommended variety (HB-1307) with appropriate production practices.

Key words: Adaptability, Food barley, improved variety

Background and Justification

In Ethiopia, cereal crops are majorly produced for several purposes where it greatly contributing towards sustaining food security. Farmers in different parts of the country are growing different types of cereal crops based on their agro-ecological suitability to address their family food demand. Particularly, farmers in highland parts of the country are producing barley for home consumption and income generation. As a result, it is commonly called as a poor man's crop that can able to give yield in environments unsuitable to other crops at higher elevation (Zerihun *et al*., 2007). It ranks 5th in terms of area (944,401.34 ha) and production (18.57 million qt) next to wheat and followed by finger millet (CSA, 2016). Several evidences indicate that Wello, Shewa, Arsi, Gojam, Bale, Gondar and Tigray are major barley growing regions. It is commonly cultivated in marginal areas where the production of other cereals is limited (Bekele *et al*, 2005; Abay *et al*., 2009). The crop grows well at altitudes of 1500–3500 masl and is predominantly grown at 2000–3000 m.a.s.l (MoA, 1998).Highland parts of Guji Zone are also found within the suitable agro-ecology for barley crop production. Farmers in the area are usually producing barley as major crop for home consumption as well as for cash earning. It ranks second next to maize both in area (23,886.10 ha) and production (414,042.53qt) in the zone. However, the production and productivity of the crop remains low (17.33qt/ha) as compared to the national (19.66qt/ha) and regional (22.28qt/ha) productivity (CSA, 2016).This may be due to several production constraints such as inaccessibility to improved barley technologies recommended by research that can have potential to give high yield there by help farmers to improve their production and productivity.

So far many improved barley varieties has been released by National and regional research centres that has wide adaptation to different agro ecologies. However, most of these varieties are not evaluated for their adaptation in Guji Zone of Southern Oromia region. Bore Agricultural research center has conducted adaptation trial in 2010 using few improved food barley varieties and recommend two adapted varieties. These varieties are still under production and have contributed for production improvement of barely for the area. But, there are no more options to use improved varieties tested and recommended for use. For this reasons most of the farmers use their varieties that has several drawbacks like low yield, late mature, susceptible to lodging, diseases and insects. Therefore, there is a need to evaluate and recommend varieties which are economically and environmentally viable for the producing farmers. Hence, the current study was initiated with objective to select and recommend high yielding, early maturing, diseases and insect pest tolerant improved food barley varieties for the study areas.

Materials and Methods

Description of the study areas

The experiment was conducted at three locations (Bore, on site), Alayo and Irba Buliyo farmers field. Songo site and Alayo farmers site are located in Bore districts whereas Irba Buliyo is located in Ana Sora district. Bore is located at 387 km away from Addis Ababa to the South and Ana Sora district is situated at about 410 and 25km to the South from Addis Ababa and Bore twon respectively. Bore and Ana Sora districts receive mean annual rain fall amount of 1180 and 1785 mm respectively.

Plant materials and Experimental Design

For this experiment seven improved food barley varieties released by different research centers of the country were collected and evaluated along with recently recommended improved food barley variety to the area as standard check (HB-1307). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications at each location. Each experimental plot has 2. 5 m long and 1.2 m wide, with 6 rows 20 cm apart, with a gross plot area of 3 m^2. Spacing between adjacent blocks 1.5 m and 1 m between plots was used. Sowing was done by hand drilling and covered lightly with soil. The seed rate and fertilizer rate were applied at the national recommendation for barley production. All other agronomic practices were also applied as recommended for barley production.

Data Collection: Data were collected from a net plot area of four rows and selected plants from the plot for agronomic and diseases data. Collected agronomic data includes; Days to heading (DTH), Days to 90% maturity (DTM), Grain filling period (GFP), Plant height (PH), Spike length (SL), Total number of tillers/plant, Total number of fertile tillers/plant, 1000-kernel weight (TKW),Grain yield/ha (Gy kg/ha).

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) as suggested by Gomez and Gomez (1984) using SAS Software (Version 9.0). Mean separation was carried out using Least Significant Difference (LSD) at 5 percent levels of significance.

Results and Discussions

The combined analysis of variance (ANOVA) for grain yield and other agronomic characters of food barley varieties grown at three locations is presented in table 1. The analysis of variance (ANOVA) indicated significant and highly significant differences at ($P \leq 0.05$ and $P \leq 0.01$) respectively among the evaluated food barley varieties for different agronomic characters. The analysis of variance (ANOVA) indicated highly significant differences among food barley varieties for days to maturity, days to heading, plant height and grain yield/ha. However, non-significant difference was observed among the varieties for grain filling period, spike length, number of fertile tillers and thousand seed weight. Significant variability of food barley for different agronomic characters were also reported by Kiflu, 2009, Wosen et al.,2015, Teshome, 2017, Shegaw,2017.

Table 1.Combined analysis of variance for different agronomic parameters of different food barley varities at songo, Abayi and Irba Buliyo during 2017/18 cropping season

Source of variation	Mean squares							
	DH	GFP	DTM	PH(cm)	SL(cm)	NPT	TSW(gm)	Gy(kg/ha)
Genotype(7)	184.69^{*}	43.27^{ns}	67.97^{**}	58.02^{*}	0.59^{ns}	0.88^{ns}	201.85^{ns}	64.94^{*}
Rep(2)	24.89^{ns}	37.63^{ns}	1.85^{ns}	72.63^{ns}	0.39^{ns}	2.63^{*}	40.96^{ns}	55.97^{ns}
Loc(2)	10719.84^{**}	1861.79^{**}	5532.35**	1692.9^{**}	172.1^{**}	56.7^{**}	3021.3^{**}	6535.8^{**}
Genotype*loc (16)	9.04^{ns}	13.59^{ns}	6.09^{ns}	78.46^{ns}	0.43^{ns}	0.64^{ns}	134.89^{ns}	18.89^{ns}
R	0.93	0.78	0.96	0.65	0.94	0.79	0.67	0.92

*** ,* and ns= highly significant at $P \leq 0.001$; *= significant at $P \leq 0.05$; ns = not significant at P= 0.05; a Numbers in parentheses are degrees of freedom associated with the corresponding source of variation; DHT: Days to heading, DTM: Days to maturity, GFP: grain filling period, PH: plant height in centimeter, SL: spike length in centimeter, TPP: tillers per plant, NPT: Number of productive tillers, TSW: thousand seed weight in gram, Gy: grain yield/ha in quintals.*

Mean performance of the varieties for the characters

Range and mean values for the eight characters are presented in Tables 2. The variation with respect to days to heading and days to maturity was ranged from 80.22 to 90.22 and 133.78 to 140.3 respectively, showing a wide range of variation among the varieties for maturity. Based on the study result, the longest days to heading was revealed by standard check and EH-1493 (90.22 days) followed by CROOS41/98(90.11 days).However, early heading was recorded for varieties Dafo(80.22 days) followed by Robera(80.56 days), Biftu(81.22 days), Abdane(82.89 days) and Dinsho(83.67 days).In other cases, variety Dafo was early maturing variety (133.78 days) followed by Robera(134days),Dinsho (134.11 days) and Biftu(134.11 days).Among the tested varieties, standard check was late maturing variety with 140.33 days followed by CROOS41/98(139.56 days) and EH-1493(138.44 days). Similar results of difference in days to heading and maturity among food barley genotypes were also reported by Kiflu, 2009, Teshome, 2017 and Shegaw, 2017.As study result indicates, significant variability was observed among the tested food barley varieties for grain yield qt/ha, which was ranged from 16.34 to 25.12 qt/ha with the mean value of 26.33 qt/ha and coefficient of variation 26.33%. The highest grain yield (25.12 qt/ha) was recorded for standard check followed by Abdane (20qt/ha). But, low yield of 16.34qt/ha was obtained for variety Dafo.

Table 2: Combined mean values of different food barley varieties for grain yield and other agronomic characters over three locations (Songo, Abayi and Irba Buliyo) during 2017/18 cropping season

Genotypes	**DH**	**GFP**	**DTM**	**PH(cm)**	**SL(cm)**	**NPT**	**TSW(gm)**	**GY(qt/ha**
Standard check	90.22^{a}	53.111^{ab}	140.33^{a}	104.32^{ab}	5.50^{b}	4.37^{ab}	64.76^{abc}	25.12^{a}
CROOS41/98	90.11^{a}	52.44^{ab}	139.56^{ab}	103.89^{ab}	6.24^{a}	4.32^{ab}	70.17^{ab}	19.21^{b}
EH-1493	90.22^{a}	51.22^{b}	138.44^{ab}	101.00^{b}	5.89^{ab}	4.45^{ab}	68.49^{abc}	18.49^{b}
ABDANE	82.89^{b}	56.89^{a}	136.78^{bc}	102.95^{ab}	5.57^{ab}	4.75^{ab}	61.34^{bc}	20.20^{b}
BIFTU	81.22^{b}	55.89^{ab}	134.11^{cd}	103.96^{ab}	5.74^{ab}	3.98^{ab}	58.97^{c}	18.26^{b}
DINSHO	83.67^{b}	53.44^{ab}	134.11^{cd}	108.61^{a}	5.79^{ab}	4.54^{ab}	71.66^{c}	18.51^{b}
ROBERA	80.56^{b}	56.44^{a}	134^{cd}	100.63b	5.42^{b}	4.17^{ab}	61.75^{bc}	17.11^{b}
DAFO	80.22^{b}	56.56^{a}	133.78^{d}	101.67^{ab}	5.65^{ab}	4.96^{a}	61.29^{bc}	16.34^{b}
Over all mean	84.89	54.5	136.39	103.38	5.73	4.44	64.80	19.16
CV (%)	7.06	9.40	2.26	7.47	12.69	19.51	15.59	26.33
LSD(0.05)	5.6	4.86	2.92	7.32	0.69	0.82	9.59	4.79

DHT: Days to heading, DTM: Days to maturity, GFP: grain filling period, PHT: plant height, SL: spike length, TPP: tillers per plant, NPT: Number of productive tillers, TSW: thousand seed weight, Gy: grain yield/ha

Conclusions and Recommendations

In area where accesses to improved technologies are very predicament, there is a need to undertake instant action to address the gap through identifying, testing and recommending suitable technologies for specific area. Therefore, the current study was conducted to address the lack of improved food barley varieties at highland agro-ecology of Guji Zone, Southern Oromia. Different food barley varieties were collected and tested for their adaptability, agronomic performance and yield stability. Based on the study result, the tested varieties had showed different performance for the characters considered. Among the varieties, Dafo and Robera showed earliness for both days to heading and maturity. However, the highest grain yield was obtained from the standard check (HB-1307) followed by Abdane. Accordingly, Standard check- HB-1307 and Abdane varieties are recommended for the farmers of the study area with appropriate barely production practices.

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Effect of Blended (NPS) Fertilizer Levels and Row Spacing on Yield and Yield Components of Food Barley (*Hordeum Vulgare* L.) at High Land of Guji Zone, Southern Oromia.

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Abstract

Barely (Hordeum Vulgare L.) is one of the most important food crops produced in the world in general and in Ethiopia in particular. Even though it is such an important cereal crops in Ethiopia, it gives low yield due to many production constraints such as lack of improved varieties, poor agronomic practice (inappropriate fertilizer rate and row spacing), diseases, weeds and low soil fertility in Ethiopia in general and in Guji zone in particular. Therefore, field experiment was conducted during the 2016-2017 main cropping seasons at Bore and Ana sora districts to assess the effect of NPS rate and row spacing on yield components and yield of barley; and to determine appropriate NPS rates and row spacing for barley production. The experiment was laid out in RCBD in factorial arrangement with three replications using a barley variety known as 'HB-1307' as a test crop. The treatments consisted of five levels of NPS rate (0, 30, 60 and 120 kg ha^{-1}) and four levels of row spacing (15, 20, 25 and 30 cm) making a total of 20 treatments. Analysis of the results revealed that days to 50% heading, days to 90% maturity, spike length and number of tillers per plant were significantly ($P<0.05$) affected by the interaction of NPS x location well as the interaction of spacing x location. Similarly the interaction of the three factors (NPS x Spacing x location) were significantly ($P<0.05$) affected grain yield and thousand kernel weight of barley. The maximum grain yield (3618kg/ha) and the highest kernels weight (53.47g) was recorded at combined application of 120kg/ha NPS and 20cm spacing at Bore and 120kg/ha NPS and 25cm spacing at Ana sora respectively. But the interaction effect of NPS x Spacing x location, NPS x location, Spacing x location and the main effect of NPS, Spacing and location did not significantly affecte plant height and number of productive tillers. The partial budget analysis revealed that combined applications of 120 kg NPS kg/ha and 20cm spacing gave the best economic benefit of 18855.45 Birr ha^{-1} with MRR of 1071.9%. Therefore, on economic basis, application of NPS 120kg/ha with 20cm spacing would be best and economically profitable way for production of barley in the study areas.

Keywords: Fertilizer, Interaction, Interaction effect, Main effect, Nutrient,

Introduction

Barely (*Hordeum Vulgare* L.) is one of the most important food crop produced in the world. It takes the fourth position in total cereal production in the world after wheat,rice and maize. Many countries grow barley as a commercial crop. Russia, Canada, Germany, Ukraine and France are the major barley producers, accounting for nearly half of the total world production (Edney and Tipples, 1997). It is also one of the most important staple food crop produced in the highland areas of Ethiopia. Its grain is used for the preparation of different foodstuffs, such as *injera, kolo,* and local drinks, such as *tela, borde* and beer. The straw is used as animal feed, especially during the dry season.

Ethiopia is also considered to be the origin and center of diversity for barley. Besides its use as food, feed and beverage barely has many important features. It is adapted to wide environmental condition, matures early and has high yield potential. (Hailu and Van Leur Joop, 1996). Despite, the importance of barely and its many useful characteristics, there are several factors affecting its production. The most important factors that reduce yield of barley in Ethiopia are poor soil fertility, water logging, drought, frost, soil acidity, diseases and insects, and weed competition (ICARDA, 2008). Poor soil fertility and low pH are among the most important constraints that threaten barley production in Ethiopia. Since the major barley producing areas of the country are mainly located in the highlands, severe soil erosion and lack of appropriate soil conservation practices in the past have resulted in soils with low fertility and pH (Grando and McPherson, 2005). Particularly deficiency of nitrogen and phosphorus is the main factor that severely reduces the yield of barely. According to Desta (1987), although soil fertility status is dynamic and variable from locality to locality, it is difficult to end up with a blanket recommendation invariably; some soil amendment studies were undertaken at different times and places.

Even though several researches have been conducted on high land areas of Ethiopia, like Bale, Arsi, Gojam, and central part of the country, there are as yet much barley producing highland areas starving of new technology, including improved varieties and appropriate rate of fertilizer, among which highland area of Guji Zone is one. In this area barley is a staple food crop for large number of people. In Bore district, from the total 16531.36 ha area of land under cultivation, barley covers 6568.79 ha which accounts for 39.7% of the total. To feed this large number of people and ever increasing population, increasing crop productivity per unit area should be given due emphasis. According to some informal surveys and information from Bureau of Agriculture and Rural Development, the area was very far from research (Personal communication). There were no research conducted concerning fertilizers, spacing and other agronomic researches, breeding etc. As a result of this fact, the farmers rely on traditional practices and local cultivars. Most of the farmers in Guji highland particularly Ana sora & Bore do not use fertilizer and spacing; few others use very much below the recommended rate and sow broadcasting. Therefore, there is a need to study the effect of different NPS rates & row spacing on the yield and yield components of barely to determine biological and economic optimum NPS rate and row spacing for barley production at Bore and Ana Sora.

Objectives

- To study the effects of rates of NPS and row spacing on yield and yield components of barley in Bore and Yirba district of Guji zone of Southern Oromia .
- To determine the most economic rate of NPS fertilizer application and row spacing for barley production for the study areas.

Materials and Methods

Description of the Study Areas

This experiment was conducted at Bore Agricultural Research Center and Ana sora district of Guji zone Southern Oromia during the 2016-2017 main cropping seasons. Bore is found at longitude of 038° 37' 54.1''E and latitude of 06o 1' 06.7''N. The altitude of the woreda ranges from 1450 to 2900 m.a.s.l (meters above sea level) with a rugged topography, and the altitude of the specific site is 2712 m.a.s.l.

Soil Analysis

For soil analysis, before planting, twenty soil samples were randomly taken from the experimental site at a depth of 30cm using an auger and the samples was mixed thoroughly to produce one representative composite sample of 1kg. Samples was also taken later at harvest from each plot and composite sample of 1kg was produced on treatment basis rather than plot base.

Experimental Methods

The treatment consists of combination of five levels of NPS (0, 30, 60, 90 and 120 kg N.ha-1) and four levels of rowspacing (15, 20, 25 and 30 cm). The twenty treatment combinations were replicated three times in factorial RCB Design. Blended (NPS) fertilizer was used. There were a total of 20x3=60 plots, each measuring 3 m x 2.4 m (7.2 m^2). Spacing of 1 m between blocks and 0.5 m between plots was used.

Data Collection and Analysis

All phenological, yield and yield component data were collected. The collected data were subjected to Analysis of Variance (ANOVA) using SAS (9.0) statistical software version 9.2. Mean separation was done using (LSD) test at 5% probability level.

Results and Discussions

Soil Physico-Chemical Properties of the Experimental Site before planting

The laboratory results of the analysis of the selected physico-chemical properties of the soil before sowing is presented in Table 1. The analytical results of the experimental soil indicated that the soil textural class is clay loam with a particle size distribution of 42% clay, 28% silt and 30% sand for Bore and 36% clay, 30% silt and 34% sand for Ana sora. Thus, the soil of experimental site is suitable for barley. The pH of the soil was 5.05 and 5.85 for Bore and Ana sora location respectively, which is strongly acidic and moderately acidic according to the rating of Tekalign (1991) for Bore and Ana Sora respectively. FAO (2000) reported that the preferable pH ranges for most crops and productive soils are 4 to 8. Mengel and Kirkby (1996) reported optimum pH range of 4.1 to 7.4 for wheat production. Thus, the pH of the experimental soil was within the range for productive soils.

According to Tekalign (1991), the soil organic carbon content (3.47% and 4.76%) of the experimental site was high at both locations. The analysis further indicated that the soil has high total nitrogen (0.35% and 0.63%) at Bore and Ana Sora according to the rating of Tekalign (1991). The results of the analysis also indicated that the soil has medium available phosphorus content (12.93 and 12.84 mg/kg) at Bore and Ana Sora respectively. This is according to the rating of Cottenie (1980). The analysis for available sulfur also indicated that the experimental soil had values of 11.51 and 12.23 mg/kg which are low according to Ethiosis (2014) at both locations. The CEC value of the soil sample is high (32.86 [Cmol (+) kg^{-1} soil] at Bore and also high (34.88 [Cmol (+) kg^{-1} soil]) at Ana sora according to the rating of Landon (1991) which indicates that the soil has high capacity to hold exchangeable cations.

Table 6.Selected physico-chemical properties of the soil of the experimental site before planting (2009)

Results						
	Parameter	Bore	A.Sora	Unit	Rating	Reference
Acidity	PH-H_2O	5.04	5.85		Strongly, moderate	Tekalign (1991)
Available Sulphur	SO4-S	11.51	12.23	Mg/kg(ppm)	Low, low	Ethiosis (2014)
Available Phosphorus	P	12.93	12.84	Mg/kg(ppm)	Medium, medium	Cottenie (1980)
Oc	OC	3.47	4.76	%	High, high	Tekalign (1991)
TN	N	0.35	0.63	%	High, high	Tekalign (1991)
C:N	C:N	9.91	7.56	-		
CEC		32.86	34.88	Meq/100g soil	High, high	London(1991)
Sand		30	34	%		
Clay		42	36	%		
Silt		28	30	%		
Textural Class		clay loam	Clay			

Phenological and Growth Parameters

Days to 50% heading

The analysis of variance revealed that the three-factor interactions of NPS x Row spacing x location as well as main effect of NPS, row spacing and location did not significantly ($P<0.05$) affect days to 50% heading of barley. The lack of significant effect on days to heading might be due to counteracting effects of P nutrition on N and S nutrition because N and S tends to increase vegetative growth, while P hastens it.In line with this result, Firehiwot (2014) reported non significant result of NP fertilizer on days to 50% heading of bread wheat. Similarly, Beena *et al.* (2012) also reported non significance effect of S application on days to flowering and physiological maturity among wheat varieties.

Table 7. Interaction effect of NPS, row spacing and location on days to 50% heading of barley

	Date to 50% heading				Date to 90% physiological maturity			
Fertilizer rate(kg/ha)	Row spacing(cm)				Row spacing(cm)			
	15	20	25	30	15	20	25	30
0	76	76.5	77.5	77	127.8	129.1	130.8	125.5
30	75.5	75.67	74.83	75.17	122.2	124.5	121.1	121.1
60	75.67	74.67	74.67	75.33	120.8	119.2	125.6	121.6
90	74.33	75.33	74.67	75.67	123	121	121.9	125.8
120	74.67	74.17	74.67	74.83	124.7	121.4	121.2	122.4
Mean	75.23	75.27	75.27	75.60	123.70	123.04	124.12	123.28
LSD(0.05)	NS				NS			
CV (%)	7.9				10.3			

Days to 90% physiological maturity

The two-factor interaction of fertilizer rate x spacing and main effect of fertilizer rate and spacing did not significantly ($P<0.05$) affect days to physiological maturity. This might be due to use of similar variety.

Plant height

The interaction of fertilizer rate x spacing x location, spacing x location, fertilizer x location and main effect of fertilizer rate, spacing and location did significantly ($P<0.05$) affect plant height. The result indicated that height of barley plants did not increase or decrease as NPS rate and spacing decreased or increased. This might be due to the fact that height of the crop is mainly controlled by the genetic makeup of a genotype.

Table 8.Interaction effect of NPS and spacing on plant height of barley

Fertilizer rate(kg/ha)	Row spacing(cm)			
	15	20	25	30
0	111	110.9	107.1	110
30	108	113.9	112.3	108.8
60	110	109.8	109.2	113.8
90	108.7	114.2	105.7	111.8
120	114.1	111.8	108.7	106.7
Mean	110.36	112.12	108.6	110.22
LSD(0.05)	NS			
CV (%)	6.2			

Spike length

The two-factor interaction of fertilizer rate x spacing were highly significantly ($P<0.01$) affected spike length of barley the main effect of fertilizer rate and spacing significantly ($P<0.05$) affect spike length.

The longest spikes (7.071 cm) were obtained at the rate of 90 kg NPS ha^{-1} and 20cm spacing which was statically at par with other combination except control (0kg NPS ha^{-1}) whereas the shortest spikes were produced at the lowest rate/control (Table 4). This result agrees with the findings of Muluneh and Nebyou (2016) who reported the highest spike length (7.7cm) for wheat at the rate of 50/150 kg N/P_2O_5 ha^{-1}. Firehiwot (2014) also reported the maximum spike length (8.29 cm) at combined application of 64 kg P_2O_5 + 46 kg N ha^{-1}. Similarly, Iqbal *et al.* (2002) reported longer spikes in response to increased application of phosphorus.

Yield Component and Yield

Number of tillers per plant

The analyzed data revealed that main effect of fertilizer rate and spacing significantly ($P<0.05$) affected number of tillers per plant in barley. But the interaction of the the two factors (fertilizer rate x spacing) did not significantly ($P<0.05$) affect spike length.

Table 9. Interaction effect of NPS and spacing on spike length of barley

Row spacing(cm)	Fertilizer rate (kg/ha)				
	0	30	60	90	120
15	4.135 b	6.81 a	6.667 a	6.417 a	6.365 a
20	6.531 a	6.61 a	6.593 a	7.071 a	6.596 a
25	6.524 a	6.767 a	6.385 a	6.451 a	6.506 a
30	6.666 a	6.224 a	6.565 a	6.496 a	6.443 a
Mean	5.96	6.60	6.55	6.61	6.48
LSD(0.05)	0.90				
CV (%)	17.3				

Number of tiller per plant increased as spacing decreased even though statistically no difference observed between 20 - 30kg/ha. This might be due to less competition at narrow spacing. The highest number tillers per plant (3.98) was recorded at 25cm whereas the minimum tillers (3.24) was 15cm spacing.In other words, the tillers number per plant was increased significantly across the increased rates of NPS fertilizer (Table 5). The maximum number of tillers per plant (4.09) was obtained from plants treated with 90kg NPS ha^{-1} whereas the minimum number of tillers per plant (3.26) was from the lower rates (0 kg NPS ha^{-1}). The improvement in total number of tillers with NPS application might be due to the role of P found in NPS in emerging radical and seminal roots during seedling establishment in barley (Cook and Veseth, 1991). Generally, number tillers per plant recorded over all the treated plots was significantly higher than the unfertilized plot/control. In agreement with this result, Iqbal *et al* (2010) reported significant effect of row spacing on on number of tillers and productive tillers of bread wheat. Likewise, Firehiwot (2014) reported higher tillers per plant (5.58) at combined application of 32 kg N and 46 kg P_2O_5 ha^{-1} in bread wheat. Similarly, Daniel *et al.* (1998) also reported enhanced number of tillers in wheat with increased rate of P application.

Table 10. Interaction effect of NPS and spacing on number of tillers and productive per plant of barley

Row spacing(cm)	Number of tiller per plant	Number of productive tiller per plantpt
15	3.242 b	2.532 b
20	3.784 a	3.097 a
25	3.982 a	3.287 a
30	3.924 a	3.218 a
LSD(0.05)	1.03	0.99
Fertilizer rate (kg/ha)		
0	3.263 b	2.592 b
30	3.787 a	3.163 a
60	3.858 a	3.14 a
90	4.091 a	3.295 a
120	3.667 ab	2.977 ab
Mean	3.73	3.03
LSD(0.05)	1.03	0.99
CV (%)	24.2	30.6

Means with the same letter(s) in the columns and rows are not significantly different at 5% level of significance, CV (%) = Coefficient of variation, LSD= Least Significant Difference at 5% level

Number of productive tillers

The analyzed data revealed that main effect of fertilizer rate and spacing significantly ($P<0.05$) affected number of productive tillers per plant of barley. But the interaction of the the two factors (fertilizer rate x spacing) did not significantly ($P<0.05$) affect spike length. Number of tiller per plant increased as spacing decreased even though statistically no difference between 20 - 30kg/ha. This might be due to less competition at narrow spacing. The highest number tillers per plant (3.28) was recorded at 25cm whereas the minimum tiller (2.50) was 15cm spacing.In other words, the tiller number per plant was increased significantly across the increased rates of NPS fertilizer (Table 5). The maximum number of tillers per plant (3.29) was produced by plants treated with 90kg NPS ha^{-1} whereas the minimum number of tillers per plant (2.59) was produced at the lower rates (0 kg NPS ha^{-1}). The improvement in total number of tillers with NPS application might be due to the role of P found in NPS in emerging radical and seminal roots during seedling establishment in barley (Cook and Veseth, 1991). The result also agree with the result obtained by Wakene *et al* (2014) and Prystupa *et al* (2004), who reported that number of productive tillers per plant was affected significantly by NP fertilizer application. Generally, number of productive tillers per plant recorded over all the treated plots was significantly higher than the unfertilized plot/control.

Thousand Kernels weight

The three-factor interaction of NPS rate x spacing were significantly ($P<0.05$) affected thousand kernel weight of barley. But the main effect of spacing, NPS rate and location did not significantly ($P<0.05$) affected thousand kernel weight of barley.

Increased rate of NPS and spacing increased thousand kernels weight of barley even though there was no consistency (Table 6). The highest thousand kernels weight (42.57 g) was recorded at combined application of 60 kg NPS ha^{-1} and 15cm spacing. On the other hand, the minimum thousand kernel weight (35.17 g) was observed at combined application of 90 kg NPS ha^{-1} and 25cm spacing. This might be due to the improvement of seed quality and size due to the interaction and synergic effect of the three nutrients.

Table 11. Interaction effect of NPS, spacing and location on thousand kernels weight (g)

Fertilizer rate (kg/ha)	Row spacing(cm)			
	15	20	25	30
0	38.28 b-f	39.31 a-e	40.51 a-d	38.61 a-f
30	39.71 a-e	38.89 a-f	37.45 c-f	36.75 def
60	42.57 a	37.81 c-f	38.31 b-f	40.27 a-e
90	42.11 ab	36.62 def	35.17 f	36.21 ef
120	37.58 c-f	40.29 a-e	36.98 c-f	40.88 abc
Mean	40.05	38.58	37.68	38.54
LSD(0.05)	4.09			
CV (%)	13.1			

Grain yield

The three-factor interaction of NPS rate x spacing x location highly significantly ($P<0.01$) affect grain yield of barley whereas the main effect of spacing and location significantly ($P<0.05$) affected grain yield of barley. But the main effect of seeding rate and NPS rate did not significantly ($P<0.05$) affected grain yield of barley. Increasing the rates of NPS fertilizers and row spacing significantly increased grain yields even though there was no consistency. Thus, the highest grain yield (3618 kg ha^{-1}) was obtained at combined application of 120 kg NPS ha^{-1} + 20 cm spacing at Bore on station whereas the lowest grain yield (1938 kg ha^{-1}) was recorded at the combinations of 0 kg NPS + 25 cm spacing at Ana sora (Table 7). The highest grain yield at the highest NPS rate might have resulted from improved root growth and increased uptake of nutrients and better growth favored due to interaction/synergetic effect of the three nutrients which enhanced yield components and yield. In line with the result of this study, Mesfin and Zemach (2015) reported that increasing NP rate increase grain yield of barley where the application of 69/30 NP ha^{-1} had 57.4% more grain yield than control. Iqbal et al (2010) also reported maximum yield at 22.5cm row spacing. Similarly, Mesfin and Zemach (2015) found that increasing NP rate increased grain yield of barley

Table 12. Interaction effect of NPS, spacing and location on grain yield

Location	Fertilizer rate (kg/ha)	Row spacing(cm)			
		15	20	25	30
Bore	0	3026 a-k	2921 a-l	2405 j-n	2856 b-m
	30	3143 a-i	3072 a-j	2820 c-m	3426 a-d
	60	3085 a-j	3007 a-l	3204 a-g	2966 a-l
	90	3566 ab	3279 a-f	3198 a-g	3342 a-e
	120	3166 a-h	3618 a	2792 d-m	3529 abc
Ana Sora	0	2701 e-m	2762 d-m	1937 n	2796 d-m
	30	3100 a-j	2865 b-m	2787 d-m	2578 f-n
	60	2461 h-n	2599 f-n	2433 i-n	2316 k-n
	90	2600 f-n	2149 mn	2704 d-m	2498 g-n
	120	2563 f-n	2611 f-n	2300 lmn	2768 d-m
Mean		2941.1	2888.3	2658	2907.5
LSD(0.05)		723.59			
CV (%)		22.3			

Partial Budget Analysis

Analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 10. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation by farmers. The studies assessed the economic benefits of the treatments to help develop recommendation from the agronomic data. This enhances selection of the right combination of resources by farmers in the study area. The results in this study indicated that the combined application of NPS and row spacing resulted in higher net benefits than the unfertilized/control treatments (Table 10). As indicated in Table 10, the partial budget analysis showed that the highest net benefit (Birr 18855.45 ha^{-1}) was recorded at the rate of combined application of 120kg NPS + 15 cm followed by 90 kg NPS + 25cm (19668.26Birr ha^{-1}), and lowest was from control treatment. To use the marginal rate of return (MRR%) as basis of fertilizer recommendation, the minimum acceptable rate of return should be between 50 to 100% (CIMMYT, 1988). In this study application of 120kg NPS ha^{-1} and 15cm gave the maximum economic benefit (18855.45 ha^{-}) with marginal rate of return (1071.9%). Therefore, on economic grounds, combined application of 120 kg NPS ha^{-1} and 20cm would be best and economical, and recommended for production of food barley in the study area and other areas with similar agro-ecological conditions.

Table 13. Partial budget and marginal rate of return analysis for response of bread wheat to NPS and N fertilizers .

Treatments NPS (kg ha^{-1})	Row spacing (cm)	Adjusted grain yield down wards by 10% (kg ha^{-1})	Gross Benefit (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR (%)
0 (control	15	2037.210	16297.68	0	16297.68	-
0	30	2543.518	20348.15	0	20348.15	-
0	25	2177.217	17417.74	0	17417.74	-
0	20	2287.092	18296.73	0	18296.73	485.73
30	15	2809.247	22473.98	860	21613.98	-
30	30	2702.003	21616.03	860	20756.03	-
30	20	2671.825	21374.60	860	20514.60	-
30	25	2523.098	20184.78	860	19324.78	-
60	15	2495.859	19966.87	1220	18746.87	-
60	30	2376.999	19015.99	1220	17795.99	-
60	25	2313.370	18506.96	1220	17286.96	-
60	20	2522.614	20180.91	1220	18960.91	560.95
90	15	2775.040	22200.32	1580	20620.32	-
90	20	2442.571	19540.57	1580	17960.57	-
90	30	2627.740	21021.92	1580	19441.92	-
90	25	2656.033	21248.26	1580	19668.26	278.74
120	15	2781.466	22251.73	1940	20311.73	-
120	30	2833.881	22671.05	1940	20731.05	-
120	25	2291.382	18331.06	1940	16391.06	-
120	20	2599.43	20795.45	1940	18855.45	1071.9

Summary and Conclusions

Field experiment was conducted during the 2016 and 2017 main cropping season at Bore Agricultural Research Center and Ana sora district to assess the effect of rates of blended NPS and row spacing on yield components and yield of barley; and to determine economically appropriate rates of blended NPS and row spacing for barley production. The experiment was laid out as a Randomized Complete Block Design (RCBD) in a factorial arrangement with three replications using a wheat variety known as ‘HB-1307’ as a test crop. The treatments consisted of four levels of NPS (0, 30, 60, 90 and 120 kg NPS ha^{-1}) and four levels of row spacing (15, 20, 25 and 30 cm). Analysis of the results revealed that days to 50% heading, days to 90% maturity, spike length and number of tiller per plant were significantly affected by the interaction of NPS x location well as the interaction of spacing x location. The maximum days to 50% heading (75.6, 76.75), days to 90% maturity (128.2, 130.3), spike length (7.143, 7.156) and number of tiller per plant (4.418, 4.428) were obtained at 30cm at Bore, 30cm at Ana sora, 20cm at Bore and at 25cm at Bore respectively while the maximum days to 50% heading (76.75), days to 90% maturity (130.3), spike length (7.156) and number of tiller per plant (4.428) were obtained at 0kg/ha at Bore, 90kg/ha at Ana sora, 90kg/ha at Bore and at 90kg/ha at Bore respectively. Similarly the interaction of the three factors significantly affected grain yield of barley. The maximum grain yield (3618kg/ha) and the highest kernels weight (53.47g) was recorded at combined application of 120kg/ha NPS and 20cm spacing at Bore and 120kg/ha NPS and 25cm spacing at Ana sora respectively. But the interaction effect of NPS x Spacing x location, NPS x location, Spacing x location and the main effect of NPS, Spacing and location did not significantly affected plant height and number of productive tiller. The partial budget analysis revealed that combined applications of 120 kg NPS kg/ha and 20cm spacing gave the best economic benefit 18855.45Birr ha^{-1} with MRR of 1071.9%. Therefore, on economic grounds application of NPS 120kg/ha with 20cm spacing would be best and economical for production of barley in the study area. But further research work has to be done including lime application/acid management and other limited nutrient to give conclusive would be recommended.

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Adaptability Study of Released Midland Maize Varieties at Midland of Guji Zone, Southern Oromia

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Abstract

Lack of improved maize variety is the most important limiting factor in different parts of Ethiopia for maize production and productivity. Guji Zone is one of such areas where the technologies are not widely addressed and adopted so far. This study was conducted by Bore agricultural research center with the objective of selecting and recommending adaptable high yielding and early maturing maize varieties for mid land agro-ecologies of the zone. The experiment was conducted at three locations Adola on station and two farmer's field (Dole and Kiltu Sorsa). Six released maize varieties with one local check were used. RCBD experimental design with three replications was used on plot size of 5mx6m. All phenological and yield data were collected and subjected to analysis using GenStat 18th edition soft ware. Combined data analysis was used to test the performance of the varieties across the testing locations. The result of the study showed that, there is significant difference among genotypes for the selected characters across the locations. Based on this result, two Maize varieties (MH-140 and BH-546) were early maturing and gave higher yield .Therefore; these varieties were selected and recommended for the study area and similar agro-ecologies of Guji Zone.

Key words: *Adaptation, early maturing, Maize*

Back ground and Justification

Maize is one of the most important field crop in terms of area coverage, production, and economic importance in Ethiopia. It grows from sea level to over 2,600 m.a.s.l. from moisture deficit semi-arid lowlands, to mid-altitude and highlands to moisture surplus areas in the humid lowlands, mid-altitudes and highlands. Of these ecologies, the mid- and low-altitude sub humid maize agro-ecologies are well known for maize cultivation in Ethiopia. The mid-altitude is mainly located in western, southern, eastern and central regions while the low altitude is found in the south eastern parts of the country. The weather conditions characterized by warm temperature and sufficient volumes of rainfall coupled with the relatively fertile soils of these regions creates favorable conditions for maize cultivation. In Ethiopia cereals account for about 80% of the annual crop production and maize is the first in total production and yield per unit area and second in area coverage among all the cereals. Total area covered by maize during the 2015/16 growing season was 2.1 million ha and the national average yield was about 33.87 q ha^{-1} (CSA, 2016). Maize improvement in Ethiopia started half a century ago. During the late1960s and early 1970s, several promising hybrids and composite varieties of East African origin were introduced and evaluated at different locations. These resulted in the recommendation of several maize varieties for the maize growing regions of the country (Abdurahman, 2009). Crops like tef, maize, wheat, barley, sorghum, finger millet and oatswith regional productivity (q/ha) of 11.18, 23.45, 18.65, 17.74, 16.26, 11.23, 9.56, respectively are cereals grown in different agro-ecologies of southern region (CSA, 2009). From this regional productivity list, it can be realized that the productivity of all crops is too low which is less than half of the potential productivity which could be obtained through using improved production technologies. The survey report which conducted at zonal level jointly by Bore Agricultural Research center (BOARC) and zone Bureau of Agriculture in 2008 also confirmed that, the yield obtained from the local cultivars is too low (30.21q/ha). And in many parts of the zone, lack of improved crops varieties and associated improved management and protection practices are some of the major constraints in the crop production systems; i.e. farmers in many remote areas of the zone even do not know the existence of the new crop varieties. To resolve specific agricultural productivity constraints in the zone, several works have been done at zonal level. Massive movement to test suitability of the existing technologies on different cereal crops such as maize, bread wheat, tef and food barley has been carried out in different agro-ecologies and the best technologies were pre-scaled up in some localities of the zone. Even though only few localities were reached with limited number of technologies in the last two years, an appreciable improvement in crop productivity was realized in the target areas. To advance improvement of crop productivity in different localities, continual identification of the best and suitable crop technologies appeared to be essential. This can be achieved through adaptability tests and generation of new technologies. Keeping this in view, the present study was conducted at Adola subite and on farm kebeles of Adola district to compare the performance of hybrid, open pollinated and commercial varieties for their adaptability and stability with the following objectives:-

- To evaluate the adaptability and performance of the improved varieties released for mid-altitude
- To identify and select the best performing variety/ies for the target area

Materials and Methods

Experimental Site

Adola district belongs to the agro-ecological classification of hot to warm sub-moist mid-lands. The district is divided into 48 PAs; it has an average altitude of 1600 m.a.s.l. The major crops produced in the area are maize, teff, wheat from cereals, haricot bean, from pulses and cash crops such as coffee and chat. The farming calendar for these major crops varied depending on the season. In the main season ‘’Belg’’ which has long rain fall starts from March/April, the land preparation starts from December. Major crops produced during this season are maize and horticultural crops. The second season ‘’Mehere’’ receives rain fall from September and lasts to 2nd weeks of November. Major crops produced during this season are teff and wheat.The predominant form of production of crop in the study area is under rain-fed condition. The productivity of farmland is influenced by the lack/unavailability of improved technologies and other production factors.

Experimental Materials and Design

The experiment was conducted by using seven released midland maize hybrid varieties which was obtained from Bako Agricultural research center. Randomized complete block design with three replications was used to conduct the experiments at each site. The Seeds was planted in rows with two seeds per hill at a rate of 25kg/ha in a plot consisting of six rows each of 6m long and 5m wide and seedlings was thinned to one plant per hill four weeks after emergence to obtain 144 plants per plot. The inter row spacing was 0.75m, while the intra row spacing was 0.25m, giving population density of 53,333 plants per hectare. Fertilizers was applied at the rate of 100/100 kg/ha DAP/Urea. Urea was applied in split (half at planting and the other half at knee height). First weed control was carried out after three weeks of planting and next weeding as needed.

Data Collected

The middle four rows were used for data collection and harvest at maturity. Individual plant base data as well as plot base data were collected on seven traits of maize varieties. Data were collected on individual plant basis from five randomly selected plants these data include plant height (cm), Ear length (cm), ears per plant, tassel length (cm) and cob weight (gm) while data on plot basis included grain yield (qt/ha).

Results and Discussions

Phenological and Growth Parameters

Days to Thasseling

The analysis of variance revealed that the main effect of variety was significant ($P < 0.05$) on days to thasseling while the main effect of location highly significantly affect days to thasseling of maize. But the two-factor interactions of variety x location did not influenced days to thasseling. The highest prolonged duration to thassel (87.89days) was observed in the local check. However, the minimum duration (84.67days) to thasseling was recorded from variety SPRH, and this was not statistically different from that of variety BH-546 (Table 2). This may be due to genetic variations among different maize varieties. In line with this result, Abduselam *et al. (2017*) reported significant difference among maize varieties. Similarly, Hussain *et al*. (2011) reported differential pattern of maize varieties for days to thassel. Other researchers also reported genetic variations among different maize hybrids (Ihsan *et al*., 2005; Haq *et al*., 2005).

Days to Silking

The analysis of variance revealed that the main effect of variety and location was significant ($P < 0.05$) on days to Silking of maize while the two-factor interactions of variety x location did not influenced days to maturity. The highest prolonged duration to silking (90days) was observed in the local check while the minimum duration to silking (85.33days) was recorded at variety MH-140 as it was not statistically different from that of the variety BH-546 (Table

2). This may be due to genetic variations among different maize varieties. In line with this result, Abduselam *et al. (2017*) reported significant difference among maize varieties.

Days to Maturity

The analysis of variance revealed that the main effect of variety was highly significantly ($P<0.01$) affected days to maturity while the main effect of location significantly ($P < 0.05$) affected days to maturity of maize. But the two-factor interactions of variety x location did not influence days to maturity. The highest prolonged duration to mature (153day) was observed in the BH-546 but it was not statistically different from that of varieties such as SBRH, MH-140 and local check while the minimum duration to maturity (146.7day) was recorded for variety SPRH (Table 2). However,, Hailegabriel *et al. (2016*) reported lower days to maturity (143.22 and 142.56 days) for MH-140 and BH-546 varieties. This variation may be due to difference in experimental locations.

Plant height

The analysis of variance revealed that the main effect of variety was significantly ($P < 0.05$) affected plant height of maize while the main effect of location and the two-factor interactions of variety x location did not influenced days to maturity. The highest plant height was observed in the variety SPRH (246.3cm) as while the minimum plant height (215.4cm) was recorded from variety MELKASA-2 (Table 3). This might be due to the reason that most hybrid varieties have desirable traits for lodging and most of them are dwarf. Similarly Hailegabriel *et al. (2016*) reported 227.7 and 238.5 cm plant height for MH-140 and BH-546 varieties respectively. Abduselam *et al. (2017*) also reported different plant height for different maize varieties.

Number of Leaf/plant

The analysis of variance revealed that the two-factor interactions of variety x location was highly significant ($P < 0.01$) on number of leaf per plant of maize while the main effect of variety and location did not influenced number of leaf per plant. The highest number of leaf per plant (21.08) was observed in the interaction of variety BH-546 and Kiltu Sorsa location while the minimum number of leaf per plant (13.33) was recorded at interaction of variety SBRH and Dole location (Table 1). This might be due to interaction effect of genetic and environment (G x E).

Table 1. Combined Mean of number of leaf/ plant of Maize at Adola , 2017

Genotype	**Location**		
	Kiltu Sorsa	**Dole**	**Onsite**
SBRH	17.48^{b-e}	13.33^{k}	15.21^{f-j}
BH-546	21.08^{a}	14.96^{h-k}	16.08^{d-h}
MH-140	18.73^{b}	13.88^{ijk}	15.79^{e-h}
Local check	15.65^{f-i}	15.13^{g-k}	16.96^{b-f}
MELKASA-2	18.07^{bc}	13.5^{jk}	16.21^{d-h}
BHQPM-548	16.23^{d-h}	14.88^{h-k}	16.79^{c-g}
SPRH	15.58^{f-i}	16.29^{c-h}	17.79^{bcd}
LSD(0.05)	1.798		
CV (%)	6.7		

Yield and Yield Component Parameters

Ear length

The analysis of variance revealed that the main effect of location significantly ($P < 0.05$) affected ear length while the two factors interaction and main effect of variety did not significantly ($P < 0.05$) affected ear length of maize. The longest ear length (17.5cm) was recorded at Dole location where as the shortest ear (15.01cm) obtained at Kiltu Sorsa as it was statistically at parity with Adola on station. Similar with this result, Hailegabriel *et al. (2016*) were also reported significant effect of environment on maize varieties and non significant effect of G x E.

Cob weight

The analysis of variance revealed that the main effect of variety and location were significantly ($P < 0.05$) affected cob weight of maize while the two-factor interactions of variety x location did not influence cob weight.

The highest cob weight was (275.6g) observed from the variety SBRH which was statistically not different from varieties such as MH-140 and BH-46 while the minimum cob weight (179.1g) was recorded from variety SPRH (Table 2). This may be due to genetic and environmental variability among maize varieties.

Number of ear per plant

The analysis of variance revealed that the main effect of variety and location is not significantly ($P < 0.05$) affected the number of ear per plant of maize as well as the two-factor interactions (Table 2). This finding in line with Kandil *et al (2017*) who reported non significant difference among maize varieties, season and there interaction.

Number of row per cob

The analysis of variance revealed that the main effect of variety is highly significantly ($P < 0.01$) affected number of row per cob of maize while the main effect of location and the two-factor interactions of variety x location did not influenced number of row per cob. The highest number of rows per cob (15.06) was observed from the variety SBRH even though it was statistically at parity with variety BH-546 while the minimum number of rows per cob (12.92) was recorded for variety SPRH (Table 2). This might be due to genetic variability among maize varieties and this may related to yield. In line with this result, Taye *et al*. (2016) were also reported different number of rows per cob for different maze varieties.

Number of seed per cob

The analysis of variance revealed that the main effect of variety was significantly ($P < 0.05$) different on number of seed per cob of maize while the main effect of location and the two-factor interactions of variety x location did not influenced number of seed per cob. The highest number of seed per cob (570.4) was observed from the variety BH-546 while the minimum number of seed per cob (452) was recorded from local check which is statistically at parity with variety SPRH, MELKASA-2 and BHQPM-548 (Table 2). This might be due to genetic variability among maize varieties.

Table 2. Combined Mean of CW, DTM, DTS, DTTH, EL, GY, NEPP, PH, TKW, NRPP, NSPC, PH & TKW of Maize at Adola , 2017

Genotype	CW	DTM	DTS	DTTH	EL	GY (kg/ha)	NEPP	NRPC	NSPC	PH	TKW
SBRH	275.6 ^{a}	151.9 ^{a}	88.67^{a}	86.67^{ab}	15.72	3920^{bc}	0.96	15.06 ^{a}	493.3^{b}	245.4ab	285.8^{b}
BH-546	269.1 ^{a}	153 ^{a}	86 ^{bc}	84.67^{c}	18.06	4656^{a}	1	14.72 ^{a}	570.4^{a}	236.7ab	251.4^{cd}
MH-140	266.4 ^{a}	152.6 ^{a}	85.33^{c}	85.3 ^{bc}	15.81	4667^{a}	1	14.44 ab	461.7^{b}	244ab	326.5^{a}
Local check	206.1 ^{b}	152.6 ^{a}	90 ^{a}	87.89^{a}	15.68	4586^{a}	1	13.36 ^{c}	452^{b}	233.4ab	274.6^{bc}
MELKASA-2	202.8 ^{b}	148.9 ^{b}	86.89^{b}	85.44^{bc}	15.15	4086^{abc}	1	13.69 bc	487.7^{b}	215.4c	253.5^{bcd}
BHQPM-548	194.8 ^{b}	149.3 ^{b}	88.8 ^{a}	86.89 ^{a}	16.14	3515^{c}	1	14.5 ^{ab}	510.1^{b}	231.2b	241.2^{d}
SPRH	179.1 ^{b}	146.7 ^{c}	86.$^{56\ bc}$	84.67^{c}	16.11	4219^{ab}	1	12.92 ^{c}	453.1^{b}	246.3a	233.5^{d}
LSD(0.05)	80.73	2.63	3.56	2.36	NS	607.05	NS	0.84	59.68	14.51	32.53
Location											
Kiltu Sorsa	248.5 ^{a}	151.1 ^{a}	83.1 ^{c}	88.43 ^{a}	15.01^{b}	4236	1	13.90	513.57	238.96	273.77
Dole	234.5 ^{a}	149.2 ^{b}	89.14^{b}	84.52 ^{b}	17.5 ^{a}	4405	1	14.17	487.88	235.12	267.87
Adola On Site	200 ^{b}	151.8 ^{a}	90.19^{a}	84.86 ^{b}	15.77^{b}	4065	0.98	14.23	467.83	234.05	258.3
LSD(0.05)	80.73	2.63	2.58	2.36	3.53	NS	NS	NS	NS	NS	NS
CV (%)	21.5	1.1	4.3	1.7	13.3	17.3	4.8	6.2	12.8	6.5	12.8

Key: CW: cob weight, DTM: date to maturity, DTS: date to ilking, DTTH: date to thassel, EL: ear length, GY: grain yield, NEPP: number of ear per plant, PH: plant height, TKW: thousand kernels weight, NRPC: number of row per cob, NSPC: number of seed per cob

Grain yield

The analysis of variance revealed that the main effect of variety was significantly ($P < 0.05$) affected grain yield of maize while the main effect of location and the two-factor interactions of variety x location did not influenced grain yield. The highest grain yield (4667kg/ha) was obtained from the variety MH-140 which was not statistically different from BH-546 variety while the minimum (3515kg/ha) grain yield was recorded from variety BHQPM-548 (Table 2). This might be due to genetic variability among maize varieties. Similar with this result, was also reported by Hailegabriel *et al. (2016*) However, the yield they record for variety MH-140 and BH-546 were greater than the currently reported yield. This might be due to environmental variation and shortage of rain fall during experimental season. Similar result was reported by Taye *et al*. (2016) and Abduselam *et al. (2017*) who evaluated and identified high yielding maize varieties among different genotypes tested.

Thousand Kernel weight

The analysis of variance revealed that the main effect of variety was highly and significantlly ($P < 0.01$) affected thousand kernel weight of maize while main effect of location and the two-factor interactions of variety x location did not influence thousand kernel weight.The highest thousand kernel weight (326.5g) was recorded from the variety MH-140 while the minimum thousand kernel weight (233.5g) was recorded from variety SPRH (Table 3). The differences in the thousand kernels weight of the maize varieties could be attributed to genetic differences. This result is inagreement with that of Taye *et al*. (2016) and Hailegabriel *et al. (2016*) who evaluated and reported different thousand kernels weight of maize varieties among different genotypes tested.

Table 3. Combined Mean of PH and TKW of Maize at Adola , 2017

Genotypes	PH	TKW
SBRH	245.4ab	285.8b
BH-546	236.7ab	251.4cd
MH-140	244ab	326.5a
Local check	233.4ab	274.6bc
MELKASA-2	215.4c	253.5bcd
BHQPM-548	231.2b	241.2d
SPRH	246.3a	233.5d
LSD(0.05)	14.51	32.53
Location		
KS	238.96	273.77
DL	235.12	267.87
OS	234.05	258.3
LSD(0.05)	NS	NS
CV (%)	6.5	12.8

Conclusions and Recommendations

Analysis of the results revealed that days to maturity, date silking, date to thasseling and cob weight were significantly affected by both main effects of variety and location where as number of row per cob, grain yield, number of seed per cob, plant height, and thousand kernels weight were only affected by main effect of variety. Similarly ear length was affect only by the main effect of location while number of leaf per plant was affected by the two factors interaction.From the tested varieties, MH-140 showed better performance for the evaluated characters and gave highest yield (4667kg/ha) followed by BH-546 (4656kg/ha). Therefore, as grain yield is an important parameter to select maize varieties, these varieties, MH-140 and BH-546 were recommended for study areas and similar agro ecologies.

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Participatory variety selection of improved tef varities for low moisture stress areas of Guji zone, Southern Oromia

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Abstract

Tef is a highly valued indigenous cereal crop produced in Ethiopia. As a result, the crop is adapted to diverse agro-ecological zones of Ethiopia and grows well under stress environments better than other cereals including low moisture stressed areas of Guji Zone, Southern Oromia. However, an access to improved tef variety is highly limited to such marginalized area. Due to this and other preceding factors, the potential of the area to tef production is not exploited. So, there is a need to develop and promote technologies that suit for the area. Hence, the current experiment was conducted at two low moisture stressed districts of Guji zone (Adola and Wadera) to select and recommend high yielding, early maturing, low moisture stress and diseases tolerant improved tef varieties through participatory variety selection. Seven low moisture stress tolerant improved tef varieties along with one local check were used as testing materials. The treatments were arranged in Randomized Completed Block Design with three replications for mother trial and farmers were used as replication for baby trials. Both agronomic and farmers data were collected based on the recommended standards. Data collected from mother trail were subjected to analysis of variance whereas matrix ranking was used for data collected from baby trial. The analysis of variance indicated the presence of significant differences at ($P \leq 0.01$, $P \leq 0.05$) among the evaluated tef varieties for all of the characters considered except number of fertile tillers per plant (NFTPP) .Significant variability was also observed among the tested tef varieties for grain yield , which was ranged from 6.0 to 16.7 qt/ha with the mean value of 9.6 qt/ha and coefficient of variation of 23.43%. The highest grain yield (16.7 qt/ha) was recorded for variety Dagim. But, low yield of 6.0 qt/ha was obtained from variety Guduru.In other cases, farmers were allowed to evaluate the varieties using their own selection criteria. Accordingly, variety Dagim was selected by farmers due to its best performance. Thus, improved tef varieties Dagim and Tesfa were selected based on their agronomic performance and farmer's preference for production to the study area and similar agro-ecologies.

<u>Key words</u>*:* Improved variety, participatory variety selection tef, ,

Introduction

Tef (*Eragrostis tef* (Zucc.) is a highly valued indigenous cereal crop produced in Ethiopia. Farmers in different parts of the county usually grow tef as a guaranteeing crop to address their socio-economic and cultural needs. Because, it is considered as low risky crop (Hailu,2002). According to Ketema, (1993), there are five main reasons for the popularity of tef as compared to other cereal crops. Its importance is based firstly on its high demand by the consumers. As a result, the crop is majorly grown for its grain that is used for preparing injera, which is a staple and very popular food in the national diet of Ethiopians. Tef contains 11% protein, 80% complex carbohydrates and 3% fat (Piccinin, 2002). In addition, its high price in the market, reduction of post-harvest management cost, fewer disease and pest problems and sustained demand from consumer, are some of the specific merits that makes tef important and preferred by farmers (Ketema, 1993).Secondly, its agronomic versatility and reliability, even under adverse condition, which suit it well to a country of contrasting and unpredictable environment, where drought, water logging, pests and disease cause recurrent famine (Ketema, 1993). It can be grown in altitudes ranging from near sea level to 3000 masl, but the best performance occurs between 1100 and 2950 m.a.s.l (Tesfaye and Ketema, 2000). Thirdly, besides its value for human grain, tef straw is equally important for livestock forage. Fourthly, tef straw reinforces mud in the construction of local buildings. Fifthly, tef can be produced in a relatively short growing season and will produce both grain for human and fodder for cattle. As a result, its national production area leads the other cereal crops with acreage of 3.02 Million hectares (23.85%). From the total annual cereal grain production, tef ranks 2nd with a total production of 52.83 million quintals (17.26%) (CSA, 2016).Out of the total national production, about 48.86% production was obtained from Oromia regional states followed by Amhara (38.6%), Southern Nations Nationalities and Peoples (SNNP) (7%), Tigray (4.88%), and Benishangul-Gumuz (0.6%). In Oromia regional state, tef is majorly produced in South West Shewa Zone with an average yield of 18qt/ha followed by West Shewa Zone 3.808 Million qt with the average yield of 18.53qt/ha. In Guji Zone, tef is grown on more than 17,005 ha of land with a production of more than 230,016 qt. However, the productivity of the crop remains low in the zone (13.53 qt ha^{-1}) as compared to the national and regional average yield of the crop which is about 17.48qt ha-^{1} and 17.88 qt ha-^{1} respectively (CSA, 2016). This might be, due to lack of improved varieties, poor management practices, biotic factors (weeds, diseases and insect pests etc.) and abiotic factors (frost), rain fall variability (intensity as well as duration) (Obsa *et al*.,2017). To overcome such problems, introducing improved technologies by involving users through participatory variety selection is very imperative. Because, it enables faster adoption of new cultivars than the formal crop improvement and also the spread of varieties from farmer-to-farmer through the local seed system can be very fast, thus guaranteeing a further good adoption (Assefa *et al*.,2014). It also enables the farmers to evaluate the materials based on important traits of their interest, help to increase on farm varietal diversity, faster varietal replacement and rapid scaling up (Asaye *et al*., 2013). In view of this, the current study was conducted to address the following objectives;

- To evaluate the performance of the different released tef varieties through PVS
- To assess farmers' selection criteria for improved tef varieties and
- To identify the most important farmers criteria for future crop improvement work in the area.

Materials and Methods

Description of the study area

The experiment was conducted at two districts on three sites (Adola on station, on farm and Wadera on farmer's field) during short season of 2017/18 cropping season to select and recommend high yielding, early maturing, low moisture stress and diseases tolerant improved tef varieties through Participatory Variety Selection (PVS) method. Adola and Wadera districts are located at about 470 km and 530 km to the South from Addis Ababa. Both districts are characterized by three agro-climatic zones, namely Dega (high land), Weina dega (mid land) and Kola (low land) with different coverage. The mean annual rain fall and temperature of the districts are about 900 mm and 12-34 ^{0}c respectively. Based on this condition, two time cropping season was commonly practiced i.e Arfasa (main cropping season) which start from March to April especially for maize, haricot bean, wheat and barley production. The second cropping season is called Gana (short cropping season) which was practiced as double cropping using small size cereal crops like tef, wheat and barley after harvesting the main cropping season crops. This study was also conducted during short cropping season at selected low moisture stress area.

Description of planting materials and Experimental Design employed

Seven low moisture stress tolerant improved tef varieties viz. Filagote, Tesfa, Kena, Dagim, Guduru, Nigusie, Boset) were used as testing materials with one local check. The treatments were arranged in Randomized Completed Block Design with three replications for mother trial (MT) (planted on station) and farmers were used as replication for baby trials (BT). For this purpose, one farmer field was used as replication for baby trials in which selected farmer's plant materials in one replication and the other host farmers were planted the two non-replicated trials. At both trial sites, the materials were planted on a plot size of, 3mx4m having 15 rows with 20 cm between rows. In puts (seeds, fertilizers) and management practices were applied as recommended for tef production. Data were collected in two ways: agronomic data & farmer's data. For agronomic data such as phenological, growth, yield and its component were collected following standard procedures.

Data Collection: Data were collected from centeral rows and selected plants of the plot for agronomic and diseases data. Collected agronomic data includes; days to heading (DTH), days to 90% maturity (DTM), grain filling period (GFP), plant height (cm), peduncle length (cm), total number of tillers/plant (NTP), number of fertile tillers per plant (NFTPP) and grain yield/ha (kg/ha).

Data analysis: Data collected from mother trials were subjected to analysis using ''SAS' 'software (version 9.0) to evaluate the variability of the tested varieties. This was done through computing analysis of variance for all characters studied according to the method suggested by

Gomez and Gomez (1984). For data collected from baby trials, matrix ranking was carried out using the method suggested by De Boef *et al.*, (2007).

Results and Discussions

The analysis of variance (ANOVA) for grain yield and other agronomic traits of eight tef varieties grown at research station as mother trail is presented in table 1. The analysis of variance (ANOVA) indicated the presence of significant differences at ($P \leq 0.05$) among the evaluated tef varieties for all the characters considered except fornumber of fertile tillers per plant (NFTPP). Similar result was also reported reported by Molla *et al.*, 2012, Daniel *et al.*, 2016, Abebe and Wondowsen, 2017, Chondie and Bekele, 2017 and Natol *et al.*, 2018.

Table 1. Analysis of Variance for different agronomic parameters of different tef Varieties from mother trial

Source of variation	Mean square							
	DH	GFP	DTM	PH(cm)	PL(cm)	NTP	NPTPP	Gy(kg/ha
Genotype(7)	0.8^{*}	15.42^{**}	16.81^{*}	341.52^{**}	82.86^{**}	2.7^{*}	1.2^{ns}	33.72^{**}
Rep(2)	4.50^{**}	124.03^{**}	81.28^{**}	295.91^{*}	78.97^{**}	7.9^{*}	1.7^{ns}	35.62^{*}
Error(14)	0.21	2.17	2.07	26.15	2.16	0.82	0.52	5.02

*** = highly significant at $P \leq 0.001$; *= significant at $P \leq 0.05$; ns = not significant at P= 0.05; a Numbers in brackets are degrees of freedom associated with the corresponding source of variation; DH: Days to heading, GFP: grain filling period, DTM: Days to maturity, , PH: plant height in centimetre, PL: Peduncle length in centimetre, Total number of tillers/plant (NTP), Number of fertile tillers per plant (NFTPP) Gy: grain yield/ha in quintals.*

Mean performance of the varieties

Phenological parameters

Range and mean values for the eight characters are presented in Table 2. The variation with respect to days to heading and days to maturity was ranged from 57.5 to 59 and 98 to 104 days respectively, showing a wide range of variation among the varieties for heading and maturity. Based on the study result, the longest day to heading was recorded for varieties Guduru and Nigusie (59 days). However, early heading was recorded for variety Dagim (57 days) followed by Tesfa and Boset (58 days). Similarly, variety Dagim was early maturing variety (98 days) followed by Nigusie (99 days). Among the tested varieties, Guduru variety was late maturing with 104 days followed by Kena (103 days). Early maturing is an important selection criteria in areas of moisture deficient to produce significant crop yield through sustaining effective crop growth stages. According to Din *et al*. (2010), higher temperature reduced the growth and development of plant and the early maturity due to high temperature was one factor for reduction in grain yield. Short growing period of crops is an important criterion in area of having moisture deficit.

Growth parameters: Among the considered growth parameters, significant variation was observed among the tested tef varieties for plant height with the mean value of 83.1cm and coefficient of variation 6.16 % (Table 2). The longest plant height was exhibited by Kena variety (96.87cm) followed by variety Guduru (95.12cm).However, the shortest plant height was recorded for Boset variety (69.32cm). Significant variation among tef variety for plant height was also reported by many authors including Daniel *et al.*, 2016, Abebe *and* Wondowsen, 2017, Chondie and Bekele, 2017 and Natol *et al.*, 2018. In contrast, non-significant variation among tef varieties for plant height was reported by Molla *et al.*, 2012.

Yield and yield related parameters

As indicated in table 2, significant variability was observed among the tested tef varities for number of tillers per plant with the range of 3.45 to 6 and mean value of 4.83. The highest number of tillers per plant was depicted by Nigusie variety followed Tesfa. In contrast, local variety exhibited the lowest number of tillers per plant. The result is in agreement with the finding of Daniel *et al*, 2016 who were reported non- significant difference among tef varieties for number of tillers per plant. The results of current study also indicated that, there is significant variability among the tested tef genotypes for grain yield , which ranged from 6.03 to 16.67 qt/ha with the mean value of 9.57 qt/ha and coefficient of variation 23.4%. The highest grain yield (16.67 qt/ha) was obtained from variety Dagim followed by variety Tesfa (10.6 qt/ha). But, low yield of 6.03 qt/ha was obtained from Guduru variety. Many authors including Daniel *et al.*, 2016, Abebe *and* Wondowsen, 2017, Chondie and Bekele, 2017 and Natol *et al.*, 2018 were also reported significant variability among tef varities for grain yield.

Table 2. Mean values of different tef varieties for grain yield and other agronomic characters

Genotypes	**DH**	**GFP**	**DTM**	**PH**	**PL**	**NTP**	**NFTP**	**GY**
Local	58.5^{ab}	43.5^{bc}	102^{bcd}	83.47^{bc}	33.57^{cd}	3.45^{c}	2.97^{c}	8.4^{bcd}
Filagote	58.5^{ab}	42^{cd}	100.5^{cde}	71.27^{d}	30.53^{ef}	4.18bc	3.88^{abc}	7.83^{bcd}
Tesfa	58^{bc}	42.5^{bcd}	100.5^{cde}	80.67^{c}	33.87^{cd}	5.95^{a}	4.67^{a}	10.6^{b}
Boset	58^{bc}	47^{a}	101.5^{bcd}	69.32^{d}	28.25^{f}	4.87^{abc}	4^{abc}	10.01^{bc}
Kena	58.5^{ab}	44.5^{abc}	103^{abc}	96.87^{a}	39.15^{b}	4.97^{abc}	4.3^{ab}	10.36^{bc}
Dagim	57.5^{c}	40.5^{d}	98^{e}	91.9^{ab}	35.38^{c}	5.4^{ab}	4.47^{a}	16.67^{a}
Guduru	59^{a}	45^{ab}	104^{a}	95.12^{a}	45.1^{a}	3.82^{bc}	3.13^{bc}	6.03^{d}
Nigusie	59^{a}	40.5^{d}	99.4^{de}	76.07^{cd}	32.68^{de}	6^{a}	4.67^{a}	6.5^{cd}
Over all mean	58.38	43.19	101.56	83.1	34.82	4.83	3.98	9.57
CV(%)	0.79	3.41	1.42	6.16	4.22	18.76	18.12	23.43
LSD(0.05)	0.81	2.58	2.52	8.97	2.57	1.59	1.26	3.92

DH: Days to heading, GFP: grain filling period, DTM: Days to maturity, , PH: plant height in centimetre, PL: Peduncle length in centimetre, Total number of tillers/plant (NTP), Number of fertile tillers per plant (NFTPP) Gy: grain yield/ha in quintals.

Farmer's variety selection criteria

In this case, farmers were allowed to evaluate the varieties using their own selection criteria. This is based on the fact that, farmers have a broad knowledge on their environments, crops and cropping systems that they built up over many years and do experiments by their own and generate innovations, even though they lack control treatment for comparison and statistical tools to test the hypothesis (Bänziger *et al.*,2000). Based on this concept, farmers were informed to set criteria for selecting best tef variety according to their area before undertaking varietal selection. This was done by making group discussion among the farmers which comprises elders, women and men. After setting the criteria they were informed to prioritize the criteria according to their interest. By doing this, farmers were allowed to select varieties by giving their own values. Accordingly, high yield, early maturity, plant height, tillering capacity, lodging tolerance, marketability, diseases resistant, paletablity were among the criteria outlined by the farmers. Based on set criteria, the evaluated varieties were revealed various values by the evaluators (farmers). With this regard, variety Tesfa and Dagim were showed better performance in tolerance to various diseases, high grain yield, early maturity, lodging tolerance, tillering capacity and plant height. Better performance of these varieties to the set criteria may reflect the importance of the varieties to the study area. For instance, early maturity of the varieties to the area may enable the varieties to produce significant yield with the available moisture during the crop growth. Asefa *et al.*, 2014 also justified early maturing variety in moisture deficit area enables the variety to produce high yield. Seed colour is also another selection criteria considered by the farmers. For tef, white seed colour is highly preferred for market value. Among the evaluated varieties, Tesfa,Dagim and Niguise were selected by farmers due to their colour . Belay *et al.,* 2006 also reported Ethiopia farmers selecte the very white seed variety for market purpose, and brown-seeded tef for home consumption.

Table 3. Farmers' preference scores and ranking for baby trial

Variety name	Farmers selection criteria										
	1	2	3	4	5	6	7	8	Total	Average	Rank
Local	3.3	3.7	4.0	4.3	4.3	4.3	5.0	5.0	34.0	4.2	5
Felagote	1.3	3.7	3.7	4.3	4.0	1.0	2.7	4.7	25.3	3.2	7
Tesfa	5.0	4.7	5.0	5.0	5.0	5.0	5.0	5.0	39.7	5.0	1
Boset	4.3	4.0	4.0	4.3	4.0	4.7	4.7	5.0	35.0	4.4	3
Kena	4.0	3.0	4.0	4.3	4.3	4.3	4.7	5.0	33.7	4.2	5
Dagim	4.3	4.3	4.7	4.7	4.7	5.0	5.0	5.0	37.7	4.7	2
Guduru	3.7	3.3	4.7	4.7	4.3	4.3	4.7	5.0	34.6	4.3	4
Nugusie	1.7	4.0	3.0	4.0	4.0	5.0	5.0	5.0	31.7	4.0	6

1=High yield, 2= Early maturity, 3=plant height,4=Tillering capacity, 5=lodging resistant, 6=Marketability, 7=Diseases tolerant, 8=Paletablity

Conclusions and recommendations

In areas where improved technologies are not widely addressed like Guji Zone of Southern Oromia, it is paramount to take immediate action towards setting appropriate research methods. In such case, Participatory Variety Selection is an effective tool in facilitating the adoption and extension of the improved technologies. Because, this helps the farmers to participate in selecting appropriate technologies by employing their own indigenous knowledge. As the result, the current study was also verified that farmers were able to participate in selecting improved tef varieties through employing their own selection criteria. Thereby, based on the agronomic performance and farmers preference criteria two improved tef varieties via Dagim and Tesfa were selected and recommended for production to the study area and similar agro-ecologies based on the current PVS study method.

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Response of Faba Bean (*Vicia faba* L.) to *Rhizobium* Inoculation and Phosphorus Nutrient Application in Bore Highlands, Guji Zone, Southern Ethiopia

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Abstract

Faba bean (Vicia faba L.) is an important legume grown in the highlands of Ethiopia. However, the yield of the crop is limited by a number of edaphic constraints out of which low soil fertility, low pH and reduced N_2 *fixation due to various biological and environmental factors are the major problems. Therefore, a field experiment was conducted at Bore Agricultural Research Center under rain-fed condition during the 2015 and 2017 main cropping seasons to evaluate effects of* Rhizobium *inoculation and application of mineral phosphorus fertilizer on nodulation, yield and yield components as well as N accumulation and P uptake of faba bean. The treatments consisted of four levels of inoculation (uninoculated, FB-1035, FB-1018 and FB-Murdoch) and five levels of phosphorus application (0, 10, 20, 30 and 40 kg P ha*$^{-1}$*) using faba bean variety Gabelcho. The experiment was laid out as a Randomized Complete Block Design in a factorial arrangement and replicated three times per treatment. Analysis of the results revealed that the main effect of* Rhizobium *inoculation as well as phosphorus fertilizer significantly affected a number of phenological and growths parameters and yield attributes. However, the two factors did not interact to influence any of the studied parameters. The highest number of nodules per plant (93.7), nodule dry weight per plant (165.2 g), plant height (126.3 cm), number of pods per plant (14.1), hundred seed weight (84.97 g), aboveground dry biomass yield (10609 kgha-1) and seed yield (3225 kgha*$^{-1}$*) were obtained in response to inoculation with FB-1035. Inoculation with FB-Murdoch increased straw nitrogen accumulation, total N accumulation, grain phosphorus uptake, and total phosphorus uptake by 27.3, 24.5, 25.9 and 23.8 respectively over uninoculated control. Phosphorus application also significantly enhanced nodulation attributes, certain phenological and growth parameters, yield and yield related traits of faba bean. Accordingly, the highest nodules per plant (91.6), nodule dry weight per plant (165.6 g), plant height (125 cm), seed yield (3242 kg ha*$^{-1}$*), harvest index (0.3), grain nitrogen accumulation (120.53 kg ha*$^{-1}$*), grain phosphorus uptake (11.62 kg ha*$^{-1}$*) and total phosphorus uptake (18.94 kg ha*$^{-1}$*) were obtained in response to phosphorus application at 40 kg ha*$^{-1}$ *which is statistically at parity with application of 30 kg ha*$^{-1}$*. The results of the economic analysis showed that the combination of* Rhizobium *strain FB-1035 and application of 30 kg P ha*$^{-1}$ *was found to have the highest marginal rate of return for faba bean production in Bore highlands of southern Ethiopia. Therefore, it is suggested that using the combination of* Rhizobium *strain FB-1035 and 30 kg P ha*$^{-1}$ *leads to the optimum yield of the crop.*

Keywords: Phosphorus rate, Rhizobium, Seed Inoculation, N accumulation, P uptake

Introduction

Faba bean (*Vicia faba* L.) belongs to the family *Fabaceae* and sub family *Papilonaceae* (Street *et al.*, 2008). It is one of the oldest crops in the world most probably domesticated in the late Neolithic period (Metayer, 2004). Faba bean is sometimes referred to as broad bean, horse bean, tic bean or field bean (Singh *et al.*, 2010). Globally, it is the third most important cool-season food legume after chickpea and field pea with concentrated in nine major agro-ecological regions: The Mediterranean Basin, the Nile Valley, Ethiopia, Central Asia, East

Asia, Oceania, Latin America, Northern Europe, and North America (Bond *et al.,* 1985). In 2012, the worldwide production was 4.023 million metric tons (mt). China with 1.53 million metric tons leads the world faba bean production in both area coverage and production. Other major producers were Ethiopia (0.944 million mt), Australia (0.425 million mt), France (0.425 million mt), United Kingdom (0.19 million mt), Morocco (0.148 million mt) and etc. (FAOSTAT, 2012). In Ethiopia faba bean is grown largely by subsistence farmers, during the cool season (June to September) (Yirga *et al*., 2012). It takes the largest share of the area and production of the pulses grown in Ethiopia and more specifically Oromia National Regional State (ONRS) and Guji Zone as well. In Ethiopia, it occupies 443,966.09 ha of land with annual production about 848654.569 tons and productivity of 1.91 t ha^{-1}. In Oromia, faba bean covers an area of 206,182.44 ha and production of 444635.469 tons annually. It also covers about 9,474.91 ha of land with annual production of 19753.079 tons in one (CSA, 2016). Moreover, despite the availability of high yielding varieties, the average national yield of faba bean under small-holder farmers is not more than 1.91 t ha^{-1} (CSA, 2016), despite the availability of high yielding varieties (> 4.0 t ha-1) (MOA, 2010). The low yields per hectare were associated with susceptibility of the crops to biotic and abiotic stresses (Musa *et al*., 2008). Among of the abiotic category, declining soil fertility and low pH (acidity) are the most determinant for low productivity of the most crops (Chilot *et al*., 2002). The causes for severe deficiency of most of the major nutrients (nitrogen and phosphorus) in Ethiopian highlands are the huge loss of soil from agricultural land, which is estimated to be 137 t ha^{-1} per year; approximately an annual loss of 10 mm soil depth (Zeleke *et al*., 2010). Annual nutrient deficit also estimated to be -41 kg N, -6kg P and -26 kg K ha^{-1} (Fassil and Charles, 2009).

Bore highlands of Guji Zone of Southern Ethiopia is also one of the highland part of the country that receive high rainfall annually and grow faba bean so far; where it occupied about 8,145.51 ha with annual production 0.0165 million tons (CSA, 2016). But it shares the same production problem with other highlands of the country. To address these nutrient deficiencies, farmers in the country have been using uniform blanket application of 100 kg Diammonium phosphate (DAP) ha^{-1} for all legumes including faba bean. However, despite the potential for increasing yields and farm income by the use of fertilizers, many smallholder farmers do not have the resources to use them. In addition, the nitrogen applied is not used by the crop; it is lost each year along money paid for it through leaching, runoff, and gaseous losses *via* de-nitrification and ammonia volatilization (Baligar and Fageria, 1997). Furthermore, in modern agriculture, the replenishment of soil nitrogen (N) by extensive application of chemical fertilizers has several negative environmental impacts (De Jong *et al*., 2008). This emphasizes the importance of developing an alternative means to meet the demand of nutrient in plants by using of symbiotic bacteria which are agronomically sustainable, environmental friendly and easily affordable to most farmers. Nitrogen (N) is an essential plant nutrient and one of the key drivers of global agricultural production. Between 150 and 200 million tons of mineral N are required each year by plants in agricultural systems to produce the world's food, animal feed and industrial products (Unkovich *et al*., 2008). The main sources of nitrogen for crops are biological nitrogen fixation (BNF) and mineral nitrogen from the soil or chemical fertilizer (Salvagiotti *et al*., 2008). The only alternative mechanism used to substitute inorganic nitrogen fertilizers is biological nitrogen fixation (BNF) (Nicolas *et al*., 2006). As stated by Shamseldin and Werner (2004), also BNF can reduce the need for nitrogen fertilizer. Therefore, BNF is becoming more attractive and economically viable and is an environmentally friendly agricultural input (Bekere *et al*., 2012). Each season, legume crops fix symbiotically about 33 to 46 Teragram (Tg) in the world (Herridge *et al*., 2008). More specifically, faba bean can fix up to 150-300 kg N ha^{-1} in a growing season (Singh *et al*., 2012). BNF can be enhanced by inoculation of legume seeds with an effective and persistent *Rhizobium* strain. In this regard, *Rhizobium* inoculation of pulse crop can fix quantities of nitrogen to eliminate the need for nitrogen fertilizer inputs (Walley *et al*., 2007).

Phosphorus is the second most plant growth limiting nutrient next to nitrogen despite being abundant in soil both as organic and inorganic forms. Many soil throughout the world are phosphorus-deficient because low free phosphorus availability (Gyaneshwar *et al*., 2002). Phosphorus deficiency has also been shown to be the major yield limiting nutrients in the highlands of Ethiopia (Bereket *et al*., 2011) particularly soils of many areas in highlands that receive high rainfall suffer from remarkable phosphorus deficiencies due to phosphorus fixation at low pH. Phosphorus is an important mineral nutrient to the growth and BNF of legumes and the requirement of phosphorus by faba bean is relatively high, which is in the range of 20-30 kg P ha^{-1} (FAO, 2000). Phosphorus is needed in relatively large amounts by legumes; in addition to promoting growth of the host legume, it has specific roles in N2 fixation, nodule initiation, nodule number, growth and development (Schulze *et al*., 2006). It also plays a vital role in increasing legume yield through its effect on plant and also on fixation process by *Rhizobium* (Sara *et al*., 2013). On the other hand, phosphorus deficiency reduces N2 fixation due to decreased nodule formation and reduced nodule sizes and finally affecting the yield and grain quality and quantity (Sadeghipour and Abbasi, 2012). Combined application of phosphorus and inoculation with effective *Rhizobium* had prominent effects on nodulation, growth and yield parameters of faba bean (Yohannes *et al*., 2014).

Several studies have been conducted on the effect of *Rhizobium* inoculation and mineral phosphorus fertilization on yield, yield components, nodulation and N_2 fixation of legumes (Habtegebrial and Singh *et al*., 2006; Yohannes *et al*., 2014). However, no study has been carried out on the effect of *Rhizobium* inoculation and application of mineral phosphorus fertilizer on faba bean grown in Bore highlands of Guji Zone. In addition to this, success in rhizobia inoculation is highly site-specific and depends on a multitude of interaction, including environmental, soil, and biological factors (Anteneh, 2012). Therefore, the present study was conducted to evaluate the response of faba bean to inoculation of *Rhizobium* and application of mineral phosphorus fertilizer in Bore highlands of Guji Zone of Southern Ethiopia. Hence the objectives of this study were:

- To evaluate the effect of *Rhizobium* inoculation and phosphorus application on nodulation, yield components and yield of faba bean

- To determine the effect of *Rhizobium* inoculation and phosphorus application on N accumulation and P uptake by the crop

Materials and Methods

Description of the Study Area

The experiment was carried out during the 2015 and 2017 main cropping seasons at Bore Agricultural Research Center, Guji Zone of Southern Oromia, which is one of the recently established Research Centers of the Oromia Agricultural Research Institute (OARI). Bore Agricultural Research Center site is located at the distance of about 8 km north of the town of Bore in Songo Bericha K*ebele'* just on the side of the main road to Addis Ababa *via* Hawassa town. Geographically, the experimental site is situated at the latitude of 06^{o}23‟55‟ N – 06^{o}24‟15‟‟ N and longitude of 38^{o}34‟45‟‟ E – 38^{o}35‟5‟‟E at an altitude of 2728 m above sea level. The research site 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 clay loam in texture and strongly acidic with pH value of around 5.13.

Description of Experimental Materials

Carrier-based moisted peat *Rhizobium* inoculants, namely: Indigenous strains (FB-1018 and FB-1035) and exotic Australian isolate (FB-Murdoch) were obtained from Soil Microbiology Laboratory of Holeta Agricultural Research Center (HARC) and were used for seed inoculation. Faba bean variety *Gabelcho* was also obtained from HARC. The variety was released in 2006. It matures of 103-167 days and has been recommended for altitudes ranging between 1900-3000 meters above sea level for areas receiving 700-1000 mm/year rainfall. It yields 2500-4400 kg ha^{-1} and 2000-3000 kg ha-1on research station and farmers‟ fields, respectively. It was selected on the basis of its adaptation and better performance in the area. The source of phosphorus was triple super phosphate (20% P or 46% P_2O_5).

Treatments and Experimental Design

The treatments consisted of factorial combinations of four levels of inoculation (uninoculated, FB-1035, FB-1018 and FB-Murdoch) and five levels of phosphorus (0, 10, 20, 30 and 40 kg P ha^{-1}). The treatments were laid out in a Randomized Complete Block Design (RCBD) with three replications.

Experimental Procedure and Crop Management

Seed treatment with Rhizobium (seed inoculation)

Seeds were inoculated with legume fix inoculants using sticker (sugar solution). The seeds of faba bean variety *Gabelcho* was divided into three (3) bowls for three different inoculants (FB-1018, FB-1035 and FB-Murdoch) with each containing a weight of about 1.0 kg of seeds (600 seeds). The carrier-based moist peat inoculants of each strain were applied at rate of 10 g inoculants/kg seed over 600 seeds of bowls of faba bean variety after sprinkling sticker solution 1:1 ratio sugar and potable water (10% of sugar solution) over seeds. The seeds and inoculants in the bowls were mixed carefully until seeds were coated with black film of inoculants. To maintain the viability of cells, inoculation was done under the shade and allowed to air dry for few minutes and then sown at recommended rate and spacing. A plot with uninoculated seeds was planted first to avoid contamination. The seeds were immediately covered with soil after sowing to avoid death of cells due to the sun's radiation.

Crop management

The experimental field was prepared by using oxen-drawn implements (local plough maresha) according to farmers' conventional farming practices. The field was ploughed three times, the first plough at the end of May and the third during the middle of July before planting the crop to fine tilth. Gross plot size was 4.0 m x 3.0 m. The blocks were separated by a 1.5 m wide-open space whereas the plots within a block were separated by a 1.0 m spacing from each other. The plots were leveled manually. The dried seeds of faba bean were planted by hand at 40 cm inter- and 10 cm intra- plant spacing by planting two seeds per hill on 23 July accommodating ten rows per plots. Plots receiving no inoculation were planted before inoculated ones to avoid the possibility of cross contamination. A uniform dose of nitrogen fertilizer (10 kg urea ha^{-1}) was applied as a starter dose to all plots. The outermost one row on both sides of each plot and three plants on both sides of each row were considered as border plants, and were not used for data collection to avoid border effects. The second and third rows on both sides were used as a source of plants of destructive sampling to record the data on nodulation and plant analysis. Thus, the net plot size was 2.4 m x 1.6 m having four rows each with 24 plants (96 plants).

All the other agronomic practices were followed as per the recommendation for raising a successful crop. The crop was harvested manually using a sickle when 90% of the leaves and pods turned gray black in mid-January and dried under the sun for 7 days before threshing.

Soil and Plant Tissue Sampling and Analysis

Soil sampling and analysis

The composite surface soil samples (0-30cm depth) were collected from 20 points in random method throughout the experimental units two weeks before the field was ploughed for determination of selected physico-chemical properties of the soil. Then, the collected samples were air-dried at room temperature under shade and ground to pass through a 2mm sieve whereas for organic carbon (OC) and nitrogen (N) determination the soil was ground to pass through a 1mm sieve. Samples were analyzed for the following parameters viz., particle size distribution (soil texture), pH, cation exchange capacity (CEC) (Cmol (+) Kg^{-1}), organic matter (%), available phosphorus (mg L-1) and total nitrogen (%), exchangeable potassium, magnesium and calcium (Cmol (+) kg^{-1}) at Horticoop Ethiopia (Horticultural) PLC Soil and Water Analysis Laboratory.

Particle size analysis was done by using the Bouyoucos Hydrometer methods as outlined by Aderson and Ingram (1993). Soil pH was measured in the supernatant suspension of 1:2.5 soils and water mixture by using a pH meter. Soil organic carbon content was determined by using the Walkley and Black method (Walkley and Black, 1934) and soil organic matter content was calculated by multiplying the OC% by a factor 1.724. Total nitrogen of the soil was determined by the Kjeldahl method (Jackson, 1958). Available phosphorus was determined by Bray II methods (Bray and Kurtz, 1945). Cation Exchangeable Capacity (CEC) was determined by leaching the soil with neutral 1N ammonium acetate (FAO, 2008). Exchangeable potassium, magnesium, and calcium were determined by Melich-3 methods (Mehlich, 1984).

Plant tissue sampling and analysis

At physiological maturity, five randomly selected plants were harvested from the rows designated for destructive sampling in each plot. The plant samples were partitioned into straw and grain. The grain and straw samples were separately air-dried and oven-dried at 70 ^{o}C to a constant weight, ground to pass through a 1mm sieve and saved for tissue analysis of grain and straw N and P concentration.

Determination of N accumulation and P uptake

Total nitrogen concentration in the grain and straw sub-samples was determined by using the Kjeldahl distillation method (Bremner and Mulvaney, 1982). Phosphorus in grain and straw sub-samples were determined using Meta vanadate method (NSL, 1994). Samples were accustomed in the furnace overnight at 450^{o}C and the ash was dissolved in 20% nitric acid (HNO3) to liberate organic P. The phosphorus in the solution was determined colorimetrically using the molybdate and metavanadate method for color development. The reading of phosphorus was made at 460 nm using a spectrophotometer. Nitrogen accumulation in the grain was determined after multiplying nitrogen content of the grain by grain yield, and straw nitrogen accumulation was determined by multiplying nitrogen content in the straw by straw yield. Total nitrogen accumulation was recorded as the sum of grain N accumulation and straw N accumulation. Similarly, phosphorus uptake by grain and straw was determined from the phosphorus content of the respective parts after multiplying with the grain yield and straw yield, respectively. Total phosphorus uptake was then calculated as the summation of grain and straw uptake.

Data Collected

Effect rhizobium inoculation and p application were investigated by measuring data on phonology, growth, yield and yield component parameters. Data on phonological parameters were measured through visual observation as the number of days from sowing to when 50% of plants in a net plot had reached flowering and 90% physiological maturity. Data on growth and yield component parameters were taken in each plot from ten randomly selected plants at physiological maturity and at harvest time, respectively. For hundred seed weight and grain yield the whole plant from the net plot area was harvested and the yield per hectare was determined by converting the yield per plot (kg per plot) into kg per hectare.

Data Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to SAS software 9.1 versions. Significance Difference (LSD) test at 5% probability level was used for mean comparison.

Economic Analysis

Economic analysis was performed using partial budget analysis following the procedure described by CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on ha basis in Birr. The concepts used in the partial budget analysis were the mean grain yield of each treatment, the field price of faba bean grain, and the gross field benefit (GFB) ha^{-1} (the product of field price and the mean yield for each treatment. The net benefit (NB) was calculated as the difference between the gross benefit and the total cost. The average yield obtained from experimental plot was reduced by 10% to adjust with the expected farmers' yield by the same treatment. The % MRR between any pair of undominated treatments was the return per unit of investment in fertilizer. To obtain an estimate of these returns the % MRR was calculated as changes in NB (raised benefit) divided by changes in cost (raised cost). Thus, a MRR of 100% implied a return of one Birr on every Birr spent on the given variable input. The fertilizer cost was calculated for the cost of each fertilizer of TSP (Birr 105 kg^{-1} of P) and *Rhizobium* strain (Birr 180 kg^{-1}). The cost of labour involved in harvesting, collection (bagging to place of threshing), threshing and winnowing (Birr 0.6 kg^{-1}of grain or Birr 60 per 100 kg grain), *Rhizobium* and phosphorus application cost (Birr 15 kg^{-1} and Birr 3 kg^{-1} respectively), packing and transportation was Birr 0.22kg^{-1} of grain and the average open price of faba bean at Bore market was Birr 12 kg^{-1} in January during harvesting time.

Results and Discussions

Soil Physico-chemical Properties of the Experimental Site

The results show that the soil is clay loam in texture with a clay content of 39%. Faba bean usually grows well under good soil conditions, medium textured, clay or loamy soils of good fertility with optimum pH of 6.5-9.0 soils usually being the best (Link *et al*., 2010). The pH of the soil is 5.13, which is strongly acid according to Tekalign (1991). At this pH value (strongly acidic condition), phosphorus is fixed to surfaces of Fe and Al oxides and hydrous oxide, which are not readily available to plants (Sikora *et al*., 1991). However, Singh *et al*. (2012) indicated that faba bean plants can grow well between pH of 4.5-9.0 ranges. Therefore, the pH of the experimental soil is suitable for faba bean production. However, the native rhizobia population is significantly influenced at low pH (acidic condition). According to Unkovich *et al*. (1997) report in acid soils with pH lower than 5, the survival and persistence of faba bean rhizobia are most likely to be poor. In similar way Drew *et al*. (2012b) reported that in soil below pH 5, aluminum and manganese toxicity become stresses that can kill rhizobia.

According to Tekalign (1991), the soil organic matter and organic carbon contents (4.69 and 2.27%, respectively) of the experimental site are medium. The analysis further indicated that the soil has medium total nitrogen (0.24%) according to the rating of Tekalign (1991). This indicates that the soil has not much potential as a source of energy for soil biota to maintain soil health and also as a source of native mineral nitrogen. Hence, it requires external application of organic matter and/or mineral nitrogen fertilizer or biological nitrogen fixation for sustainable production of crops. The medium nitrogen content is ascribable to the medium organic matter or organic carbon content. This suggestion is consistent with the suggestion of Murage *et al*. (2000) that organic matter is a surrogate of mineral nitrogen. The results of the analysis also indicated that the soil has a very low content of available phosphorus (2.39 mgL^{-1}) according to the rating of Cottenie (1980). Similarly, Wakene *et al.* (2014) reported that available phosphorus content of the soil of Bore highlands (the study site) is low most likely because of P fixation. This result indicates that application of mineral phosphorus fertilizer is important for sustainable production of crops in the study area. The cation exchange capacity (CEC) of the soil is 21.5 Cmol(+) kg^{-1} of soil; CEC of > 40, 25-40, 15-25, 5-15, <5 Cmol(+) kg-1are categorized as very high, high, medium, low and very low respectively(Landon, 1991). Therefore, CEC of the experimental soil lies in the medium range, which means that the soil has moderate capacity to hold exchangeable cation. The result of the soil analysis indicated that also the soil had low exchangeable Na, medium exchangeable K, low exchangeable Ca and Mg according to the rating of FAO (2006). The low exchangeable Na, Ca and Mg contents in the soil might be attributed to leaching due to high rainfall in the area. The medium exchangeable K value observed might be attributed to the high rate of leaching of the nutrient as a result of high precipitation in the area. However, the K content of the soil was not as low as the contents of Ca, Na, and Mg due to certain supply of the nutrient from burnt wood ash as a result of the shifting cultivation practiced in the area in past. The low exchangeable Ca and Mg were probably attributed to the high leaching of Ca and Mg in acidic soil.

Table 1. Physico-chemical properties of the experimental soil before planting

Property	Value	Rating	Reference
Depth (cm)	0-30		
Physical property			
Sand (%)	33		
Silt (%)	28		
Clay (%)	39		
Textural Class	Clayey Loam		
Chemical Property			
pH (1: 2.5 H_2O)	5.13	Strongly Acidic	Tekalign, 1991
Organic matter (%)	4.69	Medium	Tekalign, 1991
Organic carbon (%)	2.72	Medium	Tekalign, 1991
Total N (%)	0.24	Medium	Tekalign, 1991
CEC [Cmol$_{(+)}$kg^{-1}soil]	21.5	Medium	Landon, 1991
Available P (mgL^{-1})	2.39	Very Low	Cottenie, 1980
Exchangeable Base [Cmol$_{(+)}$kg^{-1}soil]			
Exchangeable Na[Cmol$_{(+)}$kg^{-1}soil]	0.12	Low	FAO, 2006
Exchangeable K[Cmol$_{(+)}$kg^{-1}soil]	0.36	Medium	FAO, 2006
Exchangeable Ca[Cmol$_{(+)}$kg^{-1}soil]	2.68	Low	FAO, 2006
Exchangeable Mg[Cmol$_{(+)}$kg^{-1}soil]	0.44	Low	FAO, 2006

Phenological Parameters

Days to 50 % flowering and maturity

The analysis of variance showed that main effect of Rhizobium inoculation, phosphorus application and its interaction with *Rhizobium* inoculation had no significant (P>0.05) effect on the number of days required for 50% flowering and maturity (Table 2).

Table 14. Main effect of *Rhizobium* Inoculation and Mineral phosphorus fertilizer application on days to 50% emergency (EM), Days to 50% flowering (DF) and 90 % physiological Maturity (90 % PM) of faba bean over two seasons at Bore, Guji zone, Southern Ethiopia

Treatment	Days to 50% Emergency	Days to 50% Flowering	Days to physiological maturity
Inoculation			
Uninoculated	10.70^{a}	58.47	144.5
FB-1035	9.90^{b}	57.93	144.7
FB-1018	10.33^{ab}	57.40	144.1
FB-Murdoch	9.97^{b}	58.77	143.2
LSD (0.05)	0.44	NS	NS
P-rate (kg P ha^{-1})			
0	10.12	57.33	145.3
10	10.00	58.92	145.4
20	10.29	57.46	143.2
30	10.42	58.42	143.2
40	10.29	58.58	143.4
LSD (0.05)	NS	NS	NS
CV (%)	8.4	11.5	2.9

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

Growth and Nodulation Parameters

Plant height

The analysis of variance showed significant (P<0.01) effect of seed inoculation with *Rhizobium* and also significance effect (P<0.05) due to phosphorus application on plant height of faba bean while their interaction had no significant effect on this parameter (Table 3).

Seed inoculation with FB-1035 strain resulted in plants that were taller by 16.8% than those in uninoculated treated plots. Further, seed inoculation with the *Rhizobium* strains FB-Murdoch and FB-1018 improved plant height by 11.38 and 10.44% over the uninoculated control treatments, respectively. This result is in agreement with that of Wassie *et al*. (2010) who reported that *Rhizobium* inoculation increased faba bean plant height up to 25% and 39% at Chencha and Bulie wereda of Southern Ethiopia, respectively.

The highest plant height was obtained from application of 40 kg P ha^{-1} which was significantly higher by 11.7% than the unfertilized control (Table 3). On the other hand, no significant variation was observed between unfertilized, 10, 20 and 30 kg P ha^{-1}. Similarly, no significance variation was also observed between 10, 20, 30 and 40 kg P ha^{-1}. This result is in accord with that of Getachew and Angaw (2006) who reported a significant response of plant height to phosphorus application in faba bean on acidic *Nitisols* of Central highlands of Ethiopia. In line with this, the other authors also reported that phosphorus application significantly enhanced plant height in an acidic *Nitisols* with a low content of available phosphorus (Getachew and Resene, 2006).

Number of nodules per plant

The analysis of variance revealed that total number of nodules was significantly ($P<0.01$) affected by the main effect of *Rhizobium* inoculation and application of mineral phosphorus fertilizer ($P < 0.05$). However, the interaction effects were not significant on this parameter of the plant (Table 3). The seed treatment with FB-1035 strain of *Rhizobium* resulted in the highest total nodules (93.16 plant^{-1}), which was significantly higher than the total number of nodules (66.44 plant^{-1}) obtained in the uninoculated and inoculated (70.49 plant^{-1}) with FB-1018 strain. Also, significantly higher number of total nodules was obtained from seed inoculation with FB-Murdoch strain (82.10 plant^{-1}) than the uninoculated control treatment. Thus, seed inoculation with FB-1035 and FB-Murdoch strains resulted in 28.7 and 23.6% higher nodules plant^{-1}, respectively than the uninoculated control (Table 3). This is in agreement with the findings of several authors who reported that *Rhizobium* inoculation significantly increased faba bean nodule number over uninoculated treatments (Wassie *et al*., 2010; Yohannes *et al*., 2014 and Dereje *et al*., 2015). However, nodule number per plant is low as compared to the previously reported research in Ethiopia **(**160-443 per plant**)** (Wassie *et al*., 2010). This might be attributed to the fact low pH (acidity) affect the nodule number per plant in the soil.

The total number of nodules per plant increased significantly in response to increasing the rate of phosphorus application. Thus, increasing the rate of phosphorus application from nil to 10 kg P ha^{-1} did not increase the total number of nodules per plant. However, increasing the rate of application of the phosphorus fertilizer further from 20 kg P ha^{-1} to 30 and 40 kg p ha^{-1} increased the total number of nodules per plant significantly by about 16.1 and 19.5%, respectively (Table 3). The application of mineral phosphorus fertilizer at the rate of 30 and 40 kg P ha^{-1} resulted in the highest number of nodules per plant. In fact, the maximum number of nodule per plant was obtained at the rate of 40 kg P ha^{-1}. These results are in line with the findings of Getachew and Angaw (2006), Yirga and Kiros (2013) and Yohannes *et al*. (2014). These authors found that application of mineral phosphorus fertilization increased nodule number per plant in faba bean significantly.

Nodule dry weight per plant

The analysis of variance revealed that nodule dry weight was significantly ($P<0.05$) affected by main effect of *Rhizobium* inoculation and application of mineral phosphorus fertilizer rate while their interaction was not significant (Table 3).

The highest nodule dry weights were recorded from FB-1035 strain. However, the nodule dry weight obtained from FB-1035 was statistical in parity with FB- Murdok. The nodules dry weight obtained from the uninoculated and inoculated with FB-1018 and FB-Murdoch strains were significantly lower, and in statistical parity (Table 3). Significant response of nodule dry weight to *Rhizobium* strain inoculation in faba bean was reported by Wassie *et al*. (2010) and Dereje *et al*. (2015). Similarly, Yohannes *et al*. (2014) reported that *Rhizobium* inoculation increased nodule dry weight in faba bean. Application of 40 kg P ha^{-1} resulted in the highest nodule dry weight which was significantly higher than the nodule dry weights obtained in response to applying the fertilizer at the rate10 kg P ha^{-1} and unfertilized control treatment.

Table 15. Main effect of *Rhizobium* Inoculation and Mineral phosphorus fertilizer application on Plant height (cm), Number of nodule per plant and Nodule dry weight (mg plant^{-1}) of faba bean over two seasons at Bore, Guji zone, Southern Ethiopia (Pooled data of two years).

Treatment	Plant height(cm)	Number of. Nodules plant^{-1}	Nodule dry weight (mg plant^{-1})
Inoculation			
Uninoculated	101.2^{c}	66.44^{c}	108.7^{c}
FB-1035	121.6^{a}	93.16^{a}	183.8^{a}
FB-1018	113.0^{b}	70.49^{c}	144.6^{b}
FB-Murdoch	114.2^{b}	82.10^{b}	137.0^{b}
LSD (0.05)	5.98	10.2	21.42
P-rate (kg P ha^{-1})			
0	104.2^{b}	63.96^{c}	105.5^{c}
10	112.6^{a}	64.87^{bc}	127.8^{bc}
20	113.1^{a}	76.12^{b}	147.5^{abc}
30	114.6^{a}	90.74^{a}	165.7^{a}
40	118.1^{a}	94.52^{a}	170.9^{a}
LSD (0.05)	6.69	11.4	23.95
CV (%)	10.4	25.5	29.1

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

The increase in nodule dry weight with the application of 40 kg P ha^{-1} was 45 and 32% higher than that nodule dry weight obtained at nil and 10 P kg ha^{-1}. However, in terms of nodule dry weight; there were no significant differences among treatments supplied with 20, 30 and 40 kg P ha^{-1}. This might be due to the fact that as phosphorus rate increase the availability of P to plant increase in acidic soil. Similarly there were no significant differences among the unfertilized treatments, the treatments that received 10 kg P ha^{-1}, and the 20 kg P ha^{-1} in terms of nodule dry weight (Table 3).Similarly, other researchers reported increases in nodule dry weight with increase in the rate of application of mineral phosphorus (Yirga and Kiros, 2013; Yohannes *et al*., 2014).

Yield Component and Yield parameters

Number of pods per plant

The analysis of variance revealed that number of pods per plant was significantly (P<0.01) influenced by the main effect of *Rhizobium* inoculation and application of mineral phosphorus fertilizer. However, the two factors did not interact to influences this parameter of the plant (Table 4).The productive potential of pulse crops is ultimately determined by number of pods per plant, which is the main yield attributing component (Abdul-Aziz, 2013; Tesfaye, 2015). The results revealed that inoculation resulted in significant differences in the number of faba bean pods produced. The highest number of pods per plant was obtained in response to inoculation with FB-1035 *Rhizobium* strain whereas the lowest was obtained from the uninoculated (control) treatment which statistical parity with FB-1018 and FB-Murdoch (Table 4). In this study, the number of pods produced by faba bean plants inoculated with FB-1035 *Rhizobium* exceeded those produced by plants inoculated with FB-1018 and FB-Murdoch by about 29 and 19%, respectively. However, the increase over the uninoculated treatment was about 54%. This result signifies that rhzobial inoculation profoundly increases pod production in faba bean, and there is also variation among rhizobial strains in effectiveness to enhance this yield component of the crop. Consistent with this result, Yohannes *et al*. (2014) reported a significant increase in number of faba bean pods per plant due to inoculation of faba bean by *Rhizobium* strain EAL-110.

Increasing the rate of phosphorus application from nil to 10 and 20 P ha^{-1} did not affect the number of pods produced per plant. However, increasing the rate further to 30 and 40 kg P ha^{-1} resulted in significantly higher numbers of pods per plant^{-1} which was statistically in par (Table 4). The number of pods produced by plants treated with 30 kg P ha^{-1} exceeded the numbers of pods produced by plants fertilized with 20, 10, and nil rates the P fertilizer by 28, 35, and 41%, respectively. This result shows that application of 30 kg P ha^{-1} is already enough to produce pods in required amounts for optimum production of the crop, and there would be no need to increase the rate of the P fertilizer above this level. The positive effect of phosphorus on production of faba bean pods might be attributed to the merit of the nutrient in promoting of both vegetative and reproductive, thereby improving the photosynthetic efficiency and partitioning of carbohydrate to pod yield. Corroborating the results of this study, Getachew and Angaw (2006); Getachew and Rezene (2006), and Yohannes *et al*. (2014) reported significant increase in number of pods per plant on faba bean due to application of phosphorus fertilizer.

Number of seeds per pod

The analysis of variance revealed no significant effect of the main factors *Rhizobium* inoculation and mineral phosphorus fertilizer rates as well as their interaction on the number of seeds pod^{-1} (Table 4). The number of seeds per pod is perceived a significant constituent that directly impacts on exploiting potential of yield recovery in leguminous crops (Devi *et al*., 2012). Most probably, the number of seeds pod^{-1} significantly varied between different genotypes and is less affected by external factors like fertilizer when single genotype is considered. Concurrent with this result, Tekle *et al*. (2015) reported that phosphorus application did not affect the number of seeds produced pod^{-1} in faba bean. Similarly, Tolera and Zerihun (2014) also stated that *Rhizobium* inoculation did not affect the number of seeds produced pod-1 in faba bean in a study done in Horro and Gedo highlands of Western Ethiopia.

Aboveground dry biomass yield

The results of the analysis of variance revealed that aboveground dry biomass yield was significantly ($P<0.01$) affected by *Rhizobium* inoculation, application of mineral phosphorus fertilizer while their interaction was not significant (Table 4). The maximum aboveground dry biomass yield was recorded in response to inoculation with FB-1035 *Rhizobium* strain. However, aboveground dry biomass yield obtained for all three rhizobial strains were in statistical parity (Table 4). The aboveground dry biomass yield obtained in response to inoculation with FB-1035 *Rhizobium* strain exceeded the aboveground dry biomass yield obtained in response to uninoculated plant by about 25%.The significant increase in biomass dry matter yield of faba bean in response to rhizobial inoculation could be due to sufficient nitrogen supply mainly from enhanced biological nitrogen fixation as a result of the inoculation. In line with this result, Abbasi *et al*. (2010) reported that the aboveground dry biomass yield of soybean was quadratically increased ranging from 39 to 75% by inoculation with different strains of *rhizobium*. Similarly, Tesfaye (2015) also reported that significant improvement of aboveground biomass yield in soybean by 67.8 and 56.6%, respectively due to inoculation with SB6 B1 and Legume fix *Bradyrhizobium* inoculation.

Table 16. Main effect of *Rhizobium* inoculation and mineral phosphorus application on number of pods plant^{-1}, number of seeds pod^{-1}aboveground dry biomass yield, seed yield, straw yield and harvest index of faba bean over two seasons at Bore, Guji zone, Southern Ethiopia

Treatment	Number of pods plant^{-1}	Number of seeds pod^{-1}	Aboveground dry biomass yield(kg ha^{-1})	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index
Inoculation						
Uninoculated	10.04^{c}	2.36	8696^{c}	2328^{b}	6368^{c}	0.28^{ab}
FB-1035	13.84^{a}	2.33	10611^{ab}	3137^{a}	7475^{b}	0.30^{a}
FB-1018	10.40^{b}	2.36	9952^{b}	2549^{b}	7403^{b}	0.26^{ab}
FB-Murdoch	10.36^{b}	2.33	11020^{a}	2574^{b}	8446^{a}	0.24^{b}
LSD (0.05)	1.64	NS	924.41	316.74	913.67	0.04
P-rate (kg P ha^{-1})						
0	8.50^{c}	2.39	8137^{d}	1939^{c}	6198^{c}	0.24
10	9.40b^{c}	2.34	9215^{c}	2318^{b}	6896^{bc}	0.26
20	10.36^{b}	2.38	10252^{b}	2570^{b}	7683^{ab}	0.25
30	14.46^{a}	2.33	11294^{a}	3105^{a}	8189^{a}	0.28
40	13.08^{a}	2.29	11451^{a}	3303^{a}	8148^{a}	0.29
LSD (5%)	1.8	NS	1033.53	354.13	1021.51	NS
CV (%)	28.8	8.7	6.7	23.4	24	28.5

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

The significant increase in the aboveground dry biomass yield in response to increasing the rate of phosphorus application proves that the soil of the study area is in fact deficient in native available soil P possibly due to fixation, and requires application of external P fertilizer application for enhancing the yield of the crop. This result is concurrent with the findings of Getachew and Angaw (2006) who reported a significant linear response of aboveground dry biomass yield to phosphorus application in faba bean on acidic *Nitisols* of central highlands of Ethiopia. In line with this result, other researchers also reported that total aboveground dry biomass yield of faba bean significantly responded to phosphorus fertilizer application in low soil available phosphorus of acidic *Nitisols* (Getachew and Resene, 2006).

Seed yield

The results of the analysis of variance showed that seed yield was significantly ($P<0.01$) affected by main effect of *Rhizobium* inoculation and that of application of mineral phosphorus fertilizer. However, the analysis showed that the two factors did not interact to influence seed yield of the crop (Table 4). Seed inoculation with *Rhizobium* strain FB-1035 resulted in the highest seed yield of the crop. This was followed by the seed yield obtained in response to inoculation with FB-Murdoch and FB-1018 strains, respectively. The lowest seed yield was obtained in response to no inoculation (control treatment) (Table 4). Thus, the seed yield obtained in response to inoculating the crop with FB-1035 strain exceeded the seed yields obtained in response to inoculating with FB-Murdoch and FB-1018 strains by about 18 and 19%, respectively. However, this increase was about 26% against the uninoculated treatment. These results could be explained by the symbiosis efficiency between faba bean and *Rhizobium* strain. This finding is similar with that of Wassie *et al.* (2010) who reported that seed yield of faba bean crop was increased by 61-68% and 52% at Bulie and Chencha districts of southern Ethiopia, respectively with proper *Rhizobium* strain.

Increasing the rate of phosphorus from nil to 10 kg P ha^{-1} did not change the seed yield of the crop. However, increasing the rate of phosphorus application from nil further to 20, 30, and 40 kg N ha^{-1} significantly increased seed yield by 24.5, 37.5, and 41.3%, respectively. The seed yields obtained at 30 and 40 kg P ha^{-1} were in statistical parity (Table 4). The highest seed yield was obtained at 40 kg P ha^{-1} whereas the lowest yield was obtained from the untreated (control) plots. Therefore, it could be assumed that there would be no need to increase P application beyond 30 kg per hectare since the highest yield was produced already at this rate of the fertilizer.

Harvest index

The analysis of variance showed that the main effect of phosphorus significantly ($P<0.05$) affected harvest index while the main effect of *Rhizobium* inoculation and its interaction with phosphorus application did not affect harvest index (Table 4).

Harvest index is very useful in measuring nutrient partitioning in crops plants, which provides an indication of how efficiently the plant utilized acquired nutrients for grain production (Tesfaye, 2015). Though statistically not significant, the highest harvest index was recorded from FB-1035 *Rhizobium* strain inoculated (0.31) treatment (Table 4). The highest mean harvest index also implies higher partitioning of the dry matter into seed. In contrast to this, Tesfaye (2015) reported that inoculation significantly increased harvest index in soybean plant. Significant difference was observed due to application of mineral phosphorus fertilizer in which 40 kg P ha-1 application resulted in the highest mean harvest index (0.30) which was in statistical parity with 10, 20 and 30 kg P ha^{-1}. Further, application of 30 and 40 kg P ha^{-1} resulted in significant increases in harvest index over unfertilized treatment. The increase in harvest index might have been mainly due to availability of phosphorus to the plant. In addition phosphorus requirement in seed formation is high (Gifole *et al*., 2011). This result is accord with that of Rafat and Sharfifi (2015) who reported that phosphorus had a significant effect on harvest index.

Grain and straw N concentration and accumulation by faba bean

The results showed that *Rhizobium* inoculation and mineral phosphorus fertilizer rates and their interaction had no significant (P>0.05) effect on nitrogen concentration in grain and straw of faba bean (Table 5). In contrast to this result, Mehana and Abdul Wahid (2002) reported that *Rhizobium* inoculation significantly improved grain and straw nitrogen concentration. The same authors also reported that application of phosphorus fertilizer had no significant effect on grain and straw nitrogen concentration in faba bean. Similarly, Talaat and Abdallah (2008) also reported that rhizobial inoculation improve nitrogen concentration as results of increasing N2 fixation capacity. This might be attributed to different varieties responding differently. The N accumulation by faba bean grains was significantly affected by both the main factors of *Rhizobium* inoculation and phosphorus application while N accumulation by straw was affected only by *Rhizobium* inoculation (Table 5). The accumulation of N by grains was significantly higher when the seeds were inoculated with FB-1035 strain than the other strains, On the other hand, there was no significant difference among uninoculated, and seed inoculated with FB-1018 and FB-Murdoch strains. The result further revealed that treating seeds with FB-1035 strain increased N accumulate by grains by 48.1, 25.4 and 22.4 % over uninoculated, inoculated with FB-1018 and FB-Murdoch strains, respectively.

Table 6. Main effect of *Rhizobium* inoculation and application of mineral phosphorus on nitrogen concentration (%), nitrogen accumulation in grain and straw and total nitrogen accumulation (kg ha^{-1}) by faba bean during 2015 and 2017 cropping season in Bore, Guji Zone, Southern Ethiopia

Treatment	Nitrogen concentration (%)		Nitrogen accumulation (kg ha^{-1})		Total Nitrogen accumulation (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Inoculation					
Uninoculated	3.81	1.49	81.3^{b}	95.9^{b}	177.2^{b}
FB-1035	3.74	1.45	120.4^{a}	106.1^{ab}	226.5^{a}
FB-1018	3.78	1.50	96.0^{b}	109.6^{ab}	205.6^{a}
FB-Murdoch	3.73	1.54	98.4^{b}	122.1^{a}	220.6^{a}
LSD	NS	NS	17.47	17.64	22.74
P-rate (kg/ha)					
0	3.83	1.48	73.74^{c}	98.0	171.8^{d}
10	3.75	1.52	88.02^{bc}	104.6	192.7c^{d}
20	3.81	1.45	95.90^{b}	108.0	203.9^{bc}

30	3.72	1.56	116.93^{a}	122.8	239.7^{a}
40	3.72	1.46	120.53^{a}	108.7	229.2^{ab}
LSD (0.05)	NS	NS	19.53	NS	25.42
CV (%)	6.5	8.5	23.9	22.0	14.0

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

Nitrogen (N) accumulation by grains increased in response to increasing P rates and it was significantly higher at 30 and 40 kg P ha^{-1} than at nil, 10 and 20 kg P ha^{-1}. Application of phosphorus did not significantly influence the accumulation of N by straw.Total N accumulation (grain + straw) was significantly influenced by *Rhizobium* and phosphorus application while their interaction was not significant (Table 5). There was no significant difference in total N accumulation by faba bean plants due to seed inoculation with *Rhizobium* trains but resulted in significantly higher total N accumulation than the uninoculated treatment. This increase in total N accumulation by the plants was 27.8, 24.5 and 16.0% with FB-1035, FB-Murdoch and FB-1018 inoculants, over uninoculated, respectively. This significant increase under these treatments may be due to significantly higher aboveground dry biomass yield over uninoculated treatment (Table 5). These results are in agreement with the findings of Mehana and Abdul Wahid (2002) who reported that *Rhizobium* inoculation significantly increased faba bean grain, straw and total nitrogen accumulation by 22.8, 42.8 and 30.6% over uninoculated treatments, respectively. Tesfaye (2015) also reported that grain, straw and total nitrogen accumulation increased by 147, 97 and 130% over control as result of SB6 B1 *Bradyrhizobium* strain inoculation in soybean.

Application of 30 kg P ha^{-1} resulted in the highest N accumulation by faba bean plants but it was in statistical parity with 40kg P ha^{-1}.There was also no significant difference between the latter treatment and 20 kg P ha-1, but there was significant increase over the unfertilized treatment. This is in agreement with the results of Mehana and Abdul Wahid (2002) who reported that phosphorus application significantly increased faba bean grain and total nitrogen N accumulation over zero phosphorus treatment. This might have been mainly due to significant role of phosphorus in increased the nodulation of faba bean plant causing more N_2 fixation and consequently resulting in higher accumulation of nitrogen in plant tissue. Similarly, Tekle and Walelign (2014) reported that phosphorus fertilization significantly affected grain nitrogen N accumulation and total nitrogen accumulation in soybean.

Grain and straw P concentration and uptake by faba bean

The response of *Rhizobium* inoculation and mineral phosphorus rates and their interaction to phosphorus concentration in grain and straw had no significant ($P > 0.05$) effect. Similarly, *Rhizobium* inoculation and application of mineral phosphorus rate and their interaction had no significant ($P > 0.05$) effect on uptake of P by faba bean straw (Appendix Table 7). Though statistically not significant, the higher uptake of P by straw was observed with inoculation and phosphorus rates over no inoculation and nil phosphorus application, respectively. In contrast to this result, Mehana and Abdul Wahid (2002) reported that *Rhizobium* inoculation and application of mineral phosphorus rate had significant effect on phosphorus concentration in straw, grain and phosphorus uptake in straw. This might be attributed due the difference in environment, soil type and the cultivar or varietal respond differently. Seed inoculation with *Rhizobium* strains and phosphorus application resulted in significant ($P<0.01$) variation in P uptake by faba bean grain and total uptake by grain plus straw (Appendix Table 7). It was revealed that the highest P uptake by grains was observed when the seeds were treated with FB-1035 strain which was significantly higher by 55.2, 28.1, and 23.3% over uninoculated, and inoculated with FB-1018 and FB-Murdoch strains, respectively.

Table 7. Main effect of *Rhizobium* Inoculation and application of Mineral phosphorus on Phosphorus concentration (%), phosphorus up take in straw and grain and total uptake (kg ha^{-1}) of faba bean during 2015 and 2017cropping season in Bore, Guji Zone, Southern Ethiopia.

Treatment	Phosphorus concentration (%)	Phosphorus accumulation (kg ha^{-1})	Total Phosphorus uptake (kg ha-1)		Total Phosphorus uptake (kg ha^{-1})
	Grain	Straw	Grain	Straw	
Inoculation					
Uninoculated	0.348	0.101	7.37^{c}	6.44	13.81^{c}
FB-1035	0.354	0.099	11.44^{a}	7.27	18.71^{a}
FB-1018	0.351 0.098	0.098	8.93^{bc}	7.19	16.12^{b}
FB-Murdoch	0.348	0.099	9.28^{b}	7.82	17.10^{ab}
LSD	NS	NS	1.56	NS	1.999
P-rate (kg/ha)					
0	0.348	0.095	6.72^{c}	6.37	13.08^{c}
10	0.353	0.097	8.28^{bc}	6.73	15.01^{bc}
20	0.349	0.102	8.76^{b}	7.56	16.33^{b}
30	0.346	0.103	10.90^{a}	7.93	18.83^{a}
40	0.357	0.099	11.62^{a}	7.37	18.94^{a}
LSD (0.05)	NS	NS	1.75	NS	2.235
CV (%)	3.9	9.6	22.8	23.0	16.5

Total P uptake by faba bean plants was also highest when the seeds were treated with *Rhizobium* FB-1035 strain but it was found to be statistically similar with total P uptake under FB-Murdoch treated seeds. Further, no significant difference was observed between FB-1018 and FB-Murdoch. However, treating seeds with *Rhizobium* FB-1035 significantly increased total P uptake by faba bean plants by 35.5 and 16.1 % over uninoculated and inoculation with FB-1018 strain (Table 7).The results also showed that all *Rhizobium* strains significantly increased P uptake over no inoculation. This is in agreement with Mehana and Abdul Wahid (2002) who reported that *Rhizobium* inoculation significantly increased faba bean grain and total phosphorus uptake by over uninoculated treatments. This result was in concurrence with Tahir *et al*. (2009) who reported that *Rhizobium* inoculation increased total phosphorus uptake by 79%. The higher phosphorus uptake due to *Rhizobium* inoculation could be attributed to the fact that some isolates of rhizobia have the ability to solubilize unavailable phosphorus components (Qin *et al*., 2011). In addition *Rhizobium* inoculation increased the nodulation of faba bean plant causing more N2 fixation and consequently the nutrients (nitrogenous materials) secreted into the soil, it is also increased rhizospheric microflora especially the acid producers and phosphate dissolvers causing more available phosphorus (Talaat and Abdallah, 2008) thereby increased phosphorus uptake in plant. Beside this, the phosphorus uptake could also be improved due to symbiotic N2 fixation in the inoculated treatments which synthesizes two moles of ammonia as the plant consumes up to 16ATP.

Partial Budget Analysis

The results (Table 7) showed that the highest gross return (Birr 41351 ha-1) was obtained with the combined application of seed treatment with *Rhizobium* strain FB-1035 and 30 kg P ha^{-1} followed by seed treatment with in same inoculant but supplied with 40 kg P ha-1 and FB-Murdoch + 40 kg P ha^{-1}.

Table 8. Partial budget and marginal rate of return analysis for response of faba bean to *Rhizobium* inoculation and application of mineral phosphorus at Bore Guji Zone, Southern Ethiopia

Treatments (Rhizobium + P-rates (kg ha^{-1})	Unadjusted grain Yield (kg ha^{-1})	Adjusted grain yield (kg ha^{-1})	Gross return (Birr ha^{-1})	Total variable cost (Birr ha^{-1})	Net return (Birr ha^{-1})	MRR (%)
FB-1035	2849	2565	28718	2531	26186	1129
FB-1035 + 10	2378	2140	23966	3225	20741	667
FB-1035 + 20	2883	2595	29059	4719	24340	1129
FB-1035 + 30	4102	3692	41351	6799	34552	3224
FB-1035 + 40	3916	3524	39470	7726	31744	1129
FB-1018	1693	1523	17063	1583	15479	1129
FB-1018 + 10	2496	2246	25157	3322	21836	1129
FB-1018 + 20	2808	2527	28306	4658	23649	1129
FB-1018 + 30	2845	2561	28674	5768	22906	452
FB-1018 + 40	2851	2566	28735	6853	21882	D
FB-Murdoch	1584	1426	15969	1494	14475	D
FB-Murdoch + 10	2504	2254	25244	3329	21915	1129
FB-Murdoch + 20	2394	2155	24133	4318	19814	697
FB-Murdoch + 30	2993	2694	30170	5889	24281	1129
FB-Murdoch + 40	3812	3430	38421	7641	30781	1129
Control	1629	1466	16423	1336	15087	0
10	1983	1784	19985	2706	17279	D
20	1956	1760	19714	3764	15950	D
30	2651	2386	26722	5414	21308	D
40	2390	2151	24089	6280	17809	D

On the other hand the highest total variable cost (Birr 7726 ha^{-1}) was found with the combined application of seed treatment with FB-1035 strain and 40 kg P ha^{-1} followed by seed treatment with *Rhizobium* strains FB-Murdoch and FB-1018 each at 40 kg P ha^{-1}.

The trend in net benefit was similar to gross return which accrued Birr 34552, Birr 31744 and Birr 30781 ha^{-1}, respectively with the combined application of FB-1035 + 30 kg P ha^{-1}, FB-1035+ 40 kg P ha-1and FB-Murdoch + 40 kg P ha^{-1}. To use the marginal rate of return (MRR %) as basis of fertilizer recommendation the minimum acceptable rate of return should be between 50 to 100% (CIMMYT, 1988). In this study inoculation of *Rhizobium* strain FB-1035 with application of 30 kg P ha-1 gave highest marginal rate of return. Therefore, on economic grounds for the combination of *Rhizobium* strain FB-1035 with 30 kg P ha^{-1} application rate would be best and economical for production of faba bean in the study area.

Conclusions and Recommendations

An ever-increasing world population requires producing more food in land which is steadily shrinking and losing its fertility each year due to over exploitation and poor soil fertility managements. Most highlands of Ethiopian soil including Bore highlands have limited potential of giving high crop yields due to the major nutrient limitations particularly that of nitrogen and phosphorus. Even though the demand for nitrogen and phosphorus in deficient soil is normally achieved by use of chemical fertilizers, it is expensive and the major pollutant of the ecosystem. This emphasizes the importance of developing an alternative means to meet the demand of nutrient in plants by using of symbiotic bacteria which are agronomically sustainable, environmental friendly and easily affordable to most farmers. Faba bean cropping depends on biological nitrogen fixations thus; inoculation with efficient strains of *Rhizobium* can produce similar or higher yield in presence of sufficient available phosphorus than those receiving nitrogen fertilizer in areas where bacteria are not efficient and persistence present.

The results of this study indicated that seed inoculation by *Rhizobium* and phosphorus application alone substantially improved nodulation parameters, agronomic parameters, yield and yield components of faba bean. Further, the results of inoculations and application of phosphorus indicated that FB-1035 followed by FB-Murdoch independently outperformed in all faba bean parameters tested regardless of phosphorus applications. Similarly, application of 30 and 40 kg P ha^{-1} independently outperformed in all faba bean parameters tested regardless of *Rhizobium* inoculations. Thus, it can be concluded that FB-1035 strains were found to be superior and can be used for faba bean inoculation in Bore highland of Guji zone Southern Oromia. Similarly, application of 30 kg P ha^{-1}(150 kg DAP ha^{-1}) was appreciable recommended for faba bean production in Bore highlands of Guji zone of Southern Oromia. Therefore it is suggested that using *Rhizobium* strain FB-1035 and 30 kg P ha^{-1} alone leads to the optimum yield of the crop. Further research work on effect of lime application and other limited nutrient in combination with phosphorus and rhizobia would be recommended.

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Effect of Phosphorus Rates in Blended Fertilizer (NPS) and Row Spacing on Production of Bushy Type Common Bean (*Phaseolus Vulgaris* L.) At Mid-land of Guji, Southern Ethiopia

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Abstract

In Ethiopia, common bean (Phaseolus Vulgaris L.) is usually grown by smallholder farmers and its average yield is low. The low yield of common bean in Ethiopia is attributed to several production constraints, which include poor agronomic practices such as low soil fertility management, untimely and inappropriate field operations, rainfall variability and diseases and insect pests. Hence, a field experiment was conducted at Adola sub-site of Bore Agricultural Research Center during the 2016-2017 main cropping seasons to determine optimum phosphorus rates in blended NPS and appropriate inter-row spacing for common bean production. The factors studied were four rates of phosphorus in blended in NPS (0, 50, 100 and 150 kg ha^{-1}) that contain 19% N, 38% P_2O_5 and 7% S and four inter row spacing of common bean (30, 40, 50, 60 cm). These were laid out in a factorial arrangement in Randomized Complete Block Design with three replications. Significantly the highest number of plant height (51.84 cm), number of total pods per plant (8.64), days to maturity (93.92), hundred seed weight (60.62) and grain yield (2494 kg ha^{-1}) were recorded at the highest rate of 150 kg P ha^{-1} whereas highest number of days (40.33 days) to reach flowering was recorded due to nil application. Among the inter-row spacing, 60 cm gave significantly the highest number of total pods per plant (9.25) and number of seeds per plant (2.99). The interaction of inter-row spacing and phosphorus rates had non-significant effect on almost all parameters except on number of primary branches per plant. Significantly the highest number of primary branches per plant (4.7) was recorded with nil application of P under wider inter-row spacing of 60 cm and it was statistically at par with P rates of 150 kg ha^{-1} for inter-row spacing of 40 cm. However, the highest net benefit (34167.56 Birr ha^{-1}) was obtained from combination of inter-row spacing of 50cm with application of 150 kg ha^{-1} NPS. Thus, it can be concluded that combined application of 150 kg ha^{-1} of P in blended NPS with variety Ibado proved to be superior and recommended for study area.

Keywords: Blended fertilizer, Ibado, inter-row, phosphorus

Introduction

Common bean (*Phaseolus vulgaris* L.), is an annual herbaceous plant domesticated independently in ancient Mesoamerica and in the Andes, and now is grown worldwide for both dry seeds or as a green bean. Thousands of legume species exist but common bean in any forms is the most eaten by human beings compared to any other legumes (Broughton *et al.*, 2003). When common bean is used for its unripe fruits, it is termed as green bean or snap bean. About 23.9 million tons of dry bean, 20.7 million tons of green bean, and 1.9 million tons of string or common bean were produced worldwide in 2012 (FAOSTAT, 2014). It is estimated that the common bean meets more than 50% of dietary protein requirements of households in Sub-Saharan Africa. The annual per capita consumption of common bean is higher among low-income people who cannot afford to buy nutritious food stuff, such as meats and fish (Broughton *et al.*, 2003). Common bean is highly preferred by Ethiopian farmers because of its fast maturing characteristics that enable households to get cash income required to purchase other food and household needs when other crops have not yet matured (Legesse *et al.*, 2006). It is also an important food and cash crop in Guji zone with an area of 15,850 ha and average productivity of 1.52 tons per hectare. Similarly, it contributed 39.49% for household consumption, 13.33% for seeds, 44.1% for sale, 0.58% for animal feed and 2.05% for other uses in the study zone (CSA, 2017). Improved common bean production encompasses a proper use of different agronomic practices which include improved variety, seed rate, spacing, fertilizer rate and pesticide application as per recommendation (Alemitu, 2011). However, the current national average yield of common bean (1485 kg ha^{-1}) is far less than the attainable yield (2500-3000 kg ha^{-1}) under good management conditions for most improved varieties. This low yield of common bean in Ethiopia is attributed to several production constraints, which include lack of improved varieties for the different agro-ecological zones, poor agronomic practices such as low soil fertility management, untimely and inappropriate field operations, rain fall variability, diseases and insect pests'.

In Ethiopia, a standard spacing of 40 cm ×10 cm has been adopted, irrespective of the growing conditions and locations. It was not clear that how this spacing was considered as the standard spacing without having planting density study. However, most farmers are not sure of the appropriate planting density to use. They use either very high or very low plant density which consequently results in poor grain yield in quality and quantity.

Adola midlands of Guji Zone of Southern Ethiopia is also one of the midland parts of the country that grows common bean where it covered area of about 15,850 ha with average annual productivity of 1.52 t ha^{-1} (CSA, 2017). But it shares the same production problem with other midland part of the country. To address these nutrient deficiencies, the farmers in the country have been using uniform blanket application of 100 kg ha^{-1} DAP (18 kg N and 46 kg ha^{-1} P_2O_5) fertilizer and spacing of 40 cm × 10 cm for common bean to increase crop yield for about half century and this did not consider soil fertility status and crop requirement. Therefore, this experiment was carried out to determine optimum phosphorus rates in blended NPS and appropriate inter-row spacing for common bean production at Adola.

Materials and Methods

Description of the Study Area

The experiment was conducted at Adola sub-site of Bore Agricultural Research Center (BOARC), Guji Zone, Oromia Regional State in Southern Ethiopia under rain-fed conditions during the 2016 cropping season (September-December). The site (55^{o}36'31”N, 38^{o}58'91”E, 1721 M) is located in Adola town in Dufa ‘*Kebele’* just on the West side of the main road to Negelle town. It is located at about 463 km south from Addis Ababa, the capital city of the country. The climatic condition of the area is a humid moisture condition, with a relatively shorter growing season. The area receives annual rainfall of 1084 mm with a bimodal pattern extending from April to November. The mean annual minimum and maximum temperature is 15.9℃ and 9.9℃, respectively. The type of the soil is red basaltic soil (*Nitisols*) and *Orthic Aerosols* (Yazachew and Kasahun, 2011). The soil is clay in texture and moderately acidic with pH of around 5.9 (Table 1).

Experimental Materials and Design

The common bean variety Ibado was used for the study. The variety was released by Hawassa Agricultural Research Center of Southern Agricultural Research Institute in 2003 (MoARD, 2008). Ibado has large sized red food types and white flower colour with a maturity period of 90-120 days with a determinate growth habit. The variety is adapted to an altitude range of 1400-2250 meter above sea level with rainfall of more than 500 mm in growing season. Ibado variety was chosen for the study because it is high yielder, well adapted, preferred red seed colour and widely grown in the area by smallholder farmers in the study area.Four inter row spacing (30, 40, 50 and 60 cm) and four phosphorus rates (0, 50, 100 and 150 kg ha^{-1}) were used. Blended NPS (19% N, 38% P_2O_5 and 7% S) was used as source of phosphorus for the study.The treatments were factorial combinations of four phosphorus fertilizer rates in blended NPS (0, 50, 100 and 150kg ha^{-1}) and four inter-row spacing (30, 40, 50 and 60 cm). The experiment was laid out as Randomized Complete Block Design (RCBD) and replicated three times per treatment in factorial combination. The gross plot size was 3.0 m × 2.8 m = 8.4 m^2. The spacing between blocks and plots was 1.0 m and 0.6 m, respectively. Each plot had 6 rows spaced 40 cm apart.

Soil Sampling and Analysis

Pre-planting soil samples was taken randomly in a zigzag fashion from the experimental plots at the depth of 0-30 cm before planting. Twenty soil core samples were taken using an auger from the whole experimental field and combined to form a composite sample in a bucket. Then, the collected samples were air-dried at room temperature under shade and ground to pass through a 2 mm sieve for laboratory analysis of soil pH, and available phosphorus. Small quantity of this 2 mm sieved soil material allowed to pass through 0.2 mm sieve for soil organic carbon (OC) and total nitrogen. The composite soil samples were analyzed for selected physicochemical properties mainly textural analysis (sand silt and clay), soil pH, total nitrogen (N), available sulphur (S), organic carbon (OC), available phosphorus (P), cation exchange capacity (CEC) (c mol kg^{-1}), exchangeable potassium, magnesium and calcium using the appropriate laboratory procedures at Horticoop Ethiopia (Horticultural) PLC Soil and Water Analysis Laboratory. Soil textural class was determined by Boycous Hydrometer Method (Aderson and Ingram 1993). Organic carbon (OC) was estimated by wet digestion method (Walkey and Black, 1934) and organic matter was calculated by multiplying the OC%

by a factor of 1.724. Total nitrogen was analyzed by Kjeldhal method (Jackson, 1962). The soil pH was measured potentiometrically in 1:2.5 soil-water suspensions with standard glass electrode pH meter (Van Reeuwijk, 1992). Cation Exchangeable Capacity (CEC) was determined by leaching the soil with neutral 1N ammonium acetate (FAO, 2008). Available phosphorus was determined by the Olsen's method using a spectrophotometer (Olsen *et al.*, 1954). Available sulfur (S) was measured using turbidimetric method (EthioSIS, 2014). Exchangeable potassium, magnesium, and calcium were determined by Melich-3 methods (Mehlich, 1984).

Crop Data Collection and Measurements

Phenological and growth parameters

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

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

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

Number of primary branches per plant: The average number of primary branches emerged directly from the main shoot was counted from ten randomly taken plants at physiological maturity and the average number of primary branches was reported as number of primary branches per plant.

Yield and yield components

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

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

Hundred seed weight (g): It was determined by taking weight of 100 randomly sampled seeds from the total harvest from each net plot area and the weight was adjusted to 10% moisture level.

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

Statistical Data Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the General Linear Model (GLM) of SAS software version 9.0 and the interpretations were made following the procedure described by Gomez and Gomez (1984). Least Significance Difference (LSD) test at 5% probability level was used for mean comparison when the ANOVA showed significant differences.

Results and Discussions

Physico-chemical Properties of the Experimental Site Soil

Soil texture is an important soil physical characteristic as it determines water intake rate (infiltration), water holding capacity of the soil, the ease of tilling, the amount of aeration, and also influences soil fertility (Gupta, 2000). It is one of the inherent soil properties less affected by management and determines nutrient status, organic matter content, air circulation and water holding capacity of a given soil. According to the soil textural class determination triangle, soil of the experimental site was found to be clay (Table 1). High clay content might indicate the better water and nutrient holding capacity of the soil of the experimental site.

According to the soil analysis test, the soil pH of the experimental site was 5.88 (Table 1). Thus, according to Landon's (1991) rating, the chemical reaction of the experimental site is moderately acidic. The available P level in the experimental site was which is 5.61 mg kg^{-1} (Table 1) is very low according to the rating of (EthioSIS, 2014). This low available phosphorus could be due to fixation in such acidic soils.

Table 1: Physico-chemical properties of the experimental site soil before planting.

Characters	Value	Rating	Reference
A. Soil texture			
Sand (%)	30		
Silt (%)	12		
Clay (%)	58		
Textural Class		Clay	
B. Chemical analysis			
Soil pH	5.88	Moderately Acidic	Landon (1991)
Organic carbon (%)	2.30	High	Hazelton and Murphy (2007)
Total N (%)	0.19	Low	EthioSIS (2014)
Available P (mg kg^{-1})	5.61	Very Low	EthioSIS (2014)
Available S (mg kg^{-1})	14.50	Low	EthioSIS (2014)
CEC [meq/100g soil)	14.9	Low	Landon (1991)

The result of laboratory analysis showed that the total nitrogen percentage (0.19%) was low as per the rating of EthioSIS (2014). Cation exchange capacity is the capacity of the soil to hold and exchange cations. It provides buffering effect to changes in pH, available nutrients, calcium levels and soil structural changes. The result showed that the CEC of the experimental soil to be 14.9 meq/100 g soils rated as moderate according to rating of Landon (1991). The total carbon content in the soil was 2.30% which was rated as high as per the classification of Hazelton and Murphy (2007). Thus, the OM content of the soil was optimum as rated by EthioSIS (2014). On the other hand, the available sulphur content in the soils has values of 14.50 mg kg^{-1} which was rated as low as per the classification of EthioSIS (2014).

Phenological and Growth Parameters of Common bean

Days to 50% flowering

The interaction of P rate in blended NPS and inter row and main effect of inter-row spacing had non- significant effect on days to 50% flowering, but the main effect of P rate were found to be highly significant ($P < 0.01$) on days to reach 50% flowering (Table 2). Significantly, highest number of days (40.33) to reach flowering was recorded due to nil application while the earliest days to flowering (38) was recorded due to application of 50, 100 and 150 kg ha^{-1}P. The result obtained from the current study clearly revealed that the increasing P rates from 0 to 150 kg P ha^{-1} shortened the time required to attain days to 50% flowering which was two days earlier than control. This variation may be due to stimulatory effect of phosphorus on growth hormones, induce early flowering in common bean. This result was in line with the findings of Wondimu and Tana who reported that increasing the NP application rate from 0 kg N, 0 kg ha^{-1} P_2O_5 to 36 kg N, 92 kg ha^{-1} P_2O_5 significantly shortened the time required to attain 50% flowering. However, Tewari and Singh (2000) reported no significant effects of P application on number of days to reach 50% flowering on common bean. Similarly, Tesemma and Alemayehu (2015) also reported that interaction of P with variety to be non-significant common bean.

Days to physiological maturity

The analysis of variance showed that the number of days required to reach physiological maturity of common bean was highly significantly ($P<0.01$) influenced by the main effect of P application rate. However, main effect of inter-row spacing and interaction effects of inter-row spacing with P application rates had no significantly influence physiological maturity. Increase in P application rate from 0 to 150 kg ha^{-1} led to a significant increase in the number of days required to reach physiological maturity. The highest number of days required to physiological maturity (93.92days) was recorded for the highest rate of P application rate (150 kg ha^{-1}) while the shortest days to physiological maturity (89.33 days) was recorded in the treatment without the P application. This finding was in contrary with that of Boutraa (2009) who reported that number of days required to 90% physiological maturity of common bean was decreased significantly from 70, 68 to 67 days, due to increased phosphorus fertilization from 25, 50 to 75 kg $ha^{-1}P_2O_5$

Number of primary branches

The interaction of P rate and inter-row spacing had significant ($P<0.05$) effect on number of primary branches. Significantly, highest number of number of primary branches (4.7) recorded with highest application of 150 kg ha^{-1} P for wider inter-row spacing of 60 cm and it was statistically at par with P rates of 150 kg ha^{-1} for inter-row spacing of 40 cm while the lowest number of primary branches (2.73) was recorded with nil application of P for inter-row spacing of 40 cm. This might be due to the fact that, as plant density decreased the available growth resources and more interception of sunlight for photosynthesis as well as optimal supply of P in the early stage of plant growth enhanced the crop lateral growth. This result was in line with the findings of Mehmet (2008) who obtained increased number of branches at the wider plant spacing for soybean and which may have resulted in production of more assimilate for partitioning towards the development of more branches.

Plant height

The analysis of variance showed highly significant ($P<0.01$) main effect of P levels in blended NPS fertilizer, while interaction of P levels and inter-row spacing did not significantly influence plant height in common bean. Increasing rates of P levels in blended NPS fertilizer from 0 to 150 kg ha^{-1} showed progressive increase in plant height (Table 3). However, no significant variation was observed for these parameters due to the main effect of inter-row spacing. Thus, the highest plant height (56.79) was recorded at the highest rate of application of (150 kg ha^{-1} P) and it was statistically at par with P rates of 100 kg ha^{-1} P, while the lowest plant height (38.01cm) was recorded for the control. The increase in plant height in response to the increased P application rate in blended NPS might be due to the maximum vegetative growth of the plants under higher P availability. In agreement with this result, Tesfaye *et al.*, (2016) reported that phosphorus have significantly increased plant height at application of 30 kg ha^{-1} P on common bean.

Table 2: Mean of primary branch number per plant as affected by the interaction of inter-row spacing and phosphorus fertilizer rates of common bean at Adola during 2016 and 2017 main cropping season

Treatment	The number of primary branches per plant			
Phosphorus rate / Inter-row spacing	0	50	100	150
30	2.733^{d}	2.767^{d}	3.5^{bcd}	3.067^{cd}
40	3.13b^{cd}	2.967^{cd}	2.83^{d}	3.97^{ab}
50	3.73^{bc}	2.83^{cd}	3.00^{cd}	4.7^{a}
60	3.1^{bcd}	3.33b^{cd}	3.23^{bcd}	3.47^{cd}
LSD (5%)	0.77			
CV (%)	14.0			

LSD=least significance difference, CV=coefficient of variation

Yield and Yield Components

Number of total pods per plant

Significant ($P<0.05$) effects of P application rate in blended NPS fertilizer and inter-row spacing were observed on the number of total pods per plant while the interaction effect did not significantly influence the number of total pods. The highest number of total pods per plant (8.64) was recorded at application rate of 150 kg ha^{-1}P whereas the lowest number of total pods (6.45) was obtained from the control. The increase in number of total pods with the increased P rates might be possibly due to adequate availability of P which might have facilitated the production of primary branches and plant height which might in turn have contributed for the production of higher number of total pods. In conformity with this result, Tessema and Alemayehu (2015) reported that number of pods per plant increased from 2.31 to 10.62 with the increase in P rate from 0 to 39.6 kg ha^{-1}. Thus, the increment of number of pods per plant due to application of P fertilizer confirms the fact that P fertilizer promotes the formation of nodes and pods in legumes. In agreement with this result, Dereje *et al.* (2015) also found that the number of pods per plant of common bean significantly increased in response to increasing rate of phosphorus up-to the highest rate (92 kg ha^{-1} P_2O_5).The main effects of inter- row spacing had a highly significant ($P<0.01$) effect on the number of pods per plant. The highest number of pods per plant (9.25) was obtained with wider inter-row spacing (60 cm) while the lowest number of pods per plant (6.02) was recorded for narrow inter-row spacing (30 cm). The variation in the number of pods per plant among the inter-row spacing might be related as the plant population increased there was high competition for the growth factors as compared to wider spacing which had impact on the number of pods per plant. The reduced competition for light and reduced overlapping from adjacent common bean plants could have enabled the plants grown at wider spacing to utilize its energy for more branching and subsequently, the greater number of pods per plant. In agreement to the present result, Khan *et al*. (2010) reported higher number of pods plant^{-1} (41.47) in the wider inter-row spacing (45cm) of chickpea.

Number of seed per pod

The analysis of variance showed that the interaction effect of P application rates and inter-row spacing were not significant, but the main effects of inter-row spacing had significantly ($P<0.05$) effect on the number of seeds per pod. The highest number of seeds per pod (2.99) was recorded for wider inter row spacing (60 cm) whereas the least number of seeds per pod (2.67) was recorded for inter-row spacing of 40 cm which statistically at par with that of 30 cm and 50cm. In agreement with the present result, Abdel (2008) reported that number of seeds per pod increased with decreased plant density of faba bean. Khan *et al*. (2010) also reported decreased number of seeds per pod from 1.87 to 1.81 as seed rate increased from 60 kg ha^{-1} to 75 kg ha^{-1} on chickpea.

Pod length

Analysis of means indicated significant variations in pod length due to the main effects of inter-row spacing. However, applied P fertilizer and it's interaction with inter-row spacing did not show significant variations in pod length (Table 3). On average, the longest pod was recorded under wider inter-row spacing of 60 cm. This might be under wider row spacing, there is better photo-assimilate translocation to other plant parts that would contribute to increments in yield attributing traits such as pod length.

Grain yield

Grain yield was highly significantly ($P<0.01$) affected by the main effect of P rates, and was not affected due to main effects of inter-row spacing and the interaction of inter row spacing with P fertilizer rates combination. The highest grain yield (2494) was recorded highest rate of P application at 150 kg ha^{-1}P which was followed by 2109 and 1965 kg ha^{-1} application of 100 and 50 kg ha^{-1} P) respectively while the lowest yield (1606) was observed for nil application of P fertilizer.The result might be attributed to the fact that applying P fertilizer increases crop growth and yield on soils which are naturally low in P and in soils that have been depleted. Similar results were reported by Gebre- Egziabher *et al*. (2014) that P application at the rate of 46 kg ha^{-1} P_2O_5 gave higher number of pods per plant and yield as compared to unfertilized plots in common bean. This result is also in agreement with that of Fisseha and Yayis (2015) who reported that the application of 27 kg N and 69 kg ha^{-1} P_2O_5 had significantly improved grain yield of common bean.

Hundred Seed Weight

The analysis of variance revealed that P application rates and inter-row interactions had no significant effect on hundred seed weight. But main effect of P application rates had significant ($P<0.05$) effect on hundred seed weight. The highest hundred seed weight (60.62 g) was recorded due to the application of highest rate of P fertilizer (150 kg ha^{-1} P), whereas the lowest hundred seed weight (55.42 g) was obtained under the control which was statistical in parity with 50 and 100 kg ha^{-1} P. This might be because nutrient use efficiency by crop was enhanced at optimum level of P since grain weight indicates the amount of resource utilized during critical growth periods.

The increase in hundred seed weight as a result of increased P application might be attributed to important roles the nutrient plays in regenerative growth of the crop (Zafar *et al.,* 2013), leading to increased seed size (Fageria, 2009), which in turn may improve hundred seed weight. Similarly, Amare *et al.* (2014) observed significant increase in thousand seed weights of common bean as a result of phosphorus application up to 40 kg ha^{-1}. In conformity with this result, Gobeze and Legese (2015) found that varieties and their interactions with P fertilizer had significant effect on bean thousand seed weight.

Table 3: Means of days to 50% flowering, days 90% maturity, plant height (cm), number of pod per plant, number of seed per pod, hundred seed weight, and grain yield, and inter row spacing of common bean at Adola during 2016 and 2017 main cropping season.

Treatment	DF	DM	PH (cm)	NPPP	PL (cm)	NSPP	HSW (g)	GY(kg ha^{-1})
Phosphorus rate								
0	40.33^{a}	89.33^{c}	33.49^{c}	6.45^{c}	9.20	2.81	55.42^{b}	1606^{c}
50	38.08^{b}	91.25^{b}	42.23^{b}	7.18^{bc}	9.65	2.8	57.50^{b}	1965^{b}
100	38^{b}	91.42^{b}	50.38^{a}	7.95^{ab}	9.22	2.77	56.88^{b}	2109^{b}
150	38.5^{a}	93.92^{a}	51.84^{a}	8.64^{a}	9.45	2.84	60.62^{a}	2494^{a}
Mean	38.33	91.48	44.50	7.55	9.38	2.81	57.60	2043.58
LSD (5%)	1.01	1.81	3.94	1.36	NS	NS	2.50	316.43
CV (%)	3.2	3.6	9.5	21.8	10.3	11.2	5.3	18.6
Inter-row spacing								
30	38.58	92.08	42.54	6.02^{c}	9.15^{ab}	2.67^{b}	57.71	2038
40	38.75	91.17	43.78	6.92^{c}	8.89^{a}	2.73^{b}	57.92	1913
50	38.92	91.0	46.02	8.03^{b}	9.65^{ab}	2.84^{ab}	58.54	2224
60	38.64	91.67	45.6	9.25^{a}	9.83^{a}	2.99^{a}	56.25	2000
Mean			44.5	7.55	9.38	2.82	57.60	2043.58
LSD (5%)	NS	NS	NS	1.10	0.74	0.23	2.90	NS
CV (%)	4.1	3.9	19.4	17.8	9.6	10.3	6.1	24.3

Where DF=days to flowering, DM=days to maturity, PH=plant height, NPPP=number of pods per plant, PL=pod length, NSPP=number of seed per pod, HSW=hundred seed weight, GY=grain yield, LSD=least significance difference, CV=coefficient of variation, NS=non-significant

Economic Analysis

The agronomic data upon which the recommendations are based must be relevant to the farmers' own agro-ecological conditions, and the evaluation of those data must be consistent with the farmers' goals and socio-economic circumstances (CIMMYT, 1988). The net benefit was computed due to common bean varieties, application of blended NPS fertilizer and interaction of varieties with application of blended NPS fertilizer. The economic analysis revealed that highest net benefit (34167.56 Birr ha^{-1}) was obtained from combination of inter row spacing of 50cm with application of 150 kg ha^{-1} NPS while the lowest net benefit (19228.69Birr ha^{-1}) was obtained from wider inter row spacing of 60cm with no application fertilizer (Table 4).Therefore, production of Ibado variety with inter row spacing of 50cm and 150 kg ha^{-1} NPS was most productive for economical production and can be recommended for the study area. Dereje *et al*. (2015) reported that planting of the cultivar Nasir produced the highest net benefit (15903.1 Birr ha^{-1}) with acceptable marginal rate of return compared to other cultivars at Areka. Fisseha and Yayis (2015) also reported net benefit of 21, 070 ETB ha^{-1} with marginal rate of return of 80% by the application of 69 kg ha^{-1} P_2O_5 at Areka.

Table 4: Result of economic analysis for effect of phosphorus rates in blended fertilizer (NPS) and row spacing for bushy type common bean (*Phaseolus vulgaris* L.) at Adola during 2016-2017 main cropping season

P+ Inter-row spacing	Adjusted yield (kg ha^1)	NPS cost	NPS application cost	Total variable cost (TC)	MP (Birr kg^{-1})	TR (Birr ha^{-1})	NB (Birr ha^{-1})
0+30	1608.87	0	0	0	13	20915.31	20915.31
0+40	1534.95	0	0	0	13	19954.35	19954.35
0+50	1799.68	0	0	0	13	23395.84	23395.84
0+60	1479.13	0	0	0	13	19228.69	19228.69
50+30	2240.59	700	420	1120	13	29127.67	28007.67
50+40	1906.02	700	420	1120	13	24778.26	23658.26
50+50	1845.48	700	420	1120	13	23991.24	22871.24
50+60	1868.68	700	420	1120	13	24292.84	23172.84
100+30	1975.81	1400	420	1820	13	25685.53	23865.53
100+40	2059.14	1400	420	1820	13	26768.82	24948.82
100+50	2427.88	1400	420	1820	13	31562.44	29742.44
100+60	1973.4	1400	420	1820	13	25654.2	23834.2
150+30	2327.65	2100	420	2520	13	30259.45	27739.45
150+40	2150.54	2100	420	2520	13	27957.02	25437.02
150+50	2822.12	2100	420	2520	13	36687.56	34167.56
150+60	2677.3	2100	420	2520	13	34804.9	32284.9

Where P=phosphorus, MP=market price, TR=total return, NB=net benefit

Conclusions and Recommendations

In Ethiopia, common bean is usually grown by smallholder farmers and the average yield of the crop is low. This low yield of common bean in Ethiopia is attributed to several production constraints, which include poor agronomic practices such as low soil fertility management, untimely and inappropriate field operations, rainfall variability and diseases and insect pests. Hence, a field experiment was conducted in Adola sub-site of Bore Agricultural Research Centre during the 2016-2017 main cropping seasons to determine optimum phosphorus rates in blended NPS and appropriate inter-row spacing for common bean production in the study area. The factors studied were four rates of phosphorus in blended in NPS (0, 50, 100 and 150 kg ha^{-1}) that contain 19% N, 38% P_2O_5 and 7% S and four inter- row spacing of common bean (30, 40, 50, 60 cm). These were laid out in a factorial arrangement in randomized complete block design with three replications. The main effect of P rate in blended NPS was significant on plant height, number of total pods per plant, days to flowering, days to maturity, hundred seed weight, number of primary branches per plant and grain yield. Significantly the highest number of plant height (51.84 cm), number of total pods per plant (8.64), days to flowering (40.5), days to maturity (93.92), hundred seed weight (60.62) and grain yield (2494 kg ha^{-1}) were recorded at the highest rate of 150 kg ha^{-1} P whereas the highest number of days (40.33) to reach flowering was recorded due to nil application. Inter-row spacing exhibited significant effect on number of total pods per plant and number of seed per plant. Among the inter-row spacing, 60 cm gave significantly the highest number of total pods per plant (9.25) and number of seed per plant (2.99). The interaction of inter-row spacing and phosphorus rates had non-significant effect on almost all parameters except number of primary branches per plant. The significantly highest number of primary branches per plant (4.7) was recorded with nil application of P under wider inter-row spacing of 60 cm and it was statistically at par with P rates of 150 kg ha^{-1} for inter-row spacing of 40 cm. The economic analysis revealed that the highest net benefit (34167.56 Birr ha^{-1}) was obtained from combination of inter-row spacing of 50cm with application of 150 kg ha^{-1} NPS while the lowest net benefit (19228.69 Birr ha^{-1}) was obtained from wider inter-row spacing of 60cm with no application fertilizer (Table 3). Therefore, production of Ibado variety with inter-row spacing of 50cm and 150 kg ha^{-1}NPS was most productive for economical production and can be recommended for the study area.

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Response of Application Time and Method of Inorganic Phosphorus Fertilizer Application to Irish Potato (*Solanum tuberosum* L.) at Bore and Ana Sora Area, Guji Zone

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Abstract

Nowadays, fertilization accounts for about 70% yields worldwide. Optimizing fertilization brings tangible benefits such as higher yields and lower fertilizer costs, but also assures the sustainability of agricultural businesses. Potatoes require optimal levels of essential nutrients throughout the growing season. Appropriate nutrient application at critical time is often a crucial and increase rapidly during the tuber bulking phase and then slow as the plant matures. In recent years, however, some producers have applied some or all of the fertilizer in a concentrated and in inefficient form at a time carelessly. There is a limiting knowledge regarding time and appropriate method of application. The field trials were conducted during 2016 and 2017 main cropping season at the Bore Agricultural Research Centre on site and Ana sora on farm which is located in Guji Zone of Southern Ethiopia to evaluate the best P application time and method. The treatments consisted of Five(5) levels of application time (pre-planting (10DBP), at planting, at first weeding, at first earthingup and second earthingup stage (45DAP) and three(3) levels of application methods (band placement (localized placement or spot application), side dressing and broadcasting) will be arranged in RCBD with factorial arrangement of three replications. Sprouted tubers was planted on plot size of 2.1mx 3.5m and spacing of 30cm between plants and 70 cm between rows. The plot consists of five rows and seven plants per single row, totally 35 plants per plot. A distance of 0.6m and 1.4m was left between plots and blocks, respectively. Data were collected on growth, yield, yield components and disease incidence and severity. The two years combined data analysis results revealed that the interaction effect of fungicides and potato varieties had influenced significantly ($P<0.05$) response on days to 50% flowering, 50% maturity, plant height, number of tubers per hill, stem number per plant, marketable tuber yield and unmarketable tuber yield and total tuber yield. The highest economic yield (50.2 t $ha^{-1}$and 49.98 t ha^{-1}) was obtained from the combined use of phosphorus at planting with banding. Generally, as a conclusive and recommendation, Irish potato growers at Bore, Ana sora and surrounding area need to grow Irish potato by applying phosphorus fertilizer at time of planting with banding method of application thereby phosphorus recovery can be improved for better use of plants.

Keywords*:* DBP, DAP, RCBD, Phosphorus,

Introduction

Agriculture is currently struggling with the challenge to increase food production by 70–100% in order to meet the food needs of a rising global population expected to reach over 9 billion people by 2050 (Bruinsma, 2009and Dubois, 2011). Options to raise food production include improving output from the current croplands, expanding existing croplands or simultaneously implementing both approaches and by adjusting the nutrient management with its efficient use of nutrients (Sanchez, 2002, IPCC, 2007 and Sasson, 2012).

Potatoes require optimal levels of essential nutrients throughout the growing season. Appropriate nutrient application at critical time is often a crucial and increase rapidly during the tuber bulking phase and then slow as the plant matures. Low fertilizer use and imbalanced nutrient application are partially responsible for low tuber yields and quality throughout. Potatoes managed for maximum productivity have a high demand on soil nutrients. Potatoes grown are valued for yield, size, and also for dry matter content. Management factors, including fertility decisions, time of nutrient application and method of application will influence potato yield and quality.In recent years, however, some producers have applied some or all of the fertilizer in a concentrated and in inefficient form. Placement of the fertilizer in a band may improve the efficiency of nutrient uptake from cold soils, because both ammonium and nitrate absorption by potato plant is reduced as soil temperatures decrease. When fertilizer (particularly phosphorus) comes in contact with soil it can be tied-up, reducing its availability to the plant. Band placement of fertilizer minimizes soil contact, reduces nutrient tie-up, and often results in increased fertilizer use efficiency.

Phosphorus is an essential plant nutrient required for optimum crop production. P is the second most limiting soil nutrient in crop production. Plants need phosphorus for growth, utilization of sugar and starch, photosynthesis, nucleus formation and cell division. There are a number of methods of applying P fertilizer placement; however, some methods are more efficient than others. To obtain good P fertilizer efficiency, adequate rates of nitrogen and other nutrients must be available to the crop. Phosphorus fertilizer is immobile in soil; therefore, plant uptake of fertilizer P may be low in the first year after application. For optimum crop production, an adequate supply of P with appropriate method and time of application is ideal. Pre-plant banding of P with nitrogen has been found to be a good alternative method of application under certain conditions. The placement of nutrients is an important issue in nutrient management because placement strongly influences the subsequent availability of nutrients. Improper placement can reduce yield and result economic loss. The right source of nutrients should be applied at the right rate during the right time and supplied to the right place to ensure their uptake. When nutrients are applied at a time when they are not required by the plant, the result can be economic and environmental losses (Mattson and Van Iersel, 2011).

An effective nutrient fertilization program coordinates amount timing and method of fertilizer application with plant demand and soil nutrient supply. Poor nutrient fertility management can lead to inefficient utilization, which can reduce crop yield (total yield), tuber quality, and pose significant environmental risk. Nitrogen is required in large amounts to maintain optimum shoot and tuber growth. The amount of nutrients available to meet a crop’s requirement depends upon the efficiency of the management system. Any effort in crop production is achieved through increasing productivity rather than expansion of production area by combination of proper use of improved seeds and agricultural techniques including land preparation, proper fertilizers application methods and time and use of proper inputs and reducing crop losses due to pest and diseases.

Nutrient application should be made on the basis of plant demand. Plant demand is a function of growth rate, growth stage climatic conditions, and cultivar. The amount of nutrients required by a potato crop is also related to a realistic yield potential for the selected cultivar and land farmed. Thus, the amount of fertilizer applied to a potato crop should depend on the supplying power of the soil, the potential for nutrient loss, and the growth potential of the cultivar (Dean, 1994). The application of essential plant nutrients in optimum quantity and right proportion, through correct method and time of application is the key to increased and sustained crop production (Cisse and Amar, 2000). The time at which P should be applied to a crop is very important because timing affects P efficiency and crop yield. Phosphatic fertilizers should not be applied much in advance of crop sowing since soluble P converts to less available form in the soil and its effectiveness declines with the time between application and the stage at which the crop is in a position to make use of nutrients (Phillips and Webb, 1971). Qureshi (1978) reported that P fertilizers should be top dressed with first irrigation rather than applied and incorporated in the soil at sowing time. Another study reported that application of P at planting was more effective than late application and the relative availability of P diminishes as the time between application and planting increases. Fixation of P increases as the time of contact between soluble P and soil particles increases. Consequently, more efficient utilization of fertilizer P is generally obtained by applying P fertilizer shortly before planting the crop (Griffith, 1983).

The potential of horticultural crops in Guji Zone is not exploited due to lack of poor management practices, lack of improved farming method and high and long duration of rainfall. As stated above, absence of improved poor management practices are the main production problems of the area. Because of those constraints information on time of nutrient application and method of application are extremely important. Therefore, the study was proposed to determine the most effective methods and time of inorganic Phosphorus fertilizer application, and to establish recommendations concerning appropriate method and time of nutrient application on Irish potato.

Materials and Methods

Description of the Study Sites

The field trials were conducted during 2016 and 2017 main cropping seasons at the Bore Agricultural Research Centre on site and Ana sora on farm which is located in Guji Zone of Southern Ethiopia. The climatic condition of the area is mostly humid and sub humid condition, with relatively longer growing season. Bore is found at latitude of $6^{o}26'52''$ N and longitude of $38^{o}56'21''$ E at an altitude of 2736 masl. The annual rainfall ranges from1400-1800 mm with a bimodal pattern that extended from April to November (Anonymous, 2013). The mean annual minimum and maximum temperature is 10.1 ^{0}C and 20^{0}C, respectively. The type of the soil is red basaltic soil (Nitosols) and Orthic Aerosols. The soil is clay loam in texture and slightly acidic with pH averagely around 4.9.

Treatments and Experimental Design

Potato variety Belete was used as a test crop to evaluate its response to application time and method of P application. Five levels of application time (pre-planting (10DBP), at planting, at first weeding, at first earthingup and second earthingup stage (45DAP) and three levels of application methods (band placement (localized placement or spot application), side dressing and broadcasting) was arranged in RCBD with factorial arrangement of three replications. Recommended N/P rate of ((82 kg N and 92 kg P ha^{-1}) (100kg urea +200 kg DAP)) for Bore area was used for comparison. Sprouted tubers was planted on plot size of 2.1mx 3.5m and spacing of 30cm between plants and 70 cm between rows. The plot consists of five rows and seven plants per single row, totally 35 plants per plot. A distance of 0.6m and 1.4m was left between plots and blocks, respectively. Urea and DAP was used as sources of N and P. The doses of nitrogen were applied in equal split doses at planting and at reproduction stage (many ear leafs were easily visible upon dissection).

Soil Sampling and Analysis

Initially soil sample (0-30cm) was taken before planting from 5-10 random locations across the plot with an auger. The soil samples was collected and air-dried and sent to Horticoop Ethiopia soil and water analysis laboratory for analysis of soil texture by hydrometer, total nitrogen following Kjedahl procedure (Baruah and Barthakur, 1997), soil pH measured potentiometrically in water and 1M KCL solution at the ratio of 1:2.5 for both soil water and soil KCL solutions using a combined glass electrode pH meter (Chopra and Kanwar, 1976) and pH will be determined by subtracting soil pH (KCL) from soil pH (H2O) method for soil. Organic carbon also was determined using wet digestion method (Walkely and Black, 1954) and available phosphorus using Olsen II method (Olsen *et al*., 1954). After harvest the crop, the soil samples was also taken from 0-30cm soils depth for each replications and composited treatment wise and analyzed for desired soil variable. Anova function of SAS and means will be compared using LSD at a probability level of 5 %.

Crop Data collected

Days to 50% emergency, flowering, maturity, plant height, stem number, average tuber weight, average tuber number per plant, marketable and unmarketable yield and total yield of the plant per plot was measured and converted to hectares.

Statistical Analysis

The collected data on various parameters of the crop under study was statistically analyzed using SAS statistical package (SAS, 2003) version 9.1.3 using Fishers protected LSD. The Least Significant Difference (LSD) test at 5% level of significance was used to separate the means when the ANOVA showed the presence of significant difference results.

Results and Discussions

A field experiment was carried out during 2016 and 2017 cropping season to determine the most effective methods and time of inorganic P fertilizer application, and to establish recommendations concerning appropriate method and time of nutrient application on Irish potato on Nitosols of Bore and Ana sora area, Guji zone. Most of the data collected from the field and laboratory analysis were subjected to statistical analysis and the results obtained are presented and discussed in the following sections.

Selected Physical and Chemical Properties of the Soil at Experimental Site

Pre-plant soil (0-30 cm) analysis of the composite soil sample taken before planting at Bore and Ana sora Woreda demonstrated that the textural class of experimental soil belongs clay sandy loam soil texture (27% sand, 25% silt and 46% clay). The pH of the soil was strongly acidic (4.91 and 4.99) for both Bore and Ana sora locations, respectively (Table 4).The total nitrogen of experimental soil was very high (0.33% and 0.34 %), having medium available P ratings (9.12 and 8.61 ppm) and medium (149 and 147.42 ppm) available potassium which have very high (5.73 and 6.12%) organic matter and high (29.90 and 30.90 meq/100g) rating of cation exchange capacity at Bore and Ana sora locations respectively (Table 1).

Table1. Selected physical and chemical properties of experimental soil (0-30 cm) before Planting

Soil characters	**Values**	
	Bore	**Ana sora**
pH (by 1: 2.5 soil water ratio)	4.91	4.99
Total nitrogen (%)	0.33	0.34
Organic carbon (%)	3.32	3.55
Available phosphorous (mg/l (pp))	9.12	8.61
Cation exchange capacity (meq/100g)	29.90	30.90
Available potassium (mg/l (ppm))	149	147.42
Organic matter (%)	5.72	6.12
Soil texture:		
Sand (%)	27	27
Silt (%)	25	25
Clay (%)	46	48
Class	**Clay sandy loam**	

Phenological and growth parameters of Irish potato

Our combined Anova analysis indicated that the main effects of time of application and different application method as well as their interaction had significant ($P<0.05$) influence on days to 50% emergency, days to 50% flowering, days to physiological maturity, plant height and number of branches in all consecutive two years (Table 2). From the ANOVA analysis the result showed that the shortest days to emergency (14.33days) was attained in broadcasting method and ten days before planting application time where the longest (25.33 days) duration was observed in the all method of application with at time of first earthing-up and forty five days after planting on both Bore and Ana sora locations for two years (Table 2). Some literature show that split P applications can improve P recovery by 25%, particularly on soils with low P content and low buffering capacity, and can improve physiological P use efficiency (PPUE) where P availability is limiting crop yield. In conformity with the results obtained from this study, Cook and Veseth (1991) also found significant effect of P placement method on days to emergence. Similarly, Tisdale et al. (2002) reported that application of fertilizer near the seeds at the time of planting has the added advantage of stimulating seed germination and seedling emergence.Generally our result reviled that different placement method and application time of phosphorus fertilizer is done for efficient use of plant nutrients from plant emergence to maturity showed significant different among treatments by avoiding fixation of phosphate and convenient to the grower.

Table 2. Combined mean analysis of days to emergency, flowering, maturity, plant height and stem number of Irish potato crop at Bore and Ana sora sites during 2016 and 2017 cropping season

Treatments	**Phenology and Growth Parameters**									
	Bore					**Ana sora**				
	DE	DF	DM	PH	STM	DE	DF	DM	PH	STM
BC*10DBP	15.0^{de}	77.00^{ab}	126.00^{cd}	85.66^{a}	5.66^{abc}	18.00^{a}	81.00^{ab}	130.33^{cd}	80.66^{a}	5.33^{abc}
BC*PLT	17.33^{c}	76.66^{ab}	117.00^{f}	80.66^{a}	7.33^{abc}	18.00^{c}	80.33^{abc}	124.00^{ef}	76.66^{a}	6.33^{ab}
BC*FWD	20.66^{b}	78.66^{a}	122.33^{de}	59.33^{b}	4.66^{c}	22.33^{b}	83.00^{a}	127.00^{de}	56.00b	3.66^{c}
BC*FERT	25.00^{a}	73.0^{abcd}	129.33^{bc}	57.3^{b}	4.33^{c}	25.66^{a}	76.7^{abcd}	132.66^{bc}	53.00^{b}	3.66^{c}
BC*45DAP	25.33^{a}	76.66^{ab}	136.00^{a}	57.3^{b}	4.66^{c}	25.66^{a}	79.66^{abc}	140.66^{a}	59.33^{b}	3.33^{c}
SDR*10DB	15.0^{de}	67.00^{e}	116.66^{f}	85.33^{a}	6.33^{abc}	17.33^{c}	74.00^{bcd}	121.66^{f}	78.00^{a}	5.33^{abc}
SDR*PLT	16.7^{cd}	69.33^{de}	117.00^{f}	86.66^{a}	7.33^{abc}	18.66^{c}	72.00^{d}	124.33^{ef}	80.66^{a}	6.33^{ab}
SDR*FWD	21.7^{b}	73.0^{abcd}	125.66^{cd}	59.7^{b}	5.33^{bc}	24.33^{ab}	76.33^{abcd}	131.33^{cd}	55.00^{b}	4.33^{bc}
SDR*FERT	24.66^{a}	75.33^{abc}	128.66^{bc}	57.0^{b}	5.33^{bc}	25.00^{a}	81.33^{a}	132.33^{bc}	53.66^{b}	4.66^{abc}
SDR*45DA	25.00^{a}	76.00^{ab}	131.66^{ab}	56.7^{b}	6.66^{abc}	25.66^{a}	79.33^{abc}	136.00^{b}	50.33^{b}	6.33^{abc}
BND*10D	14.33^{e}	67.00^{e}	120.66^{ef}	80.33^{a}	8.66^{a}	17.00^{c}	71.00^{e}	125.33^{ef}	74.66^{a}	7.33^{a}
BND*PLT	16.33^{cd}	70.00^{cde}	125.33^{cd}	84.33^{a}	8.00^{ab}	19.00^{c}	74.00^{bcd}	130.00^{cd}	79.33^{a}	7.00^{a}
BND*FWD	20.33^{b}	68.80^{de}	126.33^{cd}	61.7^{b}	6.00^{abc}	22.33^{b}	72.00^{d}	130.66^{cd}	56.66^{b}	5.00^{abc}
BND*FER	25.00^{a}	76.33^{ab}	129.33^{bc}	61.0^{b}	6.00^{abc}	25.00^{a}	79.66^{abc}	132.33^{bc}	55.66^{b}	5.00^{abc}
BND*45D	25.33^{a}	71.3^{bcde}	126.66^{cd}	53.7^{b}	6.00^{abc}	26.66^{a}	73.33^{cd}	132.00^{bc}	50.66^{b}	5.00^{abc}
Mean	20.51	73.68	125.24	68.44	6.132	22.04	77.57	130.04	64.02	5.31
LSD (5%)	1.79**	5.74**	4.63**	8.95**	3.22**	2.54**	7.00**	4.52**	11.6**	2.90**
CV (%)	5.24	4.67	2.21	7.84	31.50	6.92	5.41	2.08	10.86	32.85

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. 10DBP=ten days before planting, PLT=at planting, FWD=at first weeding, FERTH= at first earthingup, 45DAP= forty five days after planting, DE= days to emergency, DF= days to flowering, DM=days to maturity, PH=plant height, STM=stem number, LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

And also our ANOVA result showed that the maximum (78.66 and 78.00) days to flowering recorded for treatments of broadcasting and banding method of phosphorus application with first weeding and the shortest (67.00 days) days to flowering was observed for treatment combination of side dress phosphorus application method with ten days before planting. This may be because of one is application of fertilizers hastens flowering day and the other could be phosphorus fertilizer is immobile in soil; therefore, plant uptake of fertilizer P may be low at application time efficiently and reduces nutrient tie-up and increased fertilizer use efficiency. The maximum (136) days to maturity was observed for interaction effect of treatment broadcasting and forty five days after planting. Moreover, the mean days to early

(116, 117, 121 and 121.66) maturity was recorded by the interaction effect of side dress and banding method of P application with 10 DBP and P application at time of planting.

Similarly the combined mean analysis indicated that both the main and interaction effect of time and method of phosphorus application significantly ($P<0.05$) influenced plant height and stem number of the plant (Table 1). The highest (85.66, 85.33, 86.66, 84.33, 80.66 and 80.33 cm) plant height was recorded on broadcasting, side dress and banding fertilizer application method with ten days before planting and at planting time.

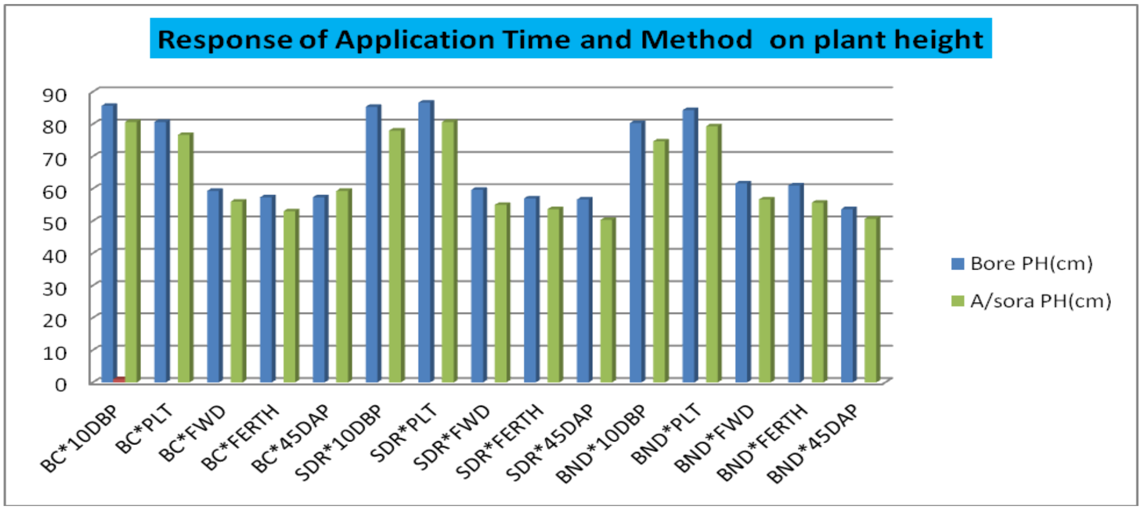

Chart 1. Plant height of the plant at Bore and A/sora locations

The increasing of plant height may be due to the role of such macro nutrient in the physiological process and cell division and elongation which indirectly effect tissue formation and consequently vegetative growth of plant. Here early application of phosphorus can therefore impact crop growth and soil fertility since retained by soils. Basically the efficiency of an application was evaluated for two seasons. But for proper evaluations of residual effects require longer time periods to truly get their full impacts (Syers *et al.*, 2008). Grewal *et al.* (1993) reviewed the effect of P in potato and concluded that both height and leaf area index are positively related to P fertilizer application in P deficient soils. Similarly Spreading fertilizer and seed in a wide band can minimize germination problems due to less direct contact between fertilizer and seed.The maximum (8.66, 8, 7.33 and 7) stem number of Irish potato was obtained by interaction effect of treatment banding with ten days before planting and at time of planting. The adverse effect on stem number per plant was more pronounced in treatment BND application method with 10DBP and at planting application time may likely be the better treatment for nutrient use efficiencies than other treatments. A goal of fertilizer placement is to maximize root-nutrient contact, especially at the critical stages of crop development, without causing emergence problems. This may be due to that placing the Phosphorus in the right method at the right time may produce highest density of fine roots that conversely develop highest stem number. This parameter is of great importance because it is directly related with the total production of tubers. The more is the number of stems/plant the more will be the number of tubers per plant.

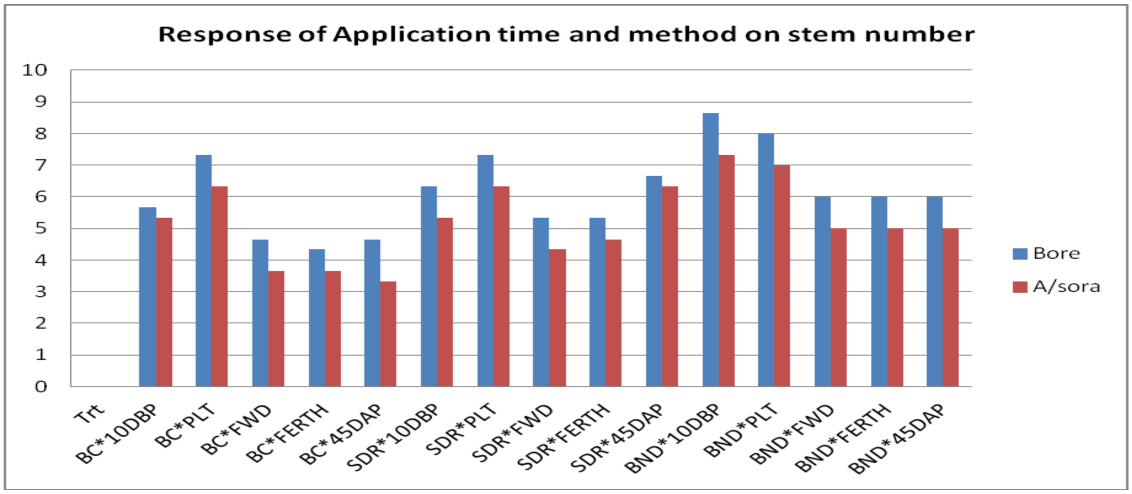

Chart 2. Average stem number per plant at Bore and A/sora locations

In many states in the western U.S. Corn Belt, recommendations exist for reducing fertilizer rates if they are applied in a band, rather than broadcast (Gerwing and Gelderman, 2002; Rehm *et al.*, 2006; Shapiro *et al.*, 2003). Often, banded and side dress rates are reduced to half of the broadcast rate.

Yield related and yield parameters of Irish potato

The main effects of application time and method as well as their interaction had significant (P<0.05) influence on Irish potato tuber number per hill and average tuber weight in all locations and years (Table 3). The maximum number of tubers per hill (19.66 and 18.33) was observed when tubers were planted and phosphorus was applied at time of planting and banding at Bore and Ana sora, respectively. And also the second most maximum (15) tuber number per plant was recorded when P was applied at time of 10 DBP with banding method of application on both Bore and Ana sora locations. Min while the minimum (3.66) number of tubers per hill was recorded when phosphorus was applied in band and broadcasting application method with forty five days after planting time of application at Bore and Ana sora locations, respectively. This may be due to the fact that contact of phosphorus at appropriate time with method to the soil has good impact on crop quality include increasing the number of tuber per plant. Agricultural land often contains significant amounts of Phosphorus. But most of this P is bound in different complexes in the soil (Rengel and Marschner, 2005). Therefore, phosphorus fertilizer needs to be added continuously to sustain optimal plant growth. Potato is considered a P-demanding crop due to its shallow and relatively short root system (Harris, 1992). Fertilizer P recommendations for potato are therefore higher than for most other crops (Albertsson, 2012; Allison *et al.*, 2001). Optimum application time enhanced release of nutrients from the soil promoted root growth and nutrient uptake, hence better root growth and yield that enhances better tuber setting.

The analysis of variance shows that the main effects of application time and application method as well as their interaction had highly significant response on tuber weight of Irish potato in both consecutive two years at both Bore and Ana sora districts (Table 3).

When fertilizers are placed at the right place then there will be minimum contact between the soil and fixation of nutrients is greatly reduced. And thus leads to residual response of fertilizers are usually higher. Then the utilization of the fertilizer of the plant will be higher. Being immobile, phosphates are better utilized when placed.

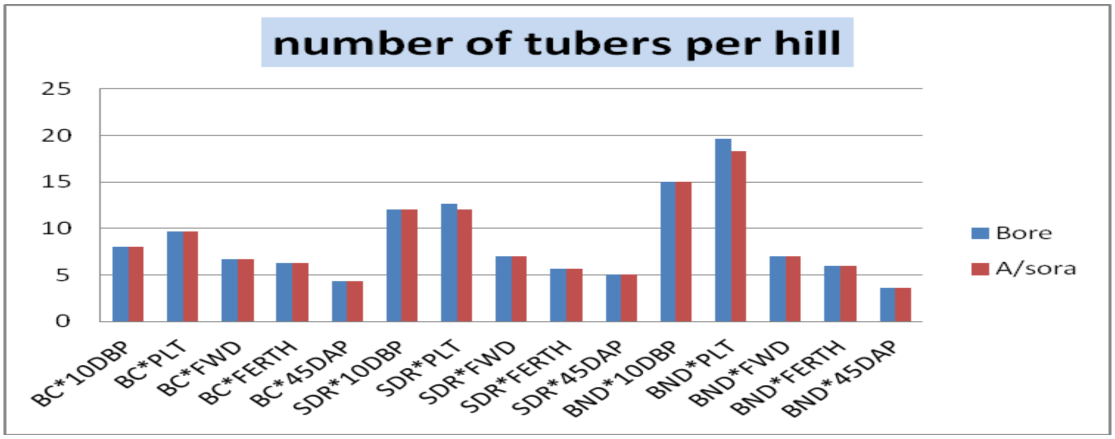

Chart 3. Average Number of tubers per plant at Bore and A/sora locations

The maximum (272.1 gm and 238.83 gm) tuber weight was recorded by banding application method of phosphorus at planting and followed (239.3 gm and 226.03 gm) by banding method of phosphorus application at ten days before planting application time. Conversely the minimum (71.5 gm, 79.66 gm, 89.93 gm, 99.83 gm, 100.9 gm and 104.8 gm) was recorded for treatments treated with all application methods with application time at first earthing up and 45DAP on both locations.Even though there is lack of researches on application time of phosphorus fertilizers our research work showed that application of P at planting and ten days before planting gives better result on number of tubers and tuber weight of Irish potato. The results of five years' experimental work comparing different methods of fertilizer placement for the potato crop showed conclusively that in the great majority of tests conducted, placement of fertilizer in band application gave best returns.

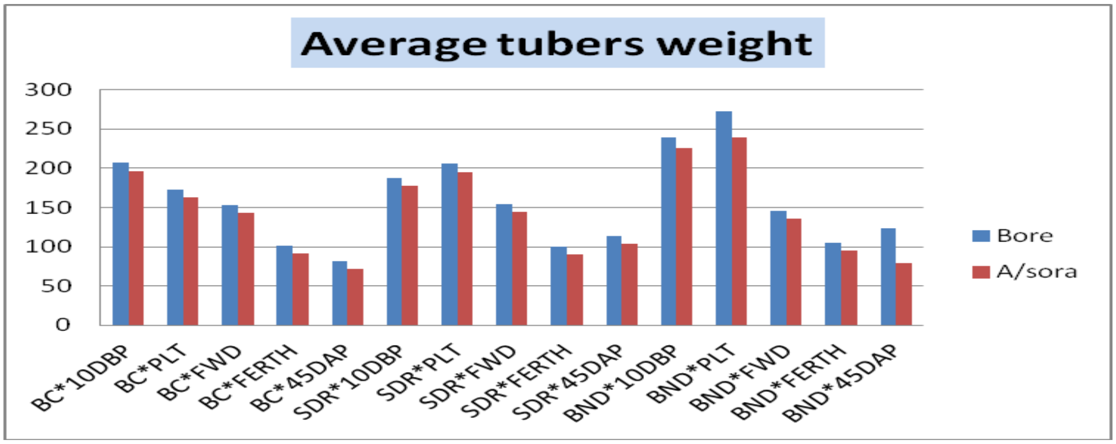

Chart 4. Average tubers weight at Bore and A/sora locations

Furthermore, Jenkins and Ali (1999) showed that optimum phosphorus application time mostly enhances early crop development and that the response to P application decreases with time. This implies phosphorus is taken up by the potato crop continuously over the growing season. However, the amount taken up per day varies depending on the phenological stage. Although P is crucial, the element is needed in relatively small amounts, 0.5 kg ton^{-1} compared with 3 kg ton^{-1} for N and 4 kg ton^{-1} for K (Stark *et al.*, 2004; Dampney *et al.*, 2002; Bennett, 1993). The highest P uptake rate in foliage and tubers occur during the tuber formation and tuber development stage (Covarrubias-Ramírez *et al.*, 2005).

Table 3. Combined mean analysis of tuber number, tuber weight, and marketable, unmarketable and total yield of Irish potato crop at Bore and Ana sora sites during 2016 and 2017 cropping season

Treatments	Yield and yield related Parameters									
	Bore					Ana sora				
	TNP (No)	ATW (gm)	MY (kut ha^{-1})	UMY (kha^{-}	TY (kut ha^{-1})	TNP (No)	ATW (gm)	MY (kut ha^{-1}	UMY (kut ha^{-1}	TY (kut ha^{-1}
BC*10DBP	8.00^{ef}	206.6^{bc}	40^{bcd}	63	465^{abc}	8.00^{de}	196.00^{bc}	394.47^{cd}	60.54^{bc}	455.0^{bcd}
BC*PLT	9.66^{de}	173.3^{cd}	385^{cd}	44	429^{abcd}	9.66^{cd}	163.33^{cd}	418.36a^{b}	19.51^{g}	437.88^{cd}
BC*FWD	6.7^{fgh}	153.5^{d}	365de	45	410b^{cd}	6.66^{efg}	143.5^{def}	361.89^{de}	28.39^{fg}	390.3^{ef}
BC*FERTH	6.3^{fgh}	100.9^{fg}	310^{f}	53	363^{f}	6.33^{efg}	90.93^{h}	313.54^{f}	46.4^{cde}	359.90^{g}
BC*45DAP	4.33^{hi}	81.50^{g}	300^{f}	71	372^{f}	4.33^{gh}	71.50^{h}	206.75^{h}	50.78^{cd}	257.52^{h}
SDR*10DBP	12.0^{cd}	187.8^{cd}	422^{ab}	68	474^{ab}	12.00^{c}	177.80^{cd}	420.00^{ab}	31.29^{efg}	451.30^{bc}
SDR*PLT	12.6^{bc}	206.1^{bc}	424^{abc}	35	460^{abcd}	12.00^{c}	195.46^{bc}	412.19^{bc}	15.65^{g}	427.84^{de}
SDR*FWD	7.00^{fg}	154.3^{de}	382^{cd}	70	452^{abcd}	7.00^{ef}	144.30^{def}	386.02^{cd}	90.07^{a}	476.09^{abc}
SDR*FERTH	5.66^{fghi}	99.83^{fg}	328^{ef}	54	382^{cdef}	5.66^{efgh}	89.83^{h}	252.60^{g}	44.12^{cdef}	296.72^{h}
SDR*45DAP	5.00^{ghi}	113.3^{efg}	316^{f}	45	361^{f}	5.00^{fgh}	103.33^{fgh}	217.92^{gh}	48.73^{cde}	266.65^{h}
BND*10DBP	15.00^{b}	239.3^{ab}	439^{ab}	50	490^{ab}	15.00^{b}	226.03^{ab}	451.63^{ab}	40.06^{def}	491.70^{ab}
BND*PLT	19.66^{a}	272.1^{a}	460^{a}	42	502^{a}	18.33^{a}	238.83^{a}	457.83^{a}	42.02^{cdef}	499.86^{a}
BND*FWD	7.00^{fg}	145.4^{def}	386^{cd}	69	456^{abcde}	7.00^{ef}	135.40^{efg}	366.01^{de}	46.28^{cdef}	412.30^{def}
BND*FERTH	6.00^{fghi}	104.8^{fg}	332^{ef}	45	377^{def}	6.00^{efg}	94.83^{gh}	330.09^{ef}	41.67^{def}	371.77^{fg}
BND*45DAP	3.66^{i}	123.0^{efg}	291^{f}	70	362^{f}	3.66^{h}	79.66^{h}	201.96^{h}	76.77^{ab}	27873^{h}
Mean	8.57	157.4	369	55	424	8.44	143.38	346.08	45.48	391.57
LSD (5%)	2.64	48.57	45.94	Ns	83.85	2.55	41.32	41.39	18.82	43.16
CV (%)	18.47	18.49	7.45	49.02	11.86	18.17	17.28	7.17	24.82	6.61

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance. 10DBP=ten days before planting, PLT=at planting, FWD=at first weeding, FERTH= at first earthingup, 45DAP= forty five days after planting, TNP= tuber number, ATW= tuber weight, MY=marketable, UMY=unmarketable and TY=total yield LSD (0.01) = Least Significant Difference at 5% level; and CV (%) = coefficient of variation in percent

The analysis of variance shows that the interaction effect of phosphorus application time and application method had significant effects on marketable and total tuber yield of Irish potato in both consecutive two years at both locations (Table 3). But our study reveals there was no significant different between each treatment by application method and application time on unmarketable yield at Bore location but difference at Ana sora site.

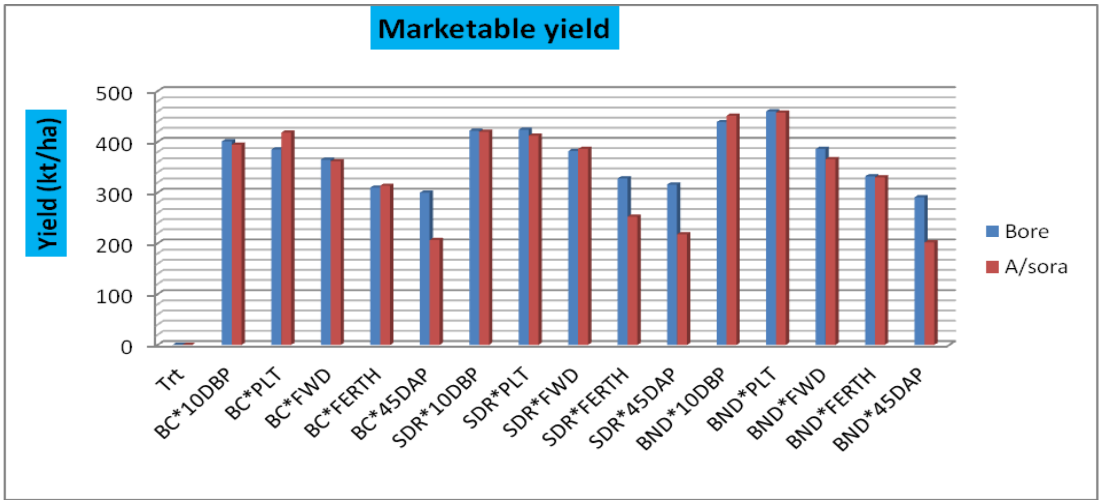

Chart 5. Marketable tuber yield at Bore and A/sora locations

Anova analysis revealed that applying phosphorus in banding at planting time produced maximum (460 kut ha^{-1} and 457.83 kut ha^{-1}) marketable yield at Bore and Ana sora locations, respectively. Here in this study applying phosphorus in banding method with applying ten days before planting give the second maximum (439 kut ha^{-1} and 451.63 kut ha^{-1}) marketable tuber yield at Bore and Ana sora locations, respectively. And the minimum (291 kut ha^{-1}, 300 kut ha^{-1}, 310 kut ha^{-1}, 316 kut ha^{-1}, 201.6 kut ha^{-1} and 206.75 kut ha^{-1}) marketable yield was produced by broadcasting, side dressing and banding method of phosphorus application with first earthing up and 45 days after planting application time. Similarly the highest (502 and 499.86 kut ha^{-1}) total fresh tuber yield was obtained from banding application method with P application a time of planting at Bore and Ana sora locations, respectively. And the lowest (361 kut ha^{-1}, 362 kut ha^{-1} and 372 kut ha^{-1}) was recorded by all type of phosphorus application method with applying phosphorus forty five days after planting at Bore and Ana sora location respectively.Top dressing of P is not expected to affect crop yield because the P would likely become bound near the soil surface and not migrate to the actively growing root system. Therefore P should be applied immediately before or at planting due to its immobility in soil. Timing fertilization with peak nutrient uptake demand is essential for optimizing both yield and quality. In general, nutrient uptake rates are highest from early to mid growing season, which is why fertilization near the time of seeding is generally very effective.

The conventional wisdom was that applying P in broadcast results in much more fertilizer-soil contact, which precipitates or sorbs P, decreasing its availability. Instead, a study with ‘radiolabelled’ P found that P banding is more effective than broadcast P because it increases the chance that active roots will contact P, rather than due to decreased fertilizer-soil contact (Sleight et al., 1984). Banded P application method at planting and 10 DBP generally increases crop yields, as compared to broadcast P, especially on low and medium P testing soils. On soils with high levels of available P, the advantage of banding is less because the crop obtains a higher proportion of P from the soil rather than from added fertilizer.Increase in tuber number per plant, tuber weight, marketable and total yield was noted in the plots that received

P at planting application time with banding method and followed by 10 DBS with band P application method indicate more P availability at higher P rates. Hussain and Haq (2000) suggested that soils of clay loam texture with high fixation capacity have higher demand for P fertilizer. Roman and Willium (1993) found that clay loam texture had maximum P fixation and to get proper amount of P availability, P-fertilizers should not be applied much before plantation to minimize P fixation.

Optimizing phosphorus (P) fertilizer management on potato (*Solanum tuberosum* L.) crop is challenging. The “4R” nutrient stewardship framework of using fertilizer at the right rate, right source, right placement and right time provides approaches to improve fertilizer use efficiency while maintaining or improving yield. Fertilizer should be applied in bands on each side of the seed piece with two inches of fertilizer-free soil interposed.This finding is in line with O'Brien *et al.* (1998) who suggest that tuber yield is positively correlated with light quantity absorbed by the crop during the first week of initiation. Since P fertilization increases the interception of solar radiation in low soil P conditions, it is likely that P fertilization has a positive effect on tuber set in such conditions during early application (Tukaki and Mahler, 1990). A field experiment was conducted to investigate impact of P levels and time of P application [40, 30, 20 and 10 days before sowing (DBS), at sowing and 15 days after sowing (DAS)] at New Developmental Agricultural Research Farm of KPK Agricultural University Peshawar, during summer 2005. The results showed that the highest level of P ha^{-1} at 10 DBS and sowing increased plant height, number of tubers per plant, tuber weight, stem number per plant and yield. In another way broadcasting is the least efficient method from a plant perspective, but the most widely used application method in practice. Precision placement of P fertilizer near the active root zone is the most commonly recommended application method. Placement of the fertilizer reduces the contact area with the soil, thus avoiding soil binding (Marschner, 1995). Placement may decrease the P sorption rate, affecting P acquisition positively. This can decrease the P fertilization requirement by approximately 50%. Therefore higher tuber yield can be obtained if the P fertilizer is placed 5 cm to the side of the seed pieces with banding instead of being placed below or mixed into the ridges by broadcasting (Grewal *et al.*, 1993).

Physio Chemical of the Soil after Crop Harvest

Table 5 summarizes some of the post-harvest physio-chemical properties of soil as affected by different P application time and method treatments. Post-harvest analysis of soil revealed an increase in organic matter respective of phosphorus application methods and application time treatments (Table 5). Under different phosphorus application methods and application time treatments the highest (6.65 %, .47 % and 6.36 %) degree of increases in organic matter was recorded in case of first earthing-uptime and side dress application method, 45 DAP with broadcasting application method and 45 days after potato planting and side dressing of phosphorus application treatments. However there was no significant (p>0.05) difference among the treatments of p application method and time. Most of the treatments respond in strongly acidic range.

Table 4. Selected physio-chemical properties of the topsoil (0-30 cm),) of experimental field at crop harvest for each treatments.

TRT(T*M)	pH	P	K	S	OC	N	C:N	CEC	Soil texture		
									sand	silt	clay
FWD*BRD	4.99	8.61	147.42	20	3.55	0.33	10.68	30.9	27	25	48
FWD*BND	5.00	8.79	147.14	16.5	3.49	0.34	10.26	30.5	25	27	48
FERTH*SDR	4.94	10.6	172.92	18	3.86	0.35	11.1	28.1	24	28	48
10DBP*SDR	4.96	7.98	130.75	21	3.65	0.37	9.81	32.2	33	24	43
45DAP*BND	4.94	10.76	162.75	1.0	3.58	0.34	10.59	29.2	31	23	46
10DAP*BND	4.9	8.44	164.77	19.5	3.58	0.34	10.65	30.6	25	229	46
FERT*BRD	4.97	13.22	162.29	21	3.57	0.35	10.29	30.6	25	31	44
PLT*SDR	4.99	7.41	131.88	16.5	3.22	0.33	9.69	32.1	27	25	48
PLT*BND	5.07	6.92	146.86	22.5	3.45	0.34	10.21	30.8	27	27	46
FERT*BND	4.97	8.16	196.1	23	3.61	0.35	10.32	29.5	28	24	48
FWD*SDR	4.96	7.94	163.84	15	3.48	0.34	10.22	31.3	31	25	44
10DBP*BRD	4.91	7.00	147.56	21	3.38	0.34	10.07	29.9	27	24	49
45DAP*BRD	4.96	10.2	163.06	24	3.75	0.34	11.13	31.6	26	24	50
PLT*BRD	5.22	9.0	180.8	22.15	3.35	0.33	10.09	26.33	30	28	42
45DAP*SDR	4.97	10.3	17.5	40.2	3.69	0.35	10.47	33.3	30	20	50

Regarding the total nitrogen content between each treatment didn't show difference. Most of the treatments show in high total nitrogen content in the soil even after crop harvest. Similarly, maximum (0.37 % and 0.35 %) increase in total N content were more perceptible in case of application of phosphorus ten days before planting with side dressing method and at first earthing up with broadcasting method treatments (Table5).The effects of different methods of P placement method and, P application time and their interaction on total soil nitrogen were non significantly ($P>0.05$) different. However, the overall effect of side dressing and banding P placement resulted in more (0.37 % and 0.35 %) soil N than both the remaining methods of P placement. This indicated that side dressing and banding P to the side of the seed had generally apparent advantage on total soil nitrogen. There was also a tendency of increasing total soil nitrogen with increasing P rates. The results of soil analysis for available soil P after harvest against treatments are presented in Table 10. There was highly significant difference in Olsen extractable available soil P across P application time and P placement methods and their combined effects with the application of P in the form of diammonium phosphate (Table 9). Side dressing and Banding of P fertilizer to the sides of the tuber at the time of planting and ten days before planting significantly ($p\leq0.05$) increased available P to 13.22 ppm, 10.76 ppm, 10.6 ppm, 10.32 ppm and 10.12 ppm over broadcasting, banding and side dressing of P (Table 5). Among the above three methods of P placements, the highest (13.22 ppm) increment in soil available P was obtained by the use of broadcasting P to the tuber at time of first earthing-up and alsoand the lowest (7 ppm) by using broadcasting P method of application at time of forty five days after planting.Cation exchange capacity (CEC) and temperature also have influences on availability of nutrient. Cation exchange capacity implies amount of nutrient available to plants as exchangeable cations and the degree to which the exchangeable complex is saturated with bases rather than H+ (Lombin, 1986). The maximum (33.3, 32.2, 32.1 and 31.6 cmol kg^{-1}) CEC of the study area was recorded from treatments of 10DBP and plating time with banding and side dress method of P application.

Summary and Conclusions

The environmental significance of P lies in its dominant role in the eutrophication of aquatic ecosystems, where P is regarded as the limiting nutrient for primary production. It has been argued recently that the soil P status should be kept close to the 'critical value'. The concept of critical value optimizes the economic returns for the farmer and reduces the risk of P losses to surface waters. Efficient use of P is crucial in order to minimize losses of P from agro-ecosystems (Syers *et al.*, 2008). Phosphorus fertilizer can be applied in several different ways to the potato crop. It can be banded, broadcast, side dressed or applied through fertigation or by foliar application. In most cases the fertilizer is spread prior to planting and then incorporated into the ridges by cultivation. However, when the fertilizer is mixed into the soil the fertilizer to soil contact area increases, which results in a high adsorption rate (Sims and Sharpley, 2005).The effective placement and timing of fertilizers can maximize both yield and nutrient use efficiency, thereby increasing net profit for the producer. A goal of fertilizer placement is to maximize root-nutrient contact, especially at the early stages of root development, without causing emergence problems. Placing fertilizer in the region that will have the highest density of fie roots, or in a location that the fertilizer will move to this region, is needed to optimize yield. Less soluble fertilizers, such as P, placed to the side of the seed will be accessed earlier in the growing season.

Unlike N, P is relatively immobile in the soil. Consequently, P placement is expected to cause larger effects on P availability and crop yield. For example banded pre-plant P application gives twice as much yields than when the same fertilizer was broadcast (Leikam et al., 1983). This advantage was partially attributed to a lack of active roots near soil demonstrating a strong economic advantage of banding P (Sims and Smith, 2002). In order to increase nutrient use efficiency, native to the soil or added through fertilizers, it is necessary to examine the many variables that interact with fertilizer application. Soil, crop, expected climatic conditions, cropping systems and general crop management are decisive factors that should be carefully studied to obtain not just the desired nutrient efficiency, but also the desired profit.

This study was conducted to evaluate four different phosphorus application time and three application times for potato production in Bore area. An experiment was conducted to determine the best combination of application time (10DBP, FWD, FERTH AND 45DAP) and three combined application method (broadcasting, side dress and banding or localized placement) for Irish potato of Belete variety produced on a clay loam soil during the year of 2016-2017. Therefore the results revealed that the interaction effect between application time and method had highly significant ($P<0.05$) responded on days to 50% emergency, 80% maturity, plant height, number of tubers per hill, stem number per plant, marketable tuber yield and total tuber yield. On the other hand our Anova result shows non-significant ($P<0.05$) effect by the application time and method on unmarketable tuber yield.Our recommendation to phosphorus application time and method provide a new opportunity to manipulate application time and method of fertilizer to maximize use of appropriate time and nutrient resources. Using phosphorus fertilizer at planting with banding has significantly ($P<0.05$) and positively increased the total tuber yield of Irish potato at Bore and Ana sora area. The highest economic yield (50.2 t $ha^{-1}$and 49.98 t ha^{-1}) was obtained from the combined use of phosphorus at planting with banding followed by second highest (49.0 t ha^{-1} and 49.17 t ha^{-1}) total tuber yield was obtained by combined application of P 10DBP and with banding at Bore and Ana sora districts, respectively.

In order to obtain high nutrient use efficiency farmers are advised to carefully consider the principles of the 4R nutrient stewardship concept. Recently IFA and IPNI have been emphasizing the use of the 4R nutrient stewardship concept as a general guideline for good practices related to nutrient use. It primarily considers that nutrients have to be applied at the right source, right rate, right time and right place. Therefore it can be concluded that different phosphorus application method and application time have remarkable effect on growth and development of Irish potato. Generally, as a conclusive and recommendation, Irish potato growers at Bore, Ana sora and surrounding area need to grow Irish potato by applying phosphorus fertilizer at time of planting with banding method of application thereby PUE and phosphorus recovery can be improved if phosphorus fertilizers are applied .Generally Fertilizer placement and timing can have substantial effects on both crop yield and quality. Placement techniques include broadcast, banded (surface or subsurface) and side dress placement. The likelihood of a placement response for a particular nutrient is related to both the mobility of that nutrient and on water availability. For example, yield responses from placement of N, which is highly mobile, are less than for P and metal micronutrients, which are relatively immobile. Timing of fertilizer application can also affect both yield and quality. Applying near the time of planting generally will produce high levels of nutrients in time for peak growth demand that occurs from early-mid growing season. In summary, appropriate placement and timing methods can aid producers in efficiently using fertilizers and maximizing economic returns, while possibly reducing weeds and potential nutrient loss from fields.

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Evaluation of Fungicides with the combinations of Potato *(Solanum tuberosum* L.) Varieties to Manage Late Blight (*Phytophthora infestans* (Mont) de Bary) in Highlands of Guji Zone, Southern Ethiopia

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Abstract

Potato late blight (Phytophthora infestans (Mont.) de Bary) is one of the most devastating plant diseases world-wide and is feared globally by farmers and industry. There is little information on the type of fungicide to be sprayed to control late blight for optimum production of the crop in the study area. Therefore, an experiment was conducted at Bore Agricultural Research Center, Southern Ethiopia during the 2015 and 2017 cropping seasons to evaluate fungicides with the combination of potato varieties to manage late blight via integrated approache and to assess the cost and benefits of different fungicides on two potato varieties viz. Gudanie and Jalenie. The treatments consisted of two potato varieties currently under production but differ in their late blight reaction and three fungicides viz. Ridomil Gold MZ 63.5%WP, Mancozeb 80% WP2 and Matico and one unsprayed treatment were used as experimental materials. The experiment was laid out in Randomized Complete Block Design (RCBD) in a 4 x 2 factorial arrangement and replicated three times per treatment. The two potato varieties were planted as the test crop in a plot size of 3 m x 2.1 m with intra and inter-row spacing of 0.30 and 0.75 m respectively. The two years combined data analysis results revealed that the interaction effect of fungicides and potato varieties had showed significantly ($P<0.05$) effect on days to 50% flowering, 50% maturity, plant height, number of tubers per hill, stem number per plant, marketable tuber yield and unmarketable tuber yield and total tuber yield. However, interaction effect of fungicides and potato varieties had non-significant ($P>0.05$) effect on days to50% emergency and average tuber weight. The two year data analysis showed that the highest (47.34 t $ha^{-1}$and 46.31 tha^{-1}) marketable tuber yield was obtained from Gudanie variety with Ridomil Gold fungicide spraying at Bore on-station and Ana sora on-farm respectively. The result of 2015 year disease data indicates that maximum (59.52% and 3.67) disease incidence and severity, respectively was recorded on unsprayed treatment of Jalenie variety and also the second year maximum (45.24 % and 2.83) disease incidence and severity was on treatment Gudanie variety unsprayed,. However, the minimum (5.48% and 1.16) disease incidence and severity of late blight was recorded on spraying Ridomil Gold on both Gudanie and Jalenie varieties in 2015 cropping seasonIn general, spraying of Ridomil Gold fungicide was more effective by reducing the disease severity and increasing tuber yield. The partial budget analysis revealed that application of Ridomil Gold on Gudanie variety resulted the highest net benefits of Birr 244,462.50 and 235,352 ha^{-1} with an acceptable marginal rate of return (MRR) of 2549.00 and 2698% . Thus, application of Ridomil Gold on Gudanie variety led to optimum marketable tuber production and economic returns. Therefore, the farmers' in highlands of Guji zone and similar agro-ecology can produce healthy and maximum potato crop of Gudanie variety by spraying Ridomil Gold fungicide with the recommended rate and frequency.

Keywords*:* Disease severity and incidence, Sprayed and Unsprayed plot, Marketable tuber yield and Partial budget analysis

Introduction

Late blight of potato (*Solanum tuberosum*, L.) caused by *Phytophthora infestans* (Mont de Bary), is a major worldwide threat to the production of high quality potatoes (Fry and Goodwin 1997). It is economically the most important and most destructive potato disease worldwide. The disease causes annual losses of several billion of dollars and it is a global threat to potato growers (Cooke and Lees, 2004). The pathogen apparently originates from Central Mexico (Zimnoch-Guzowska *et al.,* 2003). In the middle of the 19th century, the pathogen was introduced into the US and Europe, where it destroyed a great part the potato crop and is widely known as the cause of the Potato famine in 1845 (Smart and Fry, 2001).

Phytophthora infestans is a hemibiotrophic pathogen attacking living parts of plants from the family *Solanaceae*. The pathogen is economically important on potato and tomato. The pathogen causes lesions with necrotic cells in the middle, surrounded by a ring of gradually necrotizing tissue. Once infected, plants initially appear healthy, before necrotic lesions develop. Under favorable weather conditions, the pathogen can destroy potato foliage in 10 to15 days and potential yield can be reduced by 50 to 70% (Tymcenko and Jefronova, 1987).

In developed countries, potato late blight control is mainly based on intensive application of fungicides (Song *et al.,* 2003). However, late blight epidemiology is also impaired by natural resistance of varieties provided by introgression of resistance genes. The genetic background of a variety together with environmental conditions that is not conducive for the pathogen results in field resistance. Expression of so-called ‘age resistance’ is also important, when the pathogen only infects ontogenetically older parts of the plants. Natural resistance plays an important role in plant protection and optimization of fungicide protection. Therefore, breeding for resistance is a critical part of integrated late blight control in potatoes.

Current resistance of commercially used varieties of *Solanum tuberosum ssp. tuberosum L.* to potato late blight can be vertical or horizontal in character (Bradshaw and Mackay, 1994). Specific (vertical) resistance is the resistance to a certain pathogen race. It is oligogenic resistance and confers a relatively high level of resistance and is less environment dependent (years, growing localities); however, it is overcome by the emergence of new virulent races. Fungicides continue to be an important component of late blight control with up to 15-20 applications being used per season.

Late blight caused by *Phytophthora infestans* is generally the most important disease wherever potato is grown Sikka *et al.(*2000), with annual losses of about 42% (CIP 1998).The disease is primarily controlled by rigorous application of fungicides. The aim of this work was to evaluate the efficacy of systemic and contact fungicides on late blight disease and tuber yield of Gudanie and Jalenie varieties. The two systemic fungicides (Ridomil Gold and Matico) and one contact fungicides (Mancozeb) were tested for their effects on late blight of potato and consequent tuber yield in field conditions, applied as foliar sprays at seven day interval. Both types of fungicides were found highly effective in reducing disease severity level and disease progress. However, systemic fungicides are more effectively control disease severity and the disease progress than contact fungicides. Compared to control, disease severity and area under disease progress curve (AUDPC) were significantly reduced by systemic fungicide Curzate corresponding to significant increase in tuber yield. Contact fungicides contributed to reduction in disease severity and AUDPC; however, they had no effects on tuber yield. Results recorded efficacy of the tested fungicide groups in the order systemic > contact and among the systemic fungicides as Curzate > Ridomil Gold. Efficacy of systemic and contact fungicides against late blight of potato in field conditions has been widely documented. Namanda *et al.* (2004) reported that, contact fungicide Dithane was effective for reducing late blight disease progress and increasing potato yields. Mantecon (2007) documented systemic fungicides more effective than contact fungicides in reducing early and late blight disease severity and increasing tuber yields. In a study conducted during 1983 to 2007, systemic and contact fungicides programs were evaluated for late blight and tuber yields; both fungicides programs significantly controlled foliar blight of potato and contributed to tuber yield increments with major contribution from systemic fungicides Dowley *et al*. (2008).

The late blight disease caused by *P. infestans* is considered to be a major constraint for potato production wherever potato is grown. Due to this, commercial potato production would hardly exist without routine use of fungicides. Different varieties have different reaction towards late blight and varieties varied in their response to the fungicide treatments. However, different varieties which type of chemical application and which chemical by itself was not identified for different potato varieties to minimize damage of late blight of potato. Taking this into account, it is important to determine the safest varieties which incur less frequent chemical application and frequency of chemical application to minimize damage caused by late blight of potato in high lands of Guji zone. The climatic condition of highlands of Guji zone is a humid moisture condition, with a relatively longer growing season. During wet, cool weather, crop loss due to late blight can be rapid and unstoppable if preventative controls have not been used. Therefore, this research was conducted with the following objectives:

- To evaluate fungicides with the combination of potato varieties to manage late blight and to assess the cost and benefit of different fungicides on Gudanie and Jalenie potato varieties to control patato late blight.

Materials and Methods

Description of the Experimental Sites

The experiment was carried out during the 2015 and 2017 main cropping seasons at Bore Agricultural Research Center, Guji Zone of Southern Ethiopia, which is one of the recently established Research Centers of the Oromia Agricultural Research Institute (OARI). The first experimental site islocated at Bore research site at the distance of about 8 km north of the town of Bore in Songo Bericha '*Kebele'* just on the side of the main road to Addis Ababa *via* Hawassa town. Geographically, the experimental site is situated at the latitude of 06°23'55''N and longitude of 38°35'5''E at an altitude of 2728 meter above sea level. The second experimental site is located at Ana sora on farm at the distance of about 25 km East of the town of Ana sora in Yirba Buliyo '*Kebele'* just on the side of the main road to Negele Borana *via* Adola town. Geographically, the experimental site is situated at an altitude of 2600 meter above sea level. The climatic condition of the area is a humid moisture condition, with a relatively longer growing season. According to climate data from National Meteorological Agency, Awassa Branch Directorate (2015-2017), the area receives total annual rainfall of 1640.5 mm with a bimodal pattern that extends from April to November. The mean annual minimum and maximum temperatures are 8.58ºC and 18.6ºC, respectively.

During the crop growing season (2015 and 2017), the total amount of rainfall received was 1105.9 and 981.2mm out of which 300.4 and 289.6mm were received in April and May followed by 281.7 and 219.2mm in May and June respectively. The Average maximum and minimum temperatures of the growing season were 21, 8.7 and 9.6ºC, respectively (figure 1 and figure 2).

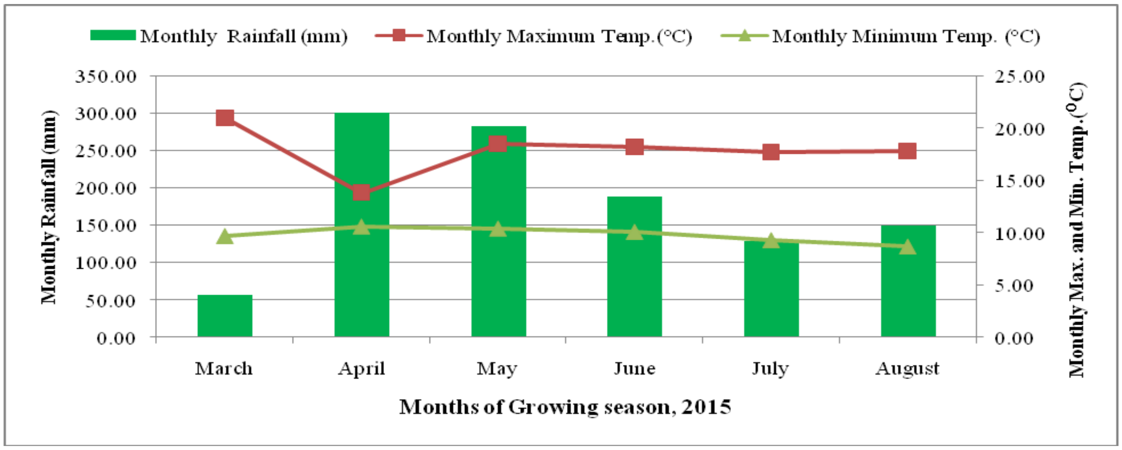

Figure 1.Monthly Rainfall and mean minimum and maximum temperatures during the 2015 growing season at Bore

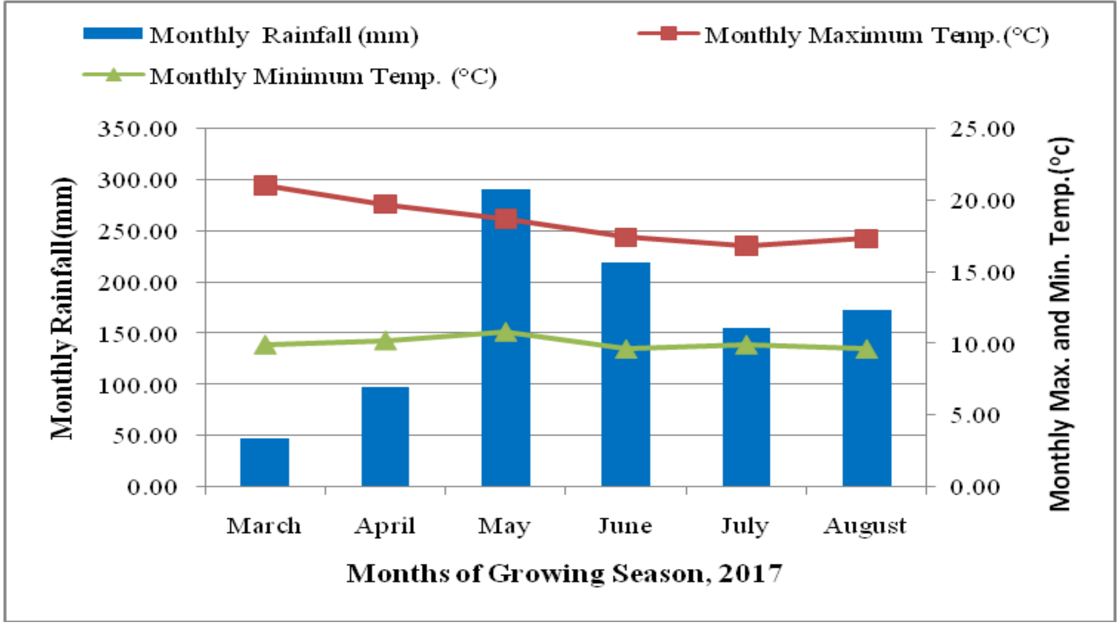

Figure 1. Monthly Rainfall and mean minimum and maximum temperatures during the 2017 growing season at Bore

The soil is clay in texture and strongly acidic with pH value of 5.1 (Arega, 2018). The traditional farming system of the area is characterized by cultivation of enset as a major crop, maize, potato, head cabbage, barley, wheat and faba bean. As far as fruit and timber crops are concerned, apple and bamboo are the cash crops. Moreover, cattle are an integral part of the farming system (BoARDO, 2015).

Treatments and Experimental Design

The treatments consisted of two potato varieties viz. Gudanie and Jalenie which are currently under production in the area but differ in their late blight reaction and three fungicides viz. Ridomil Gold MZ 63.5%WP, Mancozeb 80% WP2 and Matico and one unsprayed treatments were used as experimental materials. Fertilizers of 200 kg ha^{-1} DAP and 100 kg ha^{-1} UREA was used in split and (weeding, cultivation and earthingup) was practiced as per recommendations. The fungicides were applied on each variety at recommended rate in three different spraying schedules viz., every 7 days intervals starting from the on-set of the disease on foliages starting from the on-set of the disease at both location by using knapsack sprayer. Besides, necessary care was taken regardiing fungicide type to be used, how to apply (timing, quantity), intended target, formulation, quantity of water to be used for formulation, rates of fungicides, mode of action, hazards, safety cloothes etc. In addition, Handlers who may be exposed to the oncentrate through mixing, loading, application, or other tasks must wear (Coveralls over long-sleeved shirt and long pants, Chemical resistant gloves made of any waterproof material, Shoes plus socks, Protective eyewear, Chemical-resistant apron when mixing or loading etc.).

The treatment arrangements was; Ridomil Gold Mz 63.5 WP + Gudanie, Ridomil Gold Mz 63.5 WP + Jalenie, Mancozeb 80% WP + Gudanie, Mancozeb 80%WP + Jalenie, Matico (Metalaxyl 64% + Mancozeb 64% WP) + Gudanie, Matico (Metalaxyl 64% + Mancozeb 64% WP) + Jalenie, Unsprayed + Gudanie and Unsprayed + Jalenie. The experiment was laid out in Randomized Complete Block Design (RCBD) in a 4 x 2 factorial arrangement and replicated three times per treatment. Each material planted in plot size of 3 m x 2.1 m (6.3m^2). Each plot contained four rows of potato plants, with each row accommodating 7 plants with a total population of 35 plants per plot at the spacing of 0.75 m and 0.30 m between rows and plants, respectively. The net plot size =1.5 m (2 harvestable rows x 0.75 m) = 2.25 m^2. The spacing between plots and adjacent blocks was 1 m and 1.5 m, respectively. Plants in the two outer rows as were not considered for data collection to avoid edge effects. All other agronomic practices were employed as per recommendation.

Data collected

Days to 50% emergency, flowering, maturity, plant height(cm), stem number, average tuber weight(g), average tuber number per plant, marketable and unmarketable yield and total yield (t ha^{-1}). Disease severity assessed from randomly selected plant at 7-10 days interval. The incidence (%) and severity scale (1-6) were recorded as described by Gwary and Nahunnaro (1998) where, scale 1= trace (0) to 20% leaf infection, scale 2= 21 to 40% leaf infection, scale

3= 41 to 60% leaf infection, scale 4= 61 to 80% leaf infection, scale 5= 81 to 99% leaf infection and scale 6 = 100% leaf infection or the entire plants defoliation.

The percent of incidence was calculated as;

$$\text{Disease incidence} = \frac{\text{Number of diseased plants}}{\text{Total Number of plants assessed}} \times 100$$

Effective fungicides were determined using analysis of disease incidence and severity.

Data Analysis

The collected data on various parameters of the crop under study was statistically analyzed using SAS statistical package (SAS, 2003) version 9.1.3 using Fishers protected LSD. The Least Significant Difference (LSD) test at 5% level of significance was used to separate the means when the ANOVA showed the presence of significant difference results.

Partial Budget Analysis

The economic analysis was carried out by using the methodology described in CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. The concepts used in the partial budget analysis were the mean marketable tuber yield of each treatment, the gross benefit (GB) ha^{-1} (the mean marketable tuber yield for each treatment) and the field price of two potato varieties seed (Gudanie and Jalenie) and three fungicides(the costs of Ridomil Gold MZ 63.5%WP, Mancozeb 80% WP2 and Matico).

Adjusted yield (AjY): AjY was the average yield adjusted downward by a 10% to reflect the difference between experimental yields are often higher than the yields that farmers could expect using the same treatments; hence in economic calculations, yields of farmers are adjusted by 10% less than that of the research results (CIMMYT, 1988).

Gross field benefit (GFB): GFB was computed by multiplying field/farm gate price that farmers receive for the potato when they sale it as adjusted marketable tuber yield.

Total variable cost (TVC): Total cost was the field price of two potato varieties seed (Gudanie and Jalenie) and three fungicides (the costs of Ridomil Gold MZ 63.5%WP, Mancozeb 80% WP2 and Matico) for the experiment. The costs of other inputs (fertilizers) and production practices such as labor cost, land preparation, planting, Earthingup, weeding, top killing, and harvesting were considered the same or are insignificant among treatments.

Net Income (NI) or Net Benefit (NB): - was calculated as the amount of money left when the total variable costs for inputs (TVC) are deducted from the total revenue (TR).

NB = TR – TVC

Marginal rate of return (MRR %): was calculated by dividing change in net benefit by change in total variable cost.

$$\text{MRR\%} = \frac{\text{Change of Net Benefit} \, (\Delta \text{NB})}{\text{Change of Total Varaible Cost} \, (\Delta \text{TVC})} \times 100$$

Dominance Analysis (identification and elimination of inferior treatments): is also used to eliminate those treatments which involve higher cost but do not generate higher benefits. Any treatment that has higher TVC but net benefits that are less than or equal to the preceding treatment (with lower TVC but higher net benefit) is dominated treatment (marked as "**D**"). Identification of a candidate recommendation was from among the non-dominated treatments. That was the treatment which gives the highest net benefit and a marginal rate of return greater than the minimum considered acceptable to farmers (>1 or 100%).

Results and Discussions

Phenological parameters

The combined mean analysis results indicated that the interaction effect of fungicides and varieties had significantly ($P<0.05$) affected potato flowering at Bore on-station and also days to 50% emergency , days to 50% flowering and 90% maturity at Ana sora on-farm in both testing years (Table 1).

Table 1.Combined mean days to 50% emergency, days to 50% flowering and days to 90 % physiological maturity of Potato at Bore on site and Yirba on farm during 2015 and 2017 cropping season.

Treatments	Phenological Parameters potato					
	Bore site			Ana sora		
	DE	DF	DM	DE	DF	DM
Matico + Gudanie	14.33	57.33^{ab}	110.66	24a	55.83^{a}	100.66^{cd}
Mancozeb + Jalenie	14.5	54.00^{c}	109.33	22.67^{bc}	52.33^{bc}	107.33^{ab}
Mancozeb + Gudanie	14.33	55.00^{bc}	108.00	23.5^{ab}	55.83^{a}	102.33^{abc}
Ridomil Gold+ Jalenie	14.33	57.00^{ab}	109.00	21d	53.5^{abc}	104.00^{abc}
Matico + Jalenie	14.17	54.66^{bc}	109.66	21.83^{cd}	52.5^{bc}	108.00^{a}
Ridomil Gold+ Gudanie	14.33	58.00^{a}	110.33	22.67^{bc}	55.17^{ab}	101.66^{bcd}
Unsprayed + Jalenie	14.17	55.66^{abc}	94.33	23^{ab}	51c	98.00^{d}
Unsprayed + Gudanie	14.17	55.00^{bc}	107.33	23.17^{ab}	55^{ab}	98.00^{d}
Mean	14.3	55.83	107.33	23.00	53.9	102.5
LSD (5%)	Ns	2.75	Ns	1.79	16.28	5.87
CV (%)	3.41	2.81	2.20	6.7	25.8	3.27

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; DE=Days to emergency, DM=Days to maturity, DF=days to 50% flowering; LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

Growth and Yield component parameters of potato

The combined mean analysis of years 2015 and 2017 result indicated that, at both locations application of fungicide had significant ($P < 0.05$) effect on stem number and plant height of potato. However, the combined mean had a non- significant ($P < 0.05$) effect on average tuber weight of potato (Table 2).

Yield parameters of Potato

The combined mean analysis of years of 2015 and 2017 revealed that, unmarketable tuber yield, marketable tuber yield and total tuber yield had significantly ($P<0.05$) affected the fungicide application on potato varieties (Table 3).From the two years data analysis, the maximum (47.34 t $ha^{-1}$and 46.31 t ha^{-1}) marketable tuber yield was obtained from Gudanie variety with Ridomil Gold fungicide application. Similarly, Jalenie variety gave maximum (39.02 and 39.68 tha^{-1}) marketable tuber yield with spray of Ridomil Gold and Mancozeb fungicide at Bore and Ana sora on-farm respectively.

Table 2. Combined mean stem number, plant height and average tuber weight of Potato at Bore on site and Yirba on farm during 2015 and 2017 cropping season.

Treatments	Growth and yield component parameters of potato							
	Bore on-station				Ana sora on-farm			
	PH	STMN	NTPP	ATW	PH	STMN	NTPP	ATW
Matico+Gudanie	82.33^{bcd}	8.66^{c}	10.5^{ab}	98.7^{ab}	81.66^{bcd}	5.33^{cd}	7.66^{c}	117.8^{a}
Mancozeb+Jalenie	79.00^{cde}	9.33^{bc}	12^{a}	82.1^{b}	78.33^{cd}	5.33^{cd}	9.00^{c}	119.1^{a}
Mancozeb+Gudanie	93.00^{ab}	11.00^{ab}	9.5^{b}	126.3^{a}	92.66^{ab}	7.66^{ab}	13.33^{b}	101.2^{ab}
Ridomil Gold +Jalenie	83.66^{bc}	8.33^{c}	10.3^{ab}	104.2^{ab}	83.33^{abc}	7.33^{abc}	12.00^{b}	106.2^{ab}
Matico+Jalenie	71.66^{de}	9.00^{c}	10.8^{ab}	99.6^{ab}	71.33^{d}	5.00^{d}	8.66^{c}	102.9^{ab}
Ridomil Gold+Gudanie	95.33^{a}	11.66^{a}	11^{ab}	119.2^{ab}	94.00^{a}	9.00^{a}	17.33^{a}	124.9^{a}
Unsprayed+Jalenie	70.66^{e}	4.33^{e}	10.3^{ab}	$87.8a^{b}$	70.33^{d}	4.33^{d}	4.66^{d}	77.7^{b}
Unsprayed+Gudanie	78.00^{cde}	6.33^{d}	10.8^{ab}	$91.4a^{b}$	78.00^{d}	6.00^{bcd}	7.00^{cd}	106.5^{ab}
Mean	81.70	8.58	10.08	101.18	81.20	6.25	9.95	107.02
LSD (5%)	11.64	1.79	2.38	Ns	11.49	2.21	2.85	Ns
CV (%)	8.13	11.92	10.79	29.7	8.08	20.20	16.37	23.3

Means within the same column followed by the same letter (s) are not significantly different at 5% level of significance; PH = Plant height (cm), STMN=stem number; NTPP= number of tubers per hill, ATW= average tuber weight; LSD = Least Significant difference; NS = Not significant; CV = Coefficient of Variation

The combined data analysis result also revealed that, spraying Ridomil Gold on Gudanie and Jalenie variety gave maximum (57.67 t ha^{-1} and 57.54 t ha^{-1}) total tuber yield at Bore and Ana sora on-farm respectively. However, the lowest (38.37 t ha^{-1} and 33.67 t ha^{-1}) total tuber yield was recorded on Jalenie variety with control or unsprayed treatment, at Bore and Ana sora on-farm, respectively (Table 3).This result is in agreement with the result of Ghazanfar *et al.* (2010) who reported that, the application of Ridomil consistently retarded late blight development and increased the tuber yield. This result is also consistent with that of Harris (1992) who reported that, there was an inverse relationship between tuber yields and late blight infection: as the growth of tubers is dependent on the amount of functioning leaves and stops when 75% of the total leaf area is destroyed.Therefore, from these results, farmers around the study area can produce healthy and maximum potato crop of Gudanie and Jalenie varieties by using effective fungicides like Ridomil Gold.

Late blight Incidence and Severity

Data regarding the efficiency of the fungicides against the disease management were shown in tables 4 and 5. The result of 2015 year disease data indicates that maximum (59.52% and 3.67) disease incidence and severity, respectively was recorded on unsprayed treatment of Jalenie variety and also the second year maximum (45.24 % and 2.83) disease incidence and severity was on treatment Gudanie variety unsprayed fungicides, respectively. However, the minimum (5.48% and 1.16) disease incidence and severity of late blight was recorded on spraying Ridomil Gold Mz 63.5WP on both Gudanie and Jalenie varieties, respectively (Table 4).

Table 3. Combined mean number of tubers per hill, average tuber weight, unmarketable, marketable and total yield of Potato at Bore on site and Yirba on farm during 2015 and 2017 cropping season.

Treatments	Yield Parameters of potato (t ha^{-1})					
	Bore on-station			Ana sora on-farm		
	UNM	MRT	TYLD	UNM	MRT	TYLD
Matico+Gudanie	8.47^{abc}	36.88^{ab}	45.36^{b}	46.24^{c}	38.65^{ab}	54.70^{a}
Mancozeb+Jalenie	6.48^{c}	34.28^{b}	40.78^{b}	44.02^{c}	39.68^{ab}	53.33^{ab}
Mancozeb+Gudanie	11.36^{a}	39.17^{ab}	50.38^{ab}	44.76^{c}	36.11^{bc}	50.38^{ab}
Ridomil Gold +Jalenie	8.79^{abc}	39.02^{ab}	47.96^{ab}	33.54^{c}	36.98^{bc}	51.94^{ab}
Matico+Jalenie	7.93^{abc}	39.41^{ab}	47.58^{ab}	45.39^{c}	31.63^{bc}	48.57^{ab}
Ridomil Gold+Gudanie	10.32^{ab}	47.34^{a}	57.67^{a}	33.22^{c}	46.31^{a}	57.54^{a}
Unsprayed +Jalenie	7.99^{abc}	30.37^{b}	38.37^{c}	94.18^{a}	20.38^{d}	33.67^{c}
Unsprayed + Gudanie	6.97^{bc}	36.68^{ab}	43.66^{b}	71.42^{b}	29.27^{c}	43.64^{bc}
Mean	66.49	322.76	389.25	51.60	321.79	373.39
LSD (5%)	3.79	12.30	12.17	7.43	8.36	10.87
CV (%)	7.13	3.19	2.65	18.66	9.8	8.31

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

This result is consistent with that of Kirk *et al.* (2005) who reported that cultivation of resistant cultivar and regular applications of fungicides has reduced the foliar infection of late blight of potato. In agreement with the findings of Fontem (2001) who reported systemic fungicides (Ridomil Gold and Matico) provide better control as compared to contact (Mancozeb) fungicides. Furthermore, Beaumont (1947) and Goodwin *et al.* (1995) who reported that the amount of inoculums produced depends on the host, pathogen, environment and management conditions

Table 4. Overall combined mean analysis of treatments over locations on disease incidence (%) and severity scale (1-6) of 2015 year across locations as described by Gwary and Nahunnaro (1998)

Fungicide * Variety	Disease Incidence (%)	Disease Severity (scale 1-6)
Matico + Jalenie	17.86^{ab}	1.67^{bc}
Ridomil Gold + Jalenie	6.27^{b}	1.16^{c}
Ridomil Gold + Gudanie	5.48^{b}	1.5^{c}
Matico + Gudanie	19.05^{ab}	1.67^{bc}
Unsprayed + Jalenie	59.52^{a}	3.67^{a}
Unsprayed + Gudanie	45.24^{ab}	2.83^{ab}
Mancozeb + Jalenie	40.47^{ab}	2.83^{ab}
Mancozeb + Gudanie	26.19^{ab}	2.17^{bc}
Mean	28.76	2.18
LSD(5%)=v*f	24.62	1.19
Cv (%)	73.32	46.76

The result of data analysis for the year 2017 for disease data indicates that, maximum (80% and 4.6) disease incidence and severity, respectively was recorded on unsprayed treatment of Jalenie variety and also the maximum (60% and 3) disease incidence and severity was recorded on treatment Gudanie variety with unsprayed fungicides, respectively. However, the minimum (19.16% and 21.66%) disease incidence and minimum (1.66 and 1.5) disease incidence and severity of late blight was recorded by management of late blight by spraying Ridomil Gold Mz 63.5WP on both Gudanie and Jalenie variety, respectively. In general, Ridomil Gold and Mancozeb fungicides were more effective by reducing the disease severity and increasing tuber yield. It is generally accepted that, these fungicides have the ability to penetrate deep into host tissues and translocate up and down in the plant parts providing a barrier to *P. infestans'* further growth and development (Fernandez-Northcote *et al.*, 2000; Majeed and Muhammad, 2013).The results are also in good agreement with previous reports on the efficacy of fungicides (Mantecon, 2007; Dowley *et al.*, 2008; Rahman *et al.*, 2008).

Table 5. Overall combined mean analysis of treatments over locations on disease incidence (%) and severity scale (1-6) of 2017year across locations as described by Gwary and Nahunnaro (1998)

Fungicide * Variety	Disease Incidence (%)	Disease Severity (scale 1-6)
Matico + Jalenie	30.33^{d}	3^{b}
Ridomil Gold + Jalenie	21.66^{e}	1.5^{e}
Ridomil Gold + Gudanie	19.16^{e}	2^{cd}
Matico + Gudanie	43.33^{b}	2.16^{c}
Unsprayed + Jalenie	80^{a}	4.6^{a}
Unsprayed + Gudanie	60^{b}	3^{b}
Mancozeb + Jalenie	36.66^{cd}	2^{cd}
Mancozeb + Gudanie	33.33^{d}	1.66^{e}
Mean	40.56	2.50
LSD(5%)=v*f	8.17	0.40
Cv (%)	17.25	13.83

Partial Budget Analysis

Partial budget analysis was done based on the view of CIMMYT Economics Program (1988) recommendations, which stated that the application of fungicides with the marginal rate of return above the minimum level (100%) is economical. The results of the study indicated that the application of Ridomil Gold fungicide on Gudanie potato variety had gave high benefit over the control at both locations. The partial budget analysis revealed that, the maximum net benefit of Birr 244,462.50 and 235,352.7 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2549.00 and 2698% was recorded in the treatment that received the application of Ridomil Gold on Gudanie potato variety at both Bore on-station and Ana sora on-farm respectively (Table 6). However, the lowest net benefit of Birr 164,052.00 and 101,052.00 ha^{-1}and non- acceptable marginal rates of return (MRR) were obtained in both nil received plots of fungicide on Jalenie potato variety at both Bore on-station and Ana sora on-farm respectively. The application of Ridomil Gold fungicide to Gudanie potato variety at both Bore on-station and Ana sora on-farm generated 80,410.5 and 134,300.7 Birr ha^{-1} more compared to in both nil received plots of fungicide on Jalenie potato variety at both Bore on-station and Ana sora on-farm respectively. The application of Ridomil Gold on Gudanie potato variety at both Bore on-station and Ana sora on-farm which gives the highest net benefit and a marginal rates of return greater than the minimum considered acceptable to farmers (>1 or

100%). Based on this result, the application of Ridomil Gold on Gudanie potato variety at both Bore on-station and Ana sora on-farm were resulted in highest adjustable marketable tuber yield (43200 and 41681.7 kg ha^{-1}) respectively and profitable to the farmers in the study area (Table 6).

Table 6.Partial budget and marginal rate of return analysis demonstration of fungicides With the combination of potato varieties to manage late blight in highlands of Guji Zone, during 2015 and 2017 cropping season

Treatments	Unadjusted Myld Kg ha^{-1}	Adjusted Myld Kg ha^{-1}	Total var. cost ETB	Gross Return(GR) ETB(Adjusted Myld*6birrkg^{-1}	Net Benefit(NB) ETB	MRR (%)
Bore on-station						
Unsprayed + Jalenie	30380	27342	9000	164052	155,052.00	
Mancozeb + Jalenie	34280	30852	9795	185112	175317	2549
Matico + Jalenie	39420	35478	10162.5	212868	202,705.5	7453
Unsprayed + Gudanie	36690	33021	10800	198126	187326	D
Mancozeb + Gudanie	39030	35127	11595	210762	199167	1489
Matico + Gudanie	36880	33192	11962.5	199152	187189.5	D
Ridomil Gold + Jalenie	39170	35253	12937.5	211518	198580.5	1168
Ridomil Gold + Gudanie	48000	43200	14737.5	259200	244,462.5	2549
Ana sora on-farm						
Unsprayed + Jalenie	20380	18342	9000	110052	101052	
Mancozeb+ Jalenie	39680	35712	9795	214272	204,477	1301
Matico + Jalenie	31640	28476	10162.5	170856	160693.5	D
Unsprayed + Gudanie	29280	26352	10800	158112	147312	D
Mancozeb + Gudanie	36120	32508	11595	195048	183453	4546
Matico + Gudanie	37270	33543	11962.5	201258	189295.5	15909
Ridomil Gold + Jalenie	36985	33286.5	12937.5	199719	186781.5	D
Ridomil Gold + Gudanie	46313	41681.7	14737.5	250090.2	235,352.7	2698

Where, Potato seed cost = Birr 600 of 1000 kg^{-1}of Gudanie variety and Birr 500 of 1000 kg^{-1}of Jalenie variety, Ridomil Gold cost = Birr 1575 of 2.5 kg ha^{-1}, Matico cost = Birr 465 of 2.5 kg ha^{-1}, Mancozeb cost = Birr 265 of 3 kg ha^{-1}, Field price of potato during harvesting = Birr 6 birr kg^{-1}, Myld =Marketable tuber yield, MRR (%) = Marginal rate of return and D= Dominated treatment.

Conclusions and Recommendations

Effective management of disease requires implementation of an integrated disease Management approach. Although the most important measures are chemical controls, *P. infestans* could be controlled by fungicide treatment (contact, penetrating or systemic products) that enables destroy, weaken or suppress the pathogen applied throughout the crop cycle. The study was conducted at Bore on-station and Ana sora on-farm during 2015 and 2017 two cropping seasons with the aim to evaluate fungicides with the combination of potato varieties to manage late blight and to assess the cost and benefits of different fungicides and its efficiency on Gudanie and Jalenie potato varieties. The two years combined data analysis results revealed that the interaction effect between fungicides and variety had highly significant ($P<0.05$) response on days to 50% flowering, 50% maturity, plant height, number of tubers per hill, stem number per plant, marketable tuber yield, unmarketable tuber yield and total tuber yield. But the Anova result shows non-significant ($P>0.05$) effect on days to emergency by the application of fungicides and variety between each mean.From the two year data analysis the maximum (47.34 t ha^{-1}and 46.31 t ha^{-1}) marketable tuber yield was obtained by Gudanie variety with Ridomil Gold fungicide application at Bore and Ana sora on-farm locations, respectively. Similarly Jalenie variety gave maximum (39.02 and 39.68 t ha^{-1}) marketable tuber yield by Ridomil Gold and Mancozeb fungicide application at Bore and Ana sora on-farm locations, respectively. The combined data analysis result shows that fungicide Ridomil Gold on Gudanie and Jalenie variety gave maximum (57.67 t ha^{-1} and 57.54 t ha^{-1}) total tuber yield at Bore and Ana sora on-farm locations, respectively. However, the lowest (38.37 t ha^{-1} and 33.67 t ha^{-1}) total tuber yield was recorded on Jalenie variety with control or unsprayed treatment, at Bore and Ana sora on-farm locations, respectively.

The result of disease data shows that the maximum disease incidence and severity was recorded in control treatment of both varieties. The minimum disease incidence and severity was seen on by treatment combination of Ridomil Gold and Gudanie and Jalenie variety in both years. Here also spraying of Manacozeb fungicides on Gudanie and Jalenie variety efficient to control potato late blight under field conditions.

In conclusions, foliar blight and disease progress was significantly reduced by foliar application of Ridomil Gold and Mancozeb fungicides. Increments in tuber yields were only recorded by application of fungicides Mancozeb, Matico and Ridomil Gold. As the partial budget analysis revealed that application of Ridomil Gold on Gudanie variety result the highest net benefits of Birr 244,462.50 and 235, 352.00 ha^{-1} with an acceptable marginal rate of returns (MRR) of 2549.00 and 2698%. Thus, application of Ridomil Gold on Gudanie variety led to optimum marketable tuber production and economic returns. Therefore, the farmers' in highlands of Guji zone and similar agro-ecology can produce healthy and maximum potato crop of Gudanie by spraying Ridomil Gold fungicide with the recommended rates and frequency.

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Survey of Major Diseases of Tropical Fruit in Mid and Lowland Areas of Bale Zone

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Abstract

The objective of this study was to assess the occurrence and distribution of tropical fruits diseases in mid and lowland of Bale zone. The survey was carried out in three districts viz. Berbere, Dello Mena and Ginir in 2017/2018 cropping season which are among the potential areas of tropical fruits in Bale zone. The major fruit crops in the studied area were mango, avocado and banana as major crops,papaya,guava and orange as minor crops .Anthracnose (on mango and avocado),powdery mildew(on mango and avocado) avocado scab disease (on avocado) were identified as the most important diseases in the area. Fusarium wilt and dieback were also observed in a very few Banana and avocado orchards, respectively. Anthracnose is the most severe disease in all surveyed districts with the severity level of 28.8, 47.4and 38.1in Berbere, Dello Mena and Ginir respectively. In addition, powdery mildew was the second most severe disease in the surveyed areas. Except banana, most of the fruit crops in the studied area were attacked by different complex diseases. Fusarium oxysporum f. sp. *cubense was identified in the laboratory as a causative agent of banana wilt in the studied area. For the management of such complex diseases in the studied areas, developing IDM (integrated disease management) approach through the intervention of the research is quite needed.*

Key words*: Tropical fruits, Diseases, Survey, IDM*

Introduction

Horticultural crops are the most important and interesting crops that are produced in the tropical regions of the world .They possess a wide range of nutritional contents such as minerals, vitamins, oils, starches and proteins. Ethiopia has a comparative advantage in a number of horticultural fruit crops due to its favorable agro ecology, proximity to European and Middle Eastern markets, and cheap labor. Fruit crops play a significant role in developing country like Ethiopia, both in income and social spheres for improving income and nutrition status. In addition, it helps in maintaining ecological balance since they are reducing soil erosion, silting tanks and air pollution. In Ethiopia, many fresh fruits and processed products are exported to several countries for earning good amount of foreign currencies. The production of horticultural fruit crops is much less developed than the production of food grains crops in the country. According to CSA 2015/16, about 92,362.36 hectares of the land is under fruit crops in Ethiopia which is too small as compared to grains crops (about 12,486,270.87 hectares).

Banana, mango, avocado and orange are the major tropical fruits in the Bale. Bale zone has diverse agro-climatic condition which favors the production of all types of crops including the tropical fruits. The main tropical fruits producing districts of Bale are Dello Mena, Barbere and Ginir. Due to its ability to withstand climate change and lower labor requirement as well as the availability of irrigation water, fruit productions have a lion's share as they are a source of food for consumption and income generation in the region. However, the production of those fruits in this zone constrained by different abiotic and biotic factor. Among biotic factors, diseases are the most important constraint to the production of tropical fruit. These biotic factors constrain production indirectly reduce the yields by debilitating the plant, and directly reduces the yield or quality of fruit before and after they are harvested. As a result, the average productivity levels are low in the small scale farming sector (Misgana, 2017). Consequently, failure to recognize and manage these diseases successfully can result in catastrophic losses (Randy C. P and John A.M, 2003). Studying the status of pests in specific region helps to know the importance of those pests in the region. However, there is a little and / or no adequate information on tropical fruit diseases and its distribution. Hence, it is important to surveying and documenting the status of diseases of tropical fruits in major fruit producing districts of Bale zone for future intervension. By keeping this in mind, this survey was aimed at the following objectives;

1. To assess the occurrence and distribution of tropical fruits diseases in Bale zone and
2. To generate information this that can be used in developing integrated management strategy against these diseases.

Materials and Methods

Survey was conducted to assess the occurrence and distribution of diseases of tropical fruits in the major tropical fruits producing districts of Bale zone (Dello Mena, Berbere and Ginir). Orchard fields were sampled at intervals of about 3-5 km along the roads and the distance between sample orchards were based on the topography and the relative importance of fruit production within each district. Random sampling was employed in a “zigzag” fashion for selecting fruits and trees within the orchards. The survey was done two times because of natural character of perennial crops which their maturity is well diversified. Three to five orchards per kebele and four to five trees per orchard were assessed. The assessment was done at the three strata of the tree (upper, middle and lower). A total of 39 orchards were surveyed. Most of the diseases were identified in the field visually with the help of guide books and other references.

Isolation of banana wilts fungal pathogen

The sample of banana wilt which was taken to Plant Pathology laboratory of Sinana Agricultural Research Center (SARC) for further identification .The samples were taken from a section of the pseudo stem of the wilted banana plant where typical continuous discolored vascular strands were evident. The samples were kept in heavy paper bags until the strands can be excised.

Disease data

The disease data were recorded from the sampled plant. Data were expressed in percentage. The formula for calculating the disease incidence and severity were:

$$\text{Percent of Incidence} = \frac{\text{Number of Leaves/Fruits/stems infected}}{\textit{Total number /frui/stem counted}}\ x100$$

$$\mathrm{PSI} = \frac{Sum\ of\ all\ disease\ rating}{Total\ number\ leaf\ /fruit\ /stem\ x\ maximum\ rating\ value}\ x100$$

Where, PSI is percent severity index

Results and Discussions

Major fruit crops in the study areas were, mango (*Mangifera indica*), avocado (*Persea americana*), and banana (*Musa spp.*), Papaya (*Carica papaya*), guava (*Psidium guajava*), orange (*Citrus sinensis*) and Lemon (*Citrus limon)* were among the minor fruit crops cultivated by few farmers. Anthracnose (*C.gloeosporioides)* is the most severe disease of mango in all surveyed districts. The average severity level was 47.4, 28.8 and 38.1% in Dello-mena, Berbere and Ginir districts, respectively. Similarly, the disease was the most severe disease of avocado in all surveyed areas. However, the disease severity level recorded in the studied area was lower than that of what is reported by different authors in the southern part of Ethiopia that ranges from 60% to 75% on both avocado and mango (Minyahil, 2015 and Misgana, 2017). This may be due to agro-climatic and environmental condition differences. It indicates that, the diseases may be the most devastating disease on this crops in favorable condition if the control measures are not taken early. Hence, it needs a serious focus and attention. Powdery mildew caused by the pathogen called *Odium mangiferae* and *Oidium spp* is observed on mango and avocado.It is the second most severe disease of both mango and avocado in tropical fruit producing districts of Bale zone. The maximum mean infection level of 29.6 % and 26.8 % of the disease was recorded on avocado and mango respectively in Dello Mena district. It also needs to be controlled to reduce yield loss that occurred due to this disease on these crops. Scab is the third important disease of avocado. If control measure is not applied it reduces the quality of the product. Fusarium wilt and dieback were also observed in very few banana and avocado orchards, respectively. (Table 1)

Table 1. Incidence, severity and prevalence of tropical fruit diseases in Bale zone

District	Disease	Crop	Incidence (%)	Severity (%)	Prevalence (%)
Dello-Mena	Anthracnose	Mango	100	47.4	100
		Avocado	100	39.3	100
	Powdery mildew	Mango	100	26.8	100
		Avocado	100	29.6	100
	Scab	Avocado	100	21.4	100
	Die back	Avocado	2.7	1.1	6.7
	Fussarium wilt	Banana	3.3	-	8.3
Berbere	Anthracnose	Mango	100	28.8	100
	Powdery mildew	Mango	100	11.7	100
Ginir	Anthracnose	Mango	100	38.1	100
		Avocado	100	16.2	100
	Powdery mildew	Mango	100	19.7	100
	Fusarium wilt	Banana	6.7	-	3.3

Isolation and identification of fungal pathogen of banana wilt (*Fusarium oxysporum* f.sp. *cubense)*

The disease causal pathogen was isolated and identified according to the standard laboratory procedures (Mongkutkarn Udompongsuk and Kasem Soytong, 2016). The discolored vascular strands were cut from inner banana pseudo stem into small pieces approximately 0.5 cm and then rinsed 2 – 3 times with distilled water after soaked in 1% Sodium hypochlorite for 2 – 3 min. Place The tissue sections was placed in Water Agar (WA). Then mycelium grown from the tissue sections were transferred to Potato Dextrose Agar (PDA) and incubated at 25º C for 7 – 10 days, until it gets pure culture. The pathogen was identified according to their cultural appearances and morphological characteristics such as micro conidia, macro conidia and chlamydospores described by Pérez-Vicente et al.; 2014 and Mongkutkarn Udompongsuk and Kasem Soytong, 2016. The cultural appearances were observed on potato dextrose agar (PDA), colonies have a variable morphology. The colony was observed as hairy to cottony and the color from whitish to yellow, pink or purple shades. The fungus produces macro conidia; micro conidia and chlamydospores. The macro conidia are nearly straight, slender and thin-walled with 3 – 4 septa, a foot-shaped basal cell and a curved tapered apical cell. Micro conidia are single celled, oval to kidney-shaped and are produced in false heads. Chlamydospores are formed in hyphae or conidia, usually globose single or in pairs with a coarse protective wall. The distribution of banana wilt was lower in the studied area. However, the disease has a significant effect on banana fruits which causes poor growth and the mother plant produces many infected suckers before it dies. Since the survey was conducted after the fruits were almost completely harvested; the only pests that could be observed were scale insects on mango, orange and lemon. It needs to identify and document the major insect pest in the studied area in the future work.

Conclusions and Recommendations

The finding indicates that, the diseases of banana wilt, anthracnose and powdery mildew has a significant effect on the fruits of the studied area. The latter two diseases were the most frequently occurred and more severe in the surveyed areas attacking avocado and mango fruits. However, their severity is varied among and within the areas based on agro-ecological and production system of the fruits. Scab is the third important disease of avocado which can be causes a significant effect on quality problems of the fruit. Die back and fusarium wilt were with a less severe disease of avocado and banana, respectively in the studied are. *Fusarium oxysporum* f.sp. *cubense* was also identified as the causative agent of banana wilt. Except banana, other fruit crops (avocado and mango) in the studied area were attacked by complex diseases of different pathogens. Therefore, searching for resistance/tolerant varieties, improved agronomic practices are important for the management of the diseases. In general, IDM (Integrated disease management method) approach is required to manage the complex diseases in the studied area through the intervention by research centers.

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Application of AMMI analysis for grain yield Stability in large speckled bean genotypes grown in midlands of Bale zone

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Abstract

Genotypes–environment interaction analysis was studied for grain yield in seventeen large speckled bean genotypes grown at Goro, Ginnir and Dellomena in the midlands of Bale zone for two consecutive years (2016 to 2017) during the main cropping season. Randomized Complete Block Design with four replications was used for this study. Plot size of $6.4m^2$ *(4 rows at 40cm spacing and 4m long) was used at all the tested locations. Yield stability is one of the hinders facing plant breeders in developing widely adapted varieties with superior yield. The present study was carried out to investigate the effect of genotype by environment (GxE) on the yield stability of speckled common bean using seventeen genotypes in six test environments (Locations x years combination). The combined analysis of variance for mean grain yield revealed that, there is highly significant variation for year, environment, genotypes, and genotype by environment interaction. It revealed that 34.16% of the total variation was attributed to environment effect followed by genotypes 11.84%, and genotypes by environment interaction 2.97%. On the other hand the AMMI analysis for the grain yield revealed that 69.8% of the variation was due to environmental effect followed by genotypes (24.2) and GE (6.1%). AMMI 1 component explained 61.6% of the total interaction sum of squares whereas AMMI 2 accounted for 38.4% of the variation. Of the tested genotypes, G5 and G11 showed consistent stability across the testing environments showing slop value close to unity and deviation from regression near to zero with high mean grain yield.Therefore, these two genotypes were identified as candidate varieties to be verified in the coming cropping season for possible releases in the midlands of Bale zone and similar agro-ecologies.*

Key words: AMMI, Common bean, GSI, Stability

Introduction

A 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. In 2014, it was cultivated by 3.34 million smallholders on 340 thousand hectares of land which is about 20% of total farm land allocated for pulses crops (CSA, 2014). The concepts of GxE and yield stability have been concerns to the breeders and biometricians for a long period of time. A significant GxE for a quantitative trait is known to reduce the usefulness of the genotype means over all locations or environments for selecting and advancing superior genotypes to the next stage of selection (Pham and Kang, 1988). If there is no GxE associated with the genotype environment system relevant to a breeding objective, selection would be greatly simplified because the 'best' genotype in one environment would also be the 'best' genotype for all target environments (Basford and Cooper, 1998). Furthermore, variety trials would be conducted at only one location to provide universal results (Gauch and Zobel, 1996). Though the concept of stability is largely unclear in the plant breeding literatures partly due to the myriad of definitions that have been used to represent this concept (Basford and Cooper, 1998), it is a powerful tool to partition the G x E into mean squares responsible for its occurrence. High yield stability usually refers to a genotype's ability to perform consistently, whether at high or low yield levels, across a wide range of environments (Annicchiarico, 2002). The ultimate reason for differential stability among genotypes and for differential results from various test environments is non-repeatable G x E (Yan and Hunt, 2002). Several biometrical methods had been developed and used to analyze GEI, stability, and adaptability. But currently, AMMI and GGE bi-plot models were considered models of the first choice for multi-location trials data analysis and which genotype won where pattern discovery (Samonte *et al.*, 2005; Gauch Jr., 2006; Yan *et al.*, 2007; Gauch Jr. *et al.*, 2008; Namaratu *et al.*, 2009). Therefore, the present study was conducted to identify stable, high yielding genotypes evaluated over environments using the AMMI model.

Materials and Methods

Seventeen speckled bean genotypes were evaluated for two consecutive years (2016 to 2017) at three midland districts of Bale zone viz. Ginir, Goro and Dellomena during the main cropping season using Randomized Complete Block Design with four replications at all the three testing sites. The plot size used was 6.4m^2 (4 rows at 40cm spacing and 4m long). The two central rows were used as harvestable area to determine the mean yield of the genotypes. Combined analysis of variance, Least Significant Difference (LSD), Duncan Multiple Range Test were done using Cropstat9 software. The AMMI analysis was performed using the model suggested by Crossa *et al.* (1991). The stability parameters such as regression coefficient (bi), deviation from regression were also calculated using Cropsta9 program. AMMI stability value (ASV) was computed using the model suggested by Purchase *et al*. (2000):

$$ASV = \sqrt{\left[\frac{\text{SSIPCA1}}{\text{SSIPCA2}}(\text{IPCA1})\right]^2 + [\text{IPCA2}]^2}$$

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 and the smaller ASV scores indicate the more stable genotype across environments. Genotype Selection Index (GSI) was also calculated using the formula suggested by Farshadfar, 2003. It is calculated by summing the value of rank of mean grain yield of genotypes (RY_i) across environments and the value of rank of AMMI stability value ($RASV_i$) as indicated below.

$GSI_i = RASV_i + RY_i$

Table 1. Lists of seventeen speckled bean genotypes used in the study

Genotype Code	**Genotypes**	**Genotype Code**	**Genotypes**
G1	DAB- 359	G10	DAB- 368
G2	DAB- 378	G11	DAB- 437
G3	DAB- 376	G12	DAB- 360
G4	DAB- 457	G13	DAB- 459
G5	DAB- 410	G14	DAB- 430
G6	DAB- 369	G15	Brown Speckled
G7	DAB- 375	G16	Cranscope
G8	DAB- 439	G17	Dame
G9	DAB- 417		

Results and Discussions

The combined analysis of variance revealed that, there is highly significant variation among the test genotypes, environments and their interaction for mean grain yield at ($P< 0.01\%$). Similar findings were also reported by Mekbib (2003), Asfaw *et al.* (2008) and Tamene and Tadese (2014) in common bean varieties. Furthermore, Coimbra *et al*., (1999), Carbonell *et al.* (2004), Ribeiro *et al*. (2009), Pereira *et al.* (2009, 2011), and Torga *et al.* (2013) and Arke *et al.*, (2016) were also reported similar results common bean genotypes in multi-environment trials in Brazil The significant interactions of genotypes × environments (locations and years) suggest that, grain yield of genotypes varied across the tested environments. Significant differences for genotypes, environments and GE interaction indicated, the effect of environments in the GE interaction, genetic variability among the test genotypes and possibility of selection for stable genotypes. Chandra *et al*. (1974) reported that, GE interaction with location is more important than GE interaction with year. As GE interaction was significant, therefore, one can further proceed and estimate phenotypic stability (Farshadfar and Sutka, 2006). Of the total variation observed, 34.2% was due to the environment followed by genotypes (11.8%), and GEI (10.6%) of the total sum squares (Table 2). The significant GL, GY, LY, and GLY were also indicated that, the relative performance of the genotypes at different locations and years was not similar.

Table 2. combined ANOVA for seventeen speckled bean genotypes

Source of Variation	DF	Sums of Squares	Mean Squares	% explained
Year (Y)	1	14.4604	14.4604**	8.33
Location (L)	2	59.2928	29.6464**	34.16
Replication	3	1.37958	0.459861*	0.79
Genotype (G)	16	20.5561	1.28476**	11.84
Y X L	2	18.4517	9.22587**	10.63
L X G	32	5.16107	0.161283**	2.97
Y x L X G	48	11.0747	0.230722**	6.38
Residue	303	43.1778	0.142501**	24.88
Total	407	173.554		

Table 3 describes the mean grain yield, stability parameters such as slop (bi), deviation from regression (S^2di), the IPCA scores, ASV and GSI of the speckled bean genotypes. Purchase (2000) developed the AMMI stability value (ASV) based on the AMMI model's IPCA1 and IPCA2 (Interaction Principal Components Axes 1 and 2, respectively) scores for each genotype. Considering the ASV value, genotypes such as G16, G14, G7, G3, G13, G9, G2 and G5 showed the least ASV indicating the stability of these genotypes across the testing environments (Table 3). Since ASV consider only the IPCA scores without taking into account the mean grain yield of the genotypes, stable genotypes identified using ASV may have lowe yield. Stability *per sea* should however not be the only parameter for selection, because the most stable genotypes would not necessarily give the best yield performance (Mohammadi *et al*., 2007; Mohammadi and Amri, 2008), hence, there is a need for onother approaches that incorporate both mean yield and stability in a single index, that is why various authors introduced different selection criteria for simultaneous selection for high yield and stability (Eskridge, 1990; Kang, 1993; Dashiell *et al*., 1994; Bajpai and Prabhakaran, 2000; Rao and Prabhakaran, 2005; Farshadfar, 2008; Babarmanzoor *et al*., 2009). Therefore, in order to solve this problem, a new approach known as Genotype Selection Index (GSI) was recommended by Farshadfar (2008). Using AMMI stability value and mean yield, GSI incorporates both mean yield and stability in a single criterion. Low value of this parameter shows desirable genotypes with high mean yield and stability (Farshadfar 2011). Based on this criteria, G3, G5, G4 and G11 were considered as the most stable genotypes with higher grain yield (Table 3).

AMMI Analysis

The AMMI model combines the analysis of variance for the genotype and environment main effects with principal components analysis of the G ×E interaction (Zobel *et al*., 1988; Gauch and Zobel, 1996). The grain yield data were subjected to combined analysis of variance and AMMI analysis which is a combination of analysis of variance and multiplication effect analysis. Briefly, analysis of variance in this study is used to partition variance into three components: genotype deviations from the grand mean, environment deviations from the grand mean, and GE deviations from the grand mean. Subsequently, multiplication effect analysis is used to partition GE deviations into different Interaction Principal Component Axes (IPCA), which can be tested for statistical significance through ANOVA. In this study, the analysis of variance for AMMI model reveled significant difference for genotypes, environment and GEI interaction. Accordingly, 69.8% of the total variation was attributed to environment followed by genotypes (24.2%) and GEI (6.1%) of the total sum of squares. The AMMI model analysis had partitioned the GEI into the first two significant IPCAs with contributions of IPCA1 (61.6%) and IPCA2 (38.4%) (Table 4).

Table 3. Mean yield First and second IPCA and various yield-stability statistics investigated in small red common bean

Genotype code	Mean yield (t/ha)	RYi	Bi	MS-DEV (S^2di)	IPCA1	IPCA2	ASV	RASV	GSI
G1	1.45	8	0.66	0.67	-0.27	-0.12	0.45	15	23
G2	1.09	15	0.77	0.01	-0.17	-0.18	0.33	7	22
G3	1.57	4	1.19	0.34	0.15	0.06	0.24	4	8
G4	1.62	3	1.01	0.05	0.13	-0.28	0.35	8	11
G5	1.78	1	1.26	0.02	0.24	-0.16	0.35	8	9
G6	0.98	17	0.65	0.79	-0.28	-0.11	0.46	16	33
G7	1.2	13	0.91	0.51	-0.07	-0.06	0.13	3	16
G8	1.54	6	0.87	0.05	-0.15	0.28	0.37	10	16
G9	1.38	11	1.16	0.03	0.10	0.26	0.30	6	17
G10	1.36	10	1.40	0.89	0.34	-0.04	0.55	17	27
G11	1.65	2	0.84	0.01	-0.23	0.07	0.37	10	12
G12	1.42	9	0.91	0.06	-0.12	0.32	0.37	10	19
G13	151	7	0.84	0.02	-0.10	-0.24	0.29	5	12
G14	1.06	16	0.92	0.21	-0.07	0.04	0.12	2	18
G15	1.55	5	1.31	0.53	0.25	0.25	0.41	14	19
G16	1.22	12	1.02	0.56	0.01	0.06	0.06	1	13
G17	1.17	14	1.29	0.89	0.24	0.04	0.39	13	27

Table 4. Analysis of Variance for the AMMI Model

SOURCE	D.F.	S.S.	M.S.	% TSS
Genotype	16	2.56952	0.160595**	24.18
LOCATIONS	2	7.4116	3.7058**	69.75
G X E	32	0.645134	0.02016**	6.07
AMMI COMPONENT 1	17	0.397688	0.023393**	61.64
AMMI COMPONENT 2	15	0.247446	0.016496**	38.36
TOTAL	50	10.6262		

AMMI biplots were preferred biplots to visualize adaptability and stability of genotypes over test environments (Gauch and Zobel, 1988; Gauch and Zobel, 1996; Gauch, 2006; Gauch *et al.*, 2008). In AMMI1biplot, the genotypes with IPCA1 scores close to zero indicate general adaptation and the larger scores indicate more specific adaptation in combination with environments of the same sign IPCA1 scores (Ebdon and Gauch, 2002). Furthermore, the relative magnitude and direction of genotypes along the abscissa and ordinate axis in biplot is also important to understand the response pattern of genotypes across environments and to differentiate high yielding and adaptable genotypes (Samonte *et al.*, 2005). In Figure 1, where IPCA was plotted against mean grain yield, the vertical line passing through the origin is the grand mean. Accordingly, G12, G1, G13, G8, G15, G3, G4, G11 and G5 were gave mean grain yield above the grand mean. Environment Goro, gave the highest mean grain yield compared to the other sites since it is found in the right side of the figure 1. On the other hand those genotypes and environment which was found in the left side of the vertical line gave mean grain yield below the grand mean. Genotypes G6, G14 and G2 were more specifically adapted to Dellomena site whereas G7 and G16 were adapted to the other site, Ginir. G3, G4, G15 and G5 also more yield at Goro sites than the other sites.

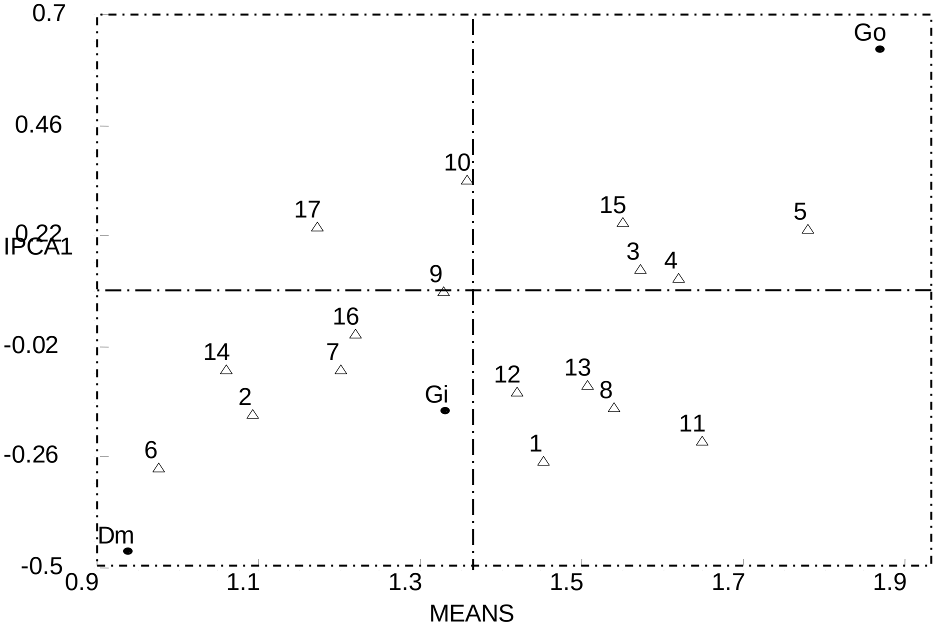

Figure 1. Biplot analysis of GEI based on AMMI 1 for IPCA 1 score and mean grain yield of genotypes and environments.

The AMMI2 biplot (Figure 2) explained 100% 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 centre of biplot show specific adaptation. In order to estimate specific adaptation and study their stability, biplot diagram was used. Mohammadi and Amri (2008) in a study of genotype × environment interaction in durum wheat revealed that, those genotypes which are far from the centre of biplot, have high G × E interaction and those genotypes that nearest to centre of biplot, have high stability. Thus, here in this study, G7, G5, G3, G11, G14 and G16 were more stable than the other genotypes since they were found near to the origin and have general adaptability. However, G7, G14 and G16 though they were stable, they gave grain yield below the grand mean. The other genotypes showed specific to the certain environments. For instance, G1, G2, G6 and G13 were more adapted to Dellomena whereas G4, G10, G15 and G17 were specifically adapted to site Goro. G8 and G12 were more favorable to Ginir site.

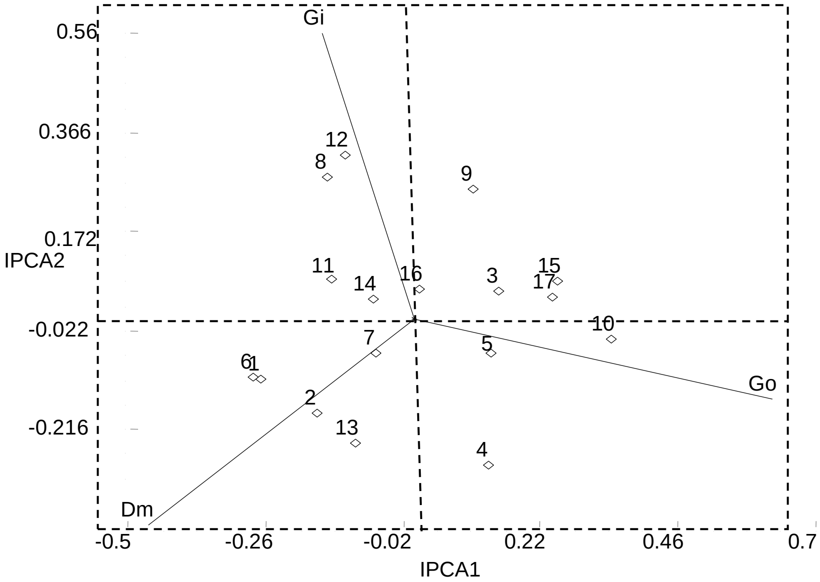

Figure 2. Biplot analysis of GEI based on AMMI 2 model for the first two IPCA scores

Conclusions

The current results indicated that, the yield performance of speckled bean genotypes was highly influenced by GE interaction effects; the magnitude of environment effect was about 2.9 times higher than that of genotype effect. When the stability parameters such as slop (bi), deviation from regression, ASV, GSI and mean grain yield taken into consideration, out of the tested genotypes G5 and G11 were found to be more stable with high mean grain yield. Therefore, these two genotypes were identified as candidate genotypes to be verified for the possible release in the coming cropping season for these test environments and similar agroecologies.

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Correlation and Path Coefficient Analysis of Yield and Yield Related Traits of Food Barley (*Hordeum Vulgare* L.) Genotypes in Mid Rift Valley of Ethiopia

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Abstract

Evaluation of genotypes for the association traits contributing for grain yield and generation of genetic information in complex traits were the key step in plant breeding to develop varieties for the targeted area of production. Hence, this research was conducted at Adami Tulu Agricultural Research Center in Mid Rift Valley of Ethiopia. Twenty-five food barley genotypes were tested in 5 x 5 Lattices Design with three replications. The objective of this study was to assess the association among yield and yield contributing traits and identify traits *those have the most direct and indirect effects on grain yield. Fifteen quantitative traits were subjected to analysis of variance. There were significant differences among genotypes for twelve quantitative traits including grain yield. Study of relationship between yield and yield contributing characters suggest that grain yield (kg ha^{-1}) had shown highly significant and positive phenotypic and genotypic correlation with thousand kernel weight, biological yield and harvest index. This implies, genetic influence for these traits was similar and grain yield could be improved directly by improving these traits. The association between yield, and yield related characters through phenotypic and genotypic path coefficients analysis revealed that, biological yield, 1000-kernel weight, number of kernels per spike and plant height exerted highest positive direct effect on grain yield and suggested grain yield will be improved via direct selection for these traits. Days to first heading and days to heading exerted negative direct effect at both phenotypic and genotypic path analysis and showing that, the direct selection of these characters would not be dependable for grain yield improvement. Yet, this study was conducted for one season and at one location which needs to be tested in subsequent trials at different locations and seasons to develop high yielding varieties.*

Keywords: Correlation, Food barley, Genotypes, Grain yield, Path analysis

Introduction

Barley (*Hordeum vulgare* L.) is the most ancient food crops in the world and it is an important cereal crop since the early stages of agricultural innovations 8,000-10,000 years ago (Giles and von Bothmer,1985). In Ethiopia, it is produced mainly for human consumption as one of the most important staple food crops. Its grain is used for preparing a diversity of recipes, and is deeply rooted in the culture and tradition of people's diets. The recipes are prepared in different forms of indigenous food and homemade beverages (Yaynu, 2011). Food barley production is 20, 249, 21.68 and 146, 46.502 tons in Ethiopia and East Shewa zone, respectively (CSA, 2016). More than 85% of the total production comes from the major barley growing regions, which include Wello, Shewa, Arsi, Gojam, Bale, Gondar and Tigray. Earlier studies on the diversity of Ethiopian barley shows that, most of the variation was due to differences among characters and only a relatively small fraction was due to differences between regions. And almost all characters are considerably influenced by altitude within the regions (Engels, 1994). There was shortage of improved barley varieties adapted to low-moisture stress areas of Ethiopia. Hence farmers are forced to grow low yielding genotypes.

Association between any two traits or among various traits is of immense importance to make desired selection of combination of traits (Ahmad *et al.*, 2003). A knowledge of correlations that exists between important characters can facilitate the interpretation of results obtained and provide the basis for planning more efficient program for the future (Martintello *et al.,* 2005). Genotypic and phenotypic correlations among traits of crop plants are useful in planning, evaluating and setting selection criteria for the desired traits in breeding program (Johansson *et al.,* 1955). Path coefficient analysis shows the extent of direct and the indirect effect of the causal component on the response component. In most studies involving the path analysis, researcher considered the predictor character as first order variable to analyze their effect over the dependent or response variables (Singh *et al*., 1997). Grain yield in crop is a complex character and is the product of several contributing factors affecting yield directly or indirectly. These factors influence grain production both directly and indirectly and the breeder is naturally interested in investigating the extent and type of association of such traits (Zafanaderi *et al*., 2013). Clear understanding of the type of plant traits, correlation and path coefficient analysis are logical steps. Although correlation and path estimates are helpful in determining the components of complex trait and relative importance of direct and indirect influences of each of the component of trait. So far, little information is generated about character associations between yield and yield contributing characters in food barley genotypes in Ethiopia. Therefore, the objective of this study was to assess the association among yield and yield contributing traits and identify traits those have the most direct and indirect effects on grain yield.

Materials and Methods

The experiment was conducted at Adami Tulu Agricultural Research Center of Oromia Agricultural Research Institute (OARI) under rain-fed condition during the 2017/18 cropping season. It is located at a latitude of 7° 9'N and longitude of 38° 7'E. It has an altitude of 1650 meters above sea level, and receives a bimodal unevenly distributed average annual rainfall of 760.9 mm per annum (ATARC 1998). The long-term mean minimum and maximum temperatures are 12.6 ^{0}C and 27 ^{0}C, respectively. The soil is fine sandy loam in texture with the soil type of sand, clay and silt in proportion of 34%, 48% and 18% respectively and a pH of 7.88 (ATARC 1998).

Experimental Materials

In the present study, a total of 25 food barley genotypes were used along with three standard checks. Twenty two of them were advanced genotypes and screened by Sinana Agricultural Research Center**.**

Experimental Design and Management

The experiment was conducted in 5×5 Triple Lattice Design with three replications. The genotypes were planted on a plot size of 1.2 m x 2.5 m. The space between plant, plots and blocks were 0.2 m, 0.5m and 1 m respectively. DAP 150 kg/ha fertilizer was applied during planting and the seed rate used was 125 kg/ha and sown by hand drilling. For data collection, the middle four rows were used. All management practices including weeding were performed uniformly to the entire plot according on the local recommendation.

Data Collection

Plant height (cm): was measured as the height in centimeter from the soil surface to the tip of spike excluding the awn at maturity and expressed as an average of randomly taken ten plants per plot.

Peduncle length (cm): Length of the peduncle in centimeter from the node to the tip of the peduncle as the average of ten randomly taken plants from the central four rows of each plot.

Awn length (cm): Length of awn in centimeter from the end of the spike to tip of the awn.

Spike length (cm): Spike length of the main plant was measured in centimeter from base to the tip excluding the awns and expressed as the average of randomly taken ten plants in a plot.

Spikelet number per spike: was recorded by counting the number of spikelet on each spike on the main tiller and expressed as the average of randomly taken ten plants in each plot.

Kernel number per spike: was determined by counting the number of kernels produced on the main tiller of each plant and expressed as an average of randomly taken ten plants in each plot.

Table 17. Lists of barely genotypes used in the study along with their origins and pedigrees.

S. N	Genotype/ Code	Origin	Pedigree
1	G1	Ethiopia	Acc#244906
2	G2	Ethiopia	Acc#244919
3	G3	ICARDA	SHEMIAL NO.3/MSEL
4	G4	ICARDA	VMORALES
5	G5	ICARDA	LIMON/BICHY2000/4/ALELI/3/ARUPO/K8755//MORA/5/MSEL
6	G6	ICARDA	CHAMICOO/M111
7	G7	ICARDA	FNCI/3/LEGACY//PENCO/CHEVRON-BAR
8	G8	ICARDA	P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1/6/LEGACY// PENCO/CHEVRON-BAR
9	G9	ICARDA	P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1/6/LEGACY//PENCO/CHEVRON-BAR
10	G10	ICARDA	CABUYA/M111/7/TRADITION/6/P.STO/3/LBIRAN/UNA80//LIGNEE40/4/BLLU/5/PETUNIA
11	G11	ICARDA	SHYRI/GRIT//FNC1
12	G12	ICARDA	P.STO/3/LBIRAN/UNA80//LIGNEE640/4/BLLU/5/PETUNIA1/6/CHNGADU 89//PENCO/CHEVRON-BAR/3/CHAMICO/TOCTE/CONGONA
13	G13	ICARDA	CANELA/C14196
14	G14	ICARDA	LIGNEE27/GARBEL/3/BOY-B*2/SURB//C12225.2D/4/GLORIA-BAR/COM
15	G15	ICARDA	SVANHALS-BAR/MSEL//AZAF/GOB24DH/3/DEFERA/DESCONNCIDA-BAR
16	G16	ICARDA	LIGNEE 27/ GERBEL /3/BOY-B*2/SURB //C12225.2 D/4/ GLORIA-BAR/COM
17	G17	ICARDA	LIGNEE27/GARBEL/3/BOY-B*2/SURB//C12225.2D/4/GLORIA-BAR/COM
18	G18	ICARDA	LIGNEE 27/ GARBEL /3/ BOY-B*2/ SURB//C 12225.2 D /4/ GLORIA-BAR/COM
19	G19	ICARDA	FRES/M1004
20	G20	ICARDA	FRES/LEGACY
21	G21	ICARDA	SEN/5/LEGACY/4/TOCTE//GOB/HUMAI10/3/ATAH92/ALELI
22	G22	ICARDA	PUEBLA/CORDO//TOCTE/3/FALCON-BAR
23	Gobe	-	Released Variety
24	Bentu	ICARDA	Released Variety
25	Robera	Ethiopia	Released Variety

Note: G1- G22=Genotypes used for study, Source: Sinana Agricultural Research Center

Days to first heading: was recorded as the number of days from seedling emergence to the date on which first head was produced in the plots.

Days to heading: was recorded as the number of days from seedling emergence to the date on which 75% of a plot has produced heads.

Days to maturity: was recorded as the number of days from seedling emergence to the stage when 75% of a plot reached maturity.

Grain filling period: was recorded as the number of days from days the date of heading to the date physiological maturity.

Number of effective tillers per m^2: Numbers of tillers m^{-2} were counted in square meter frame area. Tillers was recorded by counting the number of tillers of 2.5 meter length in two central rows of each subplot and then converted to tiller m^{-2}

Biological yield (kg/ha): was determined by weighing the total dried above ground biomass from the four central rows of each plot and expressed in kilogram per hectare.

Grain yield (kg/ha): Grain yield of the four central rows adjusted to 12.5% moisture content and expressed in kilogram per hectare.

Harvest index (%): Was calculated on plot bases from the four rows as the ratio of dry weight of the grain to the dry weight of the above ground biomass and expressed as a percentage.

$$\textbf{Harvest Index} = \frac{\text{Grain yield per plot}}{\text{Above ground biomass per plot}} * 100$$

Thousand kernel weights (g): weight in gram of random samples of thousand seeds per plot adjusted to 12.5% moisture content.

Data Analyses

Analysis of variance was done using Proc lattice and Proc GLM procedures of SAS version 9.0, (SAS, 2002) after testing the ANOVA assumptions. The difference between treatment means was compared using DMRT at 5% probability levels.

The model for lattice design is: Yil(j) = µ + ti + rj + (b|r)l(j) + eil(j)

Where, Yil (j) is the observation of the treatment i (i = 1, ., v = k2), in the block l (l = 1, ., k) of the replication j (j = 1, ., m);µ is a constant common to all observations; ti is the effect of the treatment i ;rjis the effect of the replication j;(b|r)l(j) is the effect of the block l of the replication j; eil(j)is the error associated to the observation Yil (j), where eil(j)~ N(0, s), independent.

Estimation of Phenotypic and Genotypic Correlations

Phenotypic and genotypic correlations between yield and yield related traits were estimated using the method described by Miller *et al*. (1958).

$$\text{rpxy} = \frac{\text{COVpxy}}{\sqrt{\sigma^2\text{px}.\sigma^2\text{py}}}$$

$$\text{rgxy} = \frac{\text{COVgxy}}{\sqrt{\delta^2\text{gx}.\delta^2\text{gy}}}$$

The coefficients of correlations at phenotypic level were tested for their significance by comparing the values of correlation coefficient with tabulated r-value at g-2 degree of freedom, where ‘g’ is number of genotypes. However, the coefficients of correlations at genotypic level were tested for their significance using the formula described by Robertson (1959) as described below:

$$\text{t} = \frac{\text{rgxy}}{\text{SErgxy}}$$

The calculated’ values were compared with the tabulated’’ values at g-2 degree of freedom at 5% level of significance. Where, g= number of genotypes, rgxy = genotypic correlation coefficient and SErgxy = standard error of genotypic correlation coefficient between character x and y which were calculated as:

SErgxy = $\sqrt{\frac{(1-r^2).^2}{2Hx^2.Hy^2}}$

Path Coefficient Analysis

The direct and indirect effect of yield related traits on grain yield per plot has been analyzed through path coefficient analysis. This analysis was computed as suggested by Dewey and Lu (1959) using the following formula**.**

$$r_{ij} = p_{ij} + \sum r_{ik} p_{kj}$$

The contribution of the remaining unknown factor was measured as residual effect. This was calculated as: Residual effect = $\sqrt{1-R^2}$ where $R^2 = \sum p_{ijr_{ij}}$

Results and Discussions

Analysis of Variance

The analysis of variance showed that, there was highly significant ($p \leq 0.01$) difference among the studied genotypes for days to first heading, days to heading, grain filling period, days to maturity, number of kernels per spike, plant height, spike length, awn length, grain yield, thousand kernel weight and harvest index (Table 2). Significant ($p \leq 0.05$) difference among genotypes was also observed for peduncle length. Similarly, Oettler *et al.* (2009) reported highly significant differences in barley genotype for grain yield, spikes/m^2, thousand kernel weight, dry matter, heading and plant height. However, the genotypes showed non significant difference for number of spikelet per spike, number of effective tillers and biological yield (Table 2). In harmony with this result, Dawit *et al*, (2012) reported non significant differences for biological yield and number of tillers per plant in durum wheat genotypes. Mesert (2015) was also reported non significant differences for biological yield, number of tillers per plant in food barley genotypes. The present findings indicated the existence of great variability among the tested genotypes for almost all characters measured, which could be exploited through selection, as variability with in populations is a basic requirement for plant breeding program on which selection depends to develop superior genotype for the studied area.

Table 18. Mean square values from analysis of variance (ANOVA), coefficient of variation (CV), and coefficient of determination (R^2) for 15 traits in 25 food barley genotypes grown at ATARC during the 2017/18 main cropping season.

Traits	Mean squares				
	Genotypes (df=24)	Replications (df=2)	Error (df=36)	Eff. (%)	R^2
Days to first flowering	33.58**	14.44*	4.11	97.45	0.88
Days to heading	52.61**	71.21**	9.22	99.84	0.85
Days to maturity	46.36**	9.45^{ns}	7.69	106.5	0.87
Grain filling period	33.82**	29.32^{ns}	9.99	110.35	0.78
Number of kernels per spike	168.73**	0.79^{ns}	38.54	106.86	0.77
Number of spikelet per spike	18.52^{ns}	50.20^{ns}	17.53	108.25	0.51
Plant height (cm)	143.47**	37.62^{ns}	58.35	103.98	0.73
Spike length (cm)	1.44**	0.54^{ns}	0.58	113.98	0.68
Number of effective tiller/ m^2	27330.41^{ns}	382135^{ns}	20934	100.91	0.72
Peduncle length (cm)	24.02*	30.95^{ns}	12.92	95.73	0.70
Awn length (cm)	2.14**	0.56^{ns}	0.56	102.4	0.80
Grain yield (kg ha^{-1})	3006294.33**	932421^{ns}	604639	116.54	0.80
Biological yield (kg ha^{-1})	5715842^{ns}	11166.62^{ns}	4814538.5	101.28	0.59
Thousand kernel weight	70.66**	12.84^{ns}	14	100.45	0.80
Harvest index (%)	218.20**	35.10^{ns}	50.24	114.01	0.79

df = degrees of freedom, *,** and ns, significant at $P \leq 0.05$, $P \leq 0.01$ and non-significant respectively, CV (%) = coefficient of variation, Eff. = Efficiency of Lattice design relative to RCBD.

Phenotypic and Genotypic Correlations of Yield with Phenologcal Traits

The present study revealed that grain yield (kg ha^{-1}) had highly significant ($P \leq 0.01$) and positive phenotypic and genotypic correlation with grain filling period (0.57) at phenotypic level and (0.67) at genotypic level. However, days to heading and days to first heading showed significant negative correlation with grain yield at both phenotype and genotype levels while positive non-significant for days to maturity. Indicating the both yield and days to maturity had independent QTL of their own, thus genetic effect on them was not similar. The negative correlations of grain yield with days to heading and first heading indicated that selection of genotypes for delayed days to heading might reduce grain yield. This result is in line with result of Azeb *et al.* (2016) who reported negative and significant correlation of grain yield with days to heading and days to maturity. Similarly, Bhutta and Ibrahim *et al.* (2005) reported negative correlation of grain yield with days to heading.

Phenotypic and Genotypic Correlations among Yield and Yield Components

Phenotypic and genotypic correlation coefficients between grain yield and yield components are presented in Table 3. Grain yield (kg ha^{-1}) had shown highly significant ($P \leq 0.01$) and positive phenotypic and genotypic correlation with thousand kernels weight (rg=0.46, rp=0.41), biological yield (rg=0.41, rp=0.44) harvest index (rg=0.83, rp=0.69). This indicates that simultaneous increase of thousand kernel weight, biological yield, harvest index and grain yield. These traits share the same quantitative trait loci (QTL) with that of grain yield and also the genetic influence on these traits was similar. Similarly, Solomon and Hanchinal (2013) also reported high and positive phenotypic (r=0.630) and genotypic (r=0.661) correlation of biomass yield with grain yield in wheat genotypes. Ataei (2006) and Yetsedaw *et al.* (2015) were also reported highly significant correlation between thousand seed weight and grain yield. Likewise, Jalal *et al.* (2012) and Budakli and Celik (2012) reported, positive and highly significant correlation of harvest index with grain yield.

Grain yield (kg ha^{-1}) had also shown highly significant ($P \leq 0.01$) and positive phenotypic correlation (0.323) and significant ($P \leq 0.05$) genotypic correlation (0.414) with number of kernels per spike indicating a concurrent increase of number of kernels per spike and grain yield. The present result agrees with that of Karim *et al.* (2012) who reported highly significant and positive phenotypic correlation (r=0.811) of number of seeds per spike with grain yield. Likewise, Yetsedaw *et al.* (2015) also reported significant and positive phenotypic correlation of number of seeds per plant with grain yield in malt barley. Grain yield showed positive but not significant correlation at genotypic and phenotypic levels with number of spikelet's per spike, number of effective tillers per meter square and peduncle length.

Phenotypic and Genotypic Correlations among Traits other than Yield

Days to maturity showed positive and strong phenotypic and genotypic correlation with days to first heading, days to heading, plant height, spikelet length, peduncle length and biological yield (Table 3). Similar results were also reported by Mohammed *et al.* (2011) and Desalegn *et al.* (2012) who found that biomass per plot was positively and significantly associated with days to maturity both at phenotypic and genotypic levels in durum wheat genotypes. Grain filling period had shown positive and strong phenotypic and genotypic correlation with harvest index, biological yield and peduncle length and also positive and significant correlation at phenotypic level with plant height, and thousand kernel weights while not significant correlation at genotypic level. Again, this trait had showed not significant correlation at both genotypic and phenotypic levels with number of kernels per spike, number of spikelet's per spike, spike length, number effective tillers per meter square and awn length.

Number of kernels per spike exhibited positive and significant correlation at phenotype level with awn length and harvest index while not significant correlation with other traits both at genotypic and phenotypic levels. Plant height had showed positive and strong phenotypic and genotypic correlations with days to first heading, days to heading, days to maturity, peduncle length and biological yield, whereas; it showed strong phenotypic correlation with grain filling period and negative and not significant correlation at genotypic level with grain filling period. Peduncle length had showed positive and significant correlation at phenotypic level with days to first heading, days to heading, days to maturity, plant height and biological yield. Besides, this trait had shown strong phenotypic correlation with grain filling period, spike length and awn length whereas it had showed non-significant correlation at genotypic level. Peduncle length had shown not significant correlation with the number of kernels per spike, number of spikelet's per spike, effective tillers per m^2 thousand kernel weight and harvest index. In harmony with this study, Yetsedaw *et al.* (2015) also reported correlation among yield components like spike length with plant height, number of kernel with plant height, number of tillers with plant height, number of kernels with spike length and number of tillers with spike length.

Path Coefficient Analysis

Phenotypic Path Coefficient Analysis of Grain Yield with Other Traits

Phenotypic path splits the phenotypic correlation coefficient into the measures of direct and indirect effects. The phenotypic path coefficient analysis (Table 4) showed that biological yield (0.83), 1000-kernel weight (0.78), plant height (0.51), grain filling period (0.42), and number of kernels per spike (0.30) exerted highest positive direct effect on grain yield. Harvest index (0.20) exerted moderate direct effect on the yield while biological yield, plant height, number of kernel per spike and grain filling period exerted highest and positive direct effect on grain yield, and showed positive and high significant phenotypic correlation with grain yield. Azeb *et al.* (2016) reported highest positive direct effect from biological yield (0.846) with a positive genotypic correlation coefficient of 0.649 in barley genotypes. This is also in agreement with Budakli and Celik (2012) who reported the direct effect of plant height (0.26) on grain yield in barley. Similarly, Solomon and Hanchinal (2013) also reported a strong positive direct effect of biomass yield and harvest index on grain yield in wheat. Besides, Raham (2015) also reported a high positive direct effect (0.26) of days to maturity on grain yield in barley. The role of other independent variables or grain yield related component which had not been included in this experiment were expected to influence grain yield only by 25%. From this result the residual value was relatively high and this was because most of the traits were not included in the analysis.

Genotypic Path Coefficient Analysis of Grain Yield with Other Traits

Path coefficient analysis (Table 5) shows the extent of direct and the indirect effect of the causal factor on the response component. The results of genotypic path coefficient analysis of grain yield with other traits are presented. Genotypic path coefficient analysis showed that number of kernels per spike (0.41) exerted highest positive direct effect on grain yield. Harvest index (0.28) and thousand kernel weight (0.25) exerted moderate direct effect on yield according to Dewey and Lu (1959) classification. The present finding is in agreement with Ataei (2006) who reported direct positive effect of thousand kernel weight, harvest index and number of kernels per spike on grain yield. Buttha and Ibrahim (2005) also reported significant positive correlation between grain yield and 1000- kernel weight, and number of kernels per spike in six- rowed barley genotypes.

The traits with highly negative direct effects on grain yield were days to first heading (-0.54). Days to heading (-0.02) exerted negative direct effect and negligible effect on grain yield and had negative genotypic correlation with grain yield where this finding is in agreement with Buttha and Ibrahim (2005) who reported negative direct effect of days to heading on grain yield and also a negative genotypic correlation with grain yield.

Table 3.Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients of 15 yield and yield related in 25 food barley genotypes tested at ATARC during 2017/18 cropping season

Trait	DFH	DH	DM	GFP	NKPS	NSPS	PH	SPL	ET	PL	AL	GY	BY	TKW	HI
DFH	1	0.953**	0.728**	-0.319^{ns}	-0.149^{ns}	-0.15^{ns}	0.575*	0.436*	0.163 ^{ns}	0.418*	0.305 ^{ns}	-0.419*	0.459*	-0.32 ^{ns}	-0.73**
DH	0.829**	1	0.707**	-0.408*	-0.219^{ns}	-0.069^{ns}	0.515**	0.393*	0.195 ^{ns}	0.435*	0.292 ^{ns}	-0.48**	0.416*	-0.36 ^{ns}	-0.76**
DM	0.672**	0.627**	1	0.358^{ns}	0.002^{ns}	0.031^{ns}	0.655**	0.535**	0.312 ^{ns}	0.597**	0.211 ^{ns}	0.027 ^{ns}	0.679**	0.04 ^{ns}	-0.37 ^{ns}
GFP	-0.223*	-0.476**	0.386**	1	0.291^{ns}	0.131^{ns}	0.165^{ns}	0.171^{ns}	0.145 ^{ns}	0.19 ^{ns}	-0.13 ^{ns}	0.670**	0.328 ^{ns}	0.539**	0.526**
NKPS	-0.124^{ns}	-0.146^{ns}	0.015^{ns}	0.190^{ns}	1	0.033^{ns}	0.083^{ns}	-0.001^{ns}	-0.103^{ns}	-0.09^{ns}	0.27^{ns}	0.544*	0.117 ^{ns}	-0.15 ^{ns}	0.380 ^{ns}
NSPS	-0.136^{ns}	-0.042^{ns}	-0.005^{ns}	0.044^{ns}	0.098^{ns}	1	-0.099^{ns}	-0.218^{ns}	0.323 ^{ns}	0.06 ^{ns}	-0.07 ^{ns}	0.058 ^{ns}	0.003 ^{ns}	0.212 ^{ns}	0.039 ^{ns}
PH	0.449**	0.351**	0.568**	0.226*	0.164^{ns}	0.051^{ns}	1	0.373^{ns}	0.355 ^{ns}	0.80**	0.30 ^{ns}	0.715**	0.715**	-0.28 ^{ns}	-0.19 ^{ns}
SPL	0.383**	0.350**	0.494**	0.144^{ns}	0.069^{ns}	-0.056^{ns}	0.340**	1	0.101 ^{ns}	0.37 ^{ns}	-0.03 ^{ns}	0.180 ^{ns}	0.18 ^{ns}	-0.12 ^{ns}	-0.3 ^{ns}
ET	0.088 ^{ns}	0.012 ^{ns}	0.166 ^{ns}	0.174 ^{ns}	-0.02 ^{ns}	-0.13 ^{ns}	0.216 ^{ns}	0.044 ^{ns}	1	0.31 ^{ns}	-0.07 ^{ns}	0.328 ^{ns}	0.614**	-0.03 ^{ns}	-0.02 ^{ns}
PL	0.358**	0.319**	0.532**	0.223**	0.018 ^{ns}	0.185 ^{ns}	0.781**	0.372**	0.151 ^{ns}	1	0.27 ^{ns}	0.089 ^{ns}	0.487**	-0.19 ^{ns}	-0.14 ^{ns}
AL	0.220*	0.212 ^{ns}	0.204 ^{ns}	-0.020 ^{ns}	0.270**	0.102 ^{ns}	0.343**	0.030 ^{ns}	0.028 ^{ns}	0.35**	1	-0.18 ^{ns}	0.214 ^{ns}	-0.385*	-0.26 ^{ns}
GY	-0.31**	-0.420**	0.069 ^{ns}	0.570**	0.423**	0.091 ^{ns}	0.350*	-0.01 ^{ns}	0.200^{ns}	0.19 ^{ns}	-0.08 ^{ns}	1	0.711*	0.456*	0.831**
BY	0.326**	0.189 ^{ns}	0.514**	0.36**	0.097 ^{ns}	0.095 ^{ns}	0.621**	0.229*	0.41*	0.49**	0.236*	0.444**	1	0.041 ^{ns}	-0.16 ^{ns}
TKW	-0.258*	-0.254*	0.089 ^{ns}	0.40**	-0.136 ^{ns}	0.102 ^{ns}	-0.11 ^{ns}	-0.01 ^{ns}	0.01 ^{ns}	-0.04 ^{ns}	-0.25*	0.41**	0.093 ^{ns}	1	0.400*
HI	-0.57**	-0.568**	-0.309**	0.32**	0.266*	-0.005 ^{ns}	-0.195 ^{ns}	-0.16 ^{ns}	-0.11 ^{ns}	-0.16 ^{ns}	-0.25*	0.68**	-0.31**	0.30**	1

*, ** and ns, significant at 5%, 1% probability level and non-significant, respectively, **DFH** = Days to first heading, **DH**= Days to heading, **DM**= Days to maturity, **GFP** = Grain filling period, **NKPS**= Number of kernel per plant, **NSPS**= Number of spikelet per spike, **PH**= Plant height (cm), **SPL**= Spike length (cm), **ET**= Effective tiller (m$^{2)}$ **PL** = Peduncle length (cm) **AL**= Awn length (cm), **GY**= Grain yield (kg/ha), **BY**= Biological yield (kg/ha), **TKW**= Thousand kernel weight (g), **HI** = Harvest index (%).

Table 4. Estimates of direct (bold diagonal) and indirect effect (off-diagonal) at phenotypic level of 8 traits on grain yield of 25 food barley genotypes tested at ATARC (2017/18).

Traits	DFH	DH	GFP	NKPS	PH	BY	TKW	HI	rp
DFH	**-0.11**	-0.22	-0.09	-0.04	0.24	0.27	-0.20	-0.16	-0.31**
DH	0.00	**-0.26**	-0.20	-0.04	0.19	0.37	-0.20	0.11	-0.04**
GFP	0.15	0.12	**0.42**	0.06	0.12	0.30	0.31	-0.06	0.57**
NKPS	0.00	0.04	0.08	**0.30**	0.09	0.08	-0.11	-0.05	0.42**
PH	-0.33	-0.09	0.09	0.05	**0.54**	0.15	-0.08	0.04	0.35*
BY	-0.34	-0.05	-0.50	0.03	0.34	**0.83**	0.07	0.06	0.44**
TKW	-0.42	0.07	0.17	-0.04	-0.06	0.08	**0.78**	-0.06	0.40**
HI	0.23	0.15	0.14	0.08	-0.11	-0.26	0.24	**0.20**	0.68**

Residual= **0.25,** * and ** and significant at 5%, 1% probability level respectively, **rp=** phenotypic correlation**, DFH** = Days to first heading, **DH**= Days to heading, **GFP** = Grain filling period, **NKPS**= Number of kernel per plant, **PH**= Plant height (cm), **BY**= Biological yield (kg/ha), **TKW**= Thousand kernel weight (g), **HI** = Harvest index (%).

Biological yield, harvest index, 1000- kernel weight and plant height had positive and significant genotypic correlation with grain yield (rg= 0.71), (rg= 0.83), (rg= 0.45) and (rg= 0.71) respectively and coinciding with having higher and positive direct effect on the grain yield. Hence, this result suggested that selection of genotypes with high biological yield, harvest index, 1000- kernel weight and plant height will lead to improvement of grain yield in barley. In harmony with this Ataei (2006) reported biological yield, harvest index, 1000- kernel weight and plant height showing positive and significant genotypic correlation with grain yield and had higher positive direct effect on the grain yield. Budakli and Celik (2012) also reported the indirect effect of harvest index, number of kernel per spike and plant height in barley. Azeb *et al*, (2016) reported that biological yield had the highest positive direct effect on grain yield (0.749) followed by harvest index (0.508). Genotypic correlations were also positive and significant, r=0.944 and 0.836, respectively.

Biological yield exerted moderate positive indirect effect on grain yield through plant height, grain filling period and days to maturity and had positive genotypic correlation coefficient and showed strong and high positive direct effect. Similarly, Ataei (2006) reported that biological exerted positive indirect effect on grain yield *via* plant height, number of kernel per pike, and 1000- kernel weight. The indirect effect of 1000-kernel weight and harvest index *via* all the parameters measured were almost negligible. The genotypic correlation coefficients were had with grain yield was significant and strong positive. Hence, the correlation it had with grain yield was largely due to the direct effect. Direct selection through these traits will be employed if the improvement of the grain yield is wanted. The results of residual effects (R = 0.20) revealed that 80% of the yield of barley was contributed by the characters studied in this experiment. The role of other independent variables or grain yield related components which had not been included in this analysis were expected to influence grain yield only by 20%.

Table 5. Estimates of direct (bold diagonal) and indirect effect (off diagonal) at genotypic level of traits 8 on grain yield of 25 food barley genotypes tested at ATARC (2017/18).

Traits	DFH	DH	GFP	NKPP	PH	BY	TKW	HI	Rg
DFH	**-0.54**	-0.02	-0.10	-0.08	0.12	0.10	-0.08	0.20	-0.41*
DH	-0.17	**-0.02**	-0.10	-0.09	0.10	0.10	-0.09	-0.21	-0.48**
GFP	0.16	0.01	**0.25**	0.12	0.08	0.09	0.13	0.32	0.67**
NKPS	0.01	0.00	0.05	**0.41**	0.02	0.01	-0.04	0.11	0.41*
PH	0.38	-0.01	0.05	0.03	**0.20**	0.18	-0.07	-0.05	0.71**
BY	0.24	-0.01	0.05	0.05	0.16	**0.25**	0.01	-0.04	0.40*
TKW	0.12	-0.01	-0.03	-0.06	0.06	0.01	**0.25**	0.11	0.45*
HI	0.11	-0.01	0.08	0.16	0.14	-0.04	0.10	**0.28**	0.83**

Residual= **0.20,** * and ** and significant at **5%, 1%** probability level respectively, **rg=** genotypic correlation**, DFH** = Days to first heading, **DH**= Days to heading, **GFP** = Grain filling period, **NKPS** = Number of kernel per plant, **PH**= Plant height (cm), **BY**= Biological yield (kg/ha), **TKW**= Thousand kernel weight (g), **HI** = Harvest index (%).

Conclusions

The analysis of variance revealed that there were sufficient variations among food barley genotypes for grain yield and yield related traits. There were highly significant variation among genotypes for days to first heading, days to heading, grain filling periods, days to maturity, number of kernel per spike, plant height, spike length, awn length, grain yield, thousand kernel weight and harvest index. Study of relationship between yield and yield contributing characters in food barley through genotypic and phenotypic correlations suggests that grain yield (kg ha^{-1}) had shown highly significant ($P \leq 0.01$) and positive phenotypic and genotypic correlation with thousand kernels weight, biological yield, plant height and harvest index. Thus implies that the genetic influence on these traits was similar and grain yield could be improved directly by improving these traits. The negative correlations of grain yield with days to heading and days to first heading indicated that selection of genotypes for delayed days to heading might reduce grain yield. The phenotypic path coefficients reveal that biological yield, 1000-kernel weight, number of kernel per spike, plant height and grain filling period exerted highest positive direct effect on grain yield. The result of relationship between yield, yield related characters and *via* genotypic path coefficients indicated that biological yield, harvest index, 1000- kernel weight, plant height and number of kernel per spike exerted highest positive direct effect on grain yield in coinciding with positive and significant genotypic correlation with grain yield. The residual effect was 0.25 and 0.20 at genotypic and at phenotypic levels respectively. This showed that the eight traits explained 75% at genotypic and 80% at phenotypic levels of the variability in grain yield.

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Genotype-Environment Interaction and Stability Analysis of Grain Yield of black cumin (*Nigella sativa L.*) genotypes

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Abstract

Yield data of 12 black cumin (Nigella sativa L.) genotypes tested across nine rain-fed environments during the 2007-2009 growing seasons using RCBD in 3 replications were analyzed using the AMMI model. The AMMI analysis tested in nine environments (years and locations) showed that, grain yield was significantly affected (P< 0.001) by genotypes and environment main effects, but non-significantly affected by GxE interaction . The model revealed that, variations due to environments accounted for about 85.63% of the treatment sum of squares. The genotypes and the GxE interaction also accounted for 5.17% and 9.2% respectively of the treatment Sum of Squares. The first Principal Component Axis (PCA 1) of the interaction captured 49.15% of the interaction sum of squares. Similarly,the second Principal Component Axis (PCA2) explained about 17.30% of the GEI sum of squares. The mean squares for the PCA 1 and PCA 2 were cumulatively contributed about 66.43% of the GxE interaction SS, leaving 33.57% of the variation to the GxE interaction in the residual. The AMMI and AMMI stability value (ASV) identified genetype 20750-1(G1) as the most stable and high yielding genotype. Therefore, this genotypes is recommended for release in Bale midlands and similar agroecologies

Key words: AMMI, ASV, yield, biplot, genotypes, GxE interaction, PCA.

Introduction

Plant breeders invariably encounter genotype x environment interactions (GEIs) when testing varieties across a number of environments. Depending on the interactions or the differential genotypic responses to environments, the varietal ranking can differ greatly across environments. In field crop trials, this interaction is often analysed with the aim of determining the stability of the genotypes especially when there is a reasonable genotype by environment interaction (GEI). A combined analysis of variance (ANOVA) can quantify the interactions, and describe the main effects. However, analysis of variance is uninformative for explaining GEI. Various statistical methods (parametric and non-parametric) have been proposed to study Genotype × environment interactions (Mohammadi and Amri, 2008; Mohammadi et al., 2010). The main problem with stability statistics is that, they don't provide an accurate picture of the complete response pattern (Hohls, 1995). The reason is that a genotype's response to varying environments is multivariate (Lin et al., 1988) whereas the stability indices are usually univariate (Gauch, 1988; Crossa, 1990). Since the genotype response to environmental variations is usually multivariate, therefore, a multivariate method of analysing genotype stability across environments will be the best option. One of the multivariate techniques is the Additive Main effects and Multiplicative Interaction (AMMI) model.

AMMI analysis reveals a highly significant interaction component that has a clear agronomic meaning and it has no specific design requirements, except for a two way data structure. The AMMI analysis is a combination of analysis of variance (ANOVA) and Principal Component Analysis (PCA) in which the sources of variability in genotype by environment interaction are partitioned by PCA. The AMMI is, therefore, also known as interaction PCA (Gauch and Zobel, 1990), and can have several models: AMMI0, which estimates the additive main effect of genotypes and environments, and does not include any principal component axis (IPCA); AMMI1, which combines the additive main effects from AMMI0 with the genotype by environment interaction effects estimated from the first principal component axis (IPCA 1); AMMI2, and so forth, until the full model with all IPCA axis (Gauch,1988). It has both linear and bilinear component of GEI and hence very useful in visualizing multi-environment data (understanding complex GEI and determining which genotype won which environment) and gaining accuracy (improving cultivar recommendation and accelerating progress) (Gauch, 2006). The additive main effects and multiplicative interactions (AMMI) is defined as a powerful tool for effective analysis and interpretation of multi-environment data structure in breeding programs (Ebdon and Gauch, 2002; Samonte et al., 2005; Yan et al., 2000; Zobel et al., 1988). This present study is therefore, initiated with the following objective:

Objective: To evaluate, select and verify promising accessions/lines with desirable traits.

Materials and methods

Twelve Black cumin genotypes were evaluated at three locations (Sinana on station, Goro and Ginniir) for three consecutive years (2007-2009) during *bona* production season following selection method. The trial was laid out in RCB design with three replications. Data were collected from central two rows. Data were also subjected to analyses of variance using GENSTAT soft ware program. Duncan's multiple range tests was done for grain yield to see the mean differences among the tested genotypes. The genotype by environment interaction analyses (GxE) and stability analyses were conducted using the AMMI model.

Results and Discussion

The AMMI analysis tested in nine environments (years and locations) showed that, grain yield is significantly affected ($P < 0.001$) by genotypes and environment main effects. The model revealed that differences between the environments accounted for about 85.63% of the treatment sum of squares. The genotypes and the GxE interaction was also accounted significantly for 5.17% and 9.2% respectively of the treatment Sum of Squares. The first principal component axis (PCA 1) of the interaction captured 49.15% of the interaction sum of squares. Similarly, the second principal component axis (PCA2) explained a further 17.30% of the GEI sum of squares. The mean squares for the PCA 1 and PCA 2 were cumulatively contributed for 66.43% of the GxE interaction SS, leaving 33.57% of the variation in the GxE interaction in the residual (Table 1).

Table1. Combined analysis of variance of yield data of 12 black cumin genotypes tested across 9 environments.

Source	df	SS	MS	F	F_prob	% Explained
Total	323.0	20732.0	64.2	*	*	
Treatments	107.0	12144.0	113.5	8.36	0	
Genotypes	11.0	628.0	57.1	4.21	0.00001	5.2
Environments	8.0	10399.0	1299.9	3.97	0.00022	85.6
Block	18.0	5900.0	327.8	24.14	0	
Interactions	88.0	1117.0	12.7	0.93	0.63575	9.2
IPCA1	18.0	549.0	30.5	2.25	0.00357	49.1
IPCA2	16.0	193.0	12.0	0.89	0.58563	17.3
Residuals	54.0	375.0	6.9	0.51	0.99775	33.6
Error	198.0	2688.0	13.6	*	*	

The presence of significant differences for grain yield among genotypes and environments reveals not only the amount of variability that existed among environments but also the presence of genetic variability among the genotypes.

Table 2. Environment means and IPCs scores

NE	Environment	Mean	IPCAe[1]	IPCAe[2]
E1	Ginir 2007	12.14	1.4412	-1.57873
E2	Ginir 2008	23.01	1.57605	1.54517
E3	Ginir 2009	22.31	-1.94527	0.2453
E4	Goro 2007	12.27	0.3324	0.05322
E5	Goro 2008	29.28	-0.50008	-1.50471
E6	Goro 2009	17.43	0.97296	0.19085
E7	Sinana 2007	24.31	-0.18126	0.84039
E8	Sinana 2008	13.88	0.24926	-0.03679
E9	Sinana 2009	22.31	-1.94527	0.2453

The AMMI model 1 biplot of the varietal trial was depicted in Figure 1. The abscissa shows the main effects while the ordinate shows the first PCA axis. The environments showed much variability in both main effects and interactions, however; the high potential environments were sparsely distributed in quadrant II and III, while the lower potential environments were also sparsely distributed in quadrants I and IV with high IPCA1 values (Figure 1).

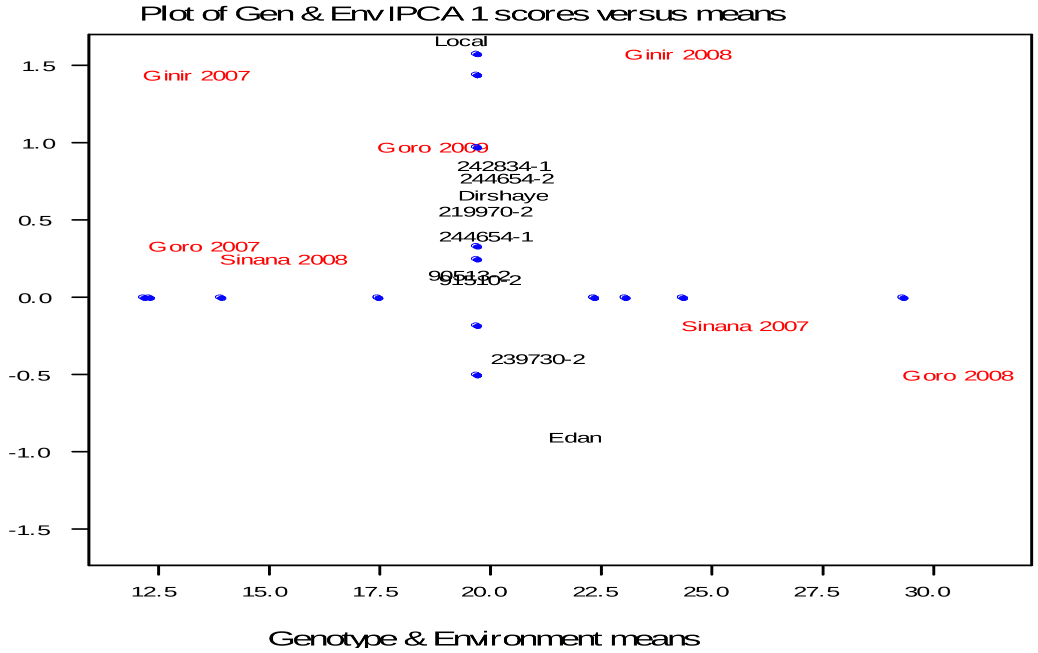

Figure 1. AMMI model I biplot of the yield of 12 black cumin genotypes evaluated in 9 environments.

Table 3. AMMI yield mean, AMMI stability values (ASV), and ranking orders of the 12 Genotypes tested across 9 environments.

Code	Genotype	Means (yield Qt/ha)	rank	IPCAg[1]	IPCAg[2]	ASV
G1	20750-1	23.63	1	0.11436	-0.96852	1.021692
G2	219970-2	18.82	9	-2.03179	-0.84074	5.840378
G3	239730-2	21.3	2	0.55986	0.54792	1.684176
G4	242834-1	19.23	7	0.14749	-0.44087	0.608591
G5	244654-1	18.83	8	-1.84124	1.29503	5.395247
G6	244654-2	19.3	5	0.39639	-0.19447	1.144202
G7	90513-2	18.58	12	1.66302	-0.14804	4.732875
G8	91510-2	18.82	10	0.66199	-0.4688	1.940548
G9	Darbera	19.45	4	0.85396	0.68312	2.523366
G10	Dirshaye	19.25	6	0.77537	0.20045	2.214676
G11	Edan	19.99	3	-0.90372	-1.12721	2.80696
G12	Local	18.72	11	-0.3957	1.46213	1.845205

In ASV method, a genotype with least ASV score is the most stable, accordingly genotype G7, followed by G1 were the most stable; while G9 scores the higher ASV and the most unstable genotype. In addition, G1 is the higher yielding genotype. Therefore, release of G1 genotype for production in the mid and lowlands of Bale will result in increased production and productivity of black cumin in the country.

Conclusions and Recommendations

AMMI analyses revealed the most stable and high yielding genotypes over ranges of environments. That is genotype G1. Therefore, release of this genotypes for production in the mid and lowlands of Bale will result in increased production and productivity of black cumin in the country. It can be concluded and recommended from this study that genotypes should be selected for wider adaptations.

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

Genotype-Environment Interaction and Stability Analysis for Grain Yield of coriander(*Coriandrum sativum L.)* genotypes

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Abstract

Yield data of ten coriander (Coriandrum sativum L.) genotypes were tested across nine rain-fed environments during the 2007-2009 growing seasons using RCBD in 3 replications and were analyzed using the AMMI model. The AMMI analysis tested in nine environments (years and locations) were showed that, the yield is significantly affected (P< 0.001) by genotypes and environment main effects as well as GxE interaction. The model revealed that, variations among the test environments accounted for about 58.16% of the treatment sum of squares. The genotypes and the GxE interaction also accounted for 12.79 % and 29.05% respectively of the treatment Sum of Squares. The first Principal Component Axis (PCA 1) of the interaction captured 41.97% of the interaction sum of squares. Similarly,the second principal component axis (PCA2) explained further 39.05% of the GEI sum of squares. The mean squares for the PCA 1 and PCA 2 were significant at P =0.01 and cumulatively contributed for about 81.02% of the GxE interaction Sum of Squares, leaving 18.98% of the variation in the GxE interaction in the residual. The AMMI and AMMI stability value (ASV) identified genotypes G8 and G3 as the stable and high yielding genotypes. Therefore, these genotypes were recommended for release in Bale midland and lowland areas as well as areas with similar agroecologies.

Key words*:* AMMI, ASV, yield, biplot, genotypes, GxE interaction, PCA.

Introduction

Plant breeders invariably encounter genotype x environment interactions (GEIs) when testing varieties across a number of environments. Depending on the interactions or the differential genotypic responses to environments, the varietal ranking can differ greatly across environments. In field crop trials, this interaction is often analysed with the aim of determining the stability of the genotypes especially when there is a reasonable genotype by environment interaction (GEI). A combined analysis of variance (ANOVA) can quantify the interactions, and describe the main effects. However, analysis of variance is uninformative for explaining GEI. Various statistical methods (parametric and non-parametric) have been proposed to study Genotype × environment interactions(Mohammadi and Amri, 2008; Mohammadi et al., 2010). The main problem with stability statistics is that they don't provide an accurate picture of the complete response pattern (Hohls, 1995). The reason is that a genotype's response to varying environments is multivariate (Lin et al., 1988) whereas the stability indices are usually univariate (Gauch, 1988; Crossa, 1990). Since the genotype response to environmental variations is usually multivariate, therefore, a multivariate method of analysing genotype stability across environments will be the best option. One of the multivariate techniques is the AMMI (additive main effects and multiplicative interaction) model.

AMMI analysis reveals a highly significant interaction component that has a clear agronomic meaning and it has no specific design requirements, except for a two way data structure. The AMMI analysis is a combination of analysis of variance (ANOVA) and principal component analysis (PCA) in which the sources of variability in genotype by environment interaction are partitioned by PCA. The AMMI is, therefore, also known as interaction PCA (Gauch and Zobel, 1990), and can have several models: AMMI0, which estimates the additive main effect of genotypes and environments, and does not include any principal component axis (IPCA); AMMI1, which combines the additive main effects from AMMI0 with the genotype by environment interaction effects estimated from the first principal component axis (IPCA 1); AMMI2, and so forth, until the full model with all IPCA axis (Gauch,1988).It has both linear and bilinear component of GEI and hence very useful in visualizing multi-environment data (understanding complex GEI and determining which genotype won which environment) and gaining accuracy (improving cultivar recommendation and accelerating progress) (Gauch, 2006). The additive main effects and multiplicative interactions (AMMI) is defined powerful tool for effective analysis and interpretation of multi-environment data structure in breeding programs (Ebdon and Gauch, 2002a; Samonte et al., 2005H; Yan et al., 2000; Zobel et al., 1988). Therefore, the present study was initiated with the following objective:

Objective: To evaluate, select and verify promising accessions/lines with desirable traits.

Materials and methods

Ten coriander genotypes were evaluated at three locations (Sinana on station, Goro and Ginniir) for three consecutive years (2007-2009) during *bona* production season following selection method. The trial was laid out in RCB design with three replications. Data were collected from central two rows and subjected to analyses of variance using GENSTAT soft ware program. Duncan's multiple range test was done for grain yield to test genotypes means. The genotype by environment interaction analyses (GxE) and stability analyses were conducted using the AMMI model.

Results and Discussion

The AMMI analysis tested in nine environments (years) were showed that the yield was significantly affected ($P< 0.001$) by genotypes and environment main effects as well as GxE interaction . The model revealed that differences between the environments accounted for about 58.16% of the treatment sum of squares. The genotypes and the GxE interaction also accounted significantly for 12.79 % and 29.05% respectively of the treatment SS. The first principal component axis (PCA 1) of the interaction captured 41.97% of the interaction sum of squares. Similarly,the second principal component axis (PCA2) explained a further 39.05% of the GEI sum of squares. The mean squares for the PCA 1 and PCA 2 were significant at $P =0.01$ and cumulatively contributed to 81.02% of the GxE interaction SS, leaving 18.98% of the variation in the GxE interaction in the residual (Table 1).

Table 1. Combined analysis of variance of yield data of coriander genotypes tested across nine environments.

Source	df	SS	MS	F	F_prob	%explained
Total	269	14082	52.3	*	*	
Treatments	89	9211	103.5	4.26	0	
Genotypes	9	1178	130.9	5.39	0	12.79
Environments	8	5357	669.6	12.84	0	58.16
Block	18	938	52.1	2.15	0.0064	
Interactions	72	2676	37.2	1.53	0.0139	29.05
IPCA(1)	16	1123	70.2	2.89	0.0003	41.97
IPCA(2)	14	1045	74.7	3.08	0.0003	39.05
Residuals	42	508	12.1	0.5	0.9953	18.98
Error	269	14082	52.3	*	*	

The presence of significant differences for grain yield among genotypes and environments reveals not only the amount of variability that existed among environments but also the presence of genetic variability among the genotypes.

Table 2. Environment means and scores

Code	Environment	Mean	IPCAe[1]	IPCAe[2]
E1	Ginir 2007	15.34	-0.29222	0.8799
E2	Ginir 2008	20.85	1.44524	1.30762
E3	Ginir 2009	14.86	-3.72563	0.04384
E4	Goro 2007	14.97	-0.02069	0.53685
E5	Goro 2008	13.66	0.26492	0.82639
E6	Goro 2009	17.87	1.68111	0.388
E7	Sinana 2007	17.53	0.00509	-0.91474
E8	Sinana 2008	19.38	0.62822	-3.71502
E9	Sinana 2009	29.12	0.01397	0.64716

The AMMI model 1 biplot of the varietal trials was demonstrated in Figure 1. The abscissa shows the main effects while the ordinate shows the first PCA axis. The environments showed much variability in both main effects and interactions. However, the high potential environments were sparsely distributed in quadrant II and III, while the lower potential environments were also sparsely distributed in quadrants I and IV with high IPCA1 values (Figure 1).

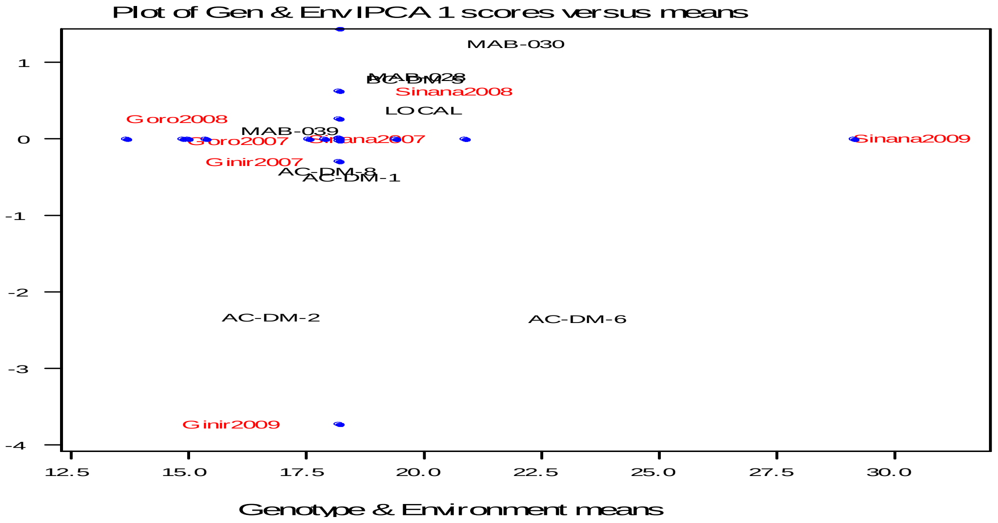

Figure 1. AMMI model I biplot of the yield of coriander genotypes evaluated in nine environments.

Table 3. AMMI yield mean, AMMI stability values (ASV), and ranking orders of the 10 Genotypes tested across nine environments.

G	Genotype	Yield(Qt/h)	IPCAg[1]	IPCAg[2]	ASV
G1	AC-DM-1	17.41	-0.5	-1.07	1.197336
G2	AC-DM-2	15.7	-2.33	1.99	3.198388
G3	AC-DM-6	22.21	0.82	-0.55	1.038761
G4	AC-DM-8	16.89	-0.42	-0.41	0.609767
G5	BC-DM-5	18.75	0.79	0.49	0.980227
G6	LOCAL	19.16	0.38	-1.43	1.487165
G7	MAB-028	18.8	-2.34	-1.37	2.863637
G8	MAB-030	20.9	1.25	-1.27	1.84861
G9	MAB-039	16.09	0.11	2.43	2.432874
G10	WALTA'I	15.82	2.24	1.19	2.685273

In ASV method, a genotype with least ASV score is the most stable, accordingly genotype G4, followed by G5 were the most stable. But G3 and G8 is high yielder and medium ASV. Therefore, release of this genotype for production in the mid and lowlands of Bale will result in increased production and productivity of coriander in the country.

Conclusions and Recommendations

AMMI analyses revealed the stable and high yielding genotypes over ranges of environments. That is genotypes G3 and G8. Therefore, release of this genotypes for production in the mid and lowlands of Bale will result in increased production and productivity of coriander in the country. It can be concluded and recommended from this study that genotypes should be selected for wider adaptations.

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Registration of ‘Tulu’ (207515)- Newly Released Medium Maturing Coriander (*Coriandrum sativum* L.) variety for mid Rift valley of Oromia.

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Abstract

Tulu is the name given to newly released medium maturing coriander variety released by Adami Tulu agricultural research center in 2017/18 from the selection made among coriander germplasm received from Ethiopian Biodiversity Institute. Twenty four coriander genotypes were tested along with one standard check for two years at four locations (Adami Tulu, Arsi Negele, Bute and Umbure) of mid rift valley of Oromia. The combined analysis over locations revealed significant variation among the genotypes for *mean seed yield and other agronomic traits. Tulu gave highest mean yield as compared to the remaining entries. During variety verification trial, this variety was most preferred varieties by the farmers as compared to the checks in the trial. It was evaluated both on farmer's field and on research station during variety verification trial along with check (Waltai) during 2017 cropping season and was officially released in 2018 for the mid to highlands of Oromia and similar agro ecologies.*

Key words: Coriander, Medium maturing, Variety verification

Introduction

Coriander (*Coriandrum sativum* L, 2n=2x=22) is a diploid annual plant, belongs to the Apiaceae/Umbliferae family medicinal plant native to Mediterranean and Western Asian regions & cultivated worldwide. Coriander plays an important role in the Ethiopian domestic spice trade. Coriander seeds are used for the flavoring of: 'berbere' (which is a spiced, hot red pepper powder used for numerous meat and vegetarian dishes), 'injera', cakes and bread. Critical evaluation of available selections of improved types with high yield potential/ traits is of great value to the breeder for crop improvement (Moniruzzaman, 2013). Mengesha and Getinetalemaw (2010) evaluated some Ethiopian coriander genotypes and reported that identification and evaluation of elite or promising genotypes for yield and quality is an important crop improvement strategy. Even though Ethiopia is one of the centers of origin of coriander, research attention given to this crop was very low till recent time Sarada and Giridhar (2011). Thus it is crucial for breeders to develop and release medium maturing coriander for mid to highland parts of Oromia.

Materials and Methods

The coriander Variety Verification Trial was conducted at four locations; Adami Tulu, Arsi Negele, Bute and Umbure under rain fed condition in 2017 main cropping season at both on station and farmers' field. Non replicated 10m x10m plots were used. Weeds were controlled by hand weeding. Data were collected on both plot and plant basis.

Results and Discussions

The combined analysis over locations revealed that there was significant variation among the genotypes for mean seed yield and other agronomic traits. From the two years data, accession number **207515** showed consistence and stable performance over the check (Waltai). The verification trial after being evaluated by the National Variety Releasing Committee, the genotype was released for the mid to highlands of mid rift valley of Oromia and similar agro ecologies. The variety was released under the name "**Tulu**" for production and cultivation.

Yield Performance

The newly released variety Tulu'had yield advantage of 43.65% over the standard check (Waltai). It has similar uniform agronomic characters such as: plant height, number of umbel per plant, lodging resistance and wider adaptation. Detail agronomic and morphological description of the newly released variety 'Tulu' is presented in Table 1.

Table 1. Agronomic and Morphological characteristics of newly released medium maturing coriander variety (Tulu)

1. Crop: Coriander
2. Variety: **Tulu** (207515)
3. Agronomic and morphological characteristics
    - Adaptation area: Mid to highland areas
    - Altitude (m.a.s.l): 1600-2500m
    - Rainfall (mm): 750-1500
    - Seed rate (kg/ha): 12kg/ha
    - Planting date: Early to mid-June
    - Fertilizer rate (Kg/ha): No
    - Days to flowering: 65
    - Days to maturity: 120
    - Plant height: 125
    - Growth habit: Annual herb
    - Seed color: Light green
    - Grain type:
    - Crop pest reaction: No pests observed
    - Yield (t/ha)
        - Research field (average): 15qtls/ha
        - Farmers field (average):12.28qtls/ha

Year of release: 2018
Breeder/maintainer: Adami Tulu Agricultural Research Center/OARI

Quality Characteristics:

It has higher essential oil and fatty acid content.

Reaction to disease:

Tolerant to major diseases and insect pests.

Adaptation and Agronomic Recommendations

Newly released coriander variety, Tulu is recommended for Adami tulu, Arsi Negele, Bute, Umbure and areas with similar agro ecologies. It is well adapted in altitude ranging from 1600-2500 m.a.s.l. with annual rainfall amount ranging from 750-1500mm. Recommended seed rate is 12kg/ha. Planting time early to mid-June

Conclusion

Tulu variety was officially released in 2018 for its higher and stable seed yield performance, higher essential oil and fatty acid contents over the check.

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Sarada, C. and G. Kalidasu (2011). Threats in production of coriander (Coriandrum sativum) in Andhra Pradesh. Journal of Spices and Aromatic Crops, 17: 158-162.

Registration of 'Batu'(90312) Newly Released Early Maturing Coriander (*Coriandrum sativum* L.) variety for mid Rift valley of Oromia.

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Abstract

Batu is the name given to newly released early maturing coriander variety released by Adami Tulu agricultural research center in 2017/18 from the selection made among coriander germplasm received from Ethiopian Biodiversity Institute. Eighteen coriander genotypes were tested along with one standard check for two years at four locations (Adami Tulu, Arsi Negele, Bute and Umbure) of mid rift valley of Oromia. The combined analysis over locations revealed significant variation among the genotypes for mean seed yield and other agronomic traits. Batu gave highest mean yield as compared to the remaining test entries. During variety verification trial, this variety was most preferred by the farmers as compared to the check in the trial. It was evaluated both on farmers field as well as on research station during variety verification trial along with check (Waltai) during 2017 main cropping season and was officially released in 2018 for the mid lands of Oromia and similar agro ecologies.

Key words: Coriander, Early maturing, Variety verification

Introduction

Coriander (*Coriandrum sativum* L, 2n=2x=22) is a diploid annual plant, belongs to the Apiaceae/Umbliferae family medicinal plant native to Mediterranean and Western Asian regions & cultivated worldwide. Coriander plays an important role in the Ethiopian domestic spice trade. Coriander seeds are used for the flavoring of: 'berbere' (which is a spiced, hot red pepper powder used for numerous meat and vegetarian dishes), 'injera', cakes and bread. Critical evaluation of available selections of improved types with high yield potential/ traits is of great value to the breeder for crop improvement (Moniruzzaman, 2013). Mengesha and Getinetalemaw (2010) evaluated some Ethiopian coriander genotypes and reported that identification and evaluation of elite or promising genotypes for yield and quality is an important crop improvement strategy. Even though Ethiopia is one of the centers of origin of coriander, research attention given to this crop was very low till recent time Sarada and Giridhar (2011). Therefore, there is a need to develop and release early maturing coriander for low to midland parts of Oromia.

Materials and Methods

The coriander Variety Verification Trial was conducted at four locations; Adami Tulu, Arsi Negele, Bute and Umbure under rain fed condition in 2017 main cropping season at both on station and farmers field. Non replicated 10m x10m plots were used. Weeds were controlled by hand weeding. Data were collected both on plot and plant basis.

Results and Discusions

The combined analysis variance over locations revealed that there was significant variation among the genotypes for mean seed yield and other agronomic traits. From the two years data, accession number **90312** showed consistence and stable yield performance over the check variety (Waltai).The verification trial after being evaluated by the National

Variety Releasing Committee, the genotype was released for the low to mid lands of mid rift valley of Oromia and similar agro ecologies. The variety was released under the name “**Batu**” for cultivation and production in the intended agroecologies.

Yield Performance

The newly released variety had yield advantage of 18.6% over the standard check (Waltai). It has uniform general agronomic characters such as: plant height, number of umbel per plant, lodging resistance and wider adaptation. Details of the agronomic and morphological description of the released variety ‘Batu’ is indicated in Table 1.

Table 1. Agronomic and Morphological characteristics of newly released medium maturing coriander variety (Batu)

1. Crop: Coriander
2. Variety: **Batu** (90312)
3. Agronomic and morphological characteristics
    - Adaptation area: Low to mid land areas
    - Altitude (m.a.s.l): 1500-2000m
    - Rainfall (mm): 700-1200
    - Seed rate (kg/ha): 12kg/ha
    - Planting date: Early to mid-June
    - Fertilizer rate (Kg/ha): No
    - Days to flowering: 55
    - Days to Maturity: 97
    - Plant height: 120
    - Growth habit: Annual herb
    - Seed color: Light green to brown
    - Grain type:
    - Crop pest reaction: No pests observed
    - Yield (t/ha)
        - Research field (average): 10qtls/ha
        - Farmers field (average): 8.5qtls/ha

Year of release: 2018

Breeder/maintainer: Adami Tulu Agricultural Research Center/OARI

Quality Characteristics

It has higher essential oil and fatty acid content.

Reaction to disease

Tolerant to major diseases and insect pests.

Adaptation and agronomic Recommendations

Newly released coriander variety, Batu is recommended for Adami Tulu, Arsi Negele, Bute, Umbure and areas with similar agro ecologies. It is well adapted in altitude ranging from 1500-2000 m.a.s.l. with annual Rain fall amount ranging from700-1200mm. Recommended seed rate is 12kg/ha. Planting time early to mid-June

Conclusion

Batu variety was officially released in 2018 for its early maturity, higher and stable seed yield performance, higher essential oil and fatty acid contents over the check.

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Mengesha, B. and G. Getinetalemaw (2010). Variability in Ethiopian coriander accessions for agronomic and quality traits. African Crop Science Journal, 18(2): 43-49.

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Sarada, C. and G. Kalidasu (2011). Threats in production of coriander (Coriandrum sativum) in Andhra Pradesh. Journal of Spices and Aromatic Crops, 17: 158-162.

Genotype-Environment Interaction and Stability Analysis for Grain Yield of Fenugreek (*Trigonella foenum-graecum* L.) genotypes

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Abstract

Yield data of 12 Fenugreek (Trigonella foenum-graecum L.) genotypes tested across nine rain-fed environments during the 2007-2009 growing seasons using RCBD in three replications were analyzed using the AMMI model. The AMMI analysis tested in nine environments (years and locations) showed that, the grain yield is significantly affected (P< 0.001) by environmental main effects, however; it is not significantly affected by genotypes main effect as well as GxE interaction. The model revealed that differences among the environments accounted for about 91.28% of the treatment sum of squares. The genotypes and the GxE interaction also accounted significantly about 0.92 % and 7.79% respectively of the treatment Sum of Squares. The first Principal Component Axis (PCA 1) of the interaction captured 48.61% of the interaction sum of squares. Similarly, the second principal component axis (PCA2) explained further about 24 % of the GEI sum of squares. The mean squares for the PCA 1 and PCA 2 were significant at P =0.01 and cumulatively contributed about 72.61% of the GxE interaction Sum of Squares, leaving 27.44% of the variation to the GxE interaction in the residual. The AMMI and AMMI stability value (ASV) identified genotypes G7 and G5 as the stable and high yielding genotypes.

Key words: AMMI, ASV, yield, biplot, genotypes, GxE interaction, PCA.

Introduction

Plant breeders invariably encounter genotype x environment interactions (GEIs) when testing varieties across a number of environments. Depending on the interactions or the differential genotypic responses to environments, the varietal ranking can differ greatly across environments. In field crop trials, this interaction is often analysed with the aim of determining the stability of the genotypes especially when there is a reasonable genotype by environment interaction (GEI). A combined analysis of variance (ANOVA) can quantify the interactions, and describe the main effects. However, analysis of variance is uninformative for explaining GEI. Various statistical methods (parametric and non-parametric) have been proposed to study Genotype × environment interactions(Mohammadi and Amri, 2008; Mohammadi et al., 2010). The main problem with stability statistics is that they don't provide an accurate picture of the complete response pattern (Hohls, 1995). The reason is that a genotype's response to varying environments is multivariate (Lin et al., 1988) whereas the stability indices are usually univariate (Gauch, 1988; Crossa, 1990). Since the genotype response to environmental variations is usually multivariate, therefore, a multivariate method of analysing genotype stability across environments will be the best option. One of the multivariate techniques is the AMMI (additive main effects and multiplicative interaction) model. AMMI analysis reveals a highly significant interaction component that has a clear agronomic meaning and it has no specific design requirements, except for a two way data structure. The AMMI analysis is a combination of analysis of variance (ANOVA) and principal component analysis (PCA) in which the sources of variability in genotype by environment interaction are partitioned by PCA. The AMMI is, therefore, also known as interaction PCA (Gauch and Zobel, 1990), and can have several models: AMMI0, which estimates the additive main effect of genotypes and environments, and does not include any principal component axis (IPCA); AMMI1, which combines the additive main effects from AMMI0 with the genotype by environment interaction effects estimated from the first principal component axis (IPCA 1); AMMI2, and so forth, until the full model with all IPCA axis (Gauch,1988).It has both linear and bilinear component of GEI and hence very useful in visualizing multi-environment data (understanding complex GEI and determining which genotype won which environment) and gaining accuracy (improving cultivar recommendation and accelerating progress) (Gauch, 2006). The additive main effects and multiplicative interactions (AMMI) is defined powerful tool for effective analysis and interpretation of multi-environment data structure in breeding programs (Ebdon and Gauch, 2002a; Samonte et al., 2005H; Yan et al., 2000; Zobel et al., 1988). Hence, the present study was initiated with the following objective:

Objective: To evaluate, select and verify promising accessions/lines with desirable traits.

Materials and methods

Twelve fenugreek genotypes were evaluated at three locations (Sinana on station, Goro and Ginniir) for three consecutive years (2007-2009) during *bona* cropping season following selection method. The trial was laid out in RCB design with three replications. Data were collected from central two rows and was subjected to analyses of variance using GENSTAT soft ware program. Duncan's multiple range test was done for grain yield. The genotype by environment interaction analyses (GxE) and stability analyses were conducted using the AMMI model.

Results and Discussion

The AMMI analysis tested in nine environments (years and location) showed that, grain yield is significantly affected ($P< 0.001$) by environment main effects, however; it was not significantly affected by genotypes main effect as well as GxE interaction. The model revealed that, differences between the environments accounted for about 91.28% of the treatment sum of squares. The genotypes and the GxE interaction also accounted significantly for 0.92 % and 7.79% respectively of the treatment Sum of Squares. The first Principal Component Axis (PCA 1) of the interaction captured 48.61% of the interaction sum of squares. Similarly, the second principal component axis (PCA2) explained a further 24 % of the GEI sum of squares. The mean squares for the PCA 1 and PCA 2 were significant at P =0.01 and cumulatively contributed to 72.61% of the GxE interaction SS, leaving 27.44% of the variation in the GxE interaction in the residual (Table 1).

Table 1. Combined analysis of variance of yield data of Fenugreek genotypes tested across nine environments.

Source	df	SS	MS	F	F_prob	%explained
Total	323	31295	96.9	*	*	
Treatments	107	27271	254.9	13.47	0	
Genotypes	11	252	22.9	1.21	0.2827	0.92
Environments	8	24894	3111.8	202.66	0	91.28
Block	18	276	15.4	0.81	0.68579	
Interactions	88	2125	24.2	1.28	0.08287	7.79
IPCA(1)	18	1033	57.4	3.03	0.00007	48.61
IPCA(2)	16	510	31.8	1.68	0.05239	24.00
Residuals	54	583	10.8	0.57	0.99173	27.44
Error	198	3748	18.9	*	*	

Table 2. Environment means and scores

NE	Environment	Mean	IPCAe[1]	IPCAe[2]
E1	Ginir 2007	18.47	0.26035	1.25811
E2	Ginir 2008	14.34	0.99451	0.83702
E3	Ginir 2009	13.89	0.94106	0.22657
E4	Goro 2007	12.57	0.67011	1.17174
E5	Goro 2008	12.84	-0.57399	-0.16977
E6	Goro 2009	16.66	-0.80555	0.42601
E7	Sinana 2007	42.51	-3.4496	-0.94318
E8	Sinana 2008	16.11	1.80515	-2.86727
E9	Sinana 2009	18.97	0.15797	0.06077

The AMMI model 1 biplot of the varietal trials was demonstrated in Figure 1. The abscissa shows the main effects while the ordinate shows the first PCA axis. The environments showed much variability in both main effects and interactions. However, the high potential environments were sparsely distributed in quadrant II and III, while the lower potential environments were also sparsely distributed in quadrants I and IV with high IPCA1 values (Figure 1).

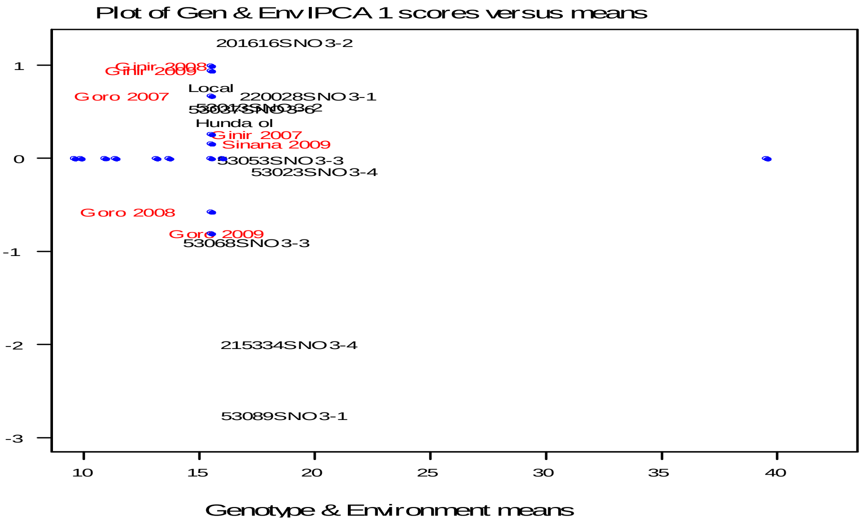

Figure 1. AMMI model I biplot of the yield of coriander genotypes evaluated in 9 environments.

Table 3. AMMI yield mean, AMMI stability values (ASV), and ranking orders of the 12 Genotypes tested across nine environments.

G	Genotype	Yield(Qt/h)	IPCAg[1]	IPCAg[2]	ASV
G1	201616SNO3-2	18.7	1.24771	-1.62107	3.002454
G2	215334SNO3-4	18.9	-1.99516	1.14587	4.200492
G3	220028SNO3-1	19.73	0.67177	-0.54236	1.464773
G4	53013SNO3-2	17.84	0.55189	1.95316	2.250426
G5	53023SNO3-4	20.23	-0.14302	0.67797	0.737266
G6	53037SNO3-6	17.51	0.53211	-1.35106	1.728288
G7	53053SNO3-3	18.76	-0.01704	0.15815	0.161872
G8	53068SNO3-3	17.28	-0.90284	-0.84161	2.013064
G9	53089SNO3-1	18.92	-2.76117	-0.98638	5.67904
G10	Ebisa	18.63	1.67095	0.23297	3.392502
G11	Hunda ol	17.82	0.38613	0.93902	1.222065
G12	Local	17.5	0.75866	0.23534	1.554575

In ASV method, a genotype with least ASV score is the most stable, accordingly genotype G7, followed by G5 were the most stable. In addition G5 is high yielder Genotype. Therefore, release of this genotype for production in the mid and lowlands of Bale will result in increased production and productivity of coriander in the country.

Conclusions and Recommendations

AMMI analyses revealed the stable and high yielding genotypes over ranges of environments. That is genotypes G5. Therefore, release of this genotypes for production in the mid and lowlands of Bale will result in increased production and productivity of coriander in the country. It can be concluded and recommended from this study that genotypes should be selected for wider adaptations.

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Genetic Variability Among Quality Traits in Advanced Bread Wheat (*Triticum aestivum* L.) Genotypes at Sinana, South Eastern Ethiopia

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Abstract

Information on the extent of genetic variation and associations among characters is important to design breeding strategies and to develop varieties for the targeted area of production. Therefore, this research was conducted at Sinana Agriculture Research Centre testing site and at Robe on farm, South eastern Ethiopia, with the objectives of evaluating advanced bread wheat genotypes for quality traits. The experiment was conducted in 2016 main cropping season using 21 promising lines and 4 released varieties in triple lattice design. Data were collected for 13 grain quality characters. Pooled analysis of data showed that there was significant (P<0.01) differences among genotypes for hectolitre weight, wet gluten content, dry gluten content, gluten index, average kernel thickness, SDS sedimentation test, protein content and moisture content. For genotype x environment interaction, wet gluten content, dry gluten content, gluten index, average kernel thickness, SDS sedimentation test, protein content and moisture content revealed significant (P<0.01) differences among genotypes. In pooled analysis, genotypic coefficient variation (GCV) and (PCV) was relatively higher for SDS sedimentation followed by wet gluten content. In all studied traits, the phenotypic coefficient of variation values were higher than genotypic coefficient of variation values across locations, indicating the higher influence of environmental factors than genetic factors for the phenotypic expression. In pooled analysis heritability in broad sense and genetic advance as percent of mean (GAM) ranged from 38.6% (dry gluten content) to 97% (SDS sedimentation test) and 2.6% (hectolitre weight) to 34.5% (SDS sedimentation). High heritability coupled with genetic advance was observed for SDS sedimentation in combined analysis. This implies the potential of improving wheat for end product use quality through direct selection. Generally, it has been observed the presence of high variability among the genotypes studied and the possibility of increasing grain quality traits to improve quality in wheat.

Key words: Bread wheat, Genetic Variability, Quaity

Introduction

Wheat (*Triticum spp*) is one of the most important and widely grown food crops with more than 25,000 different cultivars (Sapone *et al.*, 2012). Its cultivation was started with wild einkorn (diploid) and emmer (tetraploid) wheat around 10,000 years ago during Neolithic Revolution, the first series of agricultural revolutions. Due to its wide adaptability to diverse climatic conditions and its multiple end-uses along with dynamic nature of genomes and polyploidy character, it has become a crop of financial and nutritional importance especially after the emergence of hexaploid wheat (Neem, 2013).

Ethiopia is the second largest wheat producer next to South Africa in sub-Saharan Africa with more than 1.6 million ha and productivity close to 2.11 t/ha and wheat stands fourth in area coverage (FAO, 2016). 81% of the total land cultivated to grain crops is covered by cereals out of which wheat accounts for 13.14% of the area (CSA, 2011). Wheat is the second most consumed cereal in Ethiopia next to maize, accounting for approximately 11% of the national calorie intake in the country (200 kcal/day in urban areas and 310 kcal/day in rural areas). It has versatile uses in making various human foods such as bread, biscuits, cakes and sandwich (GAIN, 2014). It is also one of the major cereal crops grown in the Bale highlands of Ethiopia and this region is regarded as the largest wheat producer in Sub-Saharan Africa (Efrem *et al.*, 2000). Grain yield and quality of crop variety is the end result of interaction between variety and environment in which it is grown (Kent and Evers, 1994). Grain size and hardness, protein content and its composition as well as starch content and its ability to gelatinize are important variables that determine wheat quality (Panozzo and Eagles 2000). Wheat quality depends upon the genetic factor but environmental condition such as growth location and agronomic practices prevailing during different wheat growth stages greatly alter wheat quality attributes. Generally, wheat quality refers to its suitability for a particular end use based on physical, chemical and nutritional properties of the grain.

Genetic variability, which is due to genetic differences among individuals of a population, is the core of plant breeding because, proper management of diversity can produce permanent gain in the performance of plant and can buffer against seasonal fluctuations (Ammar *et al.*, 2008). Estimation of the magnitude of variation with in genotype for important plant attributes will enable breeders to exploit genetic diversity more efficiently. This is due to the critical role of genetic variability in determining the amount of progress to be made by selection. Hence, estimation of the extent and pattern of genetic variability existing in the available genotypes is essential to breeders (Kifle, 2016). High heritability is also needed to have better opportunity to select directly for the characters of interest. This is mainly because of the opportunity associated with high heritability in correct identification and measurement of the genotypes based on phenotypic values and in avoiding errors in genotypic classification (Ammar *et al.*, 2008). In Ethiopia, the wheat improvement research since its inception prior to 1930's (Hailu, 1991) has focused mainly on improving grain yield and disease resistance, except very recent where by quality is becoming essential breeding objective. Particularly nowadays, with the emerging agro industries using wheat as a raw material, good processing quality of wheat grain has become important breeding objective (Ermias, 2005). Information on physical and chemical quality parameters is necessary to assess the suitability of wheat varieties for different industrial uses. Generating information on variability and heritability of quality traits of advanced breeding lines is important to identify desirable quality traits for release. However, such activities are lacking in advanced bread wheat lines currently under yield trial in South Eastern Ethiopia. Rather, the trend is to check for quality traits at the end of the breeding scheme. However, such kind of attempt will not be rewarding as some promising genotypes might be discarded before reaching final stage of breeding (variety verification trial). Hence, this study is initiated with objective of determining genetic variability among advanced bread wheat genotypes for quality traits under Southeaster Highlands of Bale.

Materials and Methods

Description of experimental sites and experimental materials

The experiment was conducted during the cropping season of 2016/17 at two locations, Sinana Agricultural Research Center (SARC) on station and at Robe area on farmer’s field. SARC station is located 070 07’ N latitude and 400 10’ E longitude and at an altitude of 2400 meters above sea level. The soil texture type of the area is clay loam having black color and the soil pH ranges between 6.3-6.8 (SARC, 2013). The amount of rainfall from August to December 2016, during crop growing seasons, was 401.5 mm. The monthly mean maximum and minimum temperatures were 24.50C and 14.40C, respectively. The Robe area experiment was conducted on farmer’s field is located 7006’44’’N and 40001’33’’E with altitude 2464 m. a. s. l. The amount of rainfall from August to December 2016, during crop growing seasons, was 350.3 mm. The monthly mean maximum and minimum temperatures were 21.60C and 8.5 0C, respectively. The experimental materials comprised of 21 bread wheat genotypes and 4 released varieties obtained from SARC. The genotypes were retained from the 2015 bread wheat regional variety trials at SARC. The details of the genotypes are summarized in Table 1.

Experimental Design and Trial Management

The experiment was laid out in 5x5 triple lattice design. The plot size was 6 rows of 2.5 m length with 0.2 m spacing between rows (with a gross plot size of 3m^2), and the spacing between plots and blocks was 0.4 m and 1m, respectively. Planting was done by hand drilling. Seed rate was 150 kg/ha (45 g/plot) and Urea and DAP fertilizers were applied at the rate of 50 kg/ha and 100 kg/ha, respectively. The field was weeded twice by hand (at 25 and 45 days after planting). For data collection, the middle four rows were used (2 m^2 area). All cultural practices were applied uniformly to all experimental units.

Data Collected: Random homogeneous grain samples from each replicate of each genotype were used for quality laboratory analysis.

Thousand kernel weight (g): The weight of randomly sampled 1000 kernels.

Hectolitre weight (kg/hl): Weight of one-liter volume random sample of grain for each experimental plot.

Average kernel length (AKL): Was determined using a digital caliper by aligning 10 sets of 25 seeds end to end (brush to germ) putting crease down according to Schuler *et al.* (1994).

Average kernel width (KW): Was measured on the respective sets of 25 seeds by placing the seed crease down, side by side so that each contacted adjacent seed was taken at their widest points using digital caliper.

Average kernel thickness (AKT): Was measured in the same manner on respective sets of 25 seeds by placing them with the edge of the kernels.

Protein content (%) and moisture content (%): Were determined using Mininfra SmarT Grain Analyzer (Mininfra SmarT Grain Analyzer Operating Manual, 2013).

Wet and dry gluten content: Wet Gluten was prepared from whole meal by the Glutomatic 2200 gluten wash chamber. Gluten Index Centrifuge 2015 was used to force the wet gluten through a specially designed sieve cassette. The wet gluten is further dried in the Glutork 2020 for dry gluten content (ICC, 2000).

$$\text{Gluten index (\%)} = \frac{\text{Gluten remaining on the sieve (g)}}{\text{Total gluten (g)}} \times 100$$

Wet Gluten content (WGC) = Total wet gluten (g) X 10

Dry Gluten content (DGC) = Dry gluten weight (g) X 10

Sodium Dodecyl Sulfate (SDS) sedimentation test: The SDS sedimentation volume was measured according to AACC Method No.56-70 (AACC, 2000).

Vitreoussneous: Kernel vitreousity was estimated by using transmitted light according to ICC standard number 129 (ICC, 2000).

Grain hardness (%): was determined by particle size index (PSI) method as described in the AACC method 55-31 (AACC, 2000).

Data Analysis: The SAS GLM (General Linear Model) procedure SAS Institute Inc (2002) was employed for the analysis of variance. Duncan's Multiple Range Test (DMRT) at 5% probability level was used for mean comparisons, whenever genotypes differences were significant. Comparison of the relative efficiency of lattice design to Randomized Complete Block Design (RCBD) was done after data were analyzed for both designs and the result eventually showed that lattice design was less efficient than RCBD. Therefore, for the flexibility of lattice design (Cochran and Cox, 1957) the data were analyzed as per RCBD.

Phenotypic and genotypic variability: The phenotypic and genotypic variances and coefficient of variations were estimated according to the methods suggested by Burton and Devane (1953).

Heritability (H^2) in broad sense for all traits was computed using the formula adopted from Allard (1960) and Falconer (1990).

Genetic advance (GA) and genetic advance as percent of mean (GA %): for each trait was computed using the formula adopted from Johnson *et al.* (1955) and Allard (1960).

Table 1. Description of bread wheat genotypes used in the experiment

S.N	Genotype	Pedigree
1	ETBW 7866	CHUANMAI32//2*INQALAB 91*2/KUKUNA
2	ETBW 7524	PBW343*2/KUKUNA//AKURI
3	ETBW 7402	QUAIU/5/FRET2*2/4/SNI/TRAP#1/3/KAUZ*2/TRAP//KAUZ
4	ETBW 7559	ROLF07*2/5/FCT/3/GOV/AZ//MUS/4/DOVE/BUC
5	ETBW 7661	TUKURU//BAV92/RAYON/3/FRNCLN
6	ETBW 7409	ROLF07*2/5/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES
7	ETBW 7528	BABAX/LR42//BABAX*2/3/KUKUNA/4/TINKIO #1
8	ETBW 7527	JUCHI/HUIRIVIS #1
9	ETBW 6114	SOKOLL//SUNCO/2*PASTOR
10	ETBW 7698	FRNCLN/4/WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1
11	ETBW 7638	ATTILA/3*BCN*2//BAV92/3/KIRITATI/WBLL1/4/DANPHE
12	ETBW 7797	SERI.1B*2/3/KAUZ*2/BOW//KAUZ/4/PFAU/MILAN
13	ETBW 6873	WBLL*2/KUKUNA/5/PSN/BOW//SERI/3/MILAN/4/ATTILA/6/WBLLI*KKTS
14	ETBW 7729	MUNAL/3/KIRITATI//PRL/2*PASTOR/4/MU
15	ETBW 8005	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2
16	ETBW 7998	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2
17	ETBW 8003	SERI.1B//KAUZ/HEVO/3/AMAD/4/FLAG-2
18	ETBW 7715	MILAN/S87230//BAV92/3/AKURI#1/4/MILAN/S87230//BAV92
19	ETBW 7595	SKAUZ/BAV92//2*WBLL1*2/KKTS
20	ETBW 7435	WAXWING*2/4/BOW/NKT//CBRD/3/CBRD
21	ETBW 7718	MUNAL/3/KIRITATI//PRL/2*PASTOR/4/MUNAL
22	Dambel (2015)	AGUILAL/3/PYN/BAU//MILAN
23	Sanete (2014)	14F/HAR1685
24	Sofumer (2000)	LIRA/TAN
25	Madawalabu (2000)	TL/3/FN/NAR59*2/4/BOL'S'

Results and Discussions

Test of homogeneity of error variance showed that the error mean squares were homogeneous for hectolitre weight, wet gluten content, dry gluten content, gluten index, average kernel thickness, SDS sedimentation test, protein content and moisture content (Appendix 1). Combined data analysis was done for these above mentioned characters. Therefore, analysis of variance across locations showed that there was significant ($P<0.01$) differences among bread wheat genotypes for all combined traits. Genotype x environment interaction showed also that there were significant ($P<0.01$) differences among genotypes for wet gluten content, dry gluten content, gluten index, average kernel thickness, SDS sedimentation test, protein content and moisture content. This indicated that genotypes responded differently to varying environment for these quality traits.

Genotype performance for quality parameters: Mean performance values of the studied genotypes for different quality parameters are given in Table 2. The present study revealed that, there is significant variation among genotypes for hectolitre weight, which ranged from 79.8 kg/hL (ETBW7866) to 85 kg/hL (ETBW7661 and ETBW7528). This result agrees with result of Birhanu *et al.* (2016) who reported an average hectolitre weight of 80.06 kg/hL with a range of 76.1 kg/hL to 84.1 kg/hL. Kernel thickness ranged from 2.7 mm (ETBW7866) to 3 mm (ETBW7528, ETBW7638 and Madawalabu). Kasraei *et al.* (2015) also found comparable result with the present study, in which the value for this quality parameter ranged from 2.6 mm to 2.9 mm. The grain moisture content varied from 8.8% (ETBW7524 and ETBW7698) to 9.5% (ETBW7998). According to Shure (2013), the wheat grains with moisture content below 12% can be stored for an extended period as flour with low moisture content is more stable during storage. Highly significant variation was observed among genotypes for grain protein content, which ranged from 12.6 (ETBW7595) to 14.5% (ETBW7729). The differences in protein content among different wheat cultivars could be related to genetic difference (Kent and Evers, 1994). Ermias (2005) also reported a range of 11.5-15.4% for this trait, which falls within the range of the result of the present study. According to Kasraei *et al.* (2015), the protein content should be between 11 and 13% to produce bread with better quality in Iranian wheat cultivars they studied. Anjum *et al.* (2007) reported variation in protein content from 9.7% to 13.5% among Pakistani wheat varieties, while Mahmood (2004) found a range of 9.71% to 15.42% in protein content of different bread wheat varieties. Highly significant variability was also observed among genotypes for wet gluten content values, which ranged from 20.3% (ETBW7559) to 42.5% (ETBW7527) with the average mean value of 32.4%. Correspondingly, highly significant genetic variability with the range value of 19.7% to 43.4% was reported by Ciprian *et al.* (2014) for this trait. Shure (2013) also reported variation in wet gluten content from 13.5% to 41.4% among 23 bread wheat cultivars grown under Arsi condition. On other hand, Jirsa *et al.* (2005) reported 18.4% to 46.9% for this trait in bread wheat varieties studied at Prague. Paliwal and Singh (1985) also reported wet gluten in the range 12.77 to 44.06% in Uttar Paradesh wheat varieties, while Mohammed *et al.* (2012) found a range of 25.0 to 33.5% for within the range reported in most of these previous studies. The genotypes with the highest wet gluten content can be preferred by bread bakers since high wet gluten content increases water absorption, increase the protein content of bread, impart better gas retention and increase the volume of loaf (Mekuria *et al.*, 2015). Ciprian *et al.* (2014) concluded that excellent bread production process requires wet gluten content more than 30%. Significant difference among genotypes was also observed for dry gluten with a range value of 8.9% (ETBW7559) to 14.5% (Dambel). The dry gluten content of the protein determines the flour quality and has significant impact on bread making quality (Kent and Evers, 1994). In the same way, highly significant genetic variation was reported by Ermias (2005) and Senayit (2007). Seleiman *et al.* (2011) were also reported significant variation in dry gluten contents among Egyptian wheat cultivars, which ranged from 10.4% to 13.5%. Pasha *et al.* (2007) also reported a relatively wider range of 7.0% to 17% in Pakistani wheat cultivars, which is closely related to the results of the current study.

Table 2. Over all mean performance of bread wheat genotypes studied across locations

Genotypes	HLW	WGC	DGC	GI	KT	MC	PC	SDS
ETBW 7866	79.8^{i}	29.7^{h}	10.3^{n}	88.3^{a}	2.7^{j}	8.9^{g-i}	13.8^{b-e}	81.7^{bc}
ETBW 7524	80.6^{f-i}	34.3^{c}	13.9^{c-e}	67.8^{gh}	2.9^{e-g}	8.8^{hi}	13.8^{b-e}	64.5^{i-k}
ETBW 7402	84.3^{a-c}	26.6^{i}	9.2^{o}	75.8^{d-g}	2.9^{d-f}	9.3a-c	12.7fg	65.3^{h-j}
ETBW 7559	82.1^{d-f}	20.3^{k}	8.9^{o}	87.7^{a}	2.9^{b-e}	9.1^{b-f}	13.6^{b-e}	77.7^{cd}
ETBW 7661	85^{ab}	30.2^{h}	12.6^{f-i}	78.5^{b-f}	2.9^{a-d}	9.1^{c-g}	13^{e-g}	64.4^{i-k}
ETBW 7406	79.9^{hi}	31.5f^{g}	11.9^{i-k}	69.9^{f-h}	2.9^{e-g}	9.2^{b-f}	13.2^{d-g}	73.3^{ef}
ETBW 7528	85.0^{a}	41.4^{a}	13.5^{d-f}	70.3^{e-h}	3.0^{a}	8.9^{hi}	13.4^{c-g}	63.4^{jk}
ETBW 7527	82.9^{b-e}	42.5^{a}	15.3^{ab}	80.3^{a-d}	2.9^{f-h}	9.1^{d-g}	13.4^{c-g}	74.7^{de}
ETBW 6114	83.2^{a-e}	32.8d^{e}	13.2^{e-h}	86.8^{b}	2.8^{hi}	9.2^{b-e}	13.7^{b-e}	67.6^{g-i}
ETBW 7698	82.6^{c-f}	34.6^{c}	13.3^{e-g}	86.5^{ab}	2.9^{a-d}	8.8^{i}	14.2^{a-c}	71^{eg}
ETBW 7638	81.3^{e-i}	38.8^{b}	14.6^{a-c}	78.4^{b-f}	3.0^{a-c}	9.1^{b-f}	14.9^{a}	87^{a}
ETBW 7797	84.4^{a-c}	34.8^{c}	12.4^{g-j}	76.8^{c-f}	2.8^{ij}	9.1^{e-h}	14.1^{a-d}	51.8^{m}
ETBW 6873	82.9^{a-e}	33.0d^{e}	12.3^{i-j}	78.8^{b-e}	2.8^{f-h}	9.3^{a-d}	13.5^{c-g}	69.2^{h}
ETBW 7729	82.3^{c-f}	31.9^{ef}	14.4^{b-d}	78.5^{b-f}	2.8^{h-j}	9.0^{e-h}	14.5^{ab}	81.5^{bc}
ETBW 8005	81.9^{d-g}	32.2^{ef}	12.4^{g-j}	76.0^{c-g}	2.9^{de}	9.1^{b-f}	13.5^{c-f}	60.5^{kl}
ETBW 7998	83.1^{a-e}	33.8^{cd}	11.5^{j-l}	75.7^{d-g}	2.9^{de}	9.5^{a}	14.1^{a-c}	61.8^{j-l}
ETBW 8003	82.4^{c-f}	38.1^{b}	14.9^{a-c}	76.5^{c-g}	2.9^{d-f}	9.3^{ab}	12.9^{e-g}	58.6^{l}
ETBW 7715	82.6^{c-f}	34.8^{c}	14.4^{bc}	87.0^{ab}	2.9^{a-d}	9.1^{d-h}	13.9^{b-d}	77.7^{cd}
ETBW 7595	83.2^{a-e}	30.4^{gh}	13.2^{e-h}	78.6^{b-e}	3.0^{ab}	9.0^{e-h}	12.6^{g}	65.2^{h-j}
ETBW 7435	83.3^{a-e}	29.4^{h}	10.5^{m-n}	76.9^{c-f}	2.9^{c-e}	9.1^{b-f}	12.9^{e-g}	63.2^{jk}
ETBW 7718	82.9^{a-e}	24.7^{j}	11.1^{k-n}	85.9^{ab}	2.9^{e-g}	9.1^{e-h}	14.2^{a-c}	83.5^{ab}
Dembel	83.9^{a-d}	38.7^{b}	15.5^{a}	67.9^{gh}	2.9^{d-f}	8.9^{f-h}	13.4^{c-g}	62.7^{j-l}
Sanete	79.9^{g-i}	33.7^{cd}	11.3^{k-m}	65.3^{h}	2.8^{hi}	9.2^{b-e}	13.5^{c-g}	35.5^{n}
Sofumer	83.7^{a-d}	26.3^{i}	11.3^{k-m}	76.6^{c-f}	2.8^{g-i}	9.1^{b-f}	12.7^{fg}	49.9^{m}
Mada walabu	82.0^{d-f}	25.8^{ij}	10.7^{l-n}	84.7^{ab}	3.0^{a-c}	9.3^{a-c}	12.9^{e-g}	62^{j-l}
Means	82.6	32.4	12.5	9.1	78.2	2.9	13.5	66.9
CV	2.3	3.3	6.5	2.2	9.7	2.3	5.8	5.6

The mean gluten index in the current study ranged from 65.3% (Sanete) to 88.3% (ETBW7866). Cubadda *et al*. (1992) proposed seven gluten quality classes in durum wheat. Gluten index values between 65% and 80% are considered good while values above 80% are excellent. Based on this, in the current study, more than 35% of genotypes got high (>80%) gluten index values, while the rest of genotypes were categorized in good range (65% and 80%). The present result is comparable with Marufqual (2013), who reported 38% to 96% values for GI. Other researchers were also found highly significant differences in GI with the ranges of 59 to 96% (Bilgin *et al.*, 2004) and 56 to 99% (Ciprian *et al.*, (2014). SDS sedimentation value of genotypes ranged from 35.5 ml (Sanete) to 83.5 ml (ETBW7718). According to Petrova (2007), the sedimentation value of flours has been categorized into four classes: weakest (less than 15 ml), weak (between 16 ml and 24 ml), good (between 25 ml and 36 ml) and best (more than 36 ml). Ashima (2012) found values ranging from 56.7 ml to 92 ml for SDS sedimentation volume.

Phenotypic and genotypic coefficient of variations: This value was relatively higher for SDS sedimentation (16.7%) followed by wet gluten content (11.4%). GCV estimate gives good implication for genetic potential in crop improvement through selection (Johnson *et al.,* 1955). Hence, there could be better chance for improvement of the above characters with higher GCV values across locations. While phenotypic coefficient of variability (PCV) for pooled analysis was higher for SDS sedimentation (17.2%) followed by wet gluten content (16.3%). Similarly, Yonas (2015) was also found the highest PCV for wet gluten while Ermias (2005) was also reported highest PCV for SDS sedimentation. The present result is in agreement with the report of Mohammed *et al. (*2012) who reported moderate PCV for wet gluten and SDS sedimentation in durum wheat genotypes. The PCV was relatively greater than GCV for all the traits. However, the magnitude of the difference was relatively high for wet gluten and dry gluten content. Kotal *et al.* (2010) were reported the greater magnitude of PCV relative to GCV for all the traits studied. This implies that, there is a greater influence of environmental factors for phenotypic expression of these characters that makes difficult to exercise selection based on phenotypic performance of the genotypes to improve these characters.

Table 3. Range, mean, standard error and components of variation for different characters studied across locations

Traits	Range	Mean±SE	σ^2 g	σ^2 p	GCV	PCV	GA	GAM	H^2
HLW	79.8-85	82.6±1.5	1.4	2.2	1.4	2.0	2.2	2.6	70.7
WGC	20.3-42.5	32.4±0.9	14	27.8	11.4	16.3	7.6	23.6	70.2
DGC	8.9-15.5	12.5±0.7	0.5	3.4	5.7	14.7	1.5	11.7	38.6
GI	65.3-88	78.2±6.2	30	44.0	7.0	8.5	11.3	14.4	82.5
KT	2.7-3.0	2.9±0.05	0.007	0.009	2.7	3.1	0.2	5.7	88.9
MC	8.8-9.5	9.1±0.2	0.02	0.04	1.5	2.2	0.3	3.2	70.0
PC	12.6-14.5	13.5±0.6	0.1	0.3	2.4	4.2	0.7	4.9	56.1
SDS	35.5-83.5	66.9±3.07	125.4	132.9	16.7	17.2	23.1	34.5	97.1

Where: SE=Standard error of mean, σ^2g = Genotypic variance, σ^2p =Phenotypic variance, PCV = phenotypic coefficient of variance, GCV = Genotypic coefficient of variation, H=Broad sense heritability, GA= genetic advance, GA (%) = Genetic advance as percent of mean, HLW=hectolitre weight, WGC= wet gluten content, DGC= dry gluten content, GI= gluten index, KT=kernel thickness, MC=moisture content, PC= protein content, SDS= sodium dodecyl sulfate sedimentation test.

Estimates of heritability and genetic advance

Heritability values ranged from 38.6% (dry gluten content) to 97% (SDS sedimentation test) (Table 3). Johnson *et al*. (1955) classified heritability estimates as low (<30%), moderate (30-60%) and high (>60%). Based on this classification, high heritability values were observed for all combined traits except protein content and dry gluten content which categorized under moderate heritability estimate values. This indicates that, selection could be fairly easy and improvement is possible using selection breeding for these traits. Similarly, Moslem *et al.* (2016) reported high heritability for SDS sedimentation (94.01%) and besides, Mohammed *et al.* (2012) reported moderate heritability value for dry gluten content and grain protein content in durum wheat. In contrast to the present study, Yonas (2015) reported low heritability values for SDS sedimentation and wet gluten content. In the present study, genetic advance as a percent of mean ranged from 2.6% (hectolitre weight) to 34.5% (SDS sedimentation) (Table 3). This result indicates that, selecting the top 5% of the genotypes could result in an advance of 2.6 to 34.5% across locations over the respective population means. Deshmukh *et al.* (1986) classified genetic advance as percent of mean as low (<10%), moderate (10-20%) and high (>20%). Based on this classification, SDS sedimentation and wet gluten content had high genetic advance as percent of mean in the current study. Rudra *et al.* (2015) and Koksal (2009) also reported high genetic advance as percent of mean for SDS sedimentation volume. However, Yonas *et al.* (2016) reported moderate genetic advance as of percent mean for wet gluten content and low for SDS sedimentation, which disagrees with the present findings. Moderate genetic advance as percent of mean was obtained for dry gluten content and gluten index and the rest of the characters had low genetic advance as percent of mean. Mohammed *et al.* (2012) were also reported moderate genetic advance as percent of mean for dry gluten content which is similar to the present study.

It was suggested that considering both the genetic advance and heritability of traits simultaneously is preferable than considering them separately as this is important for determining how much progress can be made through selection (Johnson *et al.*, 1955). In this study, both heritability and genetic advance as percent of mean values were high for wet gluten content and SDS sedimentation across locations. The heritability of these traits is due to additive gene effects and selection may be effective in early generations for these characters (Ali *et al.*, 2007). These results are in agreement with the study of Bushuk (1998) who reported that most quality traits in wheat had high heritability and genetic advance as percent of mean values and indicated the potential of improving wheat for end product use quality through conventional plant breeding. Similarly, Lukow and Vetty (1991) and Peterson *et al.* (1998) reported that several characters contributing to good quality have high heritability and genetic advance values.

Conclusions

Information on the nature and magnitude of genetic variability present in a crop species is important for developing effective crop improvement program. In addition, estimation of the magnitude of variation within germplasm collections for important plant attributes will enable breeders to exploit genetic diversity more efficiently. Heritability of any trait is a significant genetic parameter for the selection of efficient improvement methods in bread wheat breeding. Single plant selection in the earlier generation may be effective for traits that have high heritability as compared to traits with low heritability and environment is another factor that interacts to genetic constitution and influence heritability.

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Appendix Table 1. Mean squares from analysis of variance for 13 Traits of 25 bread wheat genotypes evaluated at Sinana and at Robe (2016)

Sinana				Robe			
Traits	Msr (2)	MSg (24)	Mse(48)	Msr (2)	MSg (24)	Mse (48)	Hom.test(F=1.73)
TKW	13.10**	21.54**	1.56	75.11**	39.36**	4.58	2.9
HLW	5.26^{ns}	3.50^{ns}	3.20	9.46^{ns}	14.45**	3.92	1.2
WGC	0.66^{ns}	140.88**	1.29	0.20^{ns}	108.51**	0.93	1.4
DGC	1.68^{ns}	19.02**	0.67	1.03^{ns}	18.58**	0.66	1.0
GI	81.33^{ns}	200.14**	60.14	112.59^{ns}	148.08**	55.21	1.1
GH	23.48^{ns}	10.22^{ns}	15.09	0.11	34.75**	6.35	2.4
KL	0.006^{ns}	0.14**	0.009	0.001	0.11**	0.03	3.3
KW	0.006^{ns}	0.036**	0.003	0.33	2.44**	0.16	53.3
KT	0.008^{ns}	0.03**	0.004	0.001	0.03**	0.004	1.0
VI	42.87**	12.86**	5.03	32.44	49.68**	15.53	3.1
MC	0.01^{ns}	0.21**	0.04	0.18*	0.07*	0.04	1.0
PC	33.19**	1.91**	0.72	4.73**	1.63**	0.52	1.4
SDS	28.49^{ns}	412.7**	14.09	525.16**	429.94**	14.14	1.0

Integrated approach in barley shoot fly (*Delia flavibasis Stein.*) management in the southeastern highlands of Ethiopia

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Abstract

Barley is one of the strategic crops in Ethiopia for food security and it is also the major input for malting purpose. Barley shoot fly (Delia species) are among the important insect pests of barley causing significant yield loss in major barley growing areas of the country. Integrated pest management is the current approach in pest management approach which considers combining methods that are thought to be economically sound and environmentally safe. The major components in integrated pest management are host resistance, economic use of fertilizer and insecticides. The current experiment was designed with the objective of identifying sound combinations of variety, fertilizer and insecticide rates for lower shoot fly infestation and higher yield. The trials were conducted at Sinana station, Selka and Robe for two years (2016-2017) and laid out in split plot design with two varieties (IBON-174/03 and Bahati) as main plot and combined levels of NP fertilizer and seed dressing chemical in the sub-plots. Analysis of Variance for grain yield showed significant variation was contributed by the Year effect to the total variance and no interaction was tested significant. The analysis for shoot fly infestation showed Location effect had 81% share in the total variation. 16% yield advantage was obtained from IBON-174/03 over the variety Bahati when the two varieties are grown at the maximum rates of the fertilizer and the insecticide. The infestation percent varied 81% due to the location difference and the interaction of treatments existed only between variety and the chemical. Infestation was lower at Robe below 33% and it was higher at Sinana station and Selka. Correlation between grain yield and infestation percent showed decreasing yield with increasing infestation percent. The recommended approach for shoot fly management would be expanding malting barley production in less susceptible areas like Robe or integrated approach using tolerant varieties like IBON-174/03 combined with 150% and 175% of the recommended NP fertilizer and seed dressing chemical.

Key words*: IPM, Shootfly, Barely*

Introduction

Barley (*Hordeum vulgare* L.) is one of the most important cereal crops in the world ranking fourth in production and it is also the major traditional crop in Ethiopia representing about 7.8% of the total national cereal production and ranking fifth after Tef, maize, sorghum and wheat in both area and production (CSA, 2016; FAO, 2016). The total production of 1.9 million tons were forecasted to be produced in 2016/17 cropping season on 0.96 million hectares with an average yield of 2.1 t/ha (CSA, 2016). Barley productivity is hampered by diseases and insect pests among the yield reducing biotic factors.The major leaf diseases affecting barley growth and development are net blotch (*Pyrenophora teres*), scald (*Rhynchosporium secalis*), leaf blotches (Helminthosporium spp.), rusts (*Puccinia spp*.) and powdery mildew (*Erysiphae graminis*) are among the most widely distributed foliar diseases in the country (Mulatu and Grado, 2011). Russian Wheat Aphid (RWA) and barley shoot fly are the major insect pests that attack barley in

Ethiopia. *Delia arambourgi* Seguy and *D. flavibasis* Stein are the two shoot fly species recorded to occur in Ethiopia. Other field insect pests, such as the chafer grub (*Melolontha spp*.), weevil grub (*Mesoleurus spp*.) and *Epilachana spp*., are important, but affect only a few areas (Tafa and Muluken, 2007).Integrated Pest Management (IPM) was used by different researchers in various sense, the popular view was the complementary and coordinated use of all biological, cultural and artificial practices (van den Bosch and Stern, 1962). IPM is an ecosystem approach to crop production and protection that enables healthy growth of crops in a way that reduces the use of pesticides (FAO, 2012). Variety and insecticide screening have been the main focus of barley shoot fly management in Ethiopia.However, cultural practices are also considered among the more promising components of integrated pest management (IPM) due to their ease of implementation, low cost, eco-friendliness and sustainability (Tafa and Muluken, 2007).

Host plant resistance is one of the most effective means of keeping shoot fly population below economic threshold levels, as it does not involve any cost input by the farmers. It is important to identify genotypes with different mechanisms to increase the levels and diversify the bases of resistance to this insect (Dhillon et.al. 2005).Integrated pest management also includes cultural practices such as fertiliser management and sowing dates. Sowing date has been evaluated as one of the management options of barley shoot fly and hence early sowing is associated with low infestation and the damage is higher in late sowing (Tafa and Muluken, 2007). The current study was coined with the objective of evaluating integrated approaches in barley shoot fly management and recommend the best option.

Materials and Methods

The trial was conducted at Sinana research station (707'N and 39010'E) and 10-25 km away from the station at Selka and Robe locations during 2016-2018. The area is characterised by bimodal rainfall pattern with peaks in April and September. The long term average annual rainfall is 1175 mm and the minimum temperature is 9.5 ^{o}c while the maximum is 21 ^{o}c. Two malting barley varieties, a relatively tolerant 'IBON 174/03' and a susceptible 'Bahati', were used as the experimental plants. The trial was set up as main plot of varieties, subplots of Seed dressing chemical (Apron Star 42) and NP recommended fertiliser rate (41-46 kg/ha N-P_2O_5). The recommended rates of seed dressing chemical (Apron Star= Thiamethoxam 20% + Metalaxyl 20% + Difenoconazole 20%) is 250 gm/100 kg seed. The recommended rate of NP fertilizer is 41-46 kg/ha N-P_2O_5. The rates of Apron Star is 0, 25, 100 and 175% of the recommended rate i.e. 0, 62.5, 250 and 437.5 gm/100 kg seed. The recommended rate of NP is 0, 50, 100 and 150 kg/ha recommended rate i.e. 0-0, 21-23, 41-46 and 62-69 kg/ha N-P_2O_5. The data were subjected to analysis using the latest version of R- statistical software (version 3.5.1) and means were separated at $P< 0.05$ using Fisher's LSD. The assumptions of ANOVA were evaluated prior to the combined analysis using Bartlett's test for homogeneity of error variance and the normality of the data was also checked.

Results and Discussion

The combined analysis of variance (ANOVA) for grain yield over environments (locations and years) is given in Table 1. It shows that main effects of the varieties, fertilizer rates, insecticide dose and environment (year and location) are significant ($P < 0.001$) while the interaction among these factors is not significant. The most important factor on grain yield of malting barley with 35% of the total variance was attributed to the year effect. The residual error was relatively higher with 29% share in total yield variation. The variety, fertilizer rate, insecticide dose and location effect explained relatively similar amount of the variation in grain yield of 8-9%. Combined analysis is however far from being accepted since the assumption of homogeneity of error variance over locations has been violated.

Table 1. Analysis of Variance (ANOVA) for grain yield combined over years and locations

Source of Variation	DF	Sum Square	Mean Square	F value	Pr (>F)	% TSS explained
VAR	1	35538769	35538769	132.573	<2e-16	9
NP	3	36130539	12043513	44.927	<2e-16	9
SD	3	30235978	10078659	37.597	<2e-16	8
LOC	2	35002588	17501294	65.286	<2e-16	9
YR	1	142986567	142986567	533.392	<2e-16	35
REP	2	1062698	531349		0.139	0.3
VAR:NP	3	590452	196817	0.734	0.532	0.2
VAR:SD	3	57570	19190	0.072	0.975	0.01
NP:SD	9	1491658	165740	0.618	0.782	0.4
VAR:NP:SD	9	1892060	210229	0.784	0.631	0.5
Residuals	443	118755096	268070	-	-	29
Total	479	403743975	219540197	-	-	-

Df= degree of freedom, Pr>F= significance level at probability 0.05, % TSS= total sum of squares explained

The analysis showed significant yield variation observed between the two test years while the difference was minimal as the seed dressing chemical rate varied (Figure 1). The yield difference of about 1221 kg/ha was found between 2016 and 2017 at all levels of the chemical rate. Grain yield steadily increased as the chemical rate increased similarly in both years showing only 625 kg/ha difference between the yield obtained at the maximum and minimum chemical rates. This shows the significance of year variation on grain yield of malt barley rather than the dose of the seed dressing chemical. The result hence indicates that there is no need to increase the chemical rate beyond 100% of the recommended rate since the increase was at a slow rate. The chemical rate below the 100% recommended rate even reduces the yield because of susceptibility to shoot fly infestation. The liner fit to the graph showed a good fit of regression line with R^2= 0.97. This shows a good line fit and yield can linearly be expressed with the chemical rate with the formula Yield = 221.15*PCR + INT; where PCR= percent chemical rate, INT= Intercept for the two years.

The response of grain yield to NP fertilizer rate also showed a steady increase over the two years and 2017 was highly responsive than 2016 (Figure 2). The trend is similar to the chemical response above. The regression line showed a linear fit with R^2= 0.97 and the formula Yield= 236.96* PFR + INT; where PFR= percent recommended NP fertilizer rates, INT= intercept of the graph for both years. Hence, yield can be regressed on percent recommended fertilizer rate with this formula showing steady yield increase as fertilizer rate increases. Yield is lower below 100% of the recommended rate and slowly increasing beyond. Therefore, it is not recommended to reduce the chemical rate below its recommended rate or increase beyond it for maximizing yield. However, in combination of the chemical with fertilizer rate, the scenario may change.

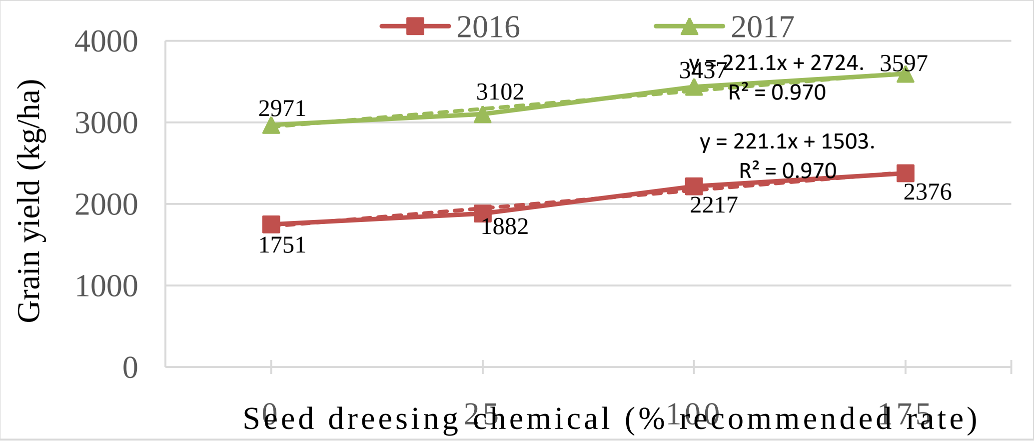

Figure 1: effect of seeding dressing chemical across years combined over locations

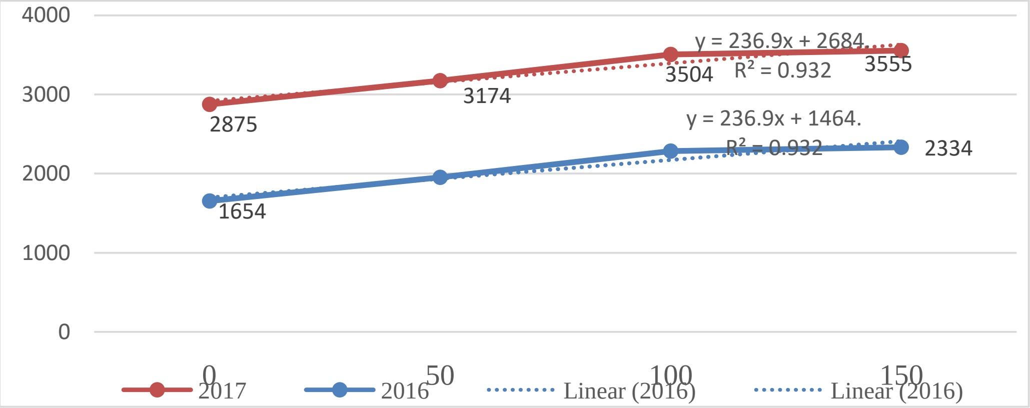

Figure 2. Grain yield response to percent recommended NP fertilizer rate

Figure 3 showed an increasing trend for yield at increasing rates of the chemical and fertilizer rates. The highest yield was obtained at the highest rates of both treatments (NP fertilizer and seed dressing chemical) and the lowest yield was obtained at the control treatments. It was exhibited that at control level of the chemical and at the maximum level of the chemical rate (175 % recommended rate), the yield difference between the nil fertilizer rate (0 %

recommended rate) and the maximum level (150 % recommended rate) was nearly 800 kg/ha. Similar level of yield difference was also observed for the chemical rate: at the nil application and the maximum percent of the recommended rate (175%), the change to grain yield is similarly 800 kg/ha. This signifies the chemical effect and the fertilizer effect on grain yield change to be similarly 800 kg/ha between the maximum and minimum levels.

The combined analysis of variety, NP fertilizer and seed dressing chemical rate indicated that the maximum yield gap was observed for the variety Bahati with the control treatments of NP fertilizer and the chemical rates as compared to the IBON-174/03 with the highest rates of the two treatments (Table 2). The highest yield of 3805 kg/ha was obtained from IBON-174/03 sown at the highest NP fertilizer rate of 150 % recommended rate and the highest chemical rate of 175% recommended rate making the yield difference of 2017 kg/ha.

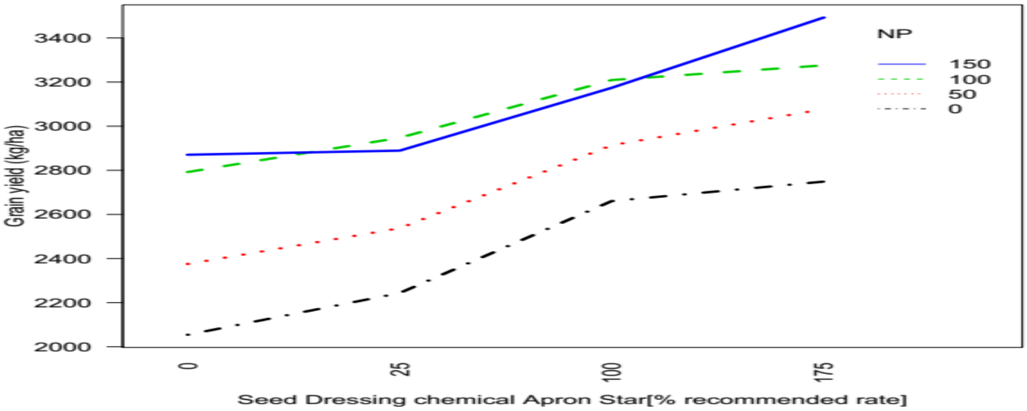

Figure 3. Grain yield versus seed dressing chemical for NP fertilizer rates

The analysis of variance for infestation percent showed that significant main effect response was obtained from the variety and the dressing chemical whereas there was no response of infestation percent from the NP fertilizer rate. The analysis of variance indicated that the highest proportion of the total experimental variation of 81% was attributed to location (Table 3) whereas the other factors contributed less to the variation except 12% and 4% contribution by the residual error and the dressing chemical, respectively. The interaction was not significant for most of the treatments except for variety x Seed Dressing chemical.

The graph below depicted that significant infestation level difference was observed between the two varieties (Figure 4). The infestation difference at no chemical application was about 4% between the two varieties whereas its difference is about 12% at 100% of the recommended chemical rate. Overall, the infestation level of the variety IBON-174/03 is lower at all percent of the seed dressing chemical indicating that this variety is better off in resistance/tolerance to shoot fly than the variety Bahati. The infestation of barley shoot fly was clearly observed across locations from the following tables (Tables 4-6). The infestation level at Robe ranged from 13 for the variety IBON-174/03 at nil application of both NP fertilizer and seed dressing chemical to 33% for the variety Bahati at 0-41/46 kg/ha NP fertilizer rate (100 % recommended rate) and 0-250 gmApronstar chemical per 100 kg seed (100% recommended rate).

Table 2. Combined effect of variety, NP fertilizer and seed dressing chemical rate over years and locations

VAR	NP	SD	Lsme	SE	df	lower.CL	upper.CL	.group
Bahati	**0 kg/ha NP**	**No Apron Star**	**1788**	**341.25**	**5.33**	**927**	**2649**	**1**
Bahati	21-23 kg/ha NP	No Apron star	2032	341.25	5.33	1170	2893	12
Bahati	0 kg/ha NP	62.5 gm Apron star	2065	341.25	5.33	1203	2926	12
Bahati	21-23 kg/ha NP	62.5 gm Apron star	2308	341.25	5.33	1446	3169	23
IBON 174/03	0 kg/ha NP	No Apron star	2321	341.25	5.33	1460	3182	234
IBON 174/03	0 kg/ha NP	62.5 gm Apron star	2423	341.25	5.33	1562	3284	345
Bahati	0 kg/ha NP	250 gm Apron star	2467	341.25	5.33	1606	3329	345
Bahati	0 kg/ha NP	437.5 gm Apron star	2540	341.25	5.33	1678	3401	3456
Bahati	41-46 kg/ha NP	62.5 gm Apron star	2550	341.25	5.33	1689	3412	3456
Bahati	62-69 kg/ha NP	No Apron star	2556	341.25	5.33	1695	3418	3456
Bahati	41-46 kg/ha NP	No Apron star	2637	341.25	5.33	1776	3499	34567
Bahati	21-23 kg/ha NP	250 gm Apronstar	2660	341.25	5.33	1799	3522	4567
Bahati	62-69 kg/ha NP	62.5 gm Apronstar	2660	341.25	5.33	1799	3522	4567
IBON	21-23 kg/ha NP	No Apronstar	2719	341.25	5.33	1858	3581	567
Bahati	21-23 kg/ha NP	437.5 gm Apronstar	2729	341.25	5.33	1868	3590	5678
IBON	21-23 kg/ha NP	62.5 gm Apronstar	2768	341.25	5.33	1906	3629	5678
Bahati	62-69 kg/ha NP	250 gm Apronstar	2836	341.25	5.33	1975	3697	6789
Bahati	41-46 kg/ha NP	250 gm Apronstar	2837	341.25	5.33	1976	3698	6789
IBON 174/03	0 kg/ha NP	250 gm Apronstar	2854	341.25	5.33	1993	3715	67890
IBON 174/03	41-46 kg/ha NP	No Apronstar	2947	341.25	5.33	2086	3808	7890
IBON	0 kg/ha NP	437.5 gm Apronstar	2958	341.25	5.33	2097	3819	890
Bahati	41-46 kg/ha NP	437.5 gm Apronstar	3064	341.25	5.33	2203	3926	890A
IBON 174/03	62-69 kg/ha NP	62.5 gm Apronstar	3118	341.25	5.33	2257	3979	90AB
IBON 174/03	21-23 kg/ha NP	250 gm Apronstar	3167	341.25	5.33	2306	4028	90ABC
Bahati	62-69 kg/ha NP	437.5 gm Apronstar	3180	341.25	5.33	2319	4041	90ABCD
IBON 174/03	62-69 kg/ha NP	No Apronstar	3185	341.25	5.33	2324	4046	0ABCD
IBON 174/03	41-46 kg/ha NP	62.5 gm Apronstar	3345	341.25	5.33	2484	4206	ABCDE
IBON 174/03	21-23 kg/ha NP	437.5 gm Apronstar	3426	341.25	5.33	2565	4287	BCDE
IBON	41-46 kg/ha NP	437.5 gm Apronstar	3488	341.25	5.33	2627	4349	CDEF
IBON	62-69 kg/ha NP	250 gm Apronstar	3513	341.25	5.33	2651	4374	DEF
IBON	41-46 kg/ha NP	250 gm Apronstar	3582	341.25	5.33	2720	4443	EF
IBON	**62-69 kg/ha NP**	**437.5gm Apronstar**	**3805**	**341.25**	**5.33**	**2944**	**4667**	**F**

Table 3. Analysis of variance for shoot fly infestation percent

Source of Variation	DF	Sum Square	Mean Square	F value	Pr(>F)	% TSS
VAR	1	6308	6308	87.312	< 2e-16***	2
NP	3	195	65	0.899	0.44136	0.1
SD	3	9935	3312	45.842	< 2e-16***	4
LOC	2	224186	112093	1551.652	< 2e-16***	81
REP	2	950	475	6.574	0.00154**	0.3
VAR:NP	3	192	64	0.886	0.44819	0.1
VAR:SD	3	981	327	4.526	0.00387**	0.4
NP:SD	9	627	70	0.964	0.46946	0.2
LOC:YR	2	0	0	0	0.99982	0.0
VAR:NP:SD	9	635	71	0.977	0.45841	0.2
Residuals	442	31930	72	-	-	12
Total	479	275939	-	-	-	-

DF= degree of freedom, %TSS= percent of total sum of squares, Pr(>F)= probability greater than F-value

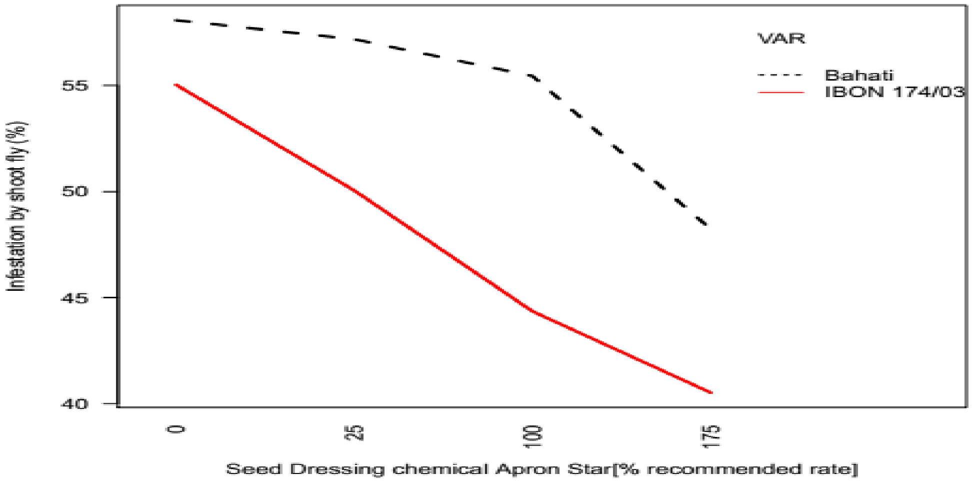

Figure 4. Infestation percent by shoot fly versus Seed Dressing chemical for varieties

The infestation level at Robe location for the variety IBON-174/03 at all levels of the NP fertilizer rates and at 100% and above levels of the Chemical rate ranged only from 13-18% while the infestation level for the variety Bahati at all levels of NP fertilizer rates and 0-250 gm Apronstar chemical per 100 kg seed ranged from 30-33%. The result therefore showed that the best combination of treatments at Robe location for low level of shoot fly infestation is to use the variety IBON-174/03 with 100% rate of the recommended Apronstar chemical which will result in infestation level of 13-18%. However, the use of no NP fertilizer rate will economize the production but care need to be taken not to limit the yield because of no fertilizer use. Therefore, the best economical combination of the fertilizer level is required to be defined.

Table 4. Infestation percent of the varieties by shoot fly on NP fertilizer and Chemical levels at Robe combined over years

VAR	NP	SD	LSm	SE	DF	lower.CL	upper.CL
IBON 174/03	21-23 kg/ha NP	437.5 gm Apronstar	13	3.40	8	-6	32
IBON 174/03	0 kg/ha NP	437.5 gm Apronstar	15	3.40	8	-4	34
IBON 174/03	62-69 kg/ha NP	437.5 gm Apronstar	16	3.40	8	-3	35
IBON 174/03	21-23 kg/ha NP	250 gm Apronstar	16	3.40	8	-3	35
IBON 174/03	41/46 kg/ha NP	437.5 gm Apronstar	17	3.40	8	-2	36
IBON 174/03	41/46 kg/ha NP	250 gm Apronstar	17	3.40	8	-2	36
IBON 174/03	62-69 kg/ha NP	250 gm Apronstar	18	3.40	8	-1	37
Bahati	62-69 kg/ha NP	437.5 gm Apronstar	20	3.40	8	1	39
IBON 174/03	0 kg/ha NP	250 gm Apronstar	21	3.40	8	2	40
IBON 174/03	41/46 kg/ha NP	62.5 gm Apronstar	21	3.40	8	2	40
IBON 174/03	21-23 kg/ha NP	62.5 gm Apronstar	22	3.40	8	3	41
IBON 174/03	62-69 kg/ha NP	62.5 gm Apronstar	23	3.40	8	4	42
Bahati	41/46 kg/ha NP	437.5 gm Apronstar	25	3.40	8	6	44
IBON 174/03	0 kg/ha NP	62.5 gm Apronstar	27	3.40	8	8	46
Bahati	0 kg/ha NP	437.5 gm Apronstar	28	3.40	8	9	47
IBON 174/03	0 kg/ha NP	No Apronstar	28	3.40	8	9	47
Bahati	0 kg/ha NP	250 gm Apronstar	28	3.40	8	9	47
Bahati	0 kg/ha NP	437.5 gm Apronstar	29	3.40	8	10	48
IBON 174/03	41-46 kg/ha NP	No Apronstar	29	3.40	8	10	48
IBON 174/03	62-69 kg/ha NP	No Apronstar	29	3.40	8	10	48
IBON 174/03	21-23 kg/ha NP	No Apronstar	30	3.40	8	11	49
Bahati	21-23 kg/ha NP	62.5 gm Apronstar	30	3.40	8	11	49
Bahati	62-69 kg/ha NP	No Apronstar	30	3.40	8	11	49
Bahati	21-23 kg/ha NP	250 gm Apronstar	31	3.40	8	12	50
Bahati	41-46 kg/ha NP	No Apronstar	31	3.40	8	12	50
Bahati	62-69 kg/ha NP	62.5 gm Apronstar	32	3.40	8	13	51
Bahati	62-69 kg/ha NP	250 gm Apronstar	32	3.40	8	13	51
Bahati	41-46 kg/ha NP	62.5 gm Apronstar	32	3.40	8	13	51
Bahati	21-23 kg/ha NP	No Apronstar	32	3.40	8	13	51
Bahati	0 kg/ha NP	62.5 gm Apronstar	33	3.40	8	14	52
Bahati	0 kg/ha NP	No Apronstar	33	3.40	8	14	52
Bahati	41-46 kg/ha NP	250 gm Apronstar	33	3.40	8	14	52

The analysis result for the experiment at Sinana station (Table 5) revealed that the lowest infestation level range of 50-55% for the variety IBON-174/03 was scored at all levels of the NP fertilizer rate and 100% and above of the seed dressing chemical rate (250-437 gm Apronstar chemical per 100 kg seed). On the other hand, the highest infestation level of 68% was scored for the variety Bahati at 100-150% of the recommended NP fertilizer rate (41/46- 62/69 kg/ha NP) and 0-25% of the recommended Seed Dressing chemical rate (0-62.5 gm Apronstar/100 kg seed). Similar trend was observed at Sinana station showing the lower infestation levels for the variety IBON-174/03 when grown with 100-175% of its recommended rate at all levels of NP fertilizer rates. However, higher fertilizer rates especially of N has resulted in higher protein content of the grain which reduces the acceptability for malting purpose.

Table 5. Infestation percent of varieties on NP fertilizer and seed dressing chemical at Sinana combined over years

VAR	NP	SD	lsmean	SE	df	lower.CL	upper.CL
IBON 174/03	21-23 kg/ha NP	437.5 gm Apronstar	50	3.4	6.0	27.7	72.9
IBON 174/03	0 kg/ha NP	437.5 gm Apronstar	52	3.4	6.0	29.8	75.0
IBON 174/03	62-69 kg/ha NP	437.5 gm Apronstar	52	3.4	6.0	30.4	75.6
IBON 174/03	21-23 kg/ha NP	250 gm Apronstar	53	3.4	6.0	30.4	75.6
IBON 174/03	41/46 kg/ha NP	437.5 gm Apronstar	53	3.4	6.0	31.2	76.4
IBON 174/03	41/46 kg/ha NP	250 gm Apronstar	54	3.4	6.0	31.7	76.9
IBON 174/03	62-69 kg/ha NP	250 gm Apronstar	55	3.4	6.0	32.4	77.6
Bahati	62-69 kg/ha NP	437.5 gm Apronstar	56	3.4	6.0	34.2	79.4
IBON 174/03	0 kg/ha NP	250 gm Apronstar	57	3.4	6.0	35.3	80.5
IBON 174/03	41/46 kg/ha NP	62.5 gm Apronstar	58	3.4	6.0	35.5	80.7
IBON 174/03	21-23 kg/ha NP	62.5 gm Apronstar	59	3.4	6.0	36.6	81.8
IBON 174/03	62-69 kg/ha NP	62.5 gm Apronstar	60	3.4	6.0	38.0	83.2
Bahati	41/46 kg/ha NP	437.5 gm Apronstar	62	3.4	6.0	39.4	84.6
IBON 174/03	0 kg/ha NP	62.5 gm Apronstar	63	3.4	6.0	41.1	86.4
Bahati	21-23 kg/ha NP	437.5 gm Apronstar	64	3.4	6.0	42.2	87.4
IBON 174/03	0 kg/ha NP	No Apronstar	65	3.4	6.0	42.7	87.9
Bahati	0 kg/ha NP	250 gm Apronstar	65	3.4	6.0	42.9	88.2
Bahati	0 kg/ha NP	437.5 gm Apronstar	66	3.4	6.0	43.4	88.7
IBON 174/03	21-23 kg/ha NP	437.5 gm Apronstar	66	3.5	6.0	42.7	89.6
IBON 174/03	41/46 kg/ha NP	No Apronstar	66	3.4	6.0	43.8	89.0
IBON 174/03	62-69 kg/ha NP	No Apronstar	66	3.4	6.0	43.9	89.1
IBON 174/03	21-23 kg/ha NP	No Apronstar	66	3.4	6.0	44.2	89.4
Bahati	21-23 kg/ha NP	62.5 gm Apronstar	67	3.4	6.0	44.6	89.8
Bahati	62-69 kg/ha NP	No Apronstar	67	3.4	6.0	44.9	90.1
Bahati	21-23 kg/ha NP	250 gm Apronstar	67	3.4	6.0	45.1	90.4
IBON 174/03	0 kg/ha NP	437.5 gm Apronstar	68	3.5	6.0	44.9	91.7
Bahati	41/46 kg/ha NP	No Apronstar	68	3.4	6.0	46.0	91.2
Bahati	62-69 kg/ha NP	62.5 gm Apronstar	68	3.4	6.0	46.3	91.5

The result at Selka showed relatively higher infestation level compared to the other two locations. The infestation percent was 68% and higher at the location across the treatments (Table 6). It was revealed that the infestation ranged from the lowest of 68% for the variety IBON-174/03 at 50% of recommended NP rate and 100-175% of the recommended Apronstar. Bahati with 100-150% recommended NP and 25-100% of recommended Apronstar also resulted in 68-69% infestation level. On the contrary, the highest infestation of 83-86% was observed for the variety Bahati at all levels of NP fertilizer and 100% and below recommended levels of Apronstar seed dressing chemical.

Table 6. Infestation percent of varieties on NP fertilizer and seed dressing chemical at Selka combined over years

VAR	NP	SD	LSmean	SE	df	lower.CL	upper.CL
IBON 174/03	21-23 kg/ha NP	437.5 gm Apronstar	68	3.5	6	45	92
IBON 174/03	21-23 kg/ha NP	250 gm Apronstar	68	3.5	6	45	92
IBON 174/03	62-69 kg/ha NP	250 gm Apronstar	68	3.4	6	46	91
IBON 174/03	41/46 kg/ha NP	62.5 gm Apronstar	69	3.4	6	46	91
IBON 174/03	21-23 kg/ha NP	No Apronstar	69	3.4	6	47	92
IBON 174/03	41/46 kg/ha NP	437.5 gm Apronstar	69	3.5	6	46	93
IBON 174/03	0 kg/ha NP	62.5 gm Apronstar	69	3.4	6	47	92
IBON 174/03	0 kg/ha NP	No Apronstar	70	3.4	6	47	92
IBON 174/03	41/46 kg/ha NP	250 gm Apronstar	70	3.5	6	46	93
IBON 174/03	41/46 kg/ha NP	250 gm Apronstar	70	3.4	6	48	93
IBON 174/03	62-69 kg/ha NP	250 gm Apronstar	70	3.5	6	48	94
IBON 174/03	62-69 kg/ha NP	437.5 gm Apronstar	72	3.5	6	49	96
IBON 174/03	0 kg/ha NP	250 gm Apronstar	73	3.5	6	50	97
IBON 174/03	41/46 kg/ha NP	62.5 gm Apronstar	74	3.5	6	50	97
IBON 174/03	21-23 kg/ha NP	62.5 gm Apronstar	75	3.5	6	51	98
IBON 174/03	62-69 kg/ha NP	62.5 gm Apronstar	76	3.5	6	53	99
Bahati	41/46 kg/ha NP	437.5 gm Apronstar	77	3.5	6	54	101
IBON 174/03	0 kg/ha NP	62.5 gm Apronstar	79	3.5	6	56	103
Bahati	21-23 kg/ha NP	437.5 gm Apronstar	80	3.5	6	57	104
IBON 174/03	0 kg/ha NP	No Apronstar	81	3.5	6	57	104
Bahati	0 kg/ha NP	250 gm Apronstar	81	3.5	6	58	104
Bahati	0 kg/ha NP	437.5 gm Apronstar	81	3.5	6	58	105
IBON 174/03	41/46 kg/ha NP	No Apronstar	82	3.5	6	58	105
IBON 174/03	62-69 kg/ha NP	No Apronstar	82	3.5	6	58	105
IBON 174/03	21-23 kg/ha NP	No Apronstar	82	3.5	6	59	106
Bahati	21-23 kg/ha NP	62.5 gm Apronstar	83	3.5	6	59	106
Bahati	62-69 kg/ha NP	No Apronstar	83	3.5	6	59	106
Bahati	21-23 kg/ha NP	250 gm Apronstar	83	3.5	6	60	107
Bahati	41/46 kg/ha NP	No Apronstar	84	3.5	6	61	107
Bahati	62-69 kg/ha NP	62.5 gm Apronstar	84	3.5	6	61	108
Bahati	62-69 kg/ha NP	250 gm Apronstar	84	3.5	6	61	108
Bahati	41/46 kg/ha NP	62.5 gm Apronstar	85	3.5	6	61	108
Bahati	21-23 kg/ha NP	No Apronstar	85	3.5	6	62	108
Bahati	0 kg/ha NP	62.5 gm Apronstar	85	3.5	6	62	109
Bahati	0 kg/ha NP	No Apronstar	85	3.5	6	62	109
Bahati	41/46 kg/ha NP	250 gm Apronstar	86	3.5	6	63	109

Figure 5 showed a significant correlation between grain yield and infestation level across the test locations. The lowest level of infestation (< 50%) was observed at Robe also with the highest grain yield records while the highest infestation levels of > 75% was observed at Selka with lowest records of grain yield. infestation level for Sinana station was in the ranges 50-75% but with similarly lower grain yield with the Selka location. In conclusion, locations Selka and Sinana station need due attention in shoot fly management since the level of infestation is higher which might cause considerable yield loss and hence need strategies such as using the relatively tolerant variety IBON-174/03 combined with higher doses of NP fertilizer and seed dressing chemical.

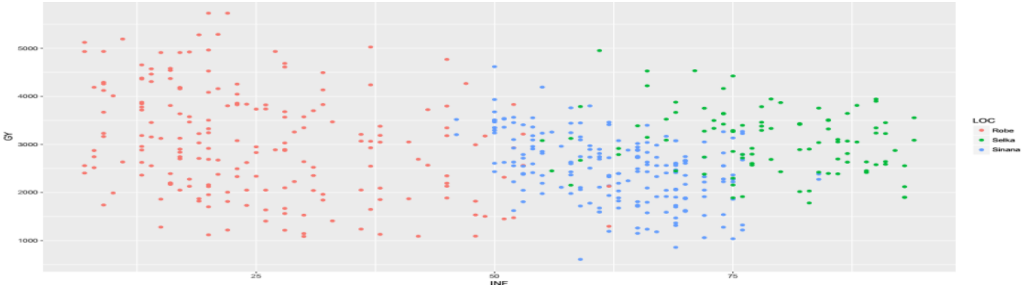

Figure 5. Correlation of grain yield with infestation percent for locations

Conclusions and Recommendations

Grain yield was influenced by the year effect with 35% of the total variance attributed whereas infestation percent was influenced by the location effect with attributed 81% of the total variation. Significant response of grain yield was observed only due to the main effects and no interaction effect of the treatments was tested significant. The linear fit to the graph of grain yield as expressed by the NP fertilizer rate and Seed Dressing Apronstar chemical showed good level of fit with R^2= 0.97. The variety Bahati at no fertilizer and chemical application showed less amount of grain yield (1788 kg/ha) compared to the highest yield (3805 kg/ha) obtained from the variety IBON-174/03 at the highest levels of NP fertilizer (62-69 kg/ha NP) and the seed dressing chemical (437.5 gm Apronstar/100 kg seed). In terms of yield, IBON-174/03 at the maximum combined rates of the fertilizer and chemical rate will produce a yield advantage of 53% compared to the variety Bahati with no fertilizer and chemical application. On the other hand the yield advantage of growing IBON-174/03 at the highest levels of fertilizer and chemical rate compared to Bahati at the highest rates of both treatments was 16% signifying the pure effect of the best variety. Infestation percent by barley shoot fly showed that interaction existed only between variety and seed dressing chemical. Hence, it was exhibited that the varieties ranged in infestation level from 4-12% across the levels of the NP fertilizer. The infestation percent was very low at Robe ranging from 13-33% across the treatments compared to the locations Sinana station with 50-68% and Selka with 68-86%. Correlation between grain yield and infestation level showed negative association indicating a decreasing yield as infestation level increases. Locations with higher infestation showed lower records of grain yield and hence need proper attention in shoot fly management. One of the approved strategies would be integrated management which considers using resistant/tolerant varieties with cultural practices and chemical options. This experiment hence identified that Sinana and Selka are locations with higher level of shoot fly infestation which is associated with considerable yield loss compared to the less than 33% infestation at Robe. The recommended practice in effective malting barley production would therefore be targeting low infested areas such as Robe or integrated approach using the variety IBON-174/03 with 150% recommend NP fertilizer rate and 175% recommended seed dressing chemical rate.

Agronomic performance and Yield stability of large red bean genotypes using AMMI model in midlands of Bale zone, South-eastern Ethiopia.

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Abstract

In order to identify the agronomic performance and yield stability of the large red bean genotypes, sixteen large red bean genotypes were evaluated in the midlands of Bale zone at three district, viz. Goro, Ginir and Dellomena for two consecutive years (2016 and 2017) during main cropping seasons. The genotypes were arranged in Randomized Complete Block Design with four replications having plot size of $6.4m^2$ *(4 rows at 40cm spacing and 4m long). The analysis of variance revealed that, there is highly significant variation for environment, genotypes and year x Location, whereas GEI (Genotypes by Environment interaction) showed significant variation for mean grain yield. Of the total sum squares of variation observed, 38.3% was accounted for environment followed by genotypes 11.5% and GEI 4.5%. The significant effect of GE interaction reflected on the differential response of genotypes in various environments and demonstrated that GE interaction had remarkable effect on genotypic performance in different environments. The application of AMMI model for partitioning the GE interaction effects showed that only the first two terms of AMMI were significant. In the AMMI analysis, out of the total GEI variation observed, the first AMMI explained 78.3% of the variation whereas 21.7% was accounted for the AMMI2. A combination of high grain yield potential, stability parameter of regression coefficient of unity and minimum deviation mean squares from regression identified G4 as moderately stable genotype with high grain yield and promoted for possible release as commercial variety for the midlands of Bale zone and similar agro-ecologies.*

Key Words: AMMI, Common bean, GEI, Stability, Variation

Introduction

Common bean (*Phaseolus vulgaris* L.) is a major grain legume consumed worldwide for its edible seeds and pods. It is a highly polymorphic warm-season, herbaceous annual. There are two plant types: erect herbaceous bushes, up to 20-60 cm high; and twining, climbing vines up to 2-5 m long (Smoliak *et al.*, 1990; Ecocrop, 2013). It has a tap root with many adventitious roots (Ecoport, 2013). The stems of bushy types are rather slender, pubescent and many-branches. In twinning types, the stems are prostrate for most of their length and rise toward the end (Ecoport, 2013). The leaves, borne on long green petioles, are green or purple in color and trifoliate. Leaflets are 6-15 cm long and 3-11 cm broad. The inflorescences are axillary or terminal, 15-35 cm long racemes. The flowers are arranged in pairs or solitary along the rachis, white to purple and typically papillonaceous (Ecoport, 2013; Wortmann, 2006). Once pollinated, each flower gives rise to one pod. Pods are slender, green, yellow, black or purple in color, sometimes striped. They can be cylindrical or flat, straight or curved, 1-1.5 cm wide and up to 20 cm in length (Wortmann, 2006). The pods may contain 4 to 12 seeds. The seeds are 0.5-2 cm long, kidney-shaped and highly variable in color depending on the variety: white, red, green, tan, purple, gray or black. It was domesticated independently in two centers of diversity, giving rise to two gene groups: Mesoamerican and Andean (Beebe *et al*., 2000). Differences between these groups can be checked in the morphology of the plant, seed size and type of phaseolin (reserve protein), among others. Andean lines have larger seed (100 seed weight above 30 grams) while Mesoamerican lines have smaller seed size (100 seed weight under 30 grams) (Gonzales *et al*., 2009). When breeding new cultivars, the main obstacles is the presence of the genotype by environment interaction (G x E). For the cultivation of common bean, numerous studies have shown the presence of such interaction, mainly for grain yield. Thus, one should seek alternatives to mitigate and/or take advantage from the interaction effects, including the use of methods for analysis of stability and adaptability, which provide detailed information about the behavior of cultivars, such as predictability and responsiveness to environmental variation (Cruz *et al*., 2004). Among the methods for studying stability, genotype recommendation index takes the combining concepts of both adaptability and stability into a single parameter. Another methodology used in stability studies is the AMMI method (Additive Main Effects and Multiplicative Interactions) which allows a more detailed analysis of the G x E interaction (Annicchiarico, 1992; Pereira *et al*., 2009). Another methodology used in stability studies is the AMMI method (Additive Main Effects and Multiplicative Interactions) (Zobel *et al*., 1988), which allows a more detailed analysis of the G x E interaction. AMMI model is a popular extension of ANOVA for studying GE interaction (Gauch, 1992). This method extracts genotype and environment main effects and uses interaction principal components (IPCs) to explain patterns in the GE interaction or residual matrix, which provides a multiplicative model (Romagosa and Fox, 1993).Therefore, the present study focused in identifying high yielding, stable large red bean genotypes for possible releases in the midlands of Bale zone, Southeastern part of Ethiopia.

Materials and Methods

In order to identify stability of genotypes across the testing environments for grain yield, sixteen large red bean genotypes were evaluated for two consecutive years (2016-2017) at three midland districts (Ginir, Goro and Dellomena) South eastern of Bale zone, Ethiopia. At all locations Randomized Complete Block Design with four replications was used to evaluate the genotypes. 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 and multiple range test were carried out using Cropstat9 software. The Additive Main Effect and Multiplicative Interaction (AMMI) analysis was performed using the model suggested by Crossa *et al.*(1991). The stability parameters such as regression coefficient (bi), deviation from regression were also calculated using Cropsta9 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) as follow:

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

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) is also calculated using the formula suggested by Farshadfar, 2003. 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. Lists of large red bean genotypes used in the study

SN	Genotypes Code	Genotype name
1	G1	DAB-525
2	G2	DAB-531
3	G3	DAB-538
4	G4	**DAB-523**
5	G5	DAB-498
6	G6	DAB-504
7	G7	DAB-491
8	G8	DAB-537
9	G9	DAB-488
10	G10	DAB-518
11	G11	DAB-496
12	G12	DAB-526
13	G13	DAB-507
14	G14	DAB-522
15	G15	Melka dima
16	G16	Red kidney

Results and discussions

The combined analysis of variance revealed that highly significant variation for environment, genotypes, and year x location. GEI for grain yield was significant across the tested environment (Table 2). The pooled analysis showed significant differences ($p<0.01$) for environments and genotypes, which confirm the variation between the studied environments and genetic variability between lines (Table2). From the total variation observed, 38.3% was accounted for the locations followed by genotypes (11.5%). This implies that the environment was much more contributes for the mean grain yield variation observed among the tested genotypes than other main effects. Mangi Lal Jat *et al*., (2012) and Peymen *et al.*, (2017), have also reported significant variation for genotypes by environment interaction in their studies.

Table 2. ANOVA for grain yield of 16 Large red bean genotypes

Source of Variation	Degree freedom	Sum Squares	Mean Squares	% of total variation
YEAR (Y)	1	11.3988	11.3988**	9.13
Location (L)	2	47.8791	23.9396**	38.33
Replication	3	0.889754	0.296585	0.71
Genotype (G)	15	14.4049	0.960329**	11.53
Y X L	2	5.14002	2.57001**	4.11
L X G	30	5.63363	0.187788*	4.51
Y X L X G	45	5.11653	0.113701	4.09
RESIDUAL	285	34.4391	0.120839	
TOTAL	383	124.902	0.326115	

Similarly, Naroui Rad *et al.,* (2013) were also reported significant variation for the environment, genotypes and their interaction in wheat under normal and drought stress conditions.

AMMI Analysis

The combined analysis of variance showed that there are highly significant differences for environment, genotype and their interactions; combined analysis of variance and AMMI analysis are shown in Table 3. These results showed that 70.5% of the total variation is attributed for environmental effect. The genotype and the GEI effects olny contributed to 21.2% and 8.3% respectively. A large sum of squares for environments indicated that the environments were diverse, with large differences among environmental means causing variation in the plant grain yields. The AMMI model demonstrated the presence of G x E interactions, and this has been partitioned among the first and second IPCAs (Interaction Principal Components Axes). Of the total variation observed, AMMI1 explained 78.3% of the interaction sum of squares; AMMI2 captured 21.7% of the interaction sum of squares (Table 3). This indicates that, the use of AMMI model fit the data well and justifies the use of AMMI2. According to Zobel *et al*. (1988) and Crossa *et al*. (1991), the first two interaction principal component axis are best predictive model that explains the interaction sum of squares. This made it possible to construct the biplot and calculate genotypes and environment effects (Guach and Zobel, 1996; Yan and Hunt, 2001; Kaya *et al.,* 2002).

Table 3. Analysis of Variance for grain yield of large red common bean for the AMMI model

Source of variation	D.F.	S.S.	M.S. F	%TSS
Genotypes	15	1.80062	0.120041	21.21
LOCATIONS	2	5.98489	2.99245	70.50
TREATMENT X SITES	30	0.704204	0.023474	8.29
AMMI COMPONENT 1	16	0.551273	0.034455	78.28
AMMI COMPONENT 2	14	0.15293	0.010924	21.72
Total	47	8.48971		

Mean of the genotypes over all environments ranged from 0.91 t/ha (G13) to 1.67 t/ha (G4) (Table 4). In relation to the stability parameters mean grain yield, slope (bi) and deviation from regression, G4 showed the maximum grain yield with bi close to unity and deviation from regression close to unity implying that this genotype is more stable than others. Amir *et al*., 2013 reported similar stability of rice genotypes for grain yield. Furthermore, 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). Accordingly, G8, G7 and G12 though they had the lowest ASV, they gave mean grain yield lower than the check and it was below that of the grand mean. On the other hand, G11, G1 and G4 had lower ASV as well as higher mean grain yield than the check and gave grain yield above the grand mean and showed wide adaptation over the testing environments (Table 4). However, since stability in itself should not be the only parameter for selection, as the most stable genotype wouldn't necessarily gives the best yield performance (Mohammadi *et al.,* 2007), hence, simultaneous consideration of grain yield and ASV in single non-parametric index is needed or the Genotype Selection Index should be used to determine the stability of the genotypes by evaluating their mean grain yield and ASV.

Genotype Selection Index (GSI), when the rank of mean grain yield of genotypes across environments and rank of AMMI stability value considered to identify the tested genotypes in relation to stability, G11 and G4 had the lowest GSI values compared to the other genotypes and showed stable performance over the testing sites. However, the mean grain yield of G11 was equal to the check used in the study. Therefore, G4 was the most stable and high yielder genotypes across the testing environments.

Table 4. Mean yield First and second IPCA and various yield-stability statistics investigated in large red common bean

Genotype code	MEAN	Rank	SLOPE (bi)	MS-DEV	IPCA1	IPCA2	ASV	Rank	GSI
G1	1.38	6	0.927	0.23	-0.05	-0.01	0.19	5	11
G2	1.01	14	1.01	0.03	-0.01	-0.26	0.26	8	22
G3	1.38	5	1.31	0.45	0.22	-0.05	0.79	11	16
G4	1.63	1	0.97	0.02	0.45	0.02	0.20	6	7
G5	1.43	4	0.618	0.01	-0.26	0.16	0.96	13	17
G6	1.23	10	0.549	0.02	-0.33	-0.18	1.21	14	24
G7	1.17	12	0.95	0.35	-0.04	-0.04	0.14	3	15
G8	1.11	13	1.004	1.02	0.00	-0.04	0.04	1	14
G9	1.31	8	1.066	0.89	0.05	0.08	0.21	7	15
G10	1.38	7	1.313	0.03	0.21	-0.29	0.80	12	19
G11	1.48	2	0.976	0.67	-0.02	0.04	0.07	2	4
G12	1.2	11	1.055	0.78	0.04	0.07	0.17	4	15
G13	0.91	16	1.434	0.05	0.33	0.32	1.23	15	31
G14	1.27	9	0.904	0.01	-0.08	-0.12	0.30	9	18
G15	1.48	2	0.497	0.01	-0.35	0.18	1.27	16	18
G16	0.98	15	0.757	0.92	-0.17	0.11	0.61	10	25

Biplots: A graphical representation of grain yield showed in AMMI biplot, the relationship between the first interaction principal component axis (AMMI component 1) and mean of cultivars and locations (Kempton, 1984), Cultivars and locations on the same equivalent line, obtain similar yields and a cultivar or location on the right-hand side of the midpoint of this axis gave higher yields than those on the left-hand side (Zobel *et al.*, 1988). The Interaction Principal Component Axes (IPCA) scores of a genotype in the AMMI analysis indicate the stability of a genotype across environments. The closer the IPCA scores are to zero, the more stable the genotypes are across their testing environments. Basically, these biplots belong to two types: AMMI 1 and AMMI 2 (Carbonell *et al.*, 2004). In AMMI 1, the genotype and environment means are plotted on the abscissa, and the IPCA scores for the same genotypes and environments, on the ordinate. For interpretation of the AMMI 1 biplot, the magnitude and signal of the scores of the IPCA1 are observed; scores close to zero are characteristic of genotypes and environments, which contribute little to the interaction, that is, they are stable.

Accordingly G4, G11, G15, G5, G3, G1, G10 and G9 found in the right hand side of the graph meaning they gave mean grain yield higher than the grand mean. From the three environments Goro site had grain yield above the grand mean of the tested genotypes, G1, G3, G4, G10, and

G11 were more adapted to Goro site. Genotypes found near the vertex of the biplot were considered as more stable to the testing sites. G7, G12, G14 and G9 were found in this stable category. The rest genotypes were more suited for the other two sites Ginir and Dellomena.

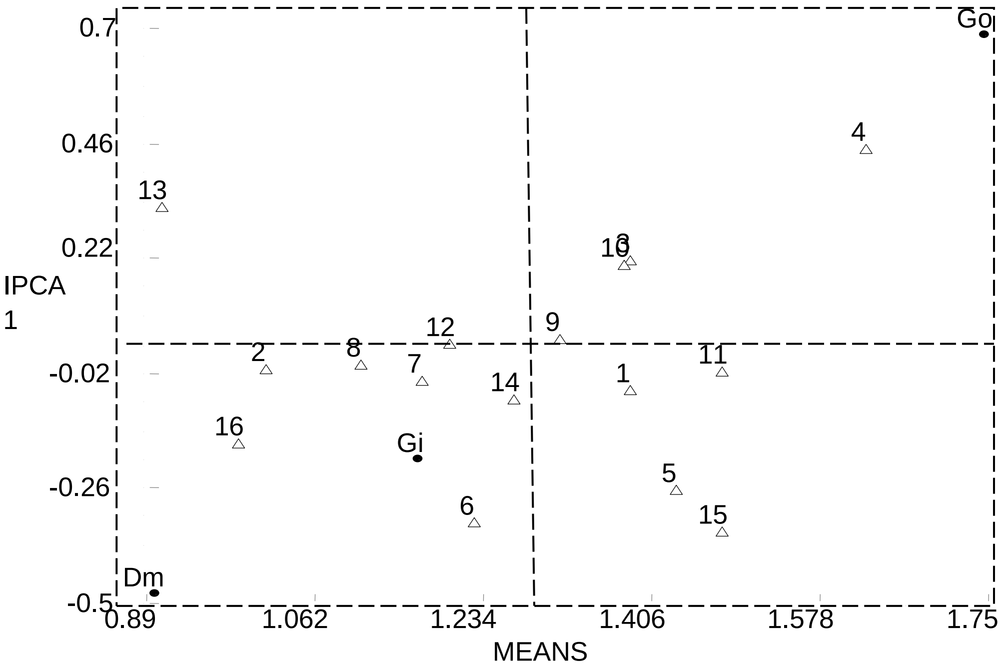

Figure 1. Biplot analysis of GEI based on AMMI 1 model for the PCA 1 scores and grain yield

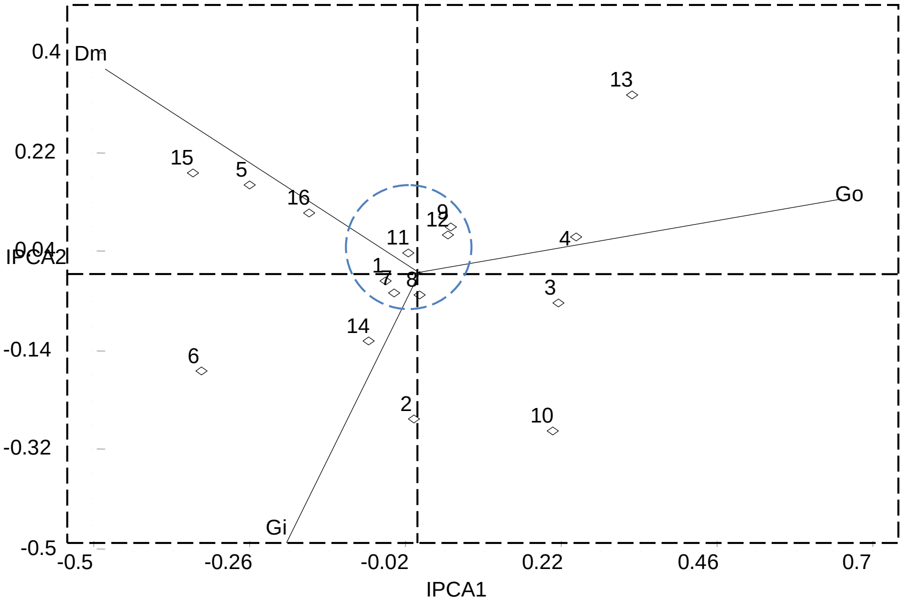

Figure 2. Biplot analysis of GEI based on AMMI 2 model for the first two IPCA scores

Regarding the other biplot, Figure 2, where IPCA 1 were plotted against IPCA 2scores, Genotypes G1, G7, G8, G11 G12 and G9 were found very close to the origin implies these genotypes were more stable than the rest of the genotypes and contributes less to the GEI variation. On the other hand G3 and G4 were found slightly far from the origin and considered as moderately stable genotypes. The rest genotypes which were found at very far distance away from the origin considered as unstable genotypes and contribute more to the GEI variation observed for grain yield. The results obtained by Figure 2 were in consistence with other stability parameters used to identify the stability of the tested genotypes.

Conclusions

The analysis of variance of the 16 genotypes in 6 environments showed that genotype (G), location (L), crop-year (Y) and their interaction were significant ($P < 0.01$) for grain yield. The AMMI model was very effective for studying GEI interaction. The first bilinear AMMI model terms accounted for 78.3% of the GEI. Regarding to the different stability parameters used to identify the stability of genotypes like slop (bi), deviation from regression, ASV and GSI Genotypes G1, G7, G8, G12, G9 and G11 were found to be more stable than the other tested genotypes but showed mean grain yield lower than the check. However, G4 had high mean grain yield and showed moderate stability across the tested environments. Therefore, G4 was selected as candidate variety to be verified in the coming bona/main cropping season across the testing sites.

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Genotype-Environment Interaction and Stability Analysis for Grain Yield of Potato (*Solanumtuberosum L.*) genotypes

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Abstract

Yield data of 12 potato (Solanumtuberosum L.) genotypes tested across nine rain-fed environments during the 2007-2009 growing seasons using RCBD in three replications were analyzed using the AMMI model. The AMMI analysis tested in nine environments (years and locations) showed that, grain yield is significantly affected (P< 0.001) by genotypes and environment main effects as well as GxE interaction. The model revealed that variation among the environments accounted for about 57.73% of the treatment sum of squares. The genotypes and the GxE interaction also accounted significantly about 16.87 % and 25.41% respectively of the treatment Sum of Squares. The first Principal Component Axis (PCA 1) of the interaction captured about 56.44% of the interaction sum of squares. Similarly, the second Principal Component Axis (PCA2) explained further about 13.67% of the GEI sum of squares. The mean squares for the PCA 1 and PCA 2 were significant at P =0.01 and cumulatively contributed about 70.11% of the GxE interaction Sum of Squares, leaving 29.89% of the variation in the GxE interaction in the residual. The AMMI and AMMI stability value (ASV) identified genotypes G3 and G12 as the stable and high yielding genotypes.

Key words: AMMI, ASV, yield, biplot, genotypes, GxE interaction, PCA.

Introduction

Plant breeders invariably encounter genotype x environment interactions (GEIs) when testing varieties across a number of environments. Depending on the interactions or the differential genotypic responses to environments, the varietal ranking can differ greatly across environments. In field crop trials, this interaction is often analysed with the aim of determining the stability of the genotypes especially when there is a reasonable genotype by environment interaction (GEI). A combined analysis of variance (ANOVA) can quantify the interactions, and describe the main effects. However, analysis of variance is uninformative for explaining GEI. Various statistical methods (parametric and non-parametric) have been proposed to study Genotype × environment interactions(Mohammadi and Amri, 2008; Mohammadi et al., 2010). The main problem with stability statistics is that they don't provide an accurate picture of the complete response pattern (Hohls, 1995). The reason is that a genotype's response to varying environments is multivariate (Lin et al., 1988) whereas the stability indices are usually univariate (Gauch, 1988; Crossa, 1990). Since the genotype response to environmental variations is usually multivariate, therefore, a multivariate method of analysing genotype stability across environments will be the best option. One of the multivariate techniques is the AMMI (additive main effects and multiplicative interaction) model. AMMI analysis reveals a highly significant interaction component that has a clear agronomic meaning and it has no specific design requirements, except for a two way data structure. The AMMI analysis is a combination of analysis of variance (ANOVA) and principal component analysis (PCA) in which the sources of variability in genotype by environment interaction are partitioned by PCA. The AMMI is, therefore, also known as interaction PCA (Gauch and Zobel, 1990), and can have several models: AMMI0, which estimates the additive main effect of genotypes and environments, and does not include any principal component axis (IPCA); AMMI1, which combines the additive main effects from AMMI0 with the genotype by environment interaction effects estimated from the first principal component axis (IPCA 1); AMMI2, and so forth, until the full model with all IPCA axis (Gauch,1988).It has both linear and bilinear component of GEI and hence very useful in visualizing multi-environment data (understanding complex GEI and determining which genotype won which environment) and gaining accuracy (improving cultivar recommendation and accelerating progress) (Gauch, 2006). The additive main effects and multiplicative interactions (AMMI) is defined powerful tool for effective analysis and interpretation of multi-environment data structure in breeding programs (Ebdon and Gauch, 2002a; Samonte et al., 2005H; Yan et al., 2000; Zobel et al., 1988). Hence, the present study initiated with the following objective.

Objective: To evaluate, select and verify promising accessions/lines with desirable traits.

Materials and methods

Twelve potato genotypes were evaluated at three locations (Sinana on station, Goba and Dinsho) for three consecutive years (2007-2009) during *bona* cropping season following selection method. The trial was laid out in RCB design with three replications. Data were collected from central two rows and subjected to analyses of variance using GENSTAT software program. Duncan's multiple range test was done for grain yield for mean separation. The genotype by environment interaction analyses (GxE) and stability analyses were conducted using the AMMI model.

Results and Discussions

The AMMI analysis tested in nine environments (years and locations) were showed that, grain yield is significantly affected (P< 0.001) by genotypes and environment main effects as well as GxE interaction. The model revealed also that differences between the environments accounted for about 57.73% of the treatment sum of squares. The genotypes and the GxE interaction also accounted significantly about 16.87 % and 25.41% respectively of the treatment Sum of Squares. The first Principal Component Axis (PCA 1) of the interaction captured about 56.44% of the interaction sum of squares. Similarly, the second Principal Component Axis (PCA2) explained further about 13.67% of the GEI sum of squares. The mean squares for the PCA 1 and PCA 2 were significant at P =0.01 and cumulatively and contributed about 70.11% of the GxE interaction Sum of Squares, leaving 29.89% of the variation in the GxE interaction in the residual (Table 1).

The presence of significant differences for grain yield among genotypes and environments reveals not only the amount of variability that existed among environments but also the presence of genetic variability among the genotypes.

Table 1. Combined analysis of variance of yield data of coriander genotypes tested across nine environments.

Source	df	SS	MS	F	F_prob	%explained
Total	323	176026	545	*	*	
Treatments	107	140070	1309	7.88	0	
Genotypes	11	23623	2148	12.93	0	16.87
Environments	8	80857	10107	59.24	0	57.73
Block	18	3071	171	1.03	0.43094	
Interactions	88	35589	404	2.44	0	25.41
IPCA(1)	18	20085	1116	6.72	0	56.44
IPCA(2)	16	4866	304	1.83	0.02933	13.67
Residuals	54	10638	197	1.19	0.20095	29.89
Error	198	32885	166	*	*	

Table 2. Environment means and scores

Code	Environment	Mean	IPCAe[1]	IPCAe[2]
E1	Dinsho2006	31.17	2.16013	2.72131
E2	Dinsho2007	24.96	-4.02097	1.13413
E3	Dinsho2008	17.53	-0.31763	-0.72134
E4	Goba2006	37.56	2.75013	1.79607
E5	Goba2007	16.57	-0.2955	0.6786
E6	Goba2008	25.29	0.3077	0.72516
E7	Sinana2006	67.89	0.9297	0.54188
E8	Sinana2007	50.39	-5.81314	-2.22988
E9	Sinana2008	43.12	4.29958	-4.64594

The AMMI model 1 biplot of the varietal trials was demonstrated in Figure 1. The abscissa shows the main effects while the ordinate shows the first PCA axis. The environments showed much variability in both main effects and interactions. However, the high potential environments were sparsely distributed in quadrant II and III, while the lower potential environments were also sparsely distributed in quadrants I and IV with high IPCA1 values (Figure 1).

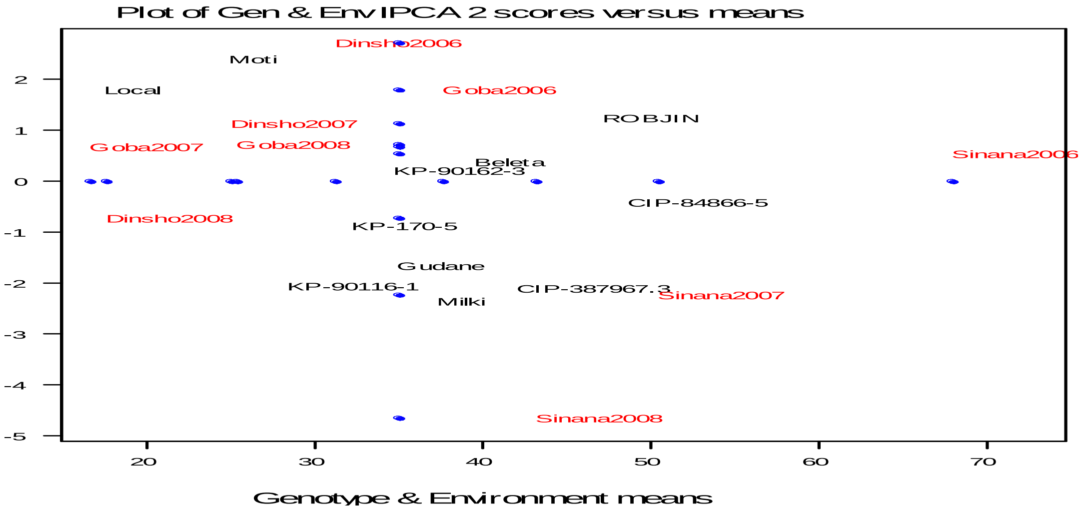

Figure 1. AMMI model I biplot of the yield of coriander genotypes evaluated in 9 environments.

Table 3. AMMI yield mean, AMMI stability values (ASV), and ranking orders of the 12 Genotypes tested across nine environments.

Code	Genotype	Yield(Qt/h)	IPCAg[1]	IPCAg[2]	ASV
G1	Beleta	39.48	1.41042	0.37999	5.834355
G2	CIP-387967.3	41.98	3.20807	-2.1019	13.40813
G3	CIP-84866-5	48.62	0.6093	-0.87377	2.662541
G4	Gudane	34.86	0.09253	-1.65359	1.697128
G5	KP-170-5	32.15	-6.72753	-0.41318	27.77315
G6	KP-90116-1	28.32	-0.02066	-2.05808	2.059846
G7	KP-90147-2	32.63	2.14374	3.41648	9.485614
G8	KP-90162-3	34.63	2.13154	0.21313	8.801207
G9	Local	17.45	-3.43121	1.79934	14.27727
G10	Milki	37.24	-0.00678	-2.3536	2.353766
G11	Moti	24.87	1.48194	2.40133	6.571636
G12	ROBJIN	47.1	-0.89135	1.24385	3.883901

In ASV method, a genotype with least ASV score is the most stable, accordingly genotype G4 was the most stable. But G3 is high yielder and medium ASV. Therefore, release of this genotype (G3) for production in the mid and lowlands of Bale will result in increased production and productivity of coriander in the country.

Conclusions and Recommendations

AMMI analyses revealed the stable and high yielding genotypes over ranges of environments. That is genotypes G3. Therefore, release of this genotypes for production in the mid and lowlands of Bale will result in increased production and productivity of coriander in the country. It can be concluded and recommended from this study that genotypes should be selected for wider adaptations.

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Registration of "Burqaa" a newly released fenugreek variety for Mid lands of Bale, Ethiopia

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Abstract

Burqa (201617Sno3-7), a medium height yellow seed variety of fenugreek was selected and developed by Sinana Agricultural Research Center, eastern Oromia, Ethiopia. The variety was released in 2008/2009 EC for Bale midlands and similar agro-ecologies. This variety was selected from variety trial tested together with 16 other test genotypes and checks (local and the previously released varieties for comparison) at 3 locations (Sinana, Goro and Ginnir) for 3 consecutive years (2005 to 2007) EC in midlands of Bale, eastern Oromia, Ethiopia. After the trial was conducted for the above three consecutive years, this variety was selected and verified for one more season at 9 locations to see performance across locations. Finally due to its superior performance, Burqaa was selected and verified during bona 2008/2009 EC cropping season and thereby released for production. This variety is characterized by deep yellow seed color, having high yield with yield advantage 14.36%, over the standard check chala. It is stable, best adapted, having large number of pods per plant, stem number, thousand seed weight, and moderately powdery mildew and rust.

Key words: Burqaa, variety registration

Introduction

Spices are well known for their flavoring, culinary uses, medicinal values, and essential oil derivatives. They have high prices at domestic as well as international markets. Having considerable demand at home and on the international market; spices have considerable importance to the Ethiopian economy. Bale mid and lowlands are well known for the production of important cash crop spices such as fenugreek, black cumin and coriander.

In Ethiopia, fenugreek-growing regions are the high plateaus (1800-2300m a.s.l.) characterized by subtropical climate of wet and dry seasons. It is also one of the crop selected for specialization at the national level for their export potential. The evaluation of fenugreek genotypes in Ethiopia has been infant and on a small-scale. Only some variety development efforts have been reported from Sinana and Debreziet Agricultural Research Center in the country (DZARC, 2004; SARC, 2005). Hence, in Ethiopia there have been only limited research efforts made so far in developing fenugreek technologies. The importance of thi crop was not fully utilized by the farmers due to the shortage of improved technologies that increase their yield and improve their market quality. Lack of improved variety, even in the country as a whole and Bale zone in particular where these spices crops are important , is one major factor constraining farmers from exploiting the potential of this crop. Hence, generating, releasing and registering superior varieties of fenugreek and made available for the farmers in the country is very crucial. Keeping these in view, the present study was initiated with the following objective:

Objective: To release and register the fenugreek variety with higher yield, tolerant to major diseases and desirable characteristics with better adaptations for Mid and low lands of Bale zone and similar agroecologies.

Materials and Methods

The experiment was carried out at three locations. One location was Sinana Agricultural Research Center on-station and the remaining sites were Goro and Ginnir on farm sites.The experiment was conducted from initial lines screening nursery till variety verification trials during 2005 to 2007 main cropping seasons under rain fed conditions at the above mentioned locations. Sinana Agricultural Research Center is situated at 7^0 N latitude and 40^0 E longitudes; and with altitude of 2400 m.a.s.l and is located 463km South east of Addis Ababa and East of Robe town, the capital of Bale zone. The other location Goro' is located 20 km away from Sinana in East direction whereas, Ginnir' is located about 56 km from away from Sinana Research Center in the Southeast direction.

Varietal characters

Burqaa has medium plant height with deep yellow seed color and basal branching growth habit. On average this variety took 51 days to flowering and 129 days to physiological maturity. It has about 22 pods per plant with a plant height of 43cm.

Yield performance

The average seed yield of Burqaa over locations and over years is about 22.21 qt/ha which is higher than two standard checks viz. Hunda'ol and Chala as well as the local check. The variety has yield advantage of 14.36%, over the recently released and currently used standard check Chala .

Reaction to major diseases

The major fenugreek diseases according their importance in the growing areas are powdery mildew and rust. In 1-9 rating scale, Burqaa scored a mean of 2.9 and 0.7 for powdery mildew and rust respectively. The variety is characterized by moderately resistance types of reaction to these major diseases at all the sites and showed better performance to these diseases as compared to standard ceheck as well as local check.

Adaptation

Newly released variety Burqaa is released for the midlands of Bale zone and for areas with similar agroecologies. It performs very well in areas having an altitude 1650-2400 m.a.s.l. and receiving annual rainfall amount of 120-500 mm. It can also be possible to extend the production of this variety to other areas having similar agro-ecologies with these areas where the present study has been conducted.

Variety maintenance

Breeder and foundation seed of the variety will be maintained by Sinana Agricultural Research Center of Oromia Agricultural Research Institute.

Table 1. Combined Summary of Mean seed yield, other agronomic traits, and Disease of fenugreek variety trial over years and over three locations.

Treatment	DF	PM	RU	DM	PH	PB	SB	PPP	SPP	BMTH	GYQH
201612Sno3-9	50	2.9	0.6	129	41.8	4	2	22	11	39	19.16
201617Sno3-7	50	3	0.7	129	39.6	3.8	1	22	11	37.8	22.21
201623Sno3-1	52	2.6	0.7	131	41.1	4.5	2	25	13	35.9	18.8
220021Sno3-1	51	3	0.6	129	38.7	4.1	2	22	11	34.6	18.75
238246Sno3-6	51	2.9	0.7	130	42.9	4.1	2	23	11	45.5	20.9
50074Sno3-1	51	2.9	0.7	130	43.3	4	2	24	10	42.4	16.89
53003	50	3	0.6	129	42.6	3.9	2	20	11	40.5	17.41
53010	50	2.9	0.5	129	42.4	4.1	2	19	11	36	16.09
53015	52	1.4	0.7	132	46.6	4	2	18	10	40.1	15.82
53019Sno3-5	59	9.9	0.6	132	50	4	1	18	10	32	15.7
53022	50	3	0.6	129	40.2	3.9	1	21	10	37.1	15.27
53024	52	2.8	0.7	134	41.6	4.5	2	24	10	46.5	14.95
53097Sno3-3	50	3	0.6	129	42.8	3.9	2	23	11	39.3	14.88
Chala	52	2.9	0.7	131	44.2	4.6	2	20	10	46.6	14.36
hunda'ol	52	3.2	0.8	129	41.4	4.3	2	24	11	41.8	14.04
Local	52	3.1	0.7	129	37.9	4	1	22	11	39.5	12.1
SE	1.3	-	-	1.5	3.1	0.4	0.4	4.3	2.2	5.3	1.294
5% LSD	3.6	-	-	4.2	8.6	1	1	11.9	6.1	14.7	2.547

Note: DF=days to flower, PH=plant height, PB= primary branches/plant SB=secondary branches/plant, DM=days to Maturity, PPP=pod/plant, BMQH= biomass mass Quintal per hectare, and SY= seed yield Quintal per hectare, RU= Rust, PM= powdery Mildew, SPP=Seed per pod

Conclusions and Recommendations

The development of cultivars, which are adapted to a wide range of diversified environments, is ultimate aim of breeders in crop improvement program. The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is grown. A variety is considered to be more stable if it has high mean yield but a low degree of fluctuation in yielding ability when planted over diverse environments (Becker, 1988). Based on the evaluation result, the variety Burqa had showed above average yield performance in most test environments, out yielded the two standard check varieties such as Chala and Hunda’ol. It has also better yield stabilty than these checks. The variety is characterized by moderate resistance types of reaction to the most important diseases in the growing areas such as powdery mildew and rust at all sites and showed better performance to these tow diseases as compared to the check varieties. Burqaa is, therefore, released and recommended for production in all fenugreek growing environments in the midlands of Bale and other similar agroecologies.

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Appendex 1. Agronomic and morphological descriptions of the newly released Burqaa variety

1. Variety: Burqaa(201617Sno3-7)
2. Agronomic and Morphological Characterstics
   2.1. Adaptation area: Bale Highlands and similar areas
      - Altitude (m.a.s.): 1650-2400
      - Rainfall (mm): 120-500
   2.2. Seed rate (kg/ha): 20
   2.3. Planting date: Mid-late September
   2.4. Fertilizer rate (kg/ha):
      - P_2O_5 : 90
      - N: 20
   2.5. Days to flowering: 50
   2.6. Days to maturity: 129
   2.7. Plant height (cm): 40
   2.8. Growth habit: Basal branching
   2.9. Seed color: Deep yellow
   2.10. Pods per plant: 22
   2.17. Crop pest reaction: Moderately susceptible to powdery mildew
   2.18. Yield (Qt/ha): 22.21
3. Year of Release: 2016
4. Breeder/Maintainer: SARC/OARI

Registration of “Sooressaa” a newly released black cumin variety for Bale Mid lands, Ethiopia

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Abstract

Sooressaa (AC-BC-15) a medium height deep black seed variety of black cumin is selected and developed by Sinana Agricultural Research Center, South Eastern Oromia, Ethiopia. The variety was released in 2008/2009 E.C for Bale midlands and similar agro-ecologies. This variety was selected from variety trial tested along with 12 other test genotypes and checks (local and the standard check -previously released variety) for comparison at three locations viz. Sinana, Goro and Ginnir for three consecutive years starting from 2005 to 2007 E.C in midlands of Bale, South Eastern Oromia, Ethiopia. After the trial was conducted for the above three consecutive years in different breeding stages starting from screening nursery till varity trial, this variety was selected and promoted to variety verification trial for evaluation and verification in variety verification trial. In this trial, the experiment was evaluated for one season during 2008/9 E.C cropping season at nine locations to see performance across locations. Finally based on overall performance of the tested genotypes, genotype AC-BC-15 was showed superior performance and officially released by the name called Sooressaa for production in the intended agroecology. This variety is characterized by deep black seed color, having high yield with yield advantage of 15.76% and 20.71 % than standard checks Dirshaye and Darbera respectively. It is stable, best adapted, having large number of capsule per plant, stem number and thousand seed weight.

Key words: *Sooressaa, variety registration, stability*

Introduction

Spices are well known for their flavoring, culinary uses, medicinal values, and essential oil derivatives. They have high prices at domestic as well as international market. Having considerable demand at home and on the international market; spices have considerable importance to the Ethiopian economy. Bale mid and lowlands are well known for the production of the important cash spices such as Fenugreek, Black cumin and Coriander. In Ethiopia, fenugreek-growing regions are the high plateaus (1800-2300 m a.s.l.) and characterized by subtropical climate of wet and dry seasons. It is also one of the crops selected for specialization at the national level for their export potential. The evaluation of black cumin genotypes in Ethiopia has been infant and on a small-scale. Only some variety development efforts have been reported from Sinana and Debreziet Agricultural Research Center in the country (DZARC, 2004; SARC, 2005). Hence, in Ethiopia there have only been limited research efforts up to this time. The importance of these crops was not fully utilized by the farmers due to the shortage of improved technologies that increase their yield and improve their market quality. Lack of improved variety, even in the country as a whole, is one the factors constraining farmers from exploiting the potential of this crop. Hence, generating, releasing and registering superior varieties of black cumin available in the country is very crucial.Hence, the present experiment was initiated with the following objective:

Objective: To register the newly released variety with higher yield and desirable characteristics for broad adaptations

Methodology

The experiment was carried out at three locations. One of the experiments was conducted at the research farm of Sinana Agricultural Research Center, Oromia Agriculture Research Institute, Sinana and the remaining were conducted on the farmers' field, at Goro and Ginnir districts. The experiment was conducted starting from the screening nursery till to variety verification trial (2005 to 2007 E.C) under rain fed conditions at each location. Sinana Agricultural Research Center is geographically located at 7^0 N latitude and 40^0 E longitudes; and has an altitude of 2400 m.a.s.l). It is located 463 km South East of Addis Ababa and East of Robe town, the capital of Bale zone. The other location 'Goro' district is located 20 km away from Sinana in the direction of East whereas 'Ginnir' district is located about 56 km away from Sinana in the direction of Southeast.

Treatment	DF	DM	PH (cm)	PB	CPB	CPP	BM (t/ha)	TSY(q/ha)
AC-BC-15	85	131	53.47	3	8	25	79.23	21.45
MAB-017	87	140	53.81	3	8	25	70.77	19.6
AC-BC-19	91	142	53.87	3	7	24	72.39	16.36
AC-BC-4	87	140	51.27	3	7	21	67.64	17.29
AC-BC-9	88	142	51.48	3	8	24	69.8	16.91
Darbera	89	142	55.28	3	7	22	82.25	17.02
Dirshaye	90	141	53.07	3	8	22	72.88	17.77
Eden	93	142	56.9	3	7	22	84.26	18.53
Local	87	141	51.81	3	8	24	72.55	17.06
AC-BC-10	86	141	50.39	3	8	24	70.84	16.53
MAB-042	87	185	49.53	3	8	22	69.05	16.67
MAB-057	86	140	51.01	3	8	22	65.37	16.84
LSD (0.05)	2.142	35.5	3.657	1.43	NS	NS	8.53	1.94
CV (%)	4.5	4.5	12.9	10.6	4.5	4.5	21.8	20.5

Varietal characters

Sooressaa has medium plant size with deep black seed color and basal branching growth habit. On average this variety needs 85 days to flowering and 131 days to physiological maturity and plant height of 53.81cm.

Table 1. Combined Summary of Mean seed yield, other agronomic traits, and Disease of fenugreek variety trial over years and over three locations.

Note: DF=days to flower, PH=plant height, cm= centimeter, PB= primary branches/plant DM=days to maturity, CPB = capsule/ primary branch, Cp=capsule/plant, BM= biomass mass, q/ha= quintal per hectare and TSY = total seed yield

Yield performance

The average seed yield of variety **Sooressaa** over locations and years is 21.45 qt/ha with a yield advantage of above 15.76% and 20.71 % over thetwo standard checks namely Edan and Dirshaye respectively. Similarly, it showed a superior yield advantage over the local check.

Adaptation

Variety **Sooressaa** is released for the midlands of Bale. It performs very well in areas having an altitude of 1650-2400 m.a.s.l. and annual rainfall amount of 120-500 mm. It can also possibly extend the production of this variety to other areas having similar agro-ecologies with Bale midlands.

Variety maintenance

Breeder and foundation seed of this variety is maintained by Sinana Agricultural Research Center of Oromia Agricultural Research Center (OARI).

Conclusions and Recommendations

The development of cultivars, which are adapted to a wide range of diversified environments, is ultimate aim of breeders in crop improvement program. The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is grown. A variety is considered to be more stable if it has high mean yield but a low degree of fluctuation in yielding ability when planted over diverse environments (Becker, 1988). The ***Sooressaa*** variety had above average yield performance in most test environments, out yielded the out yielded the standards ((Edan and Dirshaye)). It has also better yield stabilty than local check.. ***Sooressaa*** is, therefore, released for production for all black cumin growing environments in the midlands of Bale and other similar agroecologies.

Acknowledgement

We thank Oromia Agricultural Research Institute (OARI) for financing the development of the varieties. We also thank the staff of Sinana Agricultural Research Centre (SARC) for facilitating the necessary requirements during the trial. we aknowledge ato Mulugeta Geddif, Guta Legese, Habtamu Legese,Senaiet Biftu, Mohammed Abdella,Abebech Dejene, Adam A/Hamid and Shimelis Mekonnin and all horticulture research team of Sinana agriculture research center for trial management and appropriate data collection.

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Appendex 1.

1. Variety: Sooressaa (AC-BC-15)
2. Agronomic and Morphological Characterstics
   2.1. Adaptation area: Bale Highlands and similar areas
   - Altitude (m.a.s.): 1650-2400
   - Rainfall (mm): 120-500

   2.2. Seed rate (kg/ha): 15
   2.3. Planting date: Mid-late September
   2.4. Fertilizer rate (kg/ha):
   - N: 60

   2.5. Days to flowering: 85
   2.6. Days to maturity: 131
   2.7. Plant height (cm): 53.81
   2.8. Growth habit: Erects and condensed branching
   2.9. Seed color: Deep black
   2.10. Average moisture(%): 5.57
   2.11. Oleoresi : 23.8
   2.12. Crop pest reaction: No observed
   2.13. Yield (Qt/ha): 21.45
3. Year of Release: 2016
4. Breeder/Maintainer: SARC/OARI

Registration of "Gammachiis" a newly released black cumin variety for Bale Mid lands, Ethiopia

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Abstract

Gammachiis (MAB-018) a medium height deep black seed variety of black cumin is selected and developed by Sinana Agricultural Research Center, South Eastern Oromia, Ethiopia. The variety was released in 2008/2009 EC for Bale midlands and similar agro-ecologies. This variety was selected from variety trial experiment tested along with 12 other test genotypes and checks (local and the previously released varieties for comparison) at three locations viz. Sinana, Goro and Ginnir for three consecutive years (2005 to 2007 EC)in midlands of Bale, South Eastern Oromia, Ethiopia. After the trial was conducted for the three consecutive years, this variety was selected and verified for one more season at nine locations to evaluate its performance across locations. Finally due to its superior performance, Gammachiis was selected and verified during bona 2008/2009 EC cropping season and thereby released for production. This variety is characterized by deep black seed color, having high yield with yield advantage of 10.3% and 14.89 % as compared to standard checks viz.Dirshaye and Darbera respectively). It is stable, best adapted, having large number of capsule per plant, stem number and thousand seed weight.

Key words: *Gammachiis, variety registration, stability*

Introduction

Spices are well known for their flavoring, culinary uses, medicinal values, and essential oil derivatives. They have high prices at domestic as well as international market. Having considerable demand at home and on the international market; spices have considerable importance to the Ethiopian economy. Bale mid and lowlands are well known for the production of the important cash spices such as Fenugreek, Black cumin and Coriander.

In Ethiopia, fenugreek-growing regions are the high plateaus (1800-2300m a.s.l.) characterized by subtropical climate of wet and dry seasons. It is also one of the crops selected for specialization at the national level for their export potential. The evaluation of fenugreek genotypes in Ethiopia has been infant and on a small-scale. Only some variety development efforts have been reported from Sinana and Debreziet Agricultural Research Center in the country (DZARC, 2004; SARC, 2005). Hence, in Ethiopia there have only been limited research efforts up to this time. The importance of these crops was not fully utilized by the farmers due to the shortage of improved technologies that increase their yield and improve their market quality. Lack of improved variety, even in the country as a whole, is one the factors constraining farmers from exploiting the potential of this crop. Hence, generating, releasing and registering superior varieties of fenugreek available in the country is very crucial. Hence, the present experiment was initiated with the following objective:

Objective: To register the newly released fenugreek variety with higher yield and desirable characteristics for adaptation in midlands of Bale and similar agroecologies

Methodology

The experiment was conducted at three locations. One of the experiments was conducted at the research farm of Sinana Agricultural Research Center, Oromia Agriculture Research Institute, Sinana and the remaing was carried out on the farmers' field at Goro and Ginnir. Initially, the experiment was started from the screening nursery and eventually after rigrous evaluation of the test genotypes, few genoytpes including the variety Gammachiis were promoted to variety verification trial during 2007 EC for verification and release under rain fed conditions at each location. Sinana Agricultural Research Center (7^0 N latitude and 40^0 E longitudes; and 2400 m.a.s.l) is located 463km away from Addis Ababa in South Eastern direction.and East of Robe town, the capital of Bale zone. The other location 'Goro' is located 20 km away from Sinana in East direction; whereas, 'Ginnir' is located about 56 km away from Sinana in South east direction.

Table 1. Combined Summary of Mean seed yield, other agronomic traits, and Disease of fenugreek variety trial over years and over three locations.

Treatment	DF	DM	PH (cm)	PB	CPB	CPP	BM (t/ha)	TSY(q/ha)
AC-BC-13	85	131	53.47	3	8	25	79.23	17.45
MAB-018	87	140	53.81	3	8	25	70.77	19.6
AC-BC-19	91	142	53.87	3	7	24	72.39	16.36
AC-BC-4	87	140	51.27	3	7	21	67.64	17.29
AC-BC-9	88	142	51.48	3	8	24	69.8	16.91
Darbera	89	142	55.28	3	7	22	82.25	17.02
Dirshaye	90	141	53.07	3	8	22	72.88	17.77
Eden	93	142	56.9	3	7	22	84.26	18.53
Local	87	141	51.81	3	8	24	72.55	17.06
AC-BC-10	86	141	50.39	3	8	24	70.84	16.53
MAB-042	87	185	49.53	3	8	22	69.05	16.67
MAB-057	86	140	51.01	3	8	22	65.37	16.84
LSD (0.05)	2.142	35.5	3.657	1.43	NS	NS	8.53	1.94
CV (%)	4.5	4.5	12.9	10.6	4.5	4.5	21.8	20.5

Note: DF=days to flower, PH=plant height, cm= centimeter, PB= primary branches/plant DM=days to maturity, CPB = capsule/ primary branch, Cp=capsule/plant, BM= biomass mass, q/ha= quintal per hectare and TSY = total seed yield

Varietal characters

Gammachiis has medium plant size with deep black seed color and basal branching growth habit. On average this variety needs 87 days to flowering and 140 days to physiological maturity and plant height of 50.39cm.

Yield performance

The average seed yield of ***Gammachiis*** over locations and over years is 19.6qt/ha which is showed 10.3% and 14.89 % yield advantage over standard checks namely; Dirshaye and Darbera respectively and it is also superior in yiled performance as compared to the local check.

Adaptation

Gammachiis is released for the midlands of Bale. It performs very well in areas having an altitude of 1650-2400 m.a.s.l. and annual rainfall of 120-500 mm. It can also be possibly extend its production to other areas having similar agro-ecologies.

Variety maintenance

Breeder and foundation seed of this variety will be maintained by Sinana Agricultural Research center of Oromia Agricultural Research Institute (OARI).

Conclusions

The development of cultivars, which are adapted to a wide range of diversified environments, is ultimate aim of breeders in crop improvement program. The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is grown. A variety is considered to be more stable if it has high mean yield but a low degree of fluctuation in yielding ability when planted over diverse environments (Becker, 1988). The ***Gammachiis*** variety had above average yield performance in most test environments, out yielded the out yielded the standards ((Edan and Dirshaye)). It has also better yield stabilty than checks. ***Gammachiis*** is, therefore, released for production for all black cumin growing environments in the midlands of Bale and other similar agroecologies.

Acknowledgement

We thank Oromia Agricultural Research Institute (OARI) for financing the development of the varieties. We also thank the staff of Sinana Agricultural Research Centre (SARC) for facilitating the necessary requirements during the trial. we aknowledge ato Mulugeta Gaddif, Guta Lagasa, Habtamu Lagasa,Sanayt Biftu, Mahammed Abdalla,Ababech Dajanee, Adam A/Hamid and Shimalis Mokonnin and all horticulture research team of Sinana agriculture research center for trial management and appropriate data collection.

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Appendex

1. Variety: Gammachiis (MAB-018)

2. Agronomic and Morphological Characterstics

   2.1. Adaptation area: Bale Highlands and similar areas

- Altitude (m.a.s.): 1650-2400
- Rainfall (mm): 120-500

2.2. Seed rate (kg/ha): 15
2.3. Planting date: Mid-late September
2.4. Fertilizer rate (kg/ha):N: 60
2.5. Days to flowering: 87
2.6. Days to maturity: 150
2.7. Plant height (cm): 50.39
2.8. Growth habit: Erects and condensed branching
2.9. Seed color: Deep black
2.10. Average moisture (%): 5.67
2.11. Oleoresi : 28.4
2.12. Crop pest reaction: No observed
2.13. Yield (Qt/ha): 19.6
3. Year of Release: 2016
4. Breeder/Maintainer: SARC/OARI

Registration of "Wabero, Gobu and Doyo" common bean varieties released for the midlands of Bale zone and similar agro-ecologies

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Abstract

Wabero from the white, Gobu from small red, and Doyo from the speckled bean categories were released for the midlands of Bale zone and similar agro-ecologies due to their high yield performance and different merits over the checks during bona 2018 cropping season. In order to get these stable, high yielding, and tolerant varieties to major common bean diseases, screening and multiplication trials were conducted for several years so as to identify the best genotypes out of the screened and teased once. Among the common bean lines tested in three different categories (white, small red and speckled beans), fifteen lines from each categories were selected and tested under regional variety trial for three years (2013/14 to 2015/16), at two locations, Goro and Ginnir in the midlands of Bale zone. The combined analysis over locations and years revealed that, the three varieties from their categories showed consistence performance for most of the agronomic parameters and with high yield compared to their respective checks used in the trial. Accordingly, variety ICN Bunsi X B 405/5C-1C-1C-51 white bean type (Wabero) has yield advantage of 17.9%; whereas the small red bean type variety Selian-97 (Gobu) has yield advantage of 19.3%; the speckled bean types variety, SAB-627 (Doyo) has yield advantage of 21.3% over the checks Melka Awash, Nasir and Cranscop, respectively. Furthermore, these varieties have stable, best adapted, having large number of pods per plant and tolerant to common bacterial blight, Alternaria leaf spot and rust. In addition to their better agronomic performance, these varieties used for food and local and international markets. Due to these merits "Wabero, Gobu and Doyo" were released in the 2018 cropping season for the midlands of Bale zone and similar agro-ecologies.

Key words: Common bean, Doyo, Gobu, Stable, Waber

Introduction

Phaseolus vulgaris is originated from Central and South America, where it was cultivated as early as 6000 BC in Peru and 5000 BC in Mexico. It was introduced to the Old World by the Spaniards and the Portuguese. It is now widespreaded and cultivated as a major food crop in many tropical, subtropical and temperate areas of the Americas, Europe, Africa and Asia (Wortmann, 2006). It is a major staple food in eastern and southern Africa where it is recognized as the second most important source of human dietary protein and the third most important source of calories (Pachico 1993). Common bean, a major food crop in many parts of Africa, is noted for its versatility and diversity. It is adapted to varied climatic and agronomic conditions, and exhibits considerable variation in growth habit and seed type. In Africa, it is grown primarily by small scale farmers who have limited resources and usually produce the crop under adverse conditions such as low input use, marginal lands, and intercropping with competitive crops. The bean-growing agro-ecosystems of Africa are numerous and diverse (Allen and Edje 1990). Their potential for production and management requirements are determined by the interplay of many factors, including climate, soil type, and a range of socio-economic and biological factors. Biotic and abiotic constraints to bean production are numerous. The diversity of this crop and its production implies a need for much information to effectively address the problems involved.

Common bean is one of the most important pulse crop produced in the midlands of Bale zone which is used for local consumption as well as serving as cash crops. Though the crop has many advantages, its average annual production is very low due to several factors among which the lack of stable varieties to the changing environment takes the lion share. For this purpose, the development of cultivars, which are adapted to a wide range of diversified environments is the ultimate aim of plant breeders in a crop improvement program (Muhammad *et al.*, 2003).

The performance of any character is a combined result of the genotype (G) of the variety, the environment (E) and the interaction between genotype and environment (GE). To evaluate the consistency of common bean grain yield and develop genotypes that respond optimally and consistently across years and geographic regions, it is necessary to study yield stability and GE interactions (Blanche *et al.*, 2009). GE interactions exist when the responses of two genotypes to different levels of environmental stress are not consistent. Because of its importance in the zone, identifying and developing of common bean varieties that are stable and high yielder to the testing sites were very critical. So far, no variety has been released for the midlands of Bale zone. Therefore, developing and releasing of stable and high yielding varieties for the midlands of Bale was the first target in order to increase production and productivities of common bean.

Evaluation

Genotypes should be passed under different stage of evaluation in order to identify and develop high yielding and tolerant for most of the major diseases. Furthermore, testing of the genotypes over environments is crucial so as to get stable genotypes over wide range of the testing locations. So in order to reach this level, one hundred fifty genotypes from each of the three categories (white, small red and speckled) common beans classified as different sets were first evaluated in a preliminary observation nursery during the 2011/12 cropping season at Goro. Of these, from each category 25 genotypes were selected for further evaluation and tested in 2012/13 as regional preliminary yield trial at two locations, Goro and Ginnir. From the yield trial, including the checks, fifteen genotypes from each sets were retained for further evaluation in a multi-location trial to see their stability and overall performance across the two testing sites. In the regional variety trial, Wabero (white seeded) (*ICN Bunsi X B 405/5C-1C-1C-51)Gobu (*red seeded*) Selian-97*and Doyo(SAB-627) (Speckled), were evaluated at 6 environments (2 locations x 3 years) along with Melka Awash, Nasir and Cranscope as standard checks for the white, small red and the speckled bean, respectively in the midlands of Bale zone from 2013/14 to 2015/16 in major common bean production areas having an altitude of 1600-1950m.a.sl and receive annual rain fall of 500-650mm.

Varietal Characters

Wabero has erect growth type with white seed coat, yellow cotyledon, and white flowers. On average, it has an average plant height of 53cm, and requires 52 days for flowering, and 110 days to reach physiological maturity. Average thousand seeds is 190.8gm, and on average, 13 medium length pods per plant (Table 1). On the other hand Gobu has erect growth type with red seed coat, yellow cotyledon, and pink flowers. This variety has also plant height of 57cm, and requires 51 and 1108 days to give flowers and to reaches physiological maturity respectively. Similarly Doyo has erect growth type with speckled seed coat, yellow cotyledon and with pink flowers. It has plant height of 55cm, and needs 47 days for flowering and 106 days to reaches physiological maturity.

Yield performance:

The average seed yield of Wabero combined over locations and over years is (2.05t/ha) which is higher than its comparable check, Melka Awash (1.74 t/ha). Whereas for Gobu it is (2.04t/ha) andand it is higher than the standard check, Nasir (1.76t/ha), for Doyo it is (1.95t/ha) which is higher than Cranscope (standard check) (1.61t/ha). Under research field Wabero yields (1.7-3.1t/ha); Gobu (2.1-2.4t/ha) and Doyo (1.8-2.3t/ha.

Table 1. Combined mean seed yield and other agronomic traits of the three common bean varieties and checks in multi-location testing, during 2013/14-2015/16

SN	Entry	Days to flower	Days to maturity	Plant height (cm)	NO. of Pods/plant	No. of seeds/pod	1000 Seed wt	Disease score (1-9)^a CBB.	ALS		Seed yield (t/ha)
1	**ICN Bunsi X S X B 405/5C-1C-1C-51(Wabero)**	52	110	53	13	5	190.8	3	2	2	2.05
	M.Awash (St.check)	53	109	48	14	5	164.6	4	4	4	1.75
2	**Selian-97 (Gobu)**	51	108	57	11	4	348.6	3	2	2	2.04
	Nasir (St.check)	52	106	58	12	5	217.4	5	4	4	1.76
3	**SAB-627**	47	106	55	8	4	406.4	2	3	3	1.95
	Cranscope (check)	47	106	55	9	4	364.7	5	4	3	1.61

Note CBB=Common Bacterial Blight, ALS= Alternaria Leaf Spot

[a] Disease score based on 1-9 scale where 1 is highly resistance and 9 is highly susceptible

Stability performance

The three varieties were tested in 6 environments (Gx E) in order to see their stable performance over the testing sites. Accordingly, these three varieties were selected since they showed mean gain yield better than the checks with yield advantage of 17-22%. Furthermore the varieties have regression coefficient nearly unity, and they have also the least deviation from regression and mean grain yield above the checks.

Reaction to disease

The major common bean diseases according to their importance in the growing areas are Common Bacterial Blight (*Xanthomonas campestris pv. phaseoli)* Alternaria leaf Spot (*Alternaria alternata) and* Rust(*(Uromyces phaseoli)* (Asfaw *et al*., 1993). In 1-9 rating scale, with a score of 1 most resistant, the three varieties scored a mean of 2-3 for all the above mentioned diseases, and be characterized as resistant (Table 1).

Quality

The three common bean varieties are used for food consumption and can also used as a source of cash since they are used for local market as well as international market.

Adaptation

Wabero, Gobu and Doyo are released for the midlands of Bale zone, southeastern Ethiopia. It is well adapted in areas having an altitude of 1600-1950 m.a.s.l with annual rain fall of 550-650mm. Furthermore; production of these varieties can be extended to areas having similar agro-ecologies. Recommended planting time for these varieties is from the end of September to early October in Meher and to the end of March at Belg.

Variety Maintenance

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

Acknowledgement

Authors thank OARI in financing for the development of the varieties. We also thank Sinana Agricultural Research Center Administration staff's in facilitating field evaluation. We acknowledge all pulse and Oil crops research case team staff for data collection and trial management.

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Multivariate Analyses of Bread Wheat (Triticum aestivum L.) Genotypes in Mid Rift Valley of Oromia

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Abstract

Multivariate analysis techniques are suitable in identification of plant traits separately and it helps breeders in genetic improvement of different traits in crops. This research was conducted at Adami Tulu, mid rift valley of Oromia, Ethiopia, with the objectives of studying the extent of genetic diversity via cluster analysis inbread wheat genotypes and identifying the most important traits in distinguishing the genotypes. A total of 36 bread wheat genotypes including eleven released varieties were evaluated in 66 simple lattice design during 2017/18 main cropping season. Analysis of variance showed the existence of highly significant ($P \leq 0.01$) variation among genotypes for most of the studied traits. Cluster analysis revealed that the 36 bread wheat genotypes were grouped into 4 main clusters. Besides, the Principal Component Analysis (PCA) showed that the first seven principal components with Eigen values greater than one combined explained about 82.82% of the total variation. Generally, the current study showed the presence high variability and also the possibility of improving yield and other desirable agronomic characters through selection in bread wheat genotypes. However,since this study is conducted only for one growing season, further testing in different locations and for more than one cropping season is necessary to have a conclusive result.

Key words: Cluster analysis, Multivariate analysis, Principal component analysis

Introduction

Bread wheat (*Triticum aestivum* L.) and durum wheat (*Triticum durum* desf.) are the world's two principal commercial types of wheat. Bread wheat is a self-pollinating annual plant in the true grass family Gramineae (Poaceae) which is the largest cereal crop extensively grown as staple food sources in the world (Mollasadeghi and Shahryari, 2011). It is one of the most important and strategic cereal crop in the world and in Ethiopia in terms of production and utilization (Ranjana and Kumar, 2013). In Ethiopia, wheat is grown at an altitude ranging from 1500 to 3000 meters above sea level, between 6-16^{o}N latitude and 35-42^{o}E longitude. The most suitable agro ecological zones, however, fall between 1900 and 2700 m.a.s.l (Abu, 2012). Ethiopia is the second largest wheatproducing country in Africa following South Africa. Wheat accounts for about one-fourth of the nation's total cereal production. In Ethiopia, from the total cereal crops produced, about 18.24% of production is from wheat (CSA, 2016). The production losses due to both biotic and abiotic factors coupled with the increasing population has made it difficult to attain food security in the country. Improving the adaptability of crop varieties to a changing environment supported by appropriate crop management strategies is the working principle worldwide in ensuring crop productivity (Farooq *et al.*, 2015). However, crop improvement for water stress is a much complicated task as drought damage is manifested in various forms at various crop growing stages making breeding for drought tolerance uneasy task (Blum, 2005; Fischer *et al.,* 2012; Tuberosa, 2012).

Cluster analysis is very important identify diverse parents in crossing program to broaden the genetic basis of wheat crop. Principal component analysis is suitable multivariate technique in identification and determination of independent principal components that are effective on plant traits separately. Principal component analysis is also helps breeders to genetic improvement of traits such as yield (Golparvar et al., 2006). Agronomic, morphological and phenological traits are very important for grouping wheat genetic resources, and also are essential and useful for plant breeders seeking to improve existing germplasm by introducing novel genetic variation for certain traits into the breeding populations (Najaphy *et al.,* 2012).

Study on cluster analysis portrays the presence of wider genetic variability among genotypes and the possibility to broaden the genetic basis through crossing of genotypes in the different cluster. Multivariate analysis techniques are suitable in identification of plant traits separately and it helps breeders in genetic improvement of different traits in bread wheat genotypes however, this kind of study has been given little attention in moisture stress environments, particularly in the mid rift valley of Oromia. Therefore, the present study was initiated with the objectives;

- To study the cluster analysis in bread wheat genotypes and
- To identify the most important traits that distinctly distinguish the genotypes in bread wheat

Materials and Methods

Description of the Study Area

The experiment was conducted at Adami Tulu Agricultural Research Center (ATARC) during 2017 main cropping season. ATARC is located in Adami Tulu Jido Kombolcha District, East Shoa Zone of Oromia, and it is located in the mid Rift Valley of Ethiopia with about 167 km South of Addis Ababa. It lies at a latitude of 7° 9’N and longitude of 38° 7’E. It has an altitude of 1650 m.a.s.l and receives a bimodal unevenly distributed average annual rainfall of 760.9 mm per annum. The long-term mean minimum and the mean maximum temperatures are 12.6 and 27 ^{o}C, respectively. The pH of the soil is 7.9. Having sandy loamy soil type with sand, clay and silt in proportion of 34, 48 and 18% respectively (ATARC, 1998).

Experimental Materials, Design and Management

In this experiment 11 (eleven) released bread wheat varieties and 25 (twenty five) advanced breeding lines, making a total of 36 genotypes that were obtained from Kulumsa Agricultural Research Center (KARC) were used for this study. The experiment was arranged in 6x6 Simple Lattice Design. The genotypes were grown under uniform rain fed conditions. The experimental plots were composed of six rows of 2.5 m length, 1.2m width and 0.2m row space (3m^{2}). The central four rows were harvested to estimate grain yield. The spacing between adjacent replications, blocks and plots were 1m, 0.5m and 0.5m, respectively. Sowing was done on July 13, 2018 by hand drilling and covered lightly with soil. Seeding rate of 150 kg ha^{-1} and fertilizer rate of 41 and 46 kg ha^{-1} of N and P_2O_5, respectively or 89kg ha^{-1} of Urea and 100 kg ha^{-1} of DAP

(MoARD, 2012), were applied where nitrogen fertilizer was applied in split (½ at planting, ¼ at tillering and ¼ at flowering). Weeding and other management practices were practiced as per the recommendation for wheat.

Data Collection

Data were collected on plot and plant basis.

Data recorded on plot basis

Data were collected on plot basis from central rows of each plot in each replication

Days to heading: The number of days from date of emergence to the stage where 75% of the spikes have fully emerged.

Days to maturity: The number of days from date of emergence to the stage when 90% the plants in a plot have reached physiological maturity.

Grain filling period: The number of days from heading to maturity, i.e. the number of days to maturity minus the number of days to heading

Effective tillers per meter square: Number of tillers per meter square was counted in the square meter frame area. Tillers were recorded by counting the number of tillers of one meter length in four central rows of each sub plot and then converted to tiller per meter square.

Grain yield/ha (t ha^{-1}): Grain yield t ha^{-1} was estimated from grain yield (g/plot). Grain yield in grams estimated from plants in the central four rows of each plot was adjusted to 12.5% moisture content. Plants grown in 20 cm at the outer most of the plot left as border plants and yield per plot was estimated from 2.5 m x 0.8 m total harvestable area (2 m^2). Therefore, grain yield (g/plot) of each plot was used to estimate grain yield per hectare in tons.

1000-kernel weight (g): Weight of 1000 seeds in gram adjusted to 12.5% moisture content.

Biomass yields (g/plot): The plants with in the four central rows (that was harvested for yield estimate) were harvested at the point where they are attached to the ground, collected, sun dried until the constant weight attained and weighed in grams to obtain the biomass yield per plot.

Harvest index (%): was calculated on a plot basis, as the ratio of dried grain weight adjusted to 12.5% moisture content to the dried total above ground biomass weight.

Data recorded on plant basis

Ten plants were selected randomly from the four central rows of the plots before heading and were tagged for recording the following characters.

Plant height (cm): The average height in cm of ten plants in each plot which has been measured from ground level to the tip of the spike excluding the awns.

Kernels per spike: The average number of kernels per spike of ten plants in each plot.

Spikelet per spike: The average number of spikelet per spike of ten plants in each plot.

Peduncle length (cm): The average length of the peduncle of the main culm of ten plants in each plot was recorded in centimeters from the top most nodes to the base of the spike.

Spike length (cm): The average spike length of ten plants on the main culm from the base of the spike to the top of the last spikelet excluding awns was recorded in centimeter.

Awn length (cm): the average awn length of ten plants from the tip of the spike to the tip of the longest awn was recorded in centimeter.

Physiological measurements

Relative leaf water contents (%): was measured at flowering stage using Turner and Kramer (1980) method: $RWC\% = \frac{FW-DW}{TW-DW}X100$

Where, FW = fresh leaf weight; DW = dry weight (In Oven for 48 h); TW = tumescent weight.

Leaf water content (%) was calculated using Clarke and McCaig (1982) method:

$$LWC\% = \frac{FW-DW}{FW}X100$$

Where, FW = fresh leaf weight; DW = leaves placed in an oven at 50^o C for 24 h and re-weighed

Leaf area (cm^2): From the fully developed flag leaf of selected mother shoots, the maximum length and width was measured in centimeters. Plants' leaves diameter was measured with a ruler and leaves areas were calculated using the following equation (Birch *et al.*, 1998 and Montgomery, 1911): Leaf area (cm^2) = maximum leaf length × leaf width× 0.75**.**

Chlorophyll content: A flag leaf per plant from 10 sample plants per plot was measured using portable chlorophyll meter Minolta SPAD- 502 at flowering (Mohammad *et al.*, 2012). The averages of the SPAD values from sample plants at flowering stage were used for analysis in each genotype according to Moslem *et al.*, (2013) and Mihratu (2014).

Data Analyses

Analysis of variance

The data collected for each trait were subjected to analysis of variance (ANOVA) for simple lattice design. Analysis of variance was carried out using Proc lattice and Proc GLM procedures of SAS version 9.0, (SAS, 2002).The difference between treatment means was compared using DMRT at 5% probability levels.

Multivariate Analysis

Cluster Analysis

This analysis was done based on all yield and yield contributing traits. Clustering of genotypes were done using the PROC clustering strategy of SAS 9.0 (SAS, 2002) and appropriate numbers of clusters were determined from the values of Pseudo F and Pseudo T^2 statistics (SAS, 2002).

Principal Component Analysis

Principal component analysis was computed by using SAS (SAS, 2002 computer software from correlation matrix). Standardized quantitative data was used for the analysis.

Table 19 Description of bread wheat genotypes tested

S.N	Genotypes tested		Cross	Selection history	Origin	Year of release
1	Variety	K6290-Bulk	(AF.MAYOxGEM)Xromany	k6290-bulk	Kenya	1977
2	Variety	Ogolcho (ETBW5520)	WORRAKATA/2*PASTOR	2STEMRRSN#10	CIMMYT	2012
3	Variety	BIKA	PASTOR//MXL7573/2*BAU/3/SOKOLL/WBLL1	-	CIMMYT	2014
4	Variety	WANE (6130)	SOKOLL/EXCALIBUR	-	CIMMYT	2016
5	Variety	Hawii (2501)	CHIL/PRL	CM92803-91Y-0H-05Y-5M-0RES05Y	CIMMYT	1999
6	Variety	Pvon-76	VCM//CNO*S*/7C/3/KAL/BB	CM8399-D-4M-3Y-1M-1Y-1M-0Y	CIMMYT	1982
7	Variety	Derselign	CI8154/2*FR	CI8154/2*FR	Mexico	1974
8	Variety	Kakaba (Picaflor #1)	KRITATI//SERI/RAYON	CGSS02Y00152-099M-099Y-099M-46Y-0B	CIMMYT	2010
9	Variety	Gambo (Quaiu # 2)	BBAX/LR42//BABAX*/3/VIVITSI	CGSS01B00046T-099Y-099M-099M-099Y-099M--29Y-0B	CIMMYT	2011
10	Variety	KINGBIRD	TAM-200/TUI/6/PAVON-F-76//CARIANCA-422/ANAHUAC-F-75/5/BOBWHITE/ CROW// BUCKBUCK/ PAVON-F-76/3/YECORA-F-70/4/TRAP-1.	-	CIMMYT	2015
11	Variety	GALIL	not available	not available	Israel	2010
12	Advanced line (A1)		KIRITATI/4/2*SERI.1B*2/3/KAUZ*2/BOW//KAUZ/5/ HUW234+LR34/PRINIA//PBW343*2/KUKUNA/3/ROLF07	CMSS09Y00249S-099Y-099M-099Y-1M-0WGY	CIMMYT	-
13	Advanced line (A2)		KACHU*2//WHEAR/SOKOLL	CMSS09Y00818T-099TOPM-099Y-099ZTM-099NJ-099NJ-10WGY-0B	CIMMYT	-
14	Advanced line (A3)		PAURAQUE #1/3/PBW343*2/KUKUNA//PBW343*2/KUKUNA/4/BAJ #1	CMSS09Y00835T-099TOPM-099Y-099M-099Y-3WGY-0B	CIMMYT	-
15	Advanced line (A4)		WBLL1*2/BRAMBLING//SAAR/2*WAXWING/4/PBW343*2/KUKUNA//KRONSTAD F2004/3/PBW343*2/KUKUNA	CMSS09Y00843T-099TOPM-099Y-099M-099Y-12WGY-0B	CIMMYT	-
16	Advanced line (A5)		MELON//FILIN/MILAN/3/FILIN/4/PRINIA/PASTOR// HUITES/3/MILAN/OTUS//ATTILA/3*BCN/5/MELON// FILIN/MILAN/3/FILIN	CMSS09Y01061T-099TOPM-099Y-099M-099Y-8WGY-0B	CIMMYT	-
17	Advanced line (A6)		SOKOLL/3/PASTOR//HXL7573/2*BAU/4/WHEAR/SOKOLL	CMSA09Y00810S-050Y-050ZTM-0NJ-099NJ-19WGY-0B	CIMMYT	-

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18	Advanced line (A7)	MILAN//PRL/2*PASTOR/4/CROC_1/AE.SQUARROSA (213)//PGO/3/BAV92/5/PAURAQ	CMSA09M00542S-050ZTM-0NJ-099NJ-15WGY-0B	CIMMYT	-
19	Advanced line (A8)	FRANCOLIN #1/BAJ #1	CMSS09B00490S-099M-099Y-2WGY-0B	CIMMYT	-
20	Advanced line (A9)	CROC_1/AE.SQUARROSA (205)//BORL95/3/PRL/SARA//TSI/VEE#5/4/FRET2*2/5/WHEAR/SOKOLL	CMSA09M00056T-077(SR25HET)Y-050ZTM-0NJ-099NJ-8WGY-0B	CIMMYT	-
21	Advanced line (A10)	TILHI/SOKOLL*2//KINGBIRD #1	CMSS10Y00766T-099TOPM-099Y-099M-10WGY-0B	CIMMYT	-
22	Advanced line (A11)	SUP152/BAJ #1	CMSS07Y00195S-0B-099Y-099M-099Y-16M-0WGY	CIMMYT	-
23	Advanced line (A12)	KACHU*2/3/ND643//2*PRL/2*PASTOR	CMSS08B00712T-099TOPY-099M-099NJ-2WGY-0B	CIMMYT	-
24	Advanced line (A13)	*2/4/HUW234+LR34/PRINIA//PBW343*2/KUKUNA/3/ROLF07	CMSS09Y00853T-099TOPM-099Y-099M-099Y-10WGY-0B	CIMMYT	-
25	Advanced line (A14)	PREMIO/2*BAVIS	CMSA09Y00228T-050M-050Y-050BMX-0NJ-099NJ-13WGY-0B	CIMMYT	-
26	Advanced line (A15)	MILAN/KAUZ//PRINIA/3/BAV92/4/BAVIS	CMSA09Y00896S-050Y-050ZTM-0NJ-099NJ-4WGY-0B	CIMMYT	-
27	Advanced line (A16)	CHEN/AEGILOPS SQUARROSA (TAUS)//BCN/3/BAV92/4/BERKUT/5/BAVIS	CMSA09M00547S-050ZTM-0NJ-099NJ-2WGY-0B	CIMMYT	-
28	Advanced line (A17)	SHA7//PRL/VEE#6/3/FASAN/4/HAAS8446/2*FASAN/5/CBRD/KAUZ/6/MILAN/AMSEL/7/FRET2*2/KUKUNA/8/KINGBIRD #1	CMSS09B00076S-099M-099Y-12WGY	CIMMYT	-
29	Advanced line (A18)	NAVJ07/SHORTENED SR26 TRANSLOCATION/3/ATTILA/BAV92//PASTOR	CMSA09M00047T-079(SR26POS)Y-050ZTM-0NJ-099NJ-3WGY-0B	CIMMYT	-
30	Advanced line (A19)	W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1*2/5/W	CMSA09M00092T-048(SR25HET)Y-	CIMMYT	-
31	Advanced line (A20)	SERI.1B//KAUZ/HEVO/3/AMAD/4/ESDA/SHWA//BC	AISBW05-0153-11AP-0AP-0AP-2AP -	ICARDA	-
32	Advanced line (A21)	ATTILA 50Y//ATTILA/BCN/3/PFAU/MILAN	ICW05-0632-12AP-0AP-0AP-2AP-0AP-0	ICARDA	-
33	Advanced line (A22)	SERI.1B//KAUZ/HEVO/3/AMAD/4/PFAU/MILAN	ICW06-00151-8AP-0AP -03 SD-0TR	ICARDA	-
34	Advanced line (A23)	KAUZ//ALTAR 84/AOS 3/KAUZ/3/ATTILA 50Y//ATTILA/BCN/4/PASTOR-6	ICW06-50246-7AP-0AP-0AP -1 SD-0TR	ICARDA	-
35	Advanced line (A24)	ANGI-1	ICW92-0326-12AP-0L-7AP-0L-2AP-	ICARDA	-
36	Advanced line (A25)	ENKOY/FLAG-5	ICW06-00434-13AP/0KUL-0DZ/0AP-0DZ/0AP-1AP-0AP-0TR	ICARDA	-

Results and Discussions

Analysis of Variance

Analysis of variance by GLM and lattice for 18 characters are presented in Table 3. The result showed the existence of highly significant ($P\leq 0.01$) variation among genotypes for days to heading, days to maturity, grain yield, harvest index, plant height, number of kernels per spike, number of spikelet's per spike, peduncle length, spike length, leaf area and awn length. Similar results were reported by several investigators (Berhanu, 2004; Majumder *et al*., 2008; Ali *et al*., 2008; Desalegn, 2012; Degewione *et al.,* 2013 and Wani *et al.,* 2013). These authors reported the presence of highly significant differences among the studied wheat genotypes for days to maturity, days to heading, plant height, spike length, spikes per plant, grains per spike, harvest index and grain yield per plant. Adhiena (2015) also reported highly significant ($P\leq 0.01$) differences among bread wheat genotypes for days to heading, days to maturity, number of kernels per spike, spike length and biomass yield. There was also significant difference ($P\leq 0.05$) among genotypes for grain filling period, thousand kernel weight, biomass yield and chlorophyll content. However, there is no significant difference among genotypes for effective tillers per meter square, relative leaf water content and leaf water content. The presence of appreciable differences among genotypes for most of the characters studied makes the possibility to carry out further breeding and genetic analysis.

Multivariate Analyses

Cluster Analysis

Cluster analysis revealed that the 36 bread wheat genotypes were grouped into 4 clusters (Table 3) and (Figure 1). The genotypes were distributed in such way that 18 genotypes were grouped into cluster I (50%), 10 genotypes in cluster II (27.77%), five genotypes in cluster III (13.9%) and three genotypes in cluster IV (8.3%). Cluster I contains the highest mean values of chlorophyll content (51.53) (Table 4). Cluster II contains high mean values of grain yield (4.52t/ha) but the least in thousand kernel weight (39.52g), relatively high in plant height (78.23cm), number of kernels per spike (40.39), number of spikelet per spike (17.40), spike length (8.51cm), leaf water content (72.18), and awn length (4.23cm). The third cluster is characterized by high mean values of biomass yield (1625g), late in heading date (53.30), late maturing (101.40), higher effective tiller per meter square (310.07), longer peduncle length (30.79cm), higher relative leaf water content (88.11) and relatively the highest in leaf area (16.09cm^2). Cluster IV is distinguished by the highest in thousand kernel weight (40.60g) and harvest index (68.26) but the shortest in plant height (61.77cm), least in relative water content (71.14), relatively early maturing (95.67) and relatively low values for all other traits. Singh *et al.* (2014) clustered 108 wheat genotypes in four groups. Singh *et al.* (2009) also classified 300 wheat genotypes in seven clusters based on agronomic performance. In general, cluster analysis portrayed the presence of wider genetic variability among genotypes and the possibility to broaden the genetic basis through crossing of genotypes in the different cluster. For instance, genotypes in cluster IV are characterized by early maturing but low yielder, whereas, genotypes in cluster III are late maturing and high yielder. A cross made between selected genotypes in those cluster could possibly create high yielding and early maturing variety that can escape late season moisture deficit.

Principal component Analysis

Principal component analysis is a suitable multivariate technique in identification and determination of independent principal components that are effective on plant traits separately and it also helps breeders in genetic improvement of traits such as yield that have low heritability specifically in early generations *via* indirect selection for traits effective on this (Golparvar et al., 2006). Principal component analysis (PCA) indicated that the first seven vectors with Eigen values greater than one combined explained about 82.83% of the gross variation (Table 5). The first PC accounted for 20.27% of the total variation, whereas the corresponding values for the second to the seventh PCs were 17.11%, 12.99%, 10.64%, 8.9%, 7.15% and 5.72%, respectively (Table 5). The results are in line with the finding of Hajir et al., (2013) which reported four principal components for explained relation of traits in 18 bread wheat genotypes studied, which account for 76% of the total variance.

Biomass yield, plant height, peduncle length and days to maturity were the major contributor for the variation recorded in the first PC. According to (Chahal and Gosal, 2002) characters with largest absolute value closer to unity within the first principal component influence the clustering more than those with lower absolute value closer to zero. The variation in the second PC was mainly due to spike length, leaf area, awn length, number of spike per spikelet and chlorophyll content. Relative leaf water content and grain yield was among the major contributor for the variability recorded in the third PC (Table 5). Grain filling period, Effective tiller number and grain yield for the fourth PC; number of kernel per spike and effective tiller number for the fifth PC; harvest index, leaf water content and days to maturity for the 6th PC; and leaf water content and chlorophyll content was the major contributor for the 7th principal component.

Table 2 Mean squares from analysis of variance by GLM and Lattice for the 18 characters of 36 bread wheat genotypes grown at ATARC (2017)

Traits	**Mean Squares**			**CV**	**± SE**	**Efficiency (%)**	**R^2**
	Genotype *(df=35)*	**Replication*(df=1)***	**Error*(df=25)***				
DH	12.377^{**}	6.12^{ns}	3.86	3.87	1.39	101.22	0.870
DM	20.2^{**}	55.12^{**}	4.23	2.10	1.45	112.06	0.898
GFP	14.28^{*}	36.12^{*}	6.13	6.25	1.75	113.22	0.846
ETPM	7143.09^{ns}	2910.20^{ns}	5182.64	31.03	50.91	104.76	0.71
GY	1.14^{**}	10.89^{**}	0.331	14.41	0.41	193.69	0.893
TKW	16.64^{*}	2.88^{ns}	8.06	7.09	2.01	98.12	0.825
BY	100999.5^{*}	1034401.00^{*}	45361	16.29	150.60	167.10	0.853
HI	134.27^{**}	25.83^{ns}	53.16	11.82	5.16	53.158	0.809
PH	117.08^{**}	353.76^{ns}	26.83	7.14	3.66	162.1	0.894
NKPS	42.26^{**}	11.92^{ns}	11.86	8.91	2.44	108.4	0.863
NSPS	3.34^{**}	0.016^{ns}	0.45	3.94	0.48	126.93	0.938
PL	26.4^{**}	19.11^{ns}	4.85	7.94	1.56	125.09	0.910
SL	1.28^{**}	7.27^{**}	0.14	4.47	0.26	100.79	0.941
RLWC	113.37^{ns}	1231.32^{**}	87.91	11.00	6.63	93.97	0.76
LWC	21.84^{ns}	11.77^{ns}	14.87	5.39	2.73	100.25	0.72
LA	25.36^{**}	0.31^{ns}	9.16	21.36	2.14	99.25	0.843
CC	10.90^{*}	5.39^{ns}	5.19	4.47	1.61	133.28	0.841
AL	0.86^{**}	9.86^{**}	0.10	7.98	0.22	3.924	0.956

*, ** & ns, significant at $P \leq 0.05$, $P \leq 0.01$ and non-significant, respectively

Key: Df= degrees of freedom, CV= Coefficient of variation, SE= Standard Error, Efficiency(%)= Relative efficiency to Randomized complete block design, R^2 = Coefficient of determinations, DH=Days to heading(days), DM=Days to maturity(days), GFP= Grain filling Period(days), PH=Plant height (cm), SL=Spike length (cm), NSPS= No. of spikelet per spike, NKPS= No. of kernel per spike^{-1}, TKW= Thousand kernel weight (g), BY=Biomass yield g plot^{-1}, HI=Harvest index, ETPM=Effective tiller per m^2, PL=Peduncle Length(cm), GY= Grain yield (t/ha), RLWC=Relative leaf water content (%), LWC= Leaf water content (%), LA= Leaf area(cm^2), CC= Chlorophyll content, and AL=Awn Length(cm)

Table 3 The distribution of genotypes into 4 clusters for 36 bread wheat genotypes tested at ATARC (2017)

Cluster	No of genotypes	Percentage (%)	Genotypes
I	18	50	14, 23, 20, 28, 16, 27, 21, 24, 18, 32, 7, 12, 34, 36, 19, 33, 11, 15

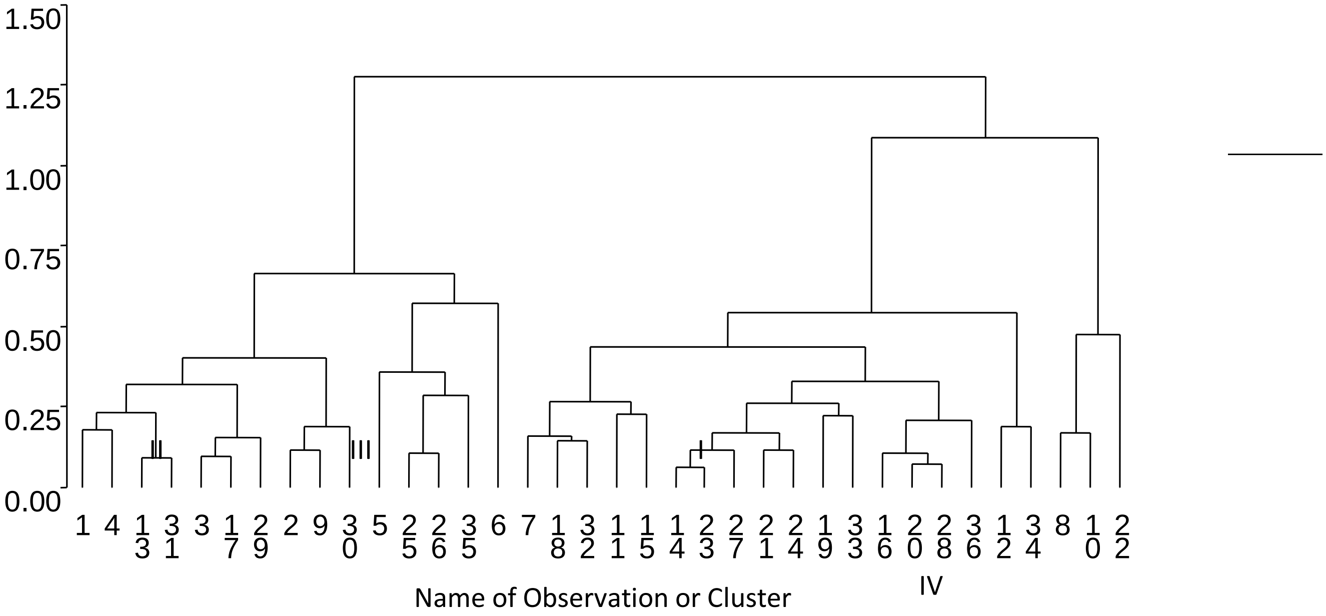

Figure 1 Clusters to which the genotypes belong and average distances between clusters.

Table 4 Mean values of 18 traits for 4 clusters of 36 bread wheat genotypes at ATARC (2017)

Traits	Cluster I	Cluster II	Cluster III	Cluster IV
DH	50.42	51.60	53.30**	45.50*
DM	96.86	99.10	101.40**	95.67*
GFP	38.94*	39.80	40.40	41.83**
ETPM	221.15	209.19*	310.07**	242.95
GY	3.72	4.52**	4.51	3.03*
TKW	40.22	39.52**	40.20	40.60**
BY	1200.56	1473.00	1625.00**	866.67*
HI	62.24	61.59	56.06*	68.26**
PH	69.70	78.23**	77.44	61.77*
NKPS	38.04	40.39**	38.35	36.77*
NSPS	17.20	17.40**	16.85	15.95*
PL	26.66	29.18	30.79**	24.47*
SL	8.50	8.51**	8.36	7.30*
RLWC	84.97	84.59	88.11**	79.71*
LWC	70.92*	72.18**	72.16	71.14
LA	13.07*	14.95	16.09**	14.92
CC	51.53**	50.99	50.01	49.83*
AL	3.78	4.23**	4.11	3.50*

*and **low and high value of the trait respectively.

Usually it is customary to choose one variable from these identified groups. Hence for the first group biomass yield (0.447), is best choice, which had the largest loading from component ones, spike length (0.409) for the second, grain yield (0.334) for the third, grain filling period (0.463) for the fourth, effective tiller per meter square (0.479) for the fifth, harvest index (0.444) for the sixth, and leaf water content (0.334) for the seventh group. Principal component analysis reflects the importance of the largest contributor to the total variation at each axis of differentiation (Sharma, 1998).

Table 5 Eigen vectors and Eigen Values of the first seven principal components of 36 bread wheat genotypes evaluated at ATARC 2017.

	Principal component analysis (PCA)						
Traits	**PC 1**	**PC 2**	**PC 3**	**PC 4**	**PC 5**	**PC 6**	**PC 7**
DH	0.222	0.239	-0.052	-0.350	0.228	-0.364	0.075
DM	0.332	0.224	-0.263	0.165	0.023	-0.034	0.046
GFP	0.160	0.122	-0.266	0.463	-0.204	0.309	-0.134
ETPM	0.089	0.055	0.155	0.321	0.479	0.072	-0.072
GY	0.237	0.144	0.334	-0.320	-0.117	0.280	0.041
TKW	-0.165	0.288	-0.016	0.154	0.249	0.364	-0.314
BY	0.447	0.009	0.125	-0.138	0.099	-0.115	-0.116
HI	-0.185	0.157	0.281	-0.200	-0.289	0.444	0.150
PH	0.373	-0.103	0.215	0.024	0.116	0.210	-0.121
NKPS	0.177	0.235	0.146	0.118	-0.520	-0.024	0.099
NSPS	0.162	0.350	-0.083	0.083	-0.291	-0.321	0.016
PL	0.336	-0.226	0.266	0.110	0.079	0.091	-0.052
SL	0.128	0.409	0.146	0.142	0.013	-0.010	-0.155
RLWC	0.188	-0.026	-0.392	-0.299	0.081	0.230	0.223
LWC	0.230	-0.007	-0.392	0.031	0.096	0.360	0.334
LA	0.120	-0.373	0.245	0.232	-0.039	-0.013	-0.014
CC	-0.122	0.304	0.225	0.080	0.311	0.002	0.305
AL	0.210	-0.362	0.063	-0.282	-0.092	-0.063	0.154
Eigen Value	3.8509	3.2516	2.4674	2.02194	1.7005	1.35821	1.08596
Difference	0.59934	0.78414	0.4455	0.32134	0.34238	0.27224	0.29813
Proportion	0.2027	0.1711	0.1299	0.1064	0.0895	0.0715	0.0572
Cumulative	0.2027	0.3738	0.5037	0.6101	0.6996	0.7711	0.8282

Key: DH=Days to heading (days), DM=Days to maturity (days), GFP= Grain filling Period (days), ETPM=Effective tiller per m^2, GY= Grain yield (t/ha), TKW= Thousand kernel weight (g), BY=Biomass yield g plot^{-1}, HI=Harvest index, PH=Plant height (cm), NKPS= No. of kernel per spike^{-1}, NSPS= No. of spikelet per spike, PL=Peduncle Length (cm), SL=Spike length (cm), RLWC=Relative leaf water content (%), LWC= Leaf water content (%), LA= Leaf area (cm^2), CC= Chlorophyll content and AL=Awn Length (cm)

Conclusions

The current study was conducted to study the extent of clustering of bread wheat genotypes and to identify the important traits in distinguishing the genotypes. Data recorded for 18 characters were subjected to analysis of variance and the results showed the presence of significant differences (P≤0.01/0.05) among the tested genotypes for almost all traits indicating the presence of appreciable level of variability among the tested 36 bread wheat genotypes. Cluster analysis revealed that the 36 bread wheat genotypes were grouped into 4 clusters. The principal component analysis extracted seven principal components PCA1 to PCA7 from the original data having Eigen values greater than one accounting nearly 82.83% of the total variation.

The present study showed the presence of possibility of improving yield and other desirable characters through selection. The study also revealed the importance of considering other characters in the process of selection of genotypes for yield. However, this study was conducted at Adami Tulu District for one growing season, therefore, it may not be sufficient to make strong conclusion and recommendation. Hence there is a need to conduct further study by considering many wheat growing areas of the district for more than one cropping season.

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Yield Gap Analysis of wheat (*Triticum species*) in Southeast Ethiopian Highlands

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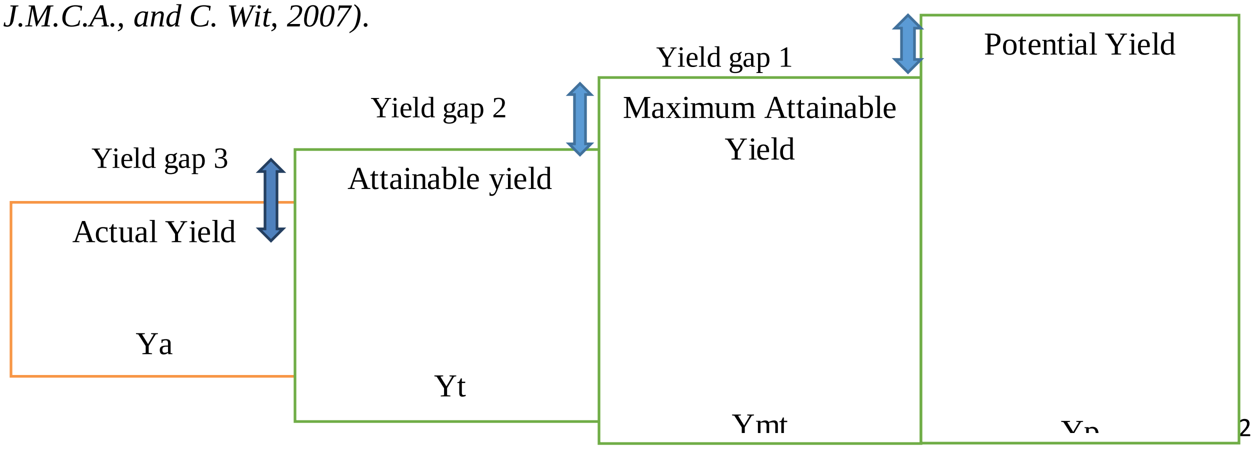
Abstract

Yield gap in the Ethiopian highlands for different crops has not been well analysed. Crop yield in Ethiopia is far behind the world average due largely to genetic, environmental and management constraints. Wheat is one of the most important crops in Ethiopia ranking third after Tef and maize. The major constraints causing low yield in wheat is biotic stresses including diseases and pests and abiotic stresses comprising of soil fertility and moisture stress. The study was conducted at Sinana Research Centre during 2014-2016 to analyse wheat yield gap. Seven improved varieties (Digalu, Mada Walabu, Dandaa, Mandoyu, Sanate, Bakalcha and Dire) with two management scenarios (farmers practice Vs improved management) and two water regimes (rain fed; water limited and non-limited potential yield). Analysis of variance showed significant contribution of Management (69%), variety (12%) and Management x Variety interaction (2%) in the total variation (sum of squares). The actual yield in the unfavourable years ranged from 0.4 ton/ha for Digalu to 4.6 t/ha for Dire. The potential yield of 3.1, 4.2, 4.7, 5.4, 5.8, 6.5 and 7.9 t/ha were obtained from varieties Digalu, Mandoyu, Sanate, Dandaa, Manda Walabu, Bakalcha and Dire, respectively during unfavourable years while the potential of these varieties in favourable seasons ranged from the least 3.5 t/ha for Digalu to the highest 8.9 t/ha for Sanate variety. The maximum attainable yield is nearly equal with the potential yield in the favourable years. The management factor increased the actual yield to attainable yield by 24%, 31%, 35%, 36% and 38% for varieties Dire, Bakalcha, Mandoyu, Sanate and Mada Walabu varieties, respectively. The genetic and management improvement would significantly boost wheat yield as high as the highest potential yield of 8.9 t/ha. This would realize a food secure the second most populous nation in Africa with around 100 million people.

Key words: *Bread wheat, Crop management, Yield gap*

Introduction

Wheat is one of the important crops of food security in the world. Ethiopia is one of the major wheat producing countries in Africa. It is the third important commodity in Ethiopia only after maize and tef. Yield is realized through the supply of the environment and the genetic demand and the environmental potential yield is determined by the grain filling period (Eugen Triboi et.al. 2006). Potentialyield (Yp)is defined as the maximum attainable yield achieved by a genotype in an environment of its adaptabilityper unit land in pest controlled andnutrient non-limiting conditions, which depends on moisture, sunshine intensity, temperature, crop-sowing date, maturity rating, plant population, and light-use efficiency of photosynthesis (Evans, 1993). In irrigated systems, yield is not limited by water availability (water-limited potential yield, Yw) but by temperature and solar radiation. Despite the importance of Yp and Yw to food production capacity, they are not explicitly considered in studies of indirect land use change as affected by policies about biofuels (Searchinger et al., 2008), conservation of biodiversity (Phalan et al., 2011), or future food security (Godfray et al., 2010). Accurate estimates of Yp and Yw are also needed to interpret yield trends in regions and countries where aggregate data indicate yield stagnation (Cassman et al., 2003; Lobell et al., 2009).Potential yield is determined by solar radiation, temperature, photoperiod, atmospheric CO_2 concentration, and genotype characteristics. Assuming water, nutrients, pests and diseases are not limiting crop growth, this is also called water non-limiting potential yield. *The yield potential* (Yp) of a crop is defined as the theoretical maximum yield in any given season solely determined by climate and germplasm assuming ample supply of water, nutrients, or other yield building factors and the complete absence of yield reducing factors such as pests and diseases (FAO and DWFI, 215). However, there may be season-to-season variability in potential yield caused by weather variability, particularly rainfall. Water-limiting potential yield for a site could be determined by growing crops without any growth constraints, except water availability. Under rain-fed situation (not under control of the farmer) water-limiting yield is considered as the maximum attainable yield. Yield potential is commonly estimated using plant growth models. *The attainable yield* (Yt) is defined as the yield achieved in farmers' fields with best management practices including water, pest, and general crop management where nutrients are not limiting. The attainable yield varies - like the yield potential - from season to season and year to year depending on climate. The optimal economic yield is often linked to the attainable yield. The maximum attainable yield (Ymt) in any given season could be close to the yield potential, if management is excellent and weather conditions are very favorable. In favorable rain-fed and irrigated areas, the yield target is often about 80-90% of the yield potential. In less favorable areas or seasons, this value is somewhat lower (70- 80% of the yield potential). Site-specific fertilizer recommendations are recommended using the attainable yield of the last 3-5 years as the yield target. *The actual yield* in farmers' fields (Ya) is often lower than the attainable yield due to constraints like water availability, pests and diseases, and poor crop and nutrient management practices (*Pasuquin, J.M.C.A., and C. Wit, 2007).*



Actual, attainable, and potential yield can be used to identify exploitable yield gaps. A management objective of farmers should be to minimize yield gap 3, the difference between attainable and actual yield (Yt-Ya). To narrow this yield gap, farmers need to evaluate promising new technologies (e.g., planting density, nutrient management) that offer improvements in yield and/or productivity against current practices. Larger yield increases can be achieved when several constraints (e.g. pests and disease problems and inappropriate nutrient management) are overcome simultaneously. Yield gap 2 is largely determined by factors that are difficult or impossible to control including the variation in climatic conditions. Best management practices such as the use of a leaf color chart (LCC) for fine tuning N management increase the likelihood of keeping yield gap 2 small. Yield gap 1 provides important guidance in the identification of constraints. If yield gap 1 is large despite following best management practices, attainable yield must be limited by an unknown constraint. If yield gap 1 is small, there is no further room for yield improvement and efforts might focus on enhancing productivity. It is usually not economical to aim at fully reducing yield gap 1 because of the large amounts of inputs required and the high risk of crop failure and profit losses. This yield gap is smaller in seasons with very favorable weather conditions (*Pasuquin, J.M.C.A., and C. Wit, 2007)*.

Assessment of potential yield and the gap between potential and actual yield is essential before any investment for improving crop production for a location is made. It is useful to know potential yield of the crop in the region of interest, and gap between the potential yield and the actual yield obtained. This analysis helps to know the major factors causing the difference between actual and attainable yield for a given site. Once the yield gap between water-limiting yield and actual yield is determined, then the relative contribution of other major constraints and limitations causing yield gap can be assessed in order to focus on the priority research or crop management needs to bridge the yield gap. The yield potential of major crops are under dispute among researchers and development practitioners. There are claims that under optimum management conditions using high yielding varieties in the major wheat growing areas of the Southeaster Ethiopian highlands, the yield of wheat may unusually go more than 10 t/ha. Therefore, this trial was initiated with the objective of determining the potential yield of wheat under water limited and non-limited scenarios and optimum management conditions.

Average farm yields in a region or country are inevitably smaller than yield potential, sometimes significantly so, because achieving yield potential requires near perfect management of crop and soil factors that influence plant growth and development throughout the crop growth cycle. As the average farm yields appear to fall off from historical yield trends, it is important to determine if this stagnation is caused by the diminishing size of the exploitable yield gap or by other factors such as soil degradation, pollution, or climate change.

Materials and Methods

The trial was conducted at Sinana on-station and Selka on farm from 2014-2016 during the main cropping season (Bona season according to the local naming of the season which extends from

August to December) and to determine the potential yield of wheat (durum and bread wheat). The trial was laid out in split plot arrangement with three factors in 2015: Main plot - Water regime (supplemental irrigation Vs rain-fed), the sub-plot factors include: - Variety (Digalu, Dandaa, Mada Walabu, Dire and Bakalcha) and – the target yield (*attainable yield* and *actual yield* scenarios). The *actual yield* scenario includes raw planting, recommended fertilizer rate with appropriate timing and use of agro-chemicals for the control of weeds and diseases. The *attainable yield* scenario includes twice inter-cultivation and high dose of fertilizers especially nitrogen (92 kg N/ha) and phosphorus fertilizer (69 kg/ha P_2O_5) in additions to the farmer's management. The trial in 2016 was conducted under rain-fed conditions with split plot design and changes were made to varieties replacing the old varieties Digalu and Danda'a with new ones Sanate and Mandoyu. The target yield was laid out in main plot and varieties were arranged in sub plot.

Results and Discussions

The result showed significant yield gap between the actual yield, attainable yield and the potential yield for all of the varieties (Table 1). Yield gap between attainable and actual yield is very wide signifying the need for farmers to apply management options to increase the yield. The actual yield of Digalu was very low due to the damage by the stem rust (so named as the Digalu race) epidemic in 2014. Therefore, if farmers apply fungicide for the control of the disease while optimizing other management options, the attainable yield would be increased by 74%. The attainable yield of wheat can be raised from the actual yield by 41%, 47% 24% and 31% for Danda'a, Mada Walabu, Dire and Bakalcha varieties, respectively. The level of yield increment was also higher for attaining maximum attainable yield which suggests that there is still further room for application of better management options for yield improvement. However, the yield gains by leaping from the maximum attainable yield to the potential yield (yield gap 1) for all varieties were proved to be minimum (less than 10% except for Bakalcha) and hence calls for focus on productivity improvement.

Table 1: Actual, attainable and potential yields (kg/ha) of wheat varieties at Sinana on-station in 2014/15 cropping season

Varieties	Digalu	Danda'a	Mada Walabu	Dire	Bakalcha
Actual Yield	443	1876	2035	4625	3224
Yield Gap 3	1244 (74%)	1325.5 (41%)	1831 (47%)	1437.5 (24%)	1466.5 (31%)
Attainable yield	1687	3201.5	3866.5	6062.5	4690.5
Yield Gap 2	1309 (44%)	1950.5 (38%)	1961.5 (34%)	754.5 (11%)	1466.5 (24%)
Maximum Attainable yield	2996	5152	5698	6817	6037
Yield Gap 1	101 (3.3%)	292 (5.4%)	130 (2.2%)	1181(15%)	487 (7.5%)
Potential yield	3097	5444	5828	7998	6524

In the next year (2015/16), replacement to Digalu and Danda'a were made by new varieties Sanate and Mandoyu and tested to determine the actual and attainable yield. Irrigation was not applied. The Analysis of Variance (ANOVA) showed significant variation among varieties and management options (Table 2). The management option contributed 69% to the source of variation. The varieties as source of variation only contributed 12% to the variance while the variety by management interaction had only 2% share in the total variation and the error contributed 11% to the total variance.

Table 2: ANOVA table of wheat potential yield (kg/ha) in 2015/16 in the highlands of Bale

Source of variation	Df	Sum Sq	Mean Sq	F-value	Pr(>F)	% TSS
VAR	4	6357921	1589480	4.748	0.008596 **	12
MGT	1	37775250	37775250	112.8398	3.498e-09***	69
Rep	2	3768552	1884276	5.6286	0.012629*	7
VAR:MGT	4	1054466	263616	0.7875	0.548244	2
Residuals	18	6025841	334769			11
Total	30	54982030	1895932			

VAR= varieties; MGT= management options; Rep= Replication; VAR:MGT= variety x management interaction; DF= degrees of freedom, Sum Sq= sum of square

The highest attainable yield (7700.93 kg/ha) was obtained from the variety Sanate with yield increment of 35.9% (Table 3). It was evident that a yield gap of 30.8 %, 23.6%, 37.5% and 34.9% could be improved for Bakalcha, Dire, Mada Walabu and Mandoyu, respectively by improved management practices.

Table 3: Effect of management on yield of wheat varieties

Category	Bakalcha	Dire	MadaWalabu	Mandoyou	Sanate
Actual yield	4757	5269	3815	4513	4931
Attainable yield	6876	6897	6101	6931	7701
Yield Gap (%)	31	24	38	35	36

The growing condition in 2015/16 was good and the maximum attainable yield was almost comparable with the potential yield (Table 4). Yield was very high for all varieties with minimum actual yield produced by the variety Mada Walabu. The maximum attainable yield is very high for Dire and Sanate varieties

Table 4: The Range of yield performance of varieties averaged over management conditions and varieties.

Yield Gap	Bakalcha	Dire	Mada Walabu	Mandoyu	Sanate
Actual yield	4540.28	5179.17	3762.5	4201.39	4755.56
Yield Gap 3	1276.39 (22%)	903.7 (15%)	1195.37 (24%)	1520.14(27%)	1560.41(25%)
Attainable yield	5816.67	6082.87	4957.87	5721.53	6315.97
Yield Gap 2	2173.61 (27%)	2136.57(26%)	1968.52 (28%)	1984.03(26%)	2604.86(29%)
Maximum attainable yield	7990.28	8219.44	6926.39	7705.56	8920.83

Conclusions

Potential yield of wheat is determined under water limited and non-limited scenarios and waternon-limited scenario was adjusted by supplemental irrigation at stress periods. The result showed that there is wider room for improving yield gap to ensure the attainable yield by paying proper attention to the management of yield reducing factors such as diseases, pests and weeds. Thevariety Digalu had very low actual yield of 474 kg/ha which was due to the severe rust pressureso named as the Digalu race (TKTTF). It was evident that by controlling this disease and other variables constant, a yield gap of 74% could be improved to attainable yield. There was also a room for improving actual yield by 24-47% from actual yield loss to attainable yield for varietiesDanda'a, Digalu, Dire and Bakalcha. The ANOVA witnessed significant contribution of the management option (68.7%) to the total variation and hence is the important part of the source ofvariation which needs proper focus for yield gap.

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Assessment of Major Hot Pepper (*Capsicum Sp.)* Diseases in Western Oromia

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Introduction

Hot pepper *(Capsicums* sp.*)* is the most important vegetable crop belonging to the family *Solanaceae* and grown as spice crop in different parts of the world (Berke, 2002). It is the most common type of *Capsicum* spp. grown in Ethiopia, since its introduction in the early 17th century by the Portuguese (Huffnagal, 1961). It is one of the world's major vegetable and spice crops valued for its aroma, taste, flavor and pungency (Zewdie *et al.*, 2004). Hot pepper covers 67.98% of all the area under vegetables in Ethiopia (CSA, 2012). The average daily consumption of hot pepper by Ethiopian adult is estimated at 15 g, which is higher than tomatoes and most other vegetables (MARC, 2004). Hot pepper is a popular vegetable and plays an important role in the national economy of the country. It serves as row material for the processing industries, important cash crop to farmers, and a source of employment to urban and rural populations.

Pepper is grown in many countries of the world and its production for culinary and vegetable uses has increased from time to time. According to FAO (2002) report, world production of pepper was 21,719,000 metric tons on 1.59 million hectare of land, of which Africa contributed 2,027,000 (9.3%) metric tons on 0.264 million hectare of land. According to the Ethiopian Agricultural Sample Enumeration (EASE, 2002), small scale farmers produced 41716.5 metric tons of green pepper and 77962.4 metric tons of red pepper on 4,672 and 56,202 ha of land, respectively. However, hot pepper production for dry pod has been low with a national average yields of 0.4 t/ha (Fekadu and Dandena, 2006) and declining with time. Western Oromia region contribute a significant portion to the country's total pepper production (CSA, 2005). However, the productivity and production of the crop is low in the region. This might be attributed to the use of low yielding varieties, drought, insect pest, diseases, poor cultural practices etc. (Fekadu and Dandena, 2006). Among these, diseases caused by different fungi, bacteria and viruses are the major production constraints and cause different levels of losses in the world. Virus caused 60 to 100 % losses of marketable fruit, while up to 100% loss was recorded from pepper anthracnose (Melanie and Sally, 2004). Bacterial spots caused by a seed borne pathogen *Xanthomonas campestris* PV. *vesicatoria* is also capable of causing severe defoliation of plants, resulting in reduced yield and loss of quality of harvested fruit when severe damage occurs on enlarging fruits (Sun *et al*., 2002). Total crop failure due to diseases has been common in the region and farmers are sometimes forced to abandon their production due to excessive infection pressure in the field (Tameru *et al*., 2003).

Different production constraints on farmers' fields at different locations of Western Oromia were observed where diseases are widely distributed (personal observation). Despite this fact, the identity and relative importance of each disease across locations has not been well documented. Therefore, this study was initiated to determine the relative occurrence, distribution and frequency of diseases across locations; and to document information which can be used in developing integrated management measures against hot pepper diseases.

Materials and Methods

Part 1: Field Survey and Sample Collection

Survey was conducted in West Shoa Zone (Bako Tibe and Ilu Galan districts) and East Wollega Zone (Sibu Sire, Wayu Tuka and Boneya Boshe districts) of Western Oromia region, in two consecutive years of 2016 and 2017 main cropping seasons. Survey areas were selected purposively based on the hot pepper production potential of the districts. However, peasant association (PA) and field selection within the PA were done randomly. The average distance between sampled fields was 5-10 km depending on crop coverage. This distances were marked using car speedometer and Geo-positioned by GPS. About 95 and 69 hot pepper farms were assessed in 2016 and 2017 respectively for severity and incidence of major diseases and other agronomic parameters. Disease incidence was calculated as the percentages of infected plants in each field at each location. i.e.

$$Disease\ Incidence = \frac{Number\ of\ diseased\ plant}{Total\ number\ of\ plants\ inspected} \times 100$$

Table 1. Disease severity was recorded using disease rating scale for each disease as indicated below.

Type of disease	Disease Rating scale	Reference
Bacterial leaf spot	0-6	Shenge. 2006
Cercospora leaf spot	0-9	Galanihe *et al.* 2015
Anthracnose leaf spot	0-5	Siddiqui *et al.* 2008
Powdery mildew	0-5	Adinarayana *et al.* 2012

During the survey, infected plant parts (root, stem, leaf and pod) which do not show suspected typical symptoms of different diseases were collected for further laboratory verification. Disease data was recorded from 1m x1m quadrant randomly thrown in the farm at three places.

Data Analysis

All collected data (Disease Incidence and Severity and isolates characters) were analyzed using descriptive statistics and SAS software.

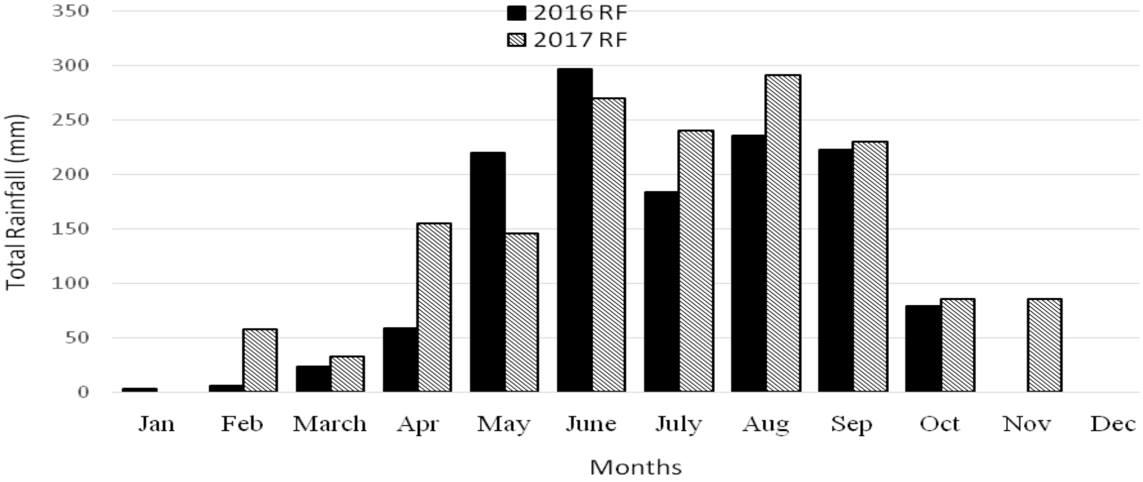

Fig 1: Rainfall distribution during the survey season in 2016 and 2017

Results and Discussions

Hot Pepper Disease Prevalence

Three fungal diseases Fusarium wilt (*Fusarium oxysporium*), Cercospora leaf spot (*Cercospora capsici),* Anthracnose (*Colletotrichum* spp) and Bacteria leaf spot (*Xanthomonas campestris* pv. *vesicatoria*) were recorded in 2016 and 2017. In addition to these diseases, powdery mildew (*Leveillula taurica)* was observed in 2017. Nematode and viral diseases were also observed during the assessment. Shiferaw and Alemayehu (2014) reported that bacterial leaf spot, fusarium wilt, Powdery mildew, anthracnose, cercospora leaf spot and viral diseases are the most prevalent diseases in hot pepper in western Oromia in agreement with the present study.

The prevalence of each disease across the surveyed area was different. In 2016, all of the assessed farms were infected with both cercospora and bacterial leaf spots. However, in 2017 cercospora leaf spot was recorded in about 98% of the assessed farms, while bacterial leaf spot was observed in 97% of the fields. About 26.32 and 15.92 % of the assessed farms were affected by fusarium wilt and anthracnose diseases in 2016, respectively. Fusarium wilt, anthracnose and powdery mildew diseases occurred in 53.6%, 26% and 15.94% of the farms, respectively in 2017. In comparison to other diseases, viral diseases occurred at low frequency in both years (Table 1 and 2). Higher disease prevalence can be related to the relatively higher amount of rain fall during the seasons(Fig. 1). Cerkauskas in 2004 indicated that cercospora leaf spot was more severe in wet weather than in dry weather and becomes destructive in high relative humidity.

Table 1: Prevalence of hot pepper diseases in different districts of western Oromia in 2016

Districts	No. farms Assessed	Fusarium Wilt (%)	Bacterial Leaf Spot (%)	Cercospora Leaf Spot (%)	Anthracnose (%)
Bako Tibe	26	42.31	100	100	42.2
Ilu Galan	16	12.50	100	100	2.50
BiloBoshe	9	11.11	100	100	5.50
Sibu Sire	21	38.10	100	100	5.80
WayuTuka	23	13.04	100	100	7.96
Total	**95**				

Table 2: Prevalence of hot pepper diseases in different selected districts of western Oromia in 2017

Districts	No. farms assessed	Fusarium wilt (%)	Bacterial Leaf Spot (%)	Cercospora leaf spot (%)	Anthracnose (%)	Powdery mildew (%)	Virus (%)
Bako Tibe	9	88.9	100	100	33	0	11
Ilu Galan	11	72.7	100	100	9	0	0
BiloBoshe	11	54.5	100	100	8	0	0
Sibu Sire	25	44.0	96	96	8	0	4
WayuTuka	13	30.7	92	100	84.6	84.5	0
Total	**69**						

At Bako Tibe and Ilu Galan districts, fusarium wilt prevalence was higher as compared to other districts which were about 88.9 and 72.7% in 2017, respectively. However it was relatively lower at Wayu Tuka and Sibu Sire districts in the same year. These may be due to the farmers managements of runoff water where it enters hot pepper fields causing high soil moisture that favors the disease and transport the pathogen to other parts of the fields. In all districts the prevalence of bacterial and cercospora leaf spot were higher which ranges from 92-100% for bacterial leaf spot and 96-100% for cercospora leaf spot. Anthracnose and powdery mildew diseases prevalence were higher at Wayu Tuka district. A very limited presence of virus infected plants was observed in the survey. Virus-infected hot pepper plants were found only in a few farms of Bako Tibe and Sibu Sire districts.

Intensity of diseases in surveyed areas

Fusarium wilt incidence was higher in Bako Tibeand Sibu Siredistricts in 2016 and Bako Tibeand Ilu Galan in 2017. It was as higher as 13.35 % at Bako Tibe and 10.95% at Sibu Sire district in 2016 (Table 3). However it was lower in Bilo Boshe, Wayu Tuka and Ilu Galan in 2016 and Wayu Tuka, Sibu Sire and Bilo Boshe in 2017. Bacterial leaf spot and cercospora leaf spot severity were higher in BiloBoshe in 2016. However, both diseases incidence were higher at Bako Tibe district in 2017 assessment period (Table 3). Anthracnose and powdery mildew diseases were observed during the survey periods. Severity of these diseases was high at Wayu Tuka district 2017; however the severity of this disease was generally lower in 2016. Generally fusarium wilt incidence was higher in 2017 than in 2016. This is because of high rainfall intensity in the area in 2017. Similar to this study, Sally *et al.*,(1996) indicated that less susceptibility of the pathogen to change in temperature and humidity, but soil moisture has greatest influence on the wilt and diseases development.

Fusarium wilt incidence was higher on silt and sand soil types. However, it was lower on clay soils (Table 4). Similar to this observation *fusarium oxysporum* occurs, survives, and grows in soils of all types, but sandy soils provide conditions that are most favorable for growth and development (Amir, and Alabouvette. 1993; Nelson. 1981). Fusarium wilt tends to be most severe in sandy soils and generally less of a problem in heavier clay soils (Amir, and Alabouvette. 1993, Larkin, Hopkins and Martin. 1993). Severity of bacterial leaf spot, cercospora leaf spot and anthracnose diseases were not significantly varied by soil type. The survey result shows powdery mildew disease incidence was higher on pepper grown on silt soil.

During the survey more than 73% of hot peppers were planted on the farm previous year sown with maize followed by teff 14.28 %. Mean fusarium wilt incidence was higher on hot pepper grown on maize fields followed by hot pepper continuously grown on hot pepper fields (Table 5). Effect of previous crop has no significant effect on bacterial leaf spot, anthracnose and powdery mildew disease severity as most of these pathogens are airborne . However, cercospora leaf spot was significantly higher on hot pepper planted on chick pea fields.

Observation on the survey indicated that bacterial leaf spot was significantly negatively correlated with altitude. However, fusarium wilt, cercospora leaf spot, anthracnose, powdery mildew and virus diseases were not significantly correlated with altitude(Table 6). Fusarium wilt was significantly positively correlated with bacterial leaf spot and cercospora leaf spot. Bacterial leaf spot was significantly positively correlated with cercospora leaf spot, anthracnose and virial diseases.

Conclusions and Recommendations

Hot pepper grown in western Ethiopia is prone to different economically important diseases. These diseases reduced yield and yield quality of hot pepper. The most frequently observed diseases in this assessment were Bacterial and Cercospora leaf spost and Fusarium wilt while anthracnose, powdery mildew and virial diseases were observed less frequently.

Based on survey results and overall field observations, disease management metohds were not used despite high prevalence of the diseases in the area.

Therefore, developing integrated disease management strategies which include cultural practices and recommended agronomic measures, development and use of resistant/tolerant variety and chemical management measures is important to improve production and productivity of the crop thereby improve the livelihood of hot pepper farmers.

Table 3: Mean Intensity of the different diseases in each surveyed districts in 2016 and 2017

District	2016				2017				
	Fusarium wilt Incidence	Bacterial Leaf Spot	Cercospora Leaf Spot	Anthracnose	Fusarium wilt	Bacterial Leaf Spot	Cercospora Leaf Spot	Anthracnose	Powdery mildew
BiloBoshe	1.67	3.07	2.19	0.00	8.82	2.55	2.09	0.09	0
Bako Tibe	13.35	2.11	2.15	0.05	38.00	3.44	2.89	0.44	0
Ilu Galan	4.69	2.45	1.60	0.01	30.91	2.54	1.91	0.09	0
Sibu Sire	10.95	2.38	1.95	0.04	7.64	2.20	1.28	0.08	0
WayuTuka	3.48	1.78	2.04	0.06	2.31	2.69	1.31	0.85	2.08

Table 4: Two years mean incidence and severity of hot pepper disease by soil type

Soil type	No. Samples	Fusarium incidence	Bacterial Leaf Spot	Cercospora Leaf Spot	Anthracnose	Powdery mildew
Clay	31	1.00	2.75	1.33	0.92	0.44
Loam	61	14.42	2.58	1.95	0.18	0.00
Sand	22	21.67	2.50	1.67	0.17	0.00
Silt	48	27.73	2.45	1.55	0.00	1.33
Mean		**14.85**	**2.58**	**1.75**	**0.28**	**0.44**

Table 5: Previous crops on hot pepper mean disease intensity

Previous Crop	Fusarium incidence	Bacterial Leaf Spot	Cercospora Leaf Spot	Anthracnose	Powdery mildew
Maize	18.58	2.54	1.73	0.24	0.37
Nug	0.00	3.00	1.00	1.00	2.00
Teff	7.50	2.38	1.75	0.13	0.00
Hot pepper	8.67	2.67	1.00	0.00	0.00
Finger millet	1.00	2.00	3.00	1.00	0.00
Chick pea	2.00	3.00	4.00	1.00	0.00
Faba bean	3.00	2.00	1.00	1.00	2.00
Fallow	2.00	2.00	1.00	0.00	0.00
Mean	**6.47**	**2.45**	**1.81**	**0.55**	**0.55**

Table 6: Correlation of diseases on hot pepper production in western Oromia

	Altitude	Fusarium wilt	Bacterial Leaf Spot	Cercospora Leaf Spot	Anthrac -nose	Powdery mildew	Virus
Altitude	1						
Fusarium wilt	-0.012ns	1					
Bacterial Leaf Spot	-0.305*	0.269*	1				
Cercospora Leaf Spot	0.086ns	0.277*	0.441**	1			
Anthracnose	-0.210ns	0.123ns	0.355**	-0.020ns	1		
Powdery mildew	-0.217ns	-0.183ns	0.178ns	-0.203ns	0.443**	1	
Virus	0.061ns	0.066ns	0.282*	0.197ns	-0.099ns	-0.067ns	1

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Early Growth Response of the Seedlings of Hararghe Coffee varieties and Selections to Soil Moisture Deficit at Mechara, Eastern Oromia

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Abstract

Drought is among the major factors that adversely affects coffee production in most parts of Ethiopia. In an attempt to screen Arabica coffee (Coffea arabica L.) genotypes for drought tolerance, an experiment was carried out at Mechara Agricultural Research Center. The experiment was conducted in a rain shelter using 5 released varieties and 10 selections. Eight pairs of true leaf coffee seedlings were subjected to two watering regimes (water-stress by withholding irrigation and well-watered control) in a randomized complete block design in three replications. It was observed that there were no significant differences among the cultivars for sensitivity to water deficit stress, as evaluated by mean values of visual stress score, Relative water content, Leaf area, Specific leaf area, extent of leaf fall (leaf shedding) and recovery leaf rate during the drought period. But, it was observed that there were significant differences among the cultivars for sensitivity to water deficit stress, as evaluated by mean values of recovery plant, root volume and tap root length during the drought period. However, based on mean values of visual root volume and tap root length, cultivars H-618/98, H-858/98, H-929/98, H-980/98, H-857/98, H-674/98, 74110 and H-823/98 were identified for more root volume and tap root length than H-968/98, H-856/98, H-739/98, H-981/98, H-622/98, H-915/98, H-822/98 cultivars. Therefore, it was concluded that coffee genotypes could be grouped in to three categories (sensitive, moderately sensitive and relatively tolerant) based on preliminary observations and visual assessments of recovery of plants. However, cultivars from each *category should also be tested for their morphological, physiological and biochemical responses to drought in order to identify more tolerant types and come up with a recommendation for further selection and breeding works for drier coffee growing areas of the country.*

Introduction

Drought is an environmental factor that causes water deficit or water stress in plants (Pinheiro et al., 2005).Overall, drought and unfavorable temperatures are the major climatic limitations for coffee production (Da Matta and Ramalho 2006). These limitations are expected to become increasingly important in several coffee growing regions due to the recognized changes in global climate and also because coffee cultivation has spread towards marginal lands, where water shortage and unfavorable temperatures constitute major constraints to coffee yield (Da Matta and Ramalho 2006; Kimemia, 2010). The plants are frequently subjected to periods of water deficit stress, which ultimately leads to reduced growth and productivity by affecting various physiological and biochemical processes. However, they have evolved different strategies to cope with water deficits through avoidance or postponement of dehydration or stress tolerance (Levitt, 1980; Turner, 1990; Pugnaire *et al*., 1999). In line with this, there exist variations among species or between genotypes within a species for acquiring different physiological, morphological and biochemical strategies for survival and even maintenance of some growth and physiological processes under stressful conditions (Levitt, 1980; Kozlowski and Pallardy, 1997; Joshi, 1999). Hence, these adaptive responses are not universal properties of plants (Nambiar *et al*., 1982; Volkmar and Woodbury, 1995) and could be used as selection criteria during screening genotypes for drought tolerance (Sanchez *et al*., 1998; Tesfaye, 2005; Tesfaye and Ismail, 2008, Tesfaye *et al*., 2013).

It has been reported that differences in mean rate of stress development (leaf folding or degree of wilting) is commonly used as an important criteria during screening of genotypes for drought tolerance (Cutler *et al*., 1980; Sloane *et al*., 1990; Rosario *et al*., 1992; Lilley and Fukai, 1994). Such a leaf movement, an adjustment of leaf angle or modification of leaf orientation to reduce the interception of solar radiation and, thus, decrease leaf temperature and water loss by transpiration is regarded as one of the drought avoidance mechanisms evolved in plants (Levitt, 1980; Ludlow and Muchow, 1990; Pugnaire *et al*., 1999; Carr, 2001). On the other hand, lower rate of stress development (less wilting symptom and gradual leaf rolling or folding) as a result of maintenance of turgor has been used as an important criteria during screening of different crop genotypes for drought tolerance (Rosario *et al*., 1992; Sloane *et al*., 1990; Carter and Rufty, 1992; Cutler *et al*., 1980; De Datta *et al*., 1988; Price *et al*., 1992; Lilley and Fukai, 1994). Similarly, stay-green under water stress conditions has also been used as one of the traits to select corn varieties for drought tolerance (Kitbamroong and Chantachume, 1992). Like other crop plants, Arabica coffee is sensitive to water stress and its growth and yield potential is greatly affected by seasonal drought. Despite its economic importance in the world market and in the national economy of some developing countries like Ethiopia, productivity of the crop is very low primarily because of periodic water deficit stresses (Rena *et al*., 1994; Barros *et al*., 1997;

Carr, 2001; Tesfaye, 2005; Tesfaye *et al.*, 2013). In fact, a number of authors, including Melaku (1982), Yacob *et al*. (1996) and Kassahun *et. al*. (2008), have reported the existence of a large diversity among the genotypes of Arabica coffee with regard to yield potential, disease resistance and adaptation to different growth conditions in its center of origin, Ethiopia. However, the variability has not been studied and documented in relation to drought tolerance. The combined effects of this phenomenon have critical impacts on coffee production.

The productivity Hararghe coffee despite its economic importance in the world market and in the national economy of Ethiopia is very low primarily because of periodic soil moisture deficit stresses and many other factors. Despite these facts, there has been little work to examine the extent and pattern of responses of various *C. arabica* genotypes to water deficit in Ethiopia. Furthermore, Mechara Agricultural Research Center in collaboration with Jimma Agricultural Research Center has released four Hararghe coffee varieties through selection from large 1998 Hararghe coffee germplasm collections without further study on their responses to drought stress. Thus, this study was conducted with the objective to identify drought tolerant genotypes in response to soil moisture stress by evaluating their morphological and physiological traits that contribute to varietal differences for further use in the study areas and breeding program.

Materials and Methods

Experimental area

An experiment was carried out at Mechara Agricultural Research Center (McARC in eastern Oromia. The center is located at an altitude of 1760 m.a.s.l and receives an average annual rainfall of about 900mm with monthly mean maximum and minimum temperatures of 26^{o}C and 14^{o}C, respectively.

Experimental materials

Fourteen (14) Hararghe coffee genotypes including four released varieties and ten promising selections were used. One released variety (74110) which is high yielding, CBD resistant and widely adaptable, was also included as a check. Seeds of those genotypes were collected from the mother tree planted in 2005 for variety verification plot in the field at Mechara ARC. The seedlings of each genotype were raised in polythene tube on standard coffee nursery with full management practices as per recommendation.

Experimental Procedures and Design

The uniform and healthy grown seedlings of each genotype were selected at seven (7) months old and eight (8) true leaves stage (field transplanting stage) and transferred to a rain shelter in plastic bucket of 5Lit capacity. The seedlings were uniformly well managed to ensure maximum rate of their establishment for a month. The genotypes were tested for their responses to soil water deficit in a RCBD design in three replications in two levels (well watered and water stressed) of watering regime.

Treatment Arrangement

For making treatment combination, each genotype was subjected to two watering levels (well watered as a control and water stressed by withholding watering). Each genotype plot contained a total of 12 coffee seedlings, six (6) seedlings per watering level. In order to make their uniform and full establishment, the seedlings of each genotypes and watering level were uniformly managed for the 30 days. After a month of establishment period, the seedlings were subjected to the respective watering treatment for 21 days and then, 2 seedlings from each plot were used to measure destructive parameters, while 4 seedlings in each water-stressed plot were re-watered for three weeks to determine the rate of recovery of each genotype.

Data Collected

1. Stress scoring: Sensitivity of coffee genotypes to soil moisture deficit was assessed visually at two days intervals since the first wilting symptom was observed (after seven days). The degree of leaf folding or wilting was scored at morning (7:00 - 8.00 am) and noon (12:00-1:00 pm) hours, using 1 to 5 scoring scales (Rosario et al., 1992) where 1 indicate all leaves green and turgid, 2: most leaves still turgid except the youngest which show leaf folding, 3: all leaves wilt and/or show leaf folding (symptoms of senescence evident), 4: most leaves (specially the older ones) turning pale green and showing severe wilting or folding and 5: all leaves turning brown and dry, mostly drooping. (see Figure 1).

Figure 1. Method of stress scoring and the corresponding 1-5 scale score values for visual assessment and screening Arabica coffee genotypes for drought tolerance in a rain shelter.

Non-Destructive Growth Parameters: plant height, number of leaves, leaves area; stem girth, growth rate, and number of wilted seedlings and percentage of rolled leaves were recorded from two seedlings in the central part of each plot. Leaf area was calculated using the method developed by Yakob *et al*. (1993) as follows:

$$LA = L \times B \times K$$

Where; LA = Leaf area (cm^2), L = Leaf length (cm), B = Maximum leaf breadth (cm) and K = Correction factor = 0.7

Destructive growth parameters: destructive plant growth parameters such as fresh and dry weights of stems, leaves and roots using 0.001gm sensitive balance, tap root length (cm), root volume (ml), root to shoot ratio, and shoot, root and total dry matter yield were recorded by uprooting two randomly selected seedlings from the central rows of each plot. Fresh weight of plant parts was measured right after harvesting, while dry matter yield was determined after its oven dried at 70-80^{o}C for 24 hours to a constant weight. Root volume of the selected seedlings was measured using displacement method (volume of water displaced by roots of a plant when the whole root system below the collar level is submerged in a 500ml graduated cylinder filled with 300 ml tap water) immediately after harvesting and careful washing to remove all soil particles. Root to shoot biomass ratio was computed as percentage using the following formula:

$$\text{Root to shoot biomass (\%)} = \frac{\text{Root dry weight (gm)}}{\text{Shoot dry weight (gm)}}$$

Recovery Rate (Rr):

After 21 days of water stressed seedlings in the stressed plots were re-watered at two days interval for three weeks and the, number of died plants and number of plants producing new growths (flushes of buds and new leaves). Survival rate, rate of leaf shade, or died were counted to estimate genotypic differences in rate of recovery from the soil drying or water stress treatment. Rate of survival was determined 15 days after frequent rewatering by counting the number of alive and dead plants per plot, while extent of leaf shedding was calculated based on the average number of leaves maintained by plants prior to and at the end of the water stress treatment.

Physiological parameters:

Three leaves were detached from the plant and immediately weight of each leaf was taken to get fresh weight (FW), each leaf was soaked in distilled water in the bucket and kept in bucket at 5^{o}C for 24 hours and re-weighed to get turgid weight/saturated (TW) and finally oven dried at 70^{o}C for 24 hours and weighed to get the dry weight (DW). RWCL was calculated using the following formula:

$$\text{RWCL} = \frac{(\text{FW} - \text{DW})}{(\text{TW} - \text{DW})} \text{X } 100$$

Leaf thickness (LT) was calculated as leaf dry weight divided by leaf area (LT = Wd/LA) (Bowyer and Danson, 2004).

Specific leaf area (SLA)

$$\text{SLA} = \frac{\text{LA}}{\text{LDW}}$$

Where: SLA = Specific leaf area; LA = Leaf area; LDW = Leaf dry weight

Data Analysis

The collected data were statistically analyzed using GenStat software 15th edition and whenever the ANOVA shows a significant difference between means Fisher's Protected Least Significant Difference was performed.

Results and Discussions

Stress Scoring

The analysis of variation shows that there was a significant difference observed among the genotype for the mean stress score (Table 1). It indicated that, genotype H-622/98, H-968/98, H-822/98, H-858/98, 74110, H-674/98 H-618/98, and H-857/98 were more sensitive to soil moisture deficit for the stress period of 21 days. But the lower stress score values for rate of leaf folding (wilting) was recorded in H-739/98, H-823/98, H-856/98, H-915/98, H-981/98, H-929/98 and H-980/98 cultivars (Table 1). Furthermore, under both well watered and water stress conditions, H-981/98 have got low stress value in the morning (Figure 2) and noon scoring (Figure 3).

Table 1: Mean stress score value for coffee cultivars under water-stressed (WS) condition on different days from start of treatment application till 21 days

Cultivar	**Days from start of treatment**					**Mean**
	Day 8	Day 11	Day 14	Day 17	Day 20	
H-618/98	1.13	1.41	1.87	2.15	3.09	1.93
H-622/98	1.14	1.56	1.95	2.29	3.02	1.99
H-674/98	1.61	1.68	2.23	2.30	3.61	2.29
H-739/98	1.28	1.66	1.93	2.53	3.65	2.21
H-822/98	1.23	1.67	2.26	2.58	3.78	2.30
H-823/98	1.05	1.53	1.87	2.13	3.08	1.93
H-856/98	1.23	1.34	1.59	1.94	3.00	1.82
H-857/98	1.41	1.80	2.32	2.54	3.41	2.30
H-858/98	1.34	1.42	1.64	1.71	2.71	1.76
H-915/98	1.41	1.91	2.27	2.53	3.57	2.34
H-929/98	1.12	1.56	2.21	2.53	3.60	2.21
H-968/98	1.05	1.30	1.88	2.27	3.81	2.06
H-980/98	1.43	1.93	2.10	2.41	3.79	2.33
H-981/98	1.04	1.09	1.36	1.58	2.53	1.52
74110	1.12	1.46	1.99	2.34	3.26	2.04
Mean	1.25	1.56	1.96	2.25	3.33	2.07
C.V (%)	19.00	28.80	27.50	5.80	21.00	21.50
LSD (0.05)	0.39	0.75	0.90	0.97	1.16	0.74

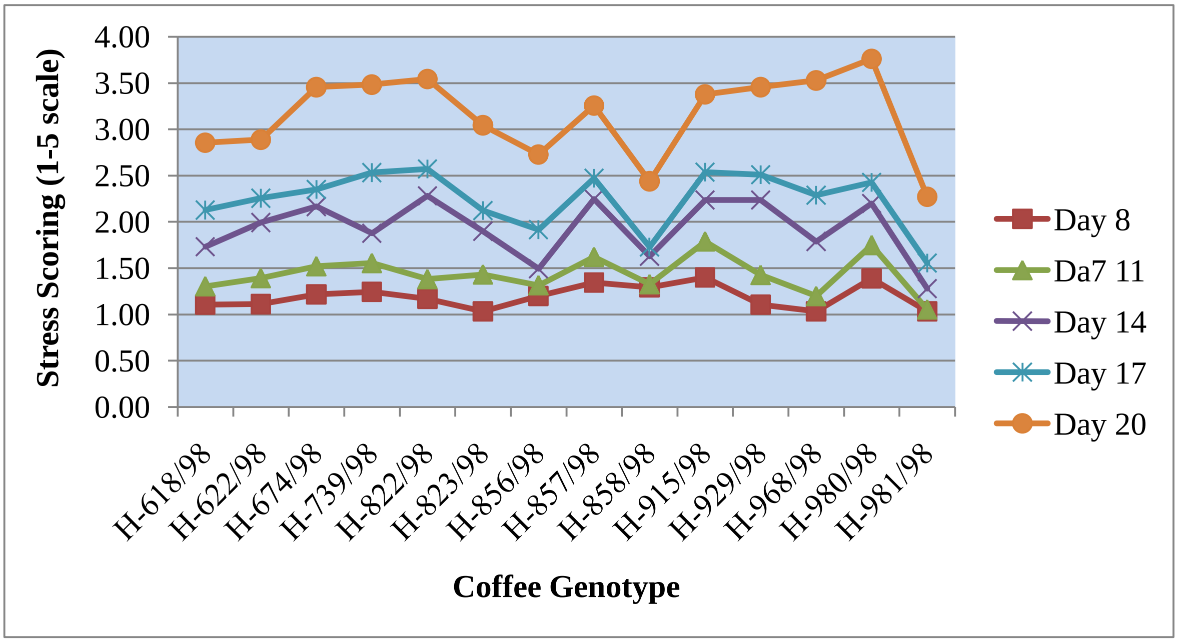

Figure 2. Morning stress score value for coffee cultivars under water-stressed (WS) condition on different days from start of treatment application

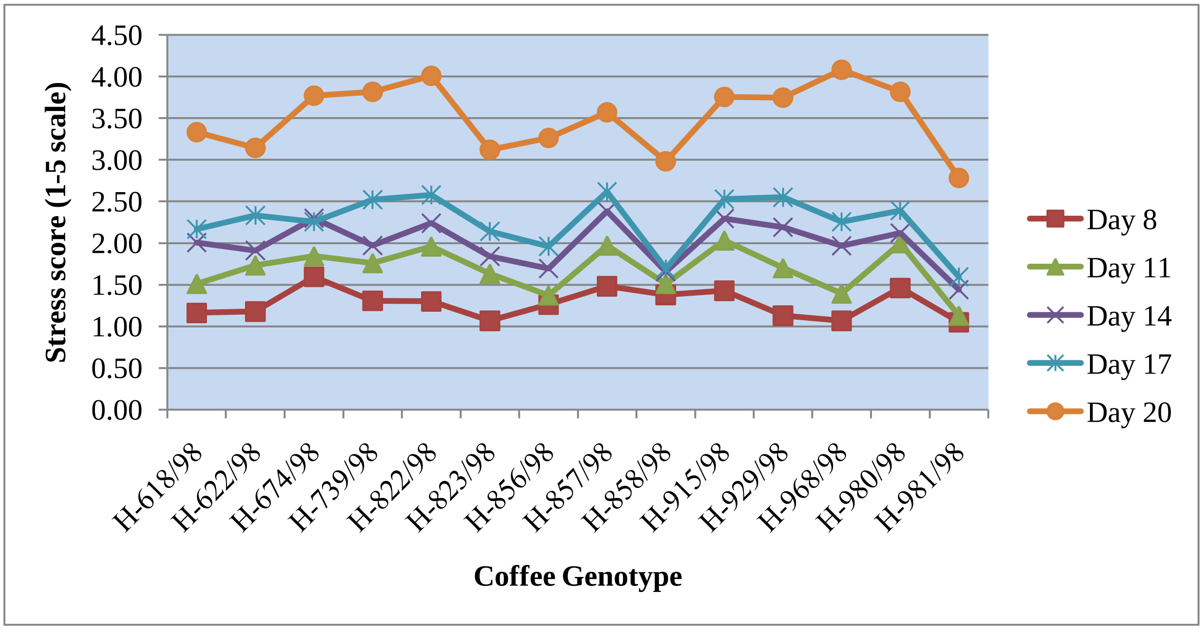

Figure 3. Noon stress score value for coffee cultivars under water-stressed (WS) condition on different days from start of treatment application

Growth parameters of the plants under soil moisture deficit

There is a difference between coffee genotypes for sensitivity to water deficit stress period of 21 days for growth parameters (Table 2). Accordingly, genotype H-981/98 is more tolerant than the rest genotypes in case of growth parameters followed by H-980/98 (Table 2).

Table 2. Early plant growth parameters of the coffee seedlings subjected to 21 days of water deficit stress

Genotypes	**Plant height (cm)**		**Girth (mm)**		**Number of leaf**		**Number of node**	
	Water stressed	Well watered	Water stressed	Well watered	Water stressed	Well watered	Water stressed	Well watered
H-618/98	32.30 a	39.33 abc	4.91 ab	5.97 bc	11.17	17.33	10.17	10.67
H-622/98	41.93 b-e	42.95 b-e	5.06 abc	5.83 bc	14.83	22.50	10.00	10.33
H-674/98	41.66 b-e	43.12 b-e	5.30 abc	5.56 b	14.50	17.67	9.83	14.33
H-739/98	40.10 a-e	40.50 a-d	5.28 abc	5.13 ab	11.33	23.83	10.33	11.33
H-822/98	42.22 cde	45.33 de	4.83 ab	5.38 b	15.33	23.17	9.67	11.00
H-823/98	37.75 a-d	37.00 a	5.48 a-d	5.03 ab	13.25	17.33	9.87	11.33
H-856/98	33.83 ab	37.65 ab	4.94 ab	5.10 ab	13.33	17.00	9.50	10.00
H-857/98	34.23 abc	41.22 a-d	5.37 abc	5.19 ab	12.50	19.17	9.17	9.83
H-858/98	34.20 abc	38.77 abc	4.71 a	4.94 a	14.00	14.17	10.17	11.17
H-915/98	36.07 a-d	40.22 a-d	4.74 a	5.34 b	13.00	19.50	10.00	11.00
H-929/98	39.42 a-e	39.97 a-d	5.94 bcd	5.80 bc	16.67	17.33	10.17	10.00
H-968/98	42.92 de	43.78 cde	6.72 d	6.88 c	14.50	19.50	10.50	11.50
H-980/98	43.30 de	44.42 cde	5.92 bcd	5.97 bc	13.83	20.67	9.67	13.33
H-981/98	46.42 e	48.03 e	6.11 cd	6.18 bc	14.00	25.33	9.67	11.33
74110	35.72 a-d	40.75 a-d	5.14 abc	6.03 bc	17.33	25.33	9.83	10.17
Mean	**38.80**	**41.54**	**5.36**	**5.56**	**3.99**	**19.99**	**9.89**	**11.16**
LSD (5%)	**8.25**	**5.92**	**1.18**	**1.26**	**5.96**	**7.16**	**1.80**	**3.27**
CV %	**12.80**	**8.50**	**13.00**	**13.60**	**25.10**	**21.50**	**10.90**	**17.60**

Tap root length and root volume

The results indicated that, there are significant difference among coffee genotypes for sensitivity to water deficit stress and for tap root length and non significance for root volume (Table 3). The longest (24 cm) tap root length was recorded for the genotype H-823/98 under water stressed period of 21 days (Table 3). In agreement with this finding, studies on Robusta coffee showed deeper root system (Pinheiro et al., 2005) and larger root dry mass in drought tolerant clones than in drought sensitive ones (DaMatta and Ramalho, 2006).

Table 3. Tap root length and root volume as affected by soil moisture deficit after 21 days of stress period

Accessions	**Tap root length (cm)**		**Root volume (ml)**	
	Water Stressed	Well Watered	Water Stressed	Well Watered
H-618/98	17.97 a-d	23.42	8.50	11.50
H-622/98	15.13 ab	18.43	9.33	19.67
H-674/98	18.57 a-e	20.98	8.67	19.00
H-739/98	16.3 abc	18.17	8.33	21.33
H-822/98	16.97 a-d	15.09	8.33	15.33
H-823/98	21.67 de	21.07	9.17	15.17
H-856/98	15.73 abc	21.03	8.00	16.17
H-857/98	23.87 e	19.43	8.83	12.17
H-858/98	21.07 cde	22.92	5.33	9.33
H-915/98	14.37 a	16.97	7.17	12.17
H-929/98	19.17 a-e	21.48	7.83	16.33
H-968/98	15.63 ab	18.43	8.33	14.83
H-980/98	17.97 a-d	21.48	9.83	18.50
H-981/98	20.03 b-e	16.55	10.00	14.83
74110	19.30 a-e	18.93	4.67	7.50
Mean	**18.25**	**9.63**	**8.16**	**14.92**
LSD (5%)	**5.35**	**5.02**	**5.39**	**8.86**
CV %	**17.6**	**15.3**	**39.6**	**35.6**

Dry matter contents of the seedlings

Root dry matter

There was a significant interaction variation among the coffee genotypes for root dry matter under watering regime. The highest root dry weight was observed for genotype H-823/98, followed by H-622/98 whereas, the minimum was observed from genotypes H-981/98 followed by H- 858/98 for water stress. On the other hand, under well watered condition, higher root dry matter was recorded for H-674/98 and H-739/98 and lowest for H-981/98, H-915/98, H-618/98 and H-823/98 (Table 4). This implies that the low reduction in root dry weight due to water stress may be associated with differences in genetic potential of the accessions to partition more dry matter to roots. The results contradict with the reports of Dias et al. (2007) which indicates that coffee plants may not shift biomass allocation to roots as a response to drought stress.

Shoot dry matter yield

There was a significant interaction effect for shoot dry matter yield due to watering and coffee genotypes factor. Accordingly, the highest shoot dry weight was observed for accession H-

968/98, followed by H-981/98, while, the lowest was observed from accession H-858/98 followed by H-618/98 for well water stressed. Under well watered condition, higher root dry matter was recorded for H-981/98 followed by H-674/98 (Table 4). Comparison of stressed and well-watered plots showed that the maximum shoot dry weight loss was due to the stress condition. Such reduction in shoot growth under moisture stress conditions was also reported for cotton (Fernández et al., 1996) and Sorghum (Muhammad et al., 2009, Al-Hussaini et al., 2013).

Total dry matter

There was significant difference among coffee accessions in total dry biomass of watered and water stressed treatments. Under well watered treatment accession H-968/98 (6.26g), H-981/98 (5.76g) and H-622/98 (5.68g) produced highest total dry biomass and the minimum was obtained from H-858/98, H-618/98 and H-915/98 under water stress condition. Whereas under well watered condition, the highest (12.13g) total dry matter was recorded for genotype H-674/98. The relatively less difference between well watered and water stressed plots of a genotypes could be attributed to the inherent potential of the genotype to produce and accumulate more assimilates. Thus, total dry matter yield was not affected much even with limited water supply and stomatal conductance and lower photosynthetic rate under soil moisture deficit condition. And this can be regarded as one of the adaptive or tolerance mechanisms to water deficit stress (Tesfaye, 2005; Tesfaye et al., 2013 and Abel et al., 2014).

Root to shoot biomass

The root to shoot ratio was significantly varied among the accessions under both stressed and non-stressed conditions. Accordingly, the highest root to shoot ratio was recorded for H-823/98 (0.639), H-822/98 (0.560), H-980/98 (0.418) and H-858/98 (0.411) and the lowest (0.257) value was recorded for the genotype of H-981/98 under water stressed condition (Table 4). Under well water condition exhibited higher shoot ratio (Table 4). Partitioning of more dry matter to roots and, thus, higher root to shoot ratio especially under soil moisture stress condition has been reported for different crops including coffee (Tesfaye, 2005), sorghum (Bibi et al., 2012) and cotton (Pace et al., 1999). On the present study, some of the coffee genotypes, such as H-980/98 and H-858/98 had relatively higher root to shoot ratio under well-watered and water stressed condition (Table 4). Therefore, this result may probably show that, in addition to other morphological, physiological and biochemical mechanisms, root to shoot ratio can also be used as a selection criteria during screening genotypes for drought tolerance (Cook 1985; Pace et al., 1999; Worku and Astatkie 2010).

Table 4. The dry matter contents of plant parts subjected to 21 days of soil water deficit

Genotype	RDMY (gm/plant)		ShDMY (gm/plant)		TDMY (gm/plant)		Root to shoot biomass	
	WS	WW	WS	WW	WS	WW	WS	WW
H-618/98	1.38	2.63	2.63	6.06	3.71	8.69	0.378	0.451
H-622/98	1.58	2.77	4.10	6.38	5.68	9.15	0.385	0.434
H-674/98	1.87	4.33	3.73	7.81	4.60	12.13	0.263	0.547
H-739/98	1.25	3.67	3.04	7.30	4.10	10.96	0.349	0.504
H-822/98	1.53	2.78	2.80	6.68	4.33	9.46	0.56	0.423
H-823/98	1.91	2.64	2.86	5.59	4.76	8.23	0.639	0.484
H-856/98	1.35	3.08	3.02	4.96	4.07	8.04	0.337	0.675
H-857/98	1.27	3.19	2.69	6.03	3.76	9.21	0.381	0.558
H-858/98	1.25	2.39	2.21	4.82	3.08	7.21	0.411	0.505
H-915/98	1.33	2.37	2.85	6.17	3.98	8.54	0.391	0.385
H-929/98	1.42	3.17	3.53	5.73	4.95	8.90	0.385	0.556
H-968/98	1.52	3.45	4.74	6.83	6.26	10.28	0.299	0.501
H-980/98	1.56	3.56	3.74	6.17	5.29	9.73	0.418	0.594
H-981/98	1.26	2.22	4.50	7.40	5.76	10.62	0.257	0.436
Mean	1.28	3.09	3.32	6.28	4.60	9.37	0.390	0.504
LSD (5%)	0.36		0.50		0.74		0.067	
CV%	38		24		24.4		34.5	

Key: WS=Water stressed; WW=Well Watered; RDMY=Root dry matter yield; ShDMY=Shoot dry matter yield; TDMY=Total dry matter yield

Relative Water Content of leaf

The present study revealed that there is a significant difference among genotypes for relative leaf water contents. From the result, all the coffee genotypes showed an average relative water content ranging from 34% (H-980/98) to 58% (H-8998) under water stress condition and from 76.9 (H-981/98) to 91.60% (H-622/98) under well watered conditions (Table 5). Comparison of stressed and well-watered plots showed that the maximum relative leaf water content loss due to the stress was measured for H-915/98 (20.7%), H-858/98 (20.6%), 74110 (19.03) and H-980/98 (18.53%) while, the minimum reduction was observed in H-857/98 (5.5%) followed by H-929/98 (7.3%) (Table 5). In the present study, lower rate of stress development coupled with higher plant water status (as the case with accession H-857/98 and H-929/98) or lower value for both parameters (such as in accession H-981/98) could be attributed to some drought tolerance mechanisms such as osmotic adjustment, which maintain turgidity of leaves, despite the water stress (Tesfaye, 2005). On the other hand, maintenance of plant water status at higher level with relatively sever leaf folding and wilting symptoms could also be regarded as one of the drought avoidance strategies in crop plant (Wiersma and Christie, 1987; Davies et al., 2000, Tesfaye 2005; Tesfaye and Ismail, 2008).

Leaf Area and Specific Leaf Area

It was observed that there were significant differences among these cultivars for sensitivity to after deficit stress, as evaluated by mean values of visual Specific Leaf Area. H- H-822/98, H-981/98 and cultivars exhibited lower specific area while in H-980/98 leaf area was lower (Table 5). In agreement with this finding, coffee genotypes were found to differ in drought adaptation mechanisms such as stomata control and soil water extraction efficiency (DaMatta and Ramalho, 2006).

Rate of Plant Recovery after Stress

It was observed that there is a significant difference between the accessions for rate of recovery after rewarding. Generally, all the accessions recovered well except H-980/98, H-981/98 and H-858/98 after resuming watering. However, out of the accessions seriously affected by moisture stress, only H857/98 and 74110 recovered quickly from the effect of moisture stress, while the rate of recovery of H-980/98 was slow (Table 5). In line with this Moore (1987) reported that plant recovery ability after drought is more important than drought tolerance. Therefore, this may imply that some accessions such as H-622/98, H-929/98 and H-915/98 regarded as drought sensitive based on their higher mean stress score (> 3.2) but showed the high rate of recovery and may be considered as potential genotypes for further study. This observation is also in agreement with the finding of Sundara (1987), who reported that recovery can be rapid, with normal growth resumed, if moisture stress has not adversely affected plant biomass and root growth.

Table 5: Means of relative water content (RWC), leaf area (LA), specific leaf area (SLA), Rate of leaf shade (RLSH), Rate of recovery plant (RV) of different coffee genotypes under water stress (WS) conditions

Genotypes	RWCL	LA	SLA	RRP	RLSH
H-618/98	54.92	64.02 a	18.98 ab	23.96 abc	82.58 a
H-622/98	49.90	60.80 a	27.36 a	27.08 abc	79.97 ab
H-674/98	52.89	64.16 a	14.10ab	21.08 abc	54.99 abc
H-739/98	53.31	68.42 a	14.14 ab	15.13 abc	71.38 abc
H-822/98	42.16	62.16 a	7.65 b	5.75 c	37.15 c
H-823/98	54.42	65.69 a	25.34 a	17.25 abc	40.79 bc
H-856/98	50.3	64.45 a	17.70 ab	24.50 abc	38.63nc
H-857/98	57.77	58.92 ab	24.35 a	16.71 abc	56.89 abc
H-858/98	53.75	58.63 ab	19.48 ab	35.42 a	51.42 abc
H-915/98	54.35	59.62 a	21.51 ab	16.67abc	72.74 abc
H-929/98	54.49	64.05 a	22.65 ab	15.63abc	61.35 abc
H-968/98	55.45	63.12 a	23.13 a	4.71 c	49.42 abc
H-980/98	34.32	44.12 b	16.72 ab	7.33 bc	89.86 a
H-981/98	57.44	61.69 a	1.07b	29.21 ab	80.61 ab
Mean	**52.34**	**62.25**	**19.27**	**19.14**	**11.03**
CV (%)	**22.25**	**14.79**	**47.73**	**71.93**	**59.56**

Note: RWCL relative water content of leaf, LA leaf area, SLA specific leaf area, RLSH Rate of leaf shade, RRP Rate of recovery plant

Conclusions and Recommendations

In general, it was observed that there were obvious differences among Arabica coffee cultivars for sensitivity to water stress. In the areas where moisture is a limiting factor to the production of coffee like Hararghe, H-981/98 genotype is more tolerant followed by H-858/98 to drought by some adaptation characteristics (mechanisms). In the area where, moisture is a limiting factor to the production of coffee like Hararghe, further breeding must be done within H-981/98 and H-858/98 cultivars. Further study on water stress tolerance and the impact of this stress on yield of adult plants should also be conducted by stressing the plants at different growth stages for different length of time.

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Effectiveness of Different Fungicides for Management of Cercospora Leaf Spot Disease (*Cercospora sesame* Zimm.) of Sesame (*Sesamum indicum* L.)

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Abstract

Sesame (Sesamum indicum) is a vital oil crop and Ethiopia is one of the major producer countries of the crop in the world. A field experiment was conducted for two years (2015/16 and 2016/17 GC) at Delo-mena site of Sinana Agricultural Research Center (SARC) with the objective of identifying effective fungicides for the management of Cercospora leaf spot of Sesame. The trial was arranged in RCB Design in three replications and the treatment were; Odeon 825 WDG, Mancozeb 80% WP, Natura 250 EW, Ridomil Gold MZ 68 WG*, Rex Duo, Tilt 250 EC and unsprayed control. Disease severity was scored on 10 randomly pre- tagged plants from the central four rows. Area under the disease progress curve (AUDPC) and disease progress rates were derived from percent disease severity index. The association of disease parameters with yield and yield related traits were assessed using Correlation and Regression analysis. ANOVA for disease severity, AUDPC and r have shown statistically significant difference ($p \leq 0.05$) between treatments. The highest Cercospora leaf spot disease severity of 41.11% and the lowest (5.00%) were recorded from unsprayed plots and Tilt 250 EC treated plots, respectively. Similarly, the highest AUDPC (1474.67 %-days) and r (*0.038292 *units^{-1}) and the lowest AUDPC (165.67 %-days) and r (*-0.004976 *units^{-1}) were similarly calculated from unsprayed control and from Tilt 250 EC treated plots, respectively. Regarding yield and yield related traits; ANOVA has shown significant variations ($P \leq 0.05$) between treatments for number* *of Capsules per plant, Capsule length, TKW and grain yield. The highest number of Capsules per plant (71.67), Capsule length (3.01 mm), TKW (3.27 g) and grain yield (618.98 kg/ha) were recorded from a plot sprayed with Tilt 250 EC treated plot; while the lowest number of Capsule per plant (21.33), Capsule length (2.30 mm), TKW (2.80 g) and grain yield (457.87 kg/ha) were recorded from unsprayed control plot. Simple linear regression of TKW and grain yield with Cercospora leaf spot severity and AUDPC have revealed significant difference ($P\leq 0.05$) between treatments; the estimated slope of the regression line obtained for Cercospora leaf spot severity in relation with grain yield was* -3.36 and for AUDPC was -0.093. *The Correlation of grain yield with Cercospora leaf spot disease severity and AUDPC have depicted that Cercospora leaf spot disease severity and AUDPC have significant negative correlation with grain yield ($r= -0.4821$, $P\leq 0.05$) and ($r= -0.4834$, $P\leq 0.05$), respectively. Therefore, based on the result of this study, a fungicide Tilt 250 EC is recommended for the management of Cercospora leaf spot disease on Sesame.*

Key words: Chocolate spot, Disease severity index, AUDPC, and Disease progress curve

Introduction

Sesame (*Sesamum indicum*) is a vital oil crop produced in the tropical and subtropical parts of the World (Kavak and Boydak, 2006). Ethiopia is one of the major producers of sesame in the World. In Ethiopia, during 2010/11 cropping season, sesame was produced on an area of 384,682.79 ha of land with total production of 3,277,409.22 quintals which increased by about 25.8% from that of 2009/10 production year (CSA, 2011). Area of land covered by the crop in Oromia Region was about 70,238.66 ha with an approximate production of 544,242.35 quintals, whereas it was 132,522.80 quintals which was produced on an area of 18,855.25 ha in Bale zone in 2010/11 cropping season (CSA, 2011). The crop is endowed with diverse natural gift, of which users can benefit. Seed from sesame is rich in oil (50-52%), protein (17-19%) and carbohydrates (16-18%) (Enikuomehin, 2005). During 2010/11 cropping season, national sesame productivity was 8.52 quintals per hectare (CSA, 2011). This is far less than Global average which is 22.5 quintals per hectare (Brigham, 1985). Diseases are reported to cause a considerable yield loss elsewhere in the World (Egonyu *et al.,* 2005). Powdery mildew and leaf spot are important fungal diseases which were reported to cause a yield loss of 45%-100% and 22-53%, respectively during severe epidemics. However, regardless of the economic importance of these diseases in Bale zone; there is no any effort made for its management. Still now, there is not any recommended fungicides are available against these severely damaging diseases. This experiment was therefore initiated to evaluate some fungicides and recommend for the end users.

Materials and Methods

Description of Experimental Site

This experiment was conducted for two years in 2015/16 and 2016/17 GC during the main cropping season at Sinana Agricultural Research Center (SARC) sub-site, Delo Mana, which is located at about 1314-1508 m.a.s.l and receives 986.2 mm mean annual rain fall and a mean annual temperature of 22.5 ºC (Daniel, 1977). The location represents the mid-land areas of major Sesame producing areas. The area is hot spot environment for development of Cercospora leaf spot (*Cercospora sesame* Zimm) of Sesame. The dominant soil of the area is Nitosol (Ermias *et al.,2008).*

Treatments and Design

The experiment was arranged in Randomized Complete Block Design in three replications with Local Sesame cultivar as a test variety. A plot size was 3m x 2.4 m with a total of 6 seeding rows with between row, plot and replication spacing of 0.4m, 2m and 2m, respectively. Fungicides sprays were started immediately after about 10-15% disease development was observed on leaves and the sprays were continued at seven (7) days interval and sprayed three (3) times (Table 2). Cercospora leaf spot disease development was rated based on a scoring scale developed for the disease on a 0-6 scale (Einkuomehin, *et al.,* 2002) (Table 1). Seed rate of 4 kg/ha and all other agronomic packages were applied as per the recommendation.

Table 1: Disease score for Cercospora leaf spot disease of sesame

Scale	Disease Severity (%)	Resistance Category	Rating	Cercospora leaf spot characteristics
1	0-14	Immune (I)	No disease	No trace of infection
2	14.1-29	Highly Resistant (HR)	Hypersensitivity	Hypersensitive spot on lower leaves only
3	29.1-43	Resistant (R)	Trace infection	Small lesion on lower leaves only
4	43.1-57	Moderately Resistant (MR)	Slight infection	Small lesions on lower and upper leaves and stems
5	57.1-71	Moderately Susceptible (MS)	Moderate infection	Advanced lesions[1] on upper and lower leaves, with or without new infection stem and petiole
6	71.1-86	Susceptible (S)	Severe infection	Advanced lesions on upper and lower leaves, flower, buds, stems and petiole and slight infection of Capsule
7	86.1-100	Highly Susceptible (HS)	Very severe infection	All features of the above with severe infection of Capsule

[1] Advanced lesion is characterized by a dark to dark-brown spot with a whitish to straw-colored or perforated center (Einkuomehin, *et al.,* 2002)

Table 2: List of Fungicides and Treatment Arrangement of the Trail

Treatment No.	Test fungicide		Application rate	Application frequency
	Trade Name	Common Name		
1	Odeon 825 WDG	Chlorothalonil	2.5 kg/ha	3
2	Mancozeb 80% WP	Mancozeb	2.5 kg/ha	3
3	Natura 250 EW	Tebuconazole	0.65 l/ha	3
4	Ridomil Gold MZ 68 WG	Metalaxyl-M	2.5 kg/ha	3
5	Rex Duo	Epoxiconazole + Thiophanate-methyl	0.5 l/ha	3
6	Tilt 250 EC	Propiconazole	0.5 l/ha	3
7	Untreated check			

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 from each treatment. The goodness of the fit of the models was tested using coefficient of determination (R^2) and Logistic model was found to fit best for the current study. 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 was used to estimate the disease progress rate in different treatments. Disease severity was recorded in 1 to 5 scale where, 1= 20% or less, 2= 20-40%, 3= 40-60%, 4= 60-80% and 5= more than 80% of the leaf area damaged by the disease and disease incidence was recorded in percentage. The disease data recorded based on scale mentioned above was converted to percentage severity index (PSI) according to Wheeler (1969). AUDPC values were calculated for each plot using the following formula the standard formula (Campbell and Madden 1990) based on PSI calculated and ANOVA was performed for disease severity index (Wheeler, 1969), AUDPC (Campbell and Madden, 1990), and rate of disease progress (r) accordingly. The association of disease parameters with yield and yield related parameters was assessed using Correlation and regression analysis. Mean separation was made based on LSD technique at 5% probability level.

$$\text{PSI} = \frac{\text{Sum of Numerical Ratings X 100}}{\text{Number of Plants Scored X Maximum Score on Scale}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

$$\text{AUDPC} = \sum_{i-1}^{n-1} 0.5(x_{i+1} + x_i)(t_{i+1} - t_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

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

Results and discussions

The combined Analysis of variance over years have shown that there was statistically significant variations across treatments for disease parameters such as disease severity (%), Area Under Disease Progress Curve (AUDPC) (%-days) and Disease Progress Rate (r) (units day^{-1}) (Table 3). Statistically significant difference (*P<0.05*) was observed for disease severity. The highest Cercospora leaf spot disease severity (41.11 %) was recorded from a plot without fungicide treatment (untreated check), while the lowest disease severity of 5.00 % was recorded from a plot sprayed with Tilt 250 EC fungicides (Figure 1 and Table 3). This result is in agreement with some studies where both synthetic and botanical fungicides reduced Cercospora leaf spot disease severity on sesame (Enikuomehin, 2005). Similarly, it was reported that the intensity of Cercospora leaf spot was significantly reduced by the effect of a fungicide treatment compared to untreated crop (Nahunnaro and Tunwari, 2012).

Table 3: Effect of Fungicide application on Sercospora leaf spot Severity (%), AUDPC (%-days) and Disease Progress Rate (r)

Treatment	**Disease Severity (%)**	**AUDPC (%-days)**	**r (units-day^{-1})**
Untreated check	41.11	1474.67	0.038292
Odeon 825 WDG	7.89	281.17	-0.002486
Ridomil Gold MZ 68 WG	6.94	241.50	-0.003333
Rex Duo	6.89	236.83	-0.004414
Mancozeb 80% WP	6.78	235.67	-0.003407
Natura 250 EW	6.11	211.17	-0.003201
Tilt 250 EC	5.00	165.67	-0.004976
CV (%)	**12**	**12.27**	**71.96**
LSD$_{(p\leq 0.05)}$	**2.42**	**87.39**	**0.003**

Note: AUDPC-Area Under Disease Progress Curve; r-Disease Progress rate

In the same way, statistically significant differences ($P<0.05$) was observed for AUDPC and disease progress rate (r). The highest AUDPC of 1474.67 %-days and the lowest 165.67 %-days) were calculated from non-treated plot and a plot sprayed with Tilt 250 EC fungicide, respectively (Table 3). This result agrees with Nahunnaro and Tunwari, 2012 which indicated that fungicide treatment significantly reduced the disease progress curve. Similarly, the highest and the lowest disease progress rate (r) of 0.038292 units-day^{-1} and -0.004976 units-day^{-1}, respectively were calculated from untreated plot and a plot sprayed with Tilt 250 EC fungicide, respectively.

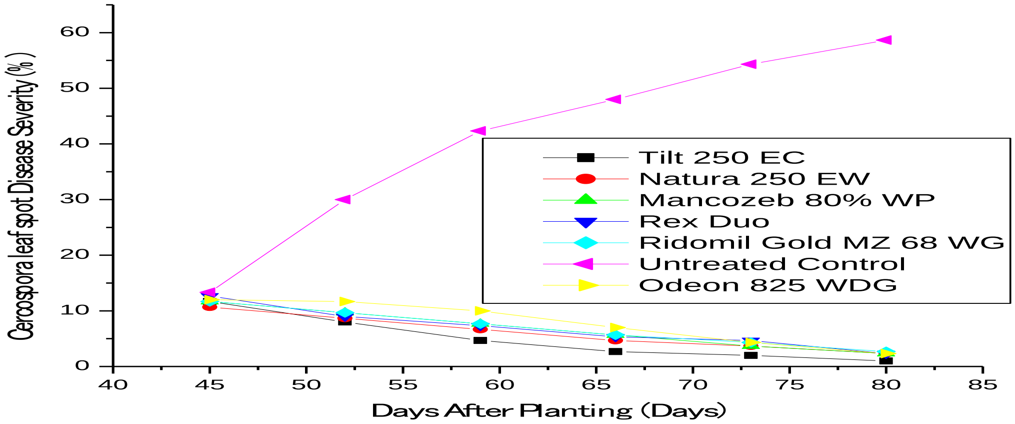

Figure 1: Cercospora leaf spot disease progress curve as affected by fungicide spray on Local landrace cultivar at Delo-Mena, Bale Zone

With regard to yield and yield related parameters, the maximum number of Capsules per plant (71.67) and the highest Capsule length (3.01 mm) were recorded from the plots sprayed with Tilt fungicide; while the smallest Capsule per plant (21.33) and Capsule length (2.30) were recorded from unsprayed plots (Table 4). Similarly, the highest plant height (144.89 cm) and the highest TKW (3.27 g) were recorded from a plot sprayed with Tilt 250 EC fungicide; while the lowest plant height of 114.22 cm and the lowest TKW of 2.80 g were recorded from unsprayed plots (Table 4) similar results were also reported by Tunwari and Nahunnaro, 2014. Likewise, the highest grain yield of 618.98 kg/ha were recorded from plot treated with Tilt; while the lowest grain yield of 457.87 kg/ha was recorded from a plot with no fungicide treatment (unsprayed control) (Table 4). All the tested fungicides have shown an overall efficacy over Cercospora leaf spot of Sesame in this trial. This result is supported by (Enikuomehin, 2005) when they found similar result from their study. Simple linear regression model was employed to assess the relationship of Cercospora leaf spot disease severity and AUDPC with TKW and Grain yield. Accordingly, the simple linear regression analysis result has revealed that there is statistically justifiable significant difference ($P \leq 0.0001$) among treatments. The estimated slope of the regression line obtained for Cercospora leaf spot disease severity in its association with TKW was -0.009566. This estimate shows that for each unit increase in percent severity of Cercospora leaf spot disease, there was a sesame grain yield loss of 0.009566 kg/ha (Figure 2A). F-statistics calculated have shown very high significance ($P \leq 0.0001$) of the over all probability of the equation. Similarly, the simple linear regression analysis between grain yield and Cercospora leaf spot disease severity has resulted in significant difference ($P \leq 0.0001$) between treatments. The estimated slope of the regression line obtained for disease severity was -3.36 which shows that for each unit increase in Cercospora leaf spot disease severity, there was a Sesame grain yield loss of 3.36 kg/ha (Figure 2B). Likewise, pair wise Pearson correlation analysis was employed to assess the degree of association between disease parameters and yield and yield related traits of Sesame. Cercospora leaf spot disease severity has significant negative correlation with number of Capsules per plant (r= -0.7112, $P<0.0001$) and grain yield (r= -0.4821, $P<0.05$). Similarly, Percent crop stand has significant negative correlation with disease severity (r= -0.6365, $P \leq 0.001$) (Table 5). Likewise, significant negative correlation (r= -0.6381, $P \leq 0.001$; r= -0.7125 and -0.4347, $P \leq 0.0001$ and r= -0.68662, $P \leq 0.0001$) were found between AUDPC and Percent crop stand, number of Capsules per plant and Capsule length, respectively. Significant positive correlations were also found between disease parameters themselves and between yield and yield related parameters themselves as well (Table 5).

Economic Analysis

The result showed that Rex Duo sprayed plot provided the highest gross returns (ETB 30,870/ha) and the lowest gross return ETB 16,030/ha was computed from untreated check. The plot sprayed with Rex Duo gave the maximum net return ETB 19,433.6/ha and also gave the highest benefit cost ratio (1.699). The Tilt 250 EC sprayed plots also provided the higher gross returns (ETB 21,665/ha) and gave the higher net return ETB 10,381.2/ha and also gave the higher benefit cost ratio (0.920). The highest (ETB 121.15) marginal rate of return was obtained from Rex Duo treated plots. In other words, for every ETB 1.00 investment in Rex Duo cost and spraying, there was a gain of ETB 1.2115. Therefore, the most economic benefit for Cercospora leaf spot management was obtained from Rex Duo sprayed plots.

Conclusions and Recommendations

In Ethiopia, during 2010/11 cropping season, sesame was produced on an area of 384,682.79 ha of land with total production of 3,277,409.22 quintals which increased by about 25.8% from that of 2009/10 production year (CSA, 2011). Currently, in the humid midland areas of Bale there is a wide expansion of Sesame production. And farmers of this area are producing the crop intensively due to its high market value. However, farmers are suffering from a huge productivity loss due to Cercospora leaf spot disease. This disease is challenging the crop productivity putting its production highly under its potential. To tackle this problem, different fungicides supposed to control/reduce the diseases are evaluated in Delo-mena district of Bale zone. All of the evaluated fungicides have showed a promising efficacy as compared to the control plot against the disease. However, out of the tested fungicides Tilt 250 and Rex Duo has showed the highest controlling potential against the disease. The most economic benefit for Cercospora leaf spot management was obtained from Rex Duo sprayed plot and followed by Tilt 250 sprayed plots. Therefore, Rex Duo and Tilt 250 are recommended for use against Cercospora leaf spot.

Table 4: Yield and Yield Components of Sesame as Influenced by the Fungicide Application against Cercospora leaf spot

Treatment	**% Stand**	**No. Capsule/plant**	**Capsule length (mm)**	**Plant height (cm)**	**TKW (gm)**	**Grain yield (kg/ha)**
Unsprayed Control	75.00	21.33	2.30	114.22	2.80	457.87
Odeon 825 WDG	81.67	57.11	2.41	119.56	3.27	564.40
Ridomil Gold MZ 68 WG	86.67	59.56	2.35	133.89	2.87	555.37
Rex Duo	88.33	62.11	2.77	117.78	3.33	581.57
Mancozeb 80% WP	86.67	54.22	2.54	133.89	2.87	558.43
Natura 250 EW	88.33	66.56	2.79	142.78	3.13	590.51
Tilt 250 EC	90.00	71.67	3.01	144.89	3.27	618.98
CV (%)	**6.53**	**26.35**	**7.73**	**12.75**	**6.84**	**15.40**
LSD$_{(p\leq 0.05)}$	**9.74**	**25.88**	**0.35**	**28.94**	**0.37**	**151.25**

Note: TKW-Thousand Kernel Weight.

Table 5: Pair wise Pearson correlation coefficients among disease parameters, yield and yield Components of Sesame

	Disease Severity	**AUDPC**	**r**	**% Stand**	**No. Capsule/plant**	**Capsule length (mm)**	**Plant height (cm)**	**TKW**	**Grain yield**
Disease Severity		0.9999***	0.9916***	-0.6365**	-0.7112***	-0.4316^{NS}	-0.3597^{NS}	-0.4297^{NS}	-0.4821*
AUDPC			0.9923***	-0.6381**	-0.7125***	-0.4347*	-0.3618^{NS}	-0.4283^{NS}	-0.4834*
R				-0.6508**	-0.7458***	-0.4221^{NS}	-0.3583^{NS}	-0.3970*	-0.5130*
% Stand					0.7261***	0.4820*	0.5549**	0.2021^{NS}	0.6271**
No. Capsule/plant						0.5263*	0.6672**	0.3176^{NS}	0.5033*
Capsule length (mm)							0.3294^{NS}	0.2551^{NS}	0.5620**
Plant height (cm)								0.0472^{NS}	0.1274^{NS}
TKW									0.0319^{NS}
Grain yield									

Note: AUDPC- Area Under Disease Progress Curve; r- Disease Progress Rate; % Stand- Percent plot Stand; TKW- Thousand Kernel Weigh

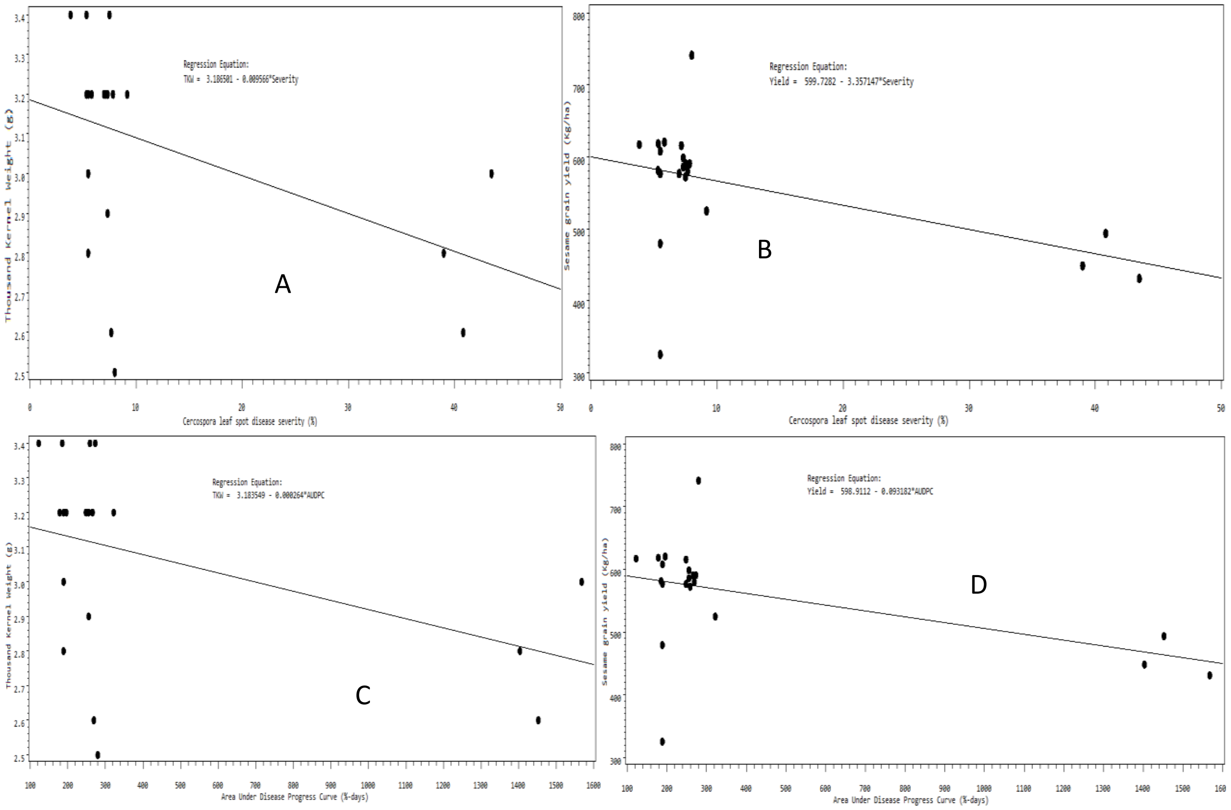

Figure 2: Estimated relationship between Sesame TKW and Cercospora leaf spot Disease (A), Sesame grain yield and Cercospora leaf spot Disease (B), TKW with Sercospora leaf spot AUDPC (C) and Sesame grain yield and AUDPC (D)

Table 6: Return and Benefit Cost Ratio of Treatment for the Control of Cercospora leaf spot on Sesame during 2015/16 and 2016/17 GC Season at Delo Mena

Treatments	**Yield obtained (Qt/ha)**	**Sale price (ETB/Qt)**	**Total Variable Costs TVC (ETB/ha)**	**Gross Return (Price X Qt) GR**	**Net Return NR (GR-TVC)**	**% of benefit (NR/TVC)**	MRR % (NR-NR of Control/TVC)
Unsprayed Control	4.58	3500	10451.6	16030	5,578.4	0.533	
Odeon 825 WDG	5.6	3500	11172	19600	8,428	0.754	25.5
Ridomil Gold MZ 68 WG	5.55	3500	11171	19425	8,254	0.739	23.95
Rex Duo	8.82	3500	11436.4	30870	19,433.6	1.699	121.15
Mancozeb 80% WP	5.58	3500	11171.6	19530	8,358.4	0.748	24.88
Natura 250 EW	5.9	3500	11378	20650	9,272	0.815	32.46
Tilt 250 EC	6.19	3500	11283.8	21665	10,381.2	0.920	43

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Yield and Yield Components of Hot Pepper (*Capsicum annum*) as affected by Fertilizer Rate and Planting Method in West Hararghe Zone, Ethiopia.

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Abstract

Hot Pepper (capsicum annum L) is one of the most important food crops in developed as well as developing countries. This crop is widely produced in West Hararghe Zone even though its production and productivity are constrained by lack of recommended agronomic practices. Thus, this activity was conducted during the 2016 and 2017 main cropping season at Daro Labu (milkaye FTC) and Boke(cabin FTC) districts of West Hararghe Zone to investigate the effect of planting methods and fertilizer rates on yield and yield components of hot pepper. Marko fana variety was used with three planting methods (broadcasting, drilling and transplanting method) and five fertilizer rates (0/0, 50/100kg, 75/150kg, 100/200kg, 125/250kg level of N and P_2O_5*). The experiment was laid out in factorial arrangement in Randomized Complete Block design in three replications.The collected data was analyzed using R-soft ware. The analysis shows that there is significant difference on all growth parameters and yield of hot pepper. Highest and lowest mean marketable yield was obtained from the treatment that received 125 kg N and 250 kg* P_2O_5 *using broadcasting method and no fertilizer with transplanting method respectively, at Boke district. There was significant difference among the treatments on canopy and fruit diameter, marketable, unmarketable and total yield, but there were non-significance differences on plant height, fruit number per plant, fruit length and fruit weight at Daro Labu over cropping seasons. Similarly, there was significant difference among the treatments on all parameters except fruit diameter across locations. Highest marketable yield (21.56 qt/ha) was obtained from 125 kg N and 250 kg* P_2O_5 *fertilizer application with broad casting method followed by 50 kg N and 100 kg* P_2O_5 *with drilling method. Partial budget analysis showed that application of 50 kg N and 100 kg* P_2O_5 *fertilizer with drilling method of planting was found to be economically viable with net income of 71,428.5 Eth birr that was 44.93% advantage over control.*

Key words: *Hot pepper, Rain-Fed, planting method, Fertilization rate, and yield*

Introduction

Hot pepper (*Capsicum annuum* L.) belongs to the genus *Capsicum* and family Solanaceae. Among the cultivated species, *Capsicum annuum* is the most widely spread all over the world (Berke *et al*., 2005). The origin of *Capsicum* species is extended from Mexico in the North to Bolivia in the South of Latin America, where it has been part of human diet since about 7500BC (Purseglove *et al*., 1981).With an annual production of 1.1million tones, India is the largest producer of chili in the world (Khan and Raj, 2006). Owing to its high cash value and consumption rate the annual trade of chilli is approximately 17% of total spice trade in the world (Ahmed *et al*., 2000). According to FAO (2007) report, world production of pepper was 28.4 million tons in both dry and green fruits from 3.3 million hectares of land with annual growth rate of 0.5 per cent. The total area devoted to pepper worldwide is estimated at 4 million hectare with an average annual increase of 5% (Weiss, 2002). Average yield of pepper in the country was about 0.6 t/ha but the yield estimate in small farmer was about 0.4 t/ha, while the average marketable yield in state farms was 0.3 - 0.9 t/ha where as under research condition it is about 1.8-2.5 t dried pepper/ha and 15 - 20 t/ha green pepper (lema *et al.*, 2008). Ethiopia is one of hot pepper producing countries from East Africa. In Ethiopia, the total area under hot pepper for dry pod (Berbere) and for green pepper (Karia) in 2008 was estimated to be 8580.69 ha, and 110405.89 ha respectively(CSA, 2009). The productivity of pepper in SNNPR was 0.73 t/ha, here as the average dried yield obtained in research condition 1.8-2.5 t/ha (OoARD, 2007). Hot pepper is in the daily diet of most Ethiopians. The average daily consumption of hot pepper by Ethiopian adult is estimated 15 gram, which is higher than tomatoes and most other vegetables (MARC, 2004). Pepper is an annual herbaceous, frost sensitive plants that in temperate areas, but in tropical areas may behave as perennial .The nutritive value of the crop is high; it is an excellent source of vitamins A, B-complex, C (ascorbic acid), and E along with minerals like molybdenum, manganese, folate, potassium, thiamine, phosphorus and calcium (Bosland and Votava ,2000). Some pepper varieties have been noted to contain seven times more vitamin C than orange (Lee and Kader, 2000). According to Borland and Votava (2000), pepper is the most recommended tropical medication for arthritis. It is not only the nutritional quality and medicinal value that makes peppers an important food crops, but peppers also stimulate the flow of saliva and gastric juices that serve in digestion (Alicon, 1984).

Low productivity of the crop could be attributed mainly to nutrient depletion (poor soil fertility), inappropriate fertilizer utilization (due to an increase in the price of fertilizers), absence of use of herbicides, lack of improved and good quality varieties, poor agronomic practices, poor disease and pest management, poor harvesting and post-harvest practices (Alemu and Ermias, 2000). Currently, cultivation is on the decline as a result of incidence of pests and diseases, inadequate use of fertilizers, inadequate irrigation facilities, lack of an organized system for vegetable processing and marketing and the low income derived by farmers during the regular growing seasons (Anon, 2012; Millennium Development Authority, 2010). Fertilizer and planting method is one of the major factors of crop production. Nitrogen is very much essential for good plant establishment and expected growth. Use of inorganic and organic fertilizers has amused a great significance in recent years in vegetables production. Too much nitrogen on the other hand can over stimulate growth, leading to very tall plant height with few, or delaying maturity and increasing risk of diseases (Boland and Vltava, 2000). Fertilizer requirements vary with soil type and previous crop history. And thus a balanced nutrient level is required for maximum production. Sundstom *et al.* (1984) in their study of N and P and plant spacing on mechanically harvested tobasco pepper found that stem diameter increased rapidly with the application of P at early growth stage and reached a point where it increased at decreasing rate of growth. The productivity of pepper is highly responsive to N fertilizer. Tumdare *et al.*, (2004) reported that nitrogen fertilizer increased fruit weight, yield and fruit number of chili peppers. Baghour *et al.* (2001) reported that vegetative growth yield and quality of pepper significantly improved through nitrogen and phosphorous fertilization. This could be attributed to the important role of each nutrient affecting growth and yield. Nitrogen is an essential constitute of protein and enzyme which directly affects several biochemical process mainly the photosynthetic activity (Marschner, 1993). Phosphorous is required for producing well developed and highly efficient rooting system (Havlin *et al*., 1999). Qawasmi *et al*.,1999) reported that increasing the rates of nitrogen applied in pepper plants increases the uptake of nitrogen by the plants and at the same time, stimulated the uptake of potassium and phosphorus through the synergistic effect of *nitrogen* on them.

Optimum dose of fertilizer increase the pepper growth, development and maximize the yield of pepper. Marketable pod yield increase in response to addition *of nutrients* in nutrient deficient soils (Matta and Cotter,1994**)**. In the study area the Agronomy practice is different from farmer to farmers, with planting method and fertilizer rate. Direct sowing is more favor in dry area to overcome shortage of rain fall and minimize growth shock. This practice is confirmed by many scholars in the world. In drought area in most time the crop is unable to grow at maturity time. Nitrogen (N) is the primary nutrients that in excessive amounts pollute our lakes, streams, and wetlands. The largest natural source of nitrogen is the Earth›s atmosphere, which is roughly 78% gaseous nitrogen, an inert and essentially biologically unavailable form of the element. Its biological unavailability is because the two nitrogen atoms form an extremely stable bond, which is not easily broken. Apart from human industrial processes that fix nitrogen gas to solid or liquid forms, the primary means of nitrogen fixation are through the high temperature and energy of lightning strikes Inorganic fertilizers are relied upon to improve crop yields and maintain soil fertility. This study was conducted to determine appropriate rate of N and P fertilizers and method of planting for optimum and economical production of hot pepper in West Hararghe.

Materials and Methods

Description of the Study Areas

The field experiment was conducted in Daro Labu (Milkaye FTC) and Boke districts (Cabin FTC) in West Hararghe zone, Oromia Regional State, during the main cropping season 2016 and 2017. Daro Lebu situated between 7.52 and 8.42 N and 40.24 and 41.91 E. The district is characterized mostly by flat and undulating land features with altitude ranging from 1350 up to 2450 m.a.s.l. Ambient temperature of the district ranges from 14^0C to 26^0C with average annual rainfall of 963 mm/year. The major soil is well-drained slightly acidic Nitosol . The pattern of rain fall is bimodal and its distribution is mostly uneven. Generally, there are two rainy seasons: the short rainy season '*Belg*' lasts from mid-February to April whereas the long rainy season '*kiremt*' is from June to September. The rainfall is erratic; onset is unpredictable, its distribution and amount are also quite irregular. Consequently most *kebeles* frequently face shortage of rain; hence moisture stress is one of major production constraints in the district (Daro Lebu WADO, 2008). Boke district is found within altitude range of 1300 to 2400 m.a.s.l. Its maximum and minimum rainfall is 1200mm and 900 mm, respectively and the average temperature is 20^0C (Boke District Agricultural office, 2013).

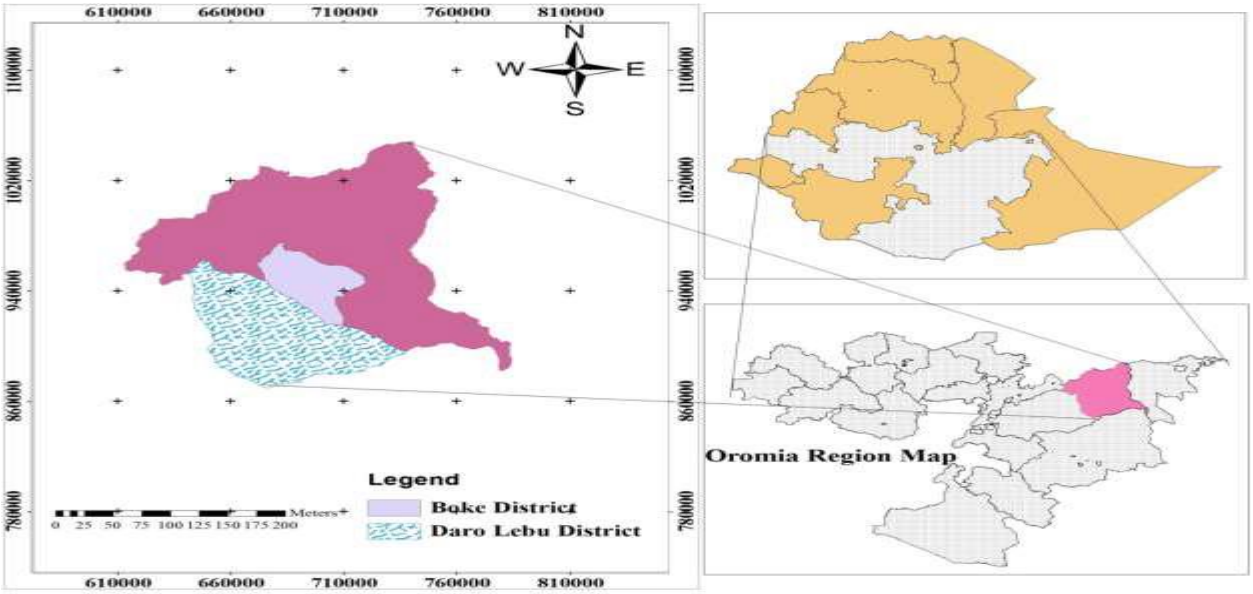

Figure 1. Map of study areas (Boke and Daro Labu Districts).

Experimental Materials, Treatments and Design.

Seed of hot pepper (*Capsicum annuum* L.) cultivar known as 'MarekoFana', which is dark red pungent, long pod size and the most widely cultivated variety that grows over awide range of agro ecologies in Ethiopia (EARO, 2004) was used for this study. The treatments consisted combination of three methods of sowing (broadcasting, drilling and transplanting) and five levels of fertilizer (50 kg of N and 100kg P_2O_5, 75 kg of N and 150kg P_2O_5, 100 kg of N and 200kg P_2O_5, 125 kg of N and 250kg P_2O_5 and 0 kg of fertilizer application as control). Thus, a total of 15 treatments were applied. The design used was factorial arrangement in a randomized complete block design in three replications. Plants were spaced 30 cm within and 70 cm between rows. The gross area of each plot was 7.2 m^2 with, 3 m length and 2.4 m width, four rows per plot were used to obtain 40 plants per plot. Agronomic practices were done as per recommendations.

Treatment Application

DAP was applied at sowing for all method of sowing (Broad Casting, Drilling and Transplanting). Urea was applied in split, half of the rate 45 days after sowing and the second half rate was applied one month after first application for direct sowing and drilling. For transplanting, the first half of the rate was applied one week after transplanting and the second half of the rate was applied one month after first application. The transplanting of the seedling was done 45 days after sowing.

Data Collection

Soil Sampling

The pre-sowing soil sample was collected before planting from entire location at a depth of 0 - 30cm and then mixed to form composite sample. The composite sample was sub-divided into working samples for analysis. An initial soil sample at a depth of 0-30 cm was taken from random spots diagonally across the experimental field. The composited soil sample was air dried, grounded and sieved. Soil sample was sent for analysis at Oromia water working design and supervision laboratory for selected physicochemical properties. Post harvest soil sample was collected from each treatment for analysis.

Phenology and Growth Parameters

Days to 50% flowering: The number of days when 50% of the plants start blooming from the days of transplanting. **Days to 95% maturity**: This refers to the number of days required from the day of transplanting until the time when 95% of the pods in the net plot area showed color change as indicated by the reddishness of the pod. It was recorded by counting the days. **Plant height(cm):** Plant height was measured from the soil surface to the top most growth points of above ground plant part. The measurement was taken as the length from plants of central rows of each plot at the last harvesting time. **Number of branches:** The number of primary and secondary branches counted from the harvestable rows was recorded at the second harvest. **Canopy diameter** was determined by measuring diameter of the plant from north to south and east to west at maturity.

Fruit Yield and Yield Components

Pod length (cm): Length of ten randomly selected pods from each plot at each harvest was measured using a ruler and mean values were taken. Pod diameter (cm): pods body width at the middle of each fruit was measured from marketable pods of sample from each plot using caliper and mean values were recorded. This procedure continued until the end of harvest in order to assess possible size variation throughout the harvest period. Pod dry weight (g): The weight of ten individual pods from each plots was taken. Number of pods per plant: The number of physiologically matured pods were counted from randomly taken plants at each successive harvest and recorded from central rows for each plot. At the final harvest, the overall recorded data was summed up and the average was taken . Marketable yield (t ha-1): The marketable yield was determined at each harvesting by sorting dried fruits according to color, shape, presence of surface defects due to insect or disease damage, shininess, firmness and size were taken as visual parameters for marketable rating. Those pods which fulfilled the above criteria were taken as marketable and those that did not were discarded and considered as unmarketable. After drying, the dried marketable fruits were separated, the weight of the respective categories are recorded and converted to t ha-1. Unmarketable yield (t ha-1): The yield which was obtained by sorting the diseased, discolored, shrunken shape and undersized .Totally unwanted pods by consumers from marketable dried pods were recorded at each harvest and converted to t ha-1. Total dry pod yield (t ha-1): Weight of total (marketable and unmarketable) fruits at each successive harvesting from the net plot area was recorded and summed up to estimate yield per hectare.

Partial Budget Analysis

To consolidate the analysis of variance of the agronomic data, economic analysis was analyzed for each treatment. For economic evaluation, cost and return, and benefit to cost ratio was calculated according to the procedure given by CIMMYT (1988). Actual marketable pod yield was adjusted downward by 10% to reflect the difference between the experimental pod yield and the pod yield that farmers would expect to get from the same treatment (CIMMYT, 1988). Data like price of fertilizers, cost incurred for transport, labor cost for field managements, and the price of the marketable yield of hot pepper pods after harvest were taken in to account to undertake cost-benefit analysis. The average marketable yield obtained from each treatment at different levels of fertilizer rates and different method of planting. The marketable pod yield from the control plot was taken as a reference and the pod yield increment at different treatments that received different rates of fertilizer (increase over the control) was considered for evaluation. The minimum acceptable marginal rate of return used in this study was assumed to be 100 % for farmer's recommendation domain. Finally, the fertilizer levels and different method of planting that gave the maximum net benefit with acceptable marginal rate of return were selected. The economic analysis was based on the formula developed by CIMMYT (1988) and given as follows: Gross average yield (GAY) (kg ha-1 or ton ha-1): is an average yield of each treatment Adjusted yield (AJY): is the average yield adjusted downward by a 10% to reflect the difference between the experimental yield and yield of farmer's field. AJY = GAY - (GAY * 0.1). Gross field benefit (GFB): was computed by multiplying field/farm gate price that farmers receive for the crop when they sale it as adjusted yield. GFB = AJY * field/farm gate price of a crop. Total cost (TC): is the cost of inputs that were used for the experiment as mean current prices of UREA, TSP, blended fertilizer, wage for fertilizers application, transport of fertilizers, were considered per hectare. Net benefit (NB): was calculated by subtracting the total costs from the gross field benefit for each treatment. NB = GFB – TC Marginal cost (MC) = change in costs between treatments. Marginal benefit (MB) = change in net benefits between treatments. Marginal rate of return: is Percent marginal rate of return was calculated as changes in net benefit (raised benefit) divided by changes in cost (raised cost). MRR (%) = (MB/ MC)*100

Data Analysis

The collected data were analyzed by R-software. All significant treatment mean differences were separated using the Least Significant Difference (LSD) test at 5% probability level. Partial Economic analysis was done by using procedure of CIMMYT(1988).

Results and discussions

Soil sample Analysis

Soil analysis showed that soil PH is 6.6 before planting and was slightly neutral nature according to (David *et al.,* 1991) in (table.1). The soil had 0.15% and 15.66%, total nitrogen and phosphors, respectively (table.1) Soil analysis after harvest showed that total available nitrogen was lower than pre sowing amount (table 2). This result may be related to shortage of moisture where loss can be due to the volatile nature of N while, available P after harvest increased in most treatments than pre sowing results.

Yield and Yield components

Plant height:- Plant height significantly influenced due to different sowing methods and fertilizer rates. The mean tallest (58.77cm) and shortest plant height(44.4 cm) at Daro Labu was recorded from 125 kg N and 250 kg P_2O_5 with drilling sowing method and 75 kg N and 150 kg P_2O_5 with transplanting method, respectively(Table 2). At Boke the mean tallest plant height(69.73cm) was recorded from 125 kg N and 250 kg P_2O_5 fertilizer rate with drilling sowing method and the mean shortest plant height (40.07cm) was from no fertilizer application with broadcasting sowing method (table 1). These results are consistent with the reports by other workers indicate average plant height at maturity in the ranges of 16.6-57.6 cm (Nsabiyera et al., 2012).

Table.1 (Left) Pre sowing and Table 2 (right) Post crop harvesting soil sample analysis results.

Parameters	Description	Composite soil lab results
PH	0-14	6.6
EC	ms/cm	0.11
Sand	%	36
Silt	%/	16
Clay	%	48
Texture Class		Clay
Total N	%	0.15
C:N		7.96
Ava.p	ppm	15.66
OC	%	1.23
CEC	Meq/100g soil	27.4

[1]BC-Broad casting, [2]DR- Drilling, [3]TP- Transplanting

N2 and P2O5 level(treatments)	Total N2 and Avil.P2O5		
	Method of sowing	Total N %	Aval. P_2o_5
0-0 kg	BC[1]	*0.10*	*16.93*
	DR[2]	*0.10*	*12.98*
	TP[3]	*0.11*	*13.80*
50 N kg &100 P2O5	BC	*0.10*	*22.25*
	DR	*0.11*	*14.01*
	TP	*0.10*	*14.63*
75 N kg &150 P2O5	BC	*0.11*	*21.22*
	DR	*0.11*	*17.09*
	TP	*0.11*	*12.98*
100 N kg &200 P2O5	BC	*0.11*	*23.71*
	DR	*0.08*	*15.04*
	TP	*0.11*	*30.90*
125 N kg &250 P2O5	BC	*0.11*	*12.36*
	DR	*0.09*	*31.72*
	TP	*0.11*	*13.23*

Fruit Length:- Fruit length was not significantly influenced by different sowing method and fertilizer rate at Daro labu. At Boke, highly significant difference in fruit length was observed due to fertilizer rate and planting method. Highest (10.1cm) and lowest(7.84cm) fruit length was recorded in 75 Kg N and 150 Kg P_2O_5 fertilizer rate with broad casting method of planting and 75 Kg N and 150 Kg P_2O_5 fertilizer rate with transplanting method of planting, respectively (table 1). Pod length is directly related with the amount of nutrients taken and the vegetative status of the plant. The result indicated that plots that received higher level of nitrogen exhibited longer fruits.

Fruit Diameter:- Effect of fertilizer rate and planting method showed significant difference on fruit Diameter at Daro labu. The highest fruit Diameter (5.26cm) was recorded from 0 kg N and 0 kg P_2O_5 fertilizer rate with transplanting method of planting and lowest fruit diameter (4.65cm) was observed in 125 kg N and 250 kg P_2O_5 fertilizer rate with broadcasting method of planting (table2). It was also significant at Boke where highest(2.58 cm) and lowest(1.96 cm) fruit diameters were recorded in 125 kg N and 250 kg P_2O_5 with broad casting method and 75 kg N and 150kg P_2O_5 with transplanting method, respectively (table 1). The result indicated that plots treated with relatively higher rates of nitrogen and phosphorus gave fruits with larger cross-sections. The result is in agreement with that of Hegde (1997) who reported that application of nitrogen and phosphorus fertilizers increase pod quality parameters including pod width in pepper. Larger and wider hot pepper pods are considered to be the best in quality and have better demand for fresh as well as dry pod use in markets (Beyene and David, 2007).

Fruit Weight:- There was no significant influence due to the impact of fertilizer rate and method of planting at Daro labu over year data result.(Table2). However, at Boke dry pod weight was significantly influenced due to the impact of fertilizer rate and method of planting. The highest(3.6gm) and lowest (2.3gm) fruit weights were recorded in 125 kg N and 250 kg P_2O_5 fertilizer rate with broad casting planting method and 100 kg N and 200 kg P_2O_5 fertilizer rate with transplanting method, respectively.(Table 1). The increase in pod dry weight in this study is in conformity with the work of Hedge (1997) and Guerpinarand Mordogan (2002) who reported that pod dry matter content of peppers was directly related to the amount of nutrient taken from the soil, which was proportional to the nutrients present in the soil or the amount of organic and inorganic fertilizers applied to the soil.

Fruit Number per Plant:- Fruit Number per Plant was non- significant at Daro labu. (Table 2). At Boke, it was significant where the largest (30 fruits) was recorded from two treatments: 50 kg N and 100 kg P_2O_5 fertilizer rate with transplanting and 125 kg N and 250 kg P_2O_5 fertilizer rate with drilling method (table 1). The result is line with the work of Adugna (2008) that says treatment combinations that received high level of nitrogen and phosphorus fertilizers gave the highest number of pods per plant as compared to the yield obtained from the controls. The lowest Fruit Number per Plant (15) at Boke was recorded from no fertilizer application using drilling method of planting (Table 1.) The result is more or less in agreement with the report of Nsabiyeraet al. (2012) who recorded mean fruit numbers in the range 12-91 for some accessions of hot pepper.

Marketable Yield (qt/ha):- The factors significantly affected marketable yield at both locations. At Boke, highest dry marketable yield (26.09 qt/ha) was observed in 125kg N and 250kg P_2O_5 with broad casting and lowest dry marketable yield (5.19 qt/ha) was recorded at no fertilizer with transplanting method of planting. (Table 1). At Daro labu highest (14.88 qt/ha) and lowest marketable yield (2.9 qt/ha) were recorded from 50kg N and 100kg P_2O_5 fertilizer rate with drilling and from 100 kg N and 200 kg P_2O_5 fertilizer rate with transplanting method of planting, respectively. (Table 1), The results are in close conformity with the findings of Kulvinder (1990) who reported that highest nitrogen rates resulted in maximum yield. Also, the results are in harmony with those obtained by Padem and Ocal (1999) who demonstrated that increasing P-humate application dose led to a significant increase in fruit weight and total yield. According to Matta and Cotter (1994), application of essential nutrients increases vegetative growth, leaf area, photosynthetic capacity and better partitioning of assimilate towards the pods. This in turn had resulted in development of pods which are relatively healthy, attractive and acceptable in markets.

Unmarketable yield (qt/ ha): Different fertilizer rates and methods of planting showed significant difference on unmarketable yield at both locations. At Boke highest unmarketable yield(7.45 qt/ha) was obtained from 0 kg fertilizer with broad casting, while the lowest (1.04 qt/ha)was from 100 kg N and 200 kg P_2O_5 with drilling method of planting.(Table 1.) At Daro Labu the highest(2.54 qt/ha) and lowest(0.84 qt/ha) unmarketable yields were from 100 kg N and 200 kg P_2O_5 fertilizer rate with transplanting method and 0 kg fertilizer with broad casting method of planting, respectivelyTable 2.

Total Dry Fruit Yield (Qt/ha):- significant difference was observed on total dry fruit yield due to different fertilizer rates and planting methods at both locations. (Tables 1 and 2). The highest (29.15 qt/ha) and the lowest(6.74 qt/ha) total yield at Boke were recorded in 125kg N and 250kg P_2O_5 with broad casting and no fertilizer with transplanting method, respectively (Table1). At Daro Labu the highest (17.39 qt/ha) and the lowest(4.37 qt/ha) total yields were recorded from 50 Kg N and 100 kg P_2O_5 fertilizer rate with drilling method and 100 kg N and 200 P_2O_5 fertilizer rate with transplanting method of planting, respectively (Table 2). The results from Boke are in agreement with previous workers.This increase in dry matter yield of fruits with increasing level of nitrogen and phosphorus fertilizers is in conformity with the result of Hegde (1997) who noted that dry matter yield of pepper fruits is directly correlated with the amount of nutrient supplied to the plant. This result is in agreement with observation of Baghour *et al*. (2001) who reported that vegetative growth yield and quality of pepper significantly improved through nitrogen and phosphorous fertilization. The effects of these factors at Daro Labu must be justified and studied.

Cost Benefit Analysis

Economic analysis of both districts over location result indicates that the highest net income (71428.5 Eth birr) was obtained from treatment 50 kg N and 100kg P_2O_5 Kg with Drilling method of planting. Tibabu, 2014 also reported the highest economic benefits of 74,096 birr/ha by using Mareko Fana variety and application of 50 kg N/ha and 92 kg P_2O_5/ha. The lowest net income (15201 Eth birr) was obtained from the treatment 100 kg N and 200 kg P_2O_5 with transplanting method of sowing. (Table 4). The maximum cost benefit ratio of 30.67 % was obtained from the drilling method of planting with application of 50 kg N/ha and 100 kg P_2O_5/ha. This result is similar with the work of (Amare, 2014) where the maximum cost benefit ratio of 42.21% was obtained from the variety Mareko fana using 46kg N ha-1 and 69 kg P_2O_5 ha-1.

Conclusions and Recommendations

This study indicates that the effect of treatments is not uniform across the locations and years. Yield and yield components of hot pepper fluctuates from year to year and location to location. The highest (21.56 qt/ha) marketable yield was obtained from treatment 125 kg N and 250 kg P_2O_5 with broad casting method of sowing followed by 50 kg N and 100 kg P_2O_5 with drilling method of planting(20.51 qt/ha). According to the partial budget analysis, the highest economic benefits of 71428.5 birr/ha was obtained by using drilling method of planting with application of 50 kg N/ha and 100 kg P_2O_5/ha. The maximum cost benefit ratio of 30.67 % was obtained from the drilling method of planting with application of 50 kg N/ha and 100 kg P_2O_5/ha. Therefore, Drilling method of planting of Mareko Fana variety with application of 50 kg N ha-1 and 100 kg P_2O_5 ha-1 is recommended for hot pepper production in Boke, Daro Labu and similar agro ecologies of the zone. However, further testing is required in different locations and on different soils.

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Table .3: The mean of growth and agronomic data of different fertilizer rates and planting method on yield and yield component of Hot pepper at Boke district during 2017 cropping season

Level of N&P	MP	PH (cm)	CD (cm)	FNPP	FL (cm)	FD(cm)	FW(g)	MY qt/h	UNMY qt/h	TYD (qt/ha)
0-0	BC	40.07f	24.03f	19a	9.26abc	2.57a	3.35abc	15.15bcd	7.45a	22.61abc
	DR	45.47ef	29.03ef	14.67b	9.35abc	2.3abc	3.23abc	13.26b-e	1.23b	14.48b-f
	TR	51.27c-f	43.43abc	26.47ab	8.54cd	2.02bc	2.39e	5.19e	1.55b	6.74f
50-100	BC	60.6a-d	33.43de	20ab	8.79bcd	2.54a	3.22abc	15.79bcd	1.92b	17.72b-e
	DR	65.73ab	37.97cd	28a	8.97abcd	2.45a	3.06a-d	21.76ab	1.67b	23.43ab
	TR	51.27c-f	49.1a	29.67a	9.12abc	2.28abc	2.53de	7.61de	1.38b	9.00ef
75-150	BC	63.6a-d	37.1cde	20.33ab	10.1a	2.55a	3.49ab	21.87ab	2.31b	24.19ab
	DR	64.33abc	37.93cd	24.33ab	8.36cd	2.33ab	3.13a-d	18.94abc	1.41b	20.35a-d
	TR	50.8def	44.1abc	27.93a	7.84d	1.96c	2.53de	8.28de	1.87b	10.16def
100-200	BC	62.07a-d	33.97de	15b	8.75bcd	2.49a	3.304a-d	21.44ab	1.71b	23.15ab
	DR	63.07abcd	38.47bcd	20.17ab	8.4cd	2.35ab	2.903b-e	14.61b-e	1.04b	15.65b-e
	TR	53.67bcde	46.87ab	26.47ab	8.37cd	2.06bc	2.31e	6.44de	1.08b	7.53ef
125-250	BC	68.4a	41.53abcd	24ab	9.79ab	2.58a	3.6a	26.09a	3.05ab	29.15a
	DR	69.73a	43.67abc	29.67a	7.93d	2.27abc	2.83cde	15.08bcd	1.67b	16.75bcde
	TR	52.93bcdef	46.77ab	27.93a	8.5cd	2.29abc	2.78cde	10.12cde	2.08b	12.20cdef
Mean		57.56	39.16	23.53	8.8	2.336	2.96	14.81	2.097	1690.79
CV (%)		14.02	13.31	30.54	7.88	9.1	12.4	39.87	29.48	38.23
LSD 5%		13.48	8.7	12	1.158	0.355	0.61	9.86	4.53	10.79
F-test		*	*	*	*	*	*	*	*	*

MP-method of planting, BC-Broad casting, TR-Transplanting, DR-Drilling. 0-0=no fertilizer rate(control),50-100=50kg N and 100 P_2O_5,75-150=75 kg of N and 150 kg of P_2O_5,100 kg of N and 200 kg of P_2O_5,125-250=125 kg of N and 250 kg of P_2O_5 Fertilizer rates.PH-plant height, CD-plant diameter, FNPP-fruit number per plant, FL-fruit length, FD-fruit diameter, FW-fruit weight, MY-marketable yield, UNMY-unmarketable yield, TYD-total yield.

Table. 4: Over year (2016 and 2017 E.C) mean of yield and yield component of different fertilizer rate and planting method of Hot pepper at Daro Labu Districts in West Hararghe Zone.

Level of N&P	Method Sow	PH(cm)	CD(cm)	FNPP	FL(cm)	FD (cm)	FW(g)	MY qt/h	UNMY qt/h	TYD(qt/ha)
0-0	BC	48.03cd	36.42b	10.04	9.85	4.75b	1.65	8.38bc	0.84b	9.17bcd
	DR	52.3abc	36.02b	13.75	8.54	4.7b	1.98	11.49ab	1.01b	12.50abc
	TR	47.8cd	37.38b	12.24	8.26	5.26a	1.83	4.69c	1.19b	5.86d
50-100	BC	54.17abc	39.78ab	13.42	9.52	4.81ab	1.99	14.90a	1.05b	15.96a
	DR	55.07ab	39.57ab	11.83	10.08	4.72b	2.1	14.88a	2.52a	17.39a
	TR	49.17bcd	38.8ab	12.53	8.89	5.07ab	2.13	3.40c	1.50ab	4.91d
75-150	BC	57.63a	40.57ab	12.17	10.11	5.06ab	1.93	11.62ab	1.29ab	12.91abc
	DR	54.23ab	42.62ab	13.93	9.38	4.85ab	1.97	12.26ab	1.23b	13.49ab
	TR	44.4d	35.83b	13.94	9.05	4.89ab	1.96	3.65c	1.74ab	5.40d
100-200	BC	55.23ab	37.97ab	12.08	9.09	5.12a	2.04	13.75ab	2.07ab	15.83a
	DR	56.23a	41.17ab	14.52	10.89	5.03ab	2.197	13.16ab	1.37ab	14.53ab
	TR	47.8cd	40ab	10.43	9.79	4.92ab	1.89	2.90c	1.46ab	4.37d
125-250	BC	52.87abc	37.82ab	12.15	9.81	4.68b	1.97	12.35ab	0.97b	13.32ab
	DR	58.77a	44.62a	15.72	8.56	5.07ab	1.92	12.85ab	1.15b	14.00ab
	TR	48.37cd	37.47b	12.71	8.98	5.03ab	2.08	5.52c	1.60ab	7.13cd
Mean		52.14	39.06	12.77	9.38	4.93	1.977	9.71	1.40	11.1
CV %		11.02	15.07	39	32.82	8.95	24.2	49.07	7.36	46.9
LSD 0.05		6.64	6.8	5.76	3.56	0.509	0.55	5.50	1.25	6.026
F-test		*	*	ns	ns	*	ns	*	*	*

MP-method of planting, BC-Broad casting, TR-Transplanting, DR-Drilling. 0-0= fertilizer rate (control),50-100=50kg N and 100 P_2O_5,75-150=75 kg of N and 150 kg of P_2O_5,100 kg of N and 200 kg of P_2O_5,125-250=125 kg of N and 250 kg of P_2O_5 Fertilizer rates.PH-plant height, CD-plant diameter, FNPP-fruit number per plant, FL-fruit length, FD-fruit diameter, FW-fruit weight, MY-marketable yield, UNMY-unmarketable yield, TYD-total yield.

Table: 5. Over location mean of yield and yield component of different fertilizer rate and planting method of Hot pepper at Daro labu and Boke Districts in West Hararghe Zone, in 2017 E .C

Level of N&P	Method Sow	PH(cm)	CD(cm)	FNPP	FL(cm)	FD(cm)	FW(g)	MY qt/h	UNMY qt/h	TYD(qt/ha)
0-0	BC	43.43e	28.9e	16.4bc	5.64abc	4.98	2.68ab	13.69cd	4.19a	17.88ab
	DR	50.33de	33.32de	17.57bc	5.6abc	4.76	2.74ab	16.07abc	1.18b	17.25abc
	TR	51.67cde	43.07ab	22.3abc	5.34bcd	5.21	2.39bc	6.78.8e	1.29b	8.08d
50-100	BC	56.87bcd	35.6cde	20.13abc	5.28bcd	4.87	2.65abc	18.82abc	1.47b	20.29ab
	DR	60.07abc	36.45bcd	21.8abc	5.48a-d	4.74	2.53abc	20.51ab	1.65b	22.17ab
	TR	50.73de	44.82a	23.73abc	5.54a-d	5.12	2.42abc	6.609e	1.50b	8.11d
75-150	BC	58.27bcd	3978a-d	18.53abc	6.07a	5.15	2.78a	19.29abc	1.95ab	21.25ab
	DR	61.3ab	40.93abc	22.3abc	5.17cd	4.93	2.67ab	17.62abc	1.22b	18.85ab
	TR	47.8e	41.43abc	24.47ab	4.94d	4.86	2.42abc	7.24e	1.97ab	9.22d
100-200	BC	58.4a-d	35.87cde	15.97c	5.33bcd	5.18	2.63abc	20.01ab	1.42b	21.44ab
	DR	61.3ab	42.33a-c	20.72abc	5.23cd	5.01	2.62abc	15.04bc	1.19b	16.23bc
	TR	51.6cde	44.95a	20.5abc	5.28bcd	4.94	2.28c	5.56.2e	1.30b	6.87d
125-250	BC	59.8abc	39.48a-d	20.63abc	5.87ab	4.81	2.76a	21.56a	2.03ab	23.60a
	DR	66.77a	44.63a	**26**.6a	5.03cd	4.98	2.57abc	16.08abc	1.25b	17.33abc
	TR	49.97de	43.3ab	22.63abc	5.36bcd	5.22	2.56abc	8.94de	1.99ab	10.94cd
Mean		55.22	39.65	20.95	5.41	4.98	2.58	14.32	1.71	16.03
CV (%)		13.28	15.5	33.79	10.28	8.599	12.51	35.84	16.54	35.09
LSD 0.05		8.47	7.11	8.18	0.64	0.495	0.372	5.93	2.30	6.50
F-test		*	*	*	*	ns	*	*	*	*

MP-method of planting, BC-Broad casting, TR-Transplanting, DR-Drilling. 0-0=no fertilizer rate(control),50-100=50kg N and 100 P_2O_5,75-150=75 kg of N and 150 kg of P_2O_5,100 kg of N and 200 kg of P_2O_5,125-250=125 kg of N and 250 kg of P_2O_5 Fertilizer rates.PH-plant height, CD-plant diameter, FNPP-fruit number per plant, FL-fruit length, FD-fruit diameter, FW-fruit weight, MY-marketable yield, UNMY-unmarketable yield, TYD-total yield.

Table:6. Economic analysis of net benefit on effect of method of sowing and level of fertilizer application on yield of Hot pepper at Over location of Boke and Daro Labu districts in West Hararghe Zone, in 2017 E .C

Treatment		Marketable yield	Adjusted yield	Growth yield benefit	Total cost	Net benefit	Cost Ratio
0-0	BC	13.69	12.321	49284	0	49284	-
	DR	16.07	14.463	57852	0	57852	-
	TR	6.788	6.1092	24436.8	0	24436.8	-
50-100	BC	15.82	13.3	53200	2407.5	50792.5	21.1
	DR	20.51	18.459	73836	2407.5	71428.5	30.66916
	TR	6.609	5.9481	23792.4	2407.5	21384.9	9.882617
75-150	BC	19.29	17.361	69444	3636.25	65807.75	19.0977
	DR	17.62	15.858	63432	3636.25	59795.75	17.44435
	TR	7.24	6.516	26064	3636.25	22427.75	7.167824
100-200	BC	20.01	18.909	75636	4815	70821	15.70841
	DR	15.04	13.536	54144	4815	49329	11.24486
	TR	5.56	5.004	20016	4815	15201	4.157009
125-250	BC	21.56	19.404	77616	6043.75	71572.25	12.84236
	DR	16.08	14.472	57888	6043.75	51844.25	9.578159
	TR	8.94	8.046	32184	6043.75	26140.25	5.325171

Note that this above economic analysis, total cost was not include the cost that are uniform for al treatment (cost of land, cultivation cost ,harvesting cost).BC-Broad casting, TR-Transplanting, DR-Drilling. 0-0=no fertilizer rate (control),50-100=50kg N and 100 P_2O_5,75-150=75 kg of N and 150 kg of P_2O_5,100 kg of N and 200 kg of P_2O_5,125-250=125 kg of N and 250 kg of P_2O_5 Fertilizer rates.

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Use of Fungicides for Management of leaf and fruit spot (*Phaeoramularia angolensis*) diseases of sweet orange in West & Kellem Wollaga Zones, Ethiopia

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Abstract

Sweet orange (Citrus sinensis) is an important fruit crop in the daily diet, good source of food nutrients and source of cash to the farmers. The leaf and fruit spot disease caused by Phaeoramularia angolensis is one of the most devastating airborne diseases and also the main constraint contributing to the low productivity of citrus plantation in 20 African countries including Ethiopia. An experiment was conducted to evaluate three fungicides (Unizeb 80% WP, Trust-cymocop 439.5 WP, and Benomyl 500 WP) and combinations of two each fungicide under field condition for the management of leaf and fruit spot disease and assess the yield loss. There was no significant difference in disease incidence between treatments while there was a significant difference in disease severity and Area under Disease Progressive Curve (AUDPC). On the final date of disease assessment, the lowest disease severity (17.33%) and (18.17%), was recorded from Unizeb sprayed plots whereas the highest disease severity (46.67%) and (45.83 %) were recorded on control plots. The highest fruit yields (6.14) and (5.94 t/ha) were recorded from plots sprayed with Unizeb 80% WP and Benomyl 500 WP fungicides, respectively. Unizeb 80% WP fungicide applied exhibited maximum net benefit. The highest (123970.00 ETB ha^{-1}) was obtained from Unizeb 80% WP followed by Benomyl 500 WP(111520.00 ETB ha^{-1}). This study shows that four time foliar spray of Unizeb 80% WP was effective in decreasing leaf and fruit spot disease and increase yield of sweet orange exhibiting maximum cost benefit ratio. Hence this fungicide can be recommended for the management of the diseases in Kellem Wollega, Oromia. Ethiopia.

Keywords: Sweet Orange, Leaf and Fruit spot disease, Fungicides, Yield and Cost benefit.

Introduction

Sweet orange (*Citrus sinensis*) is a member of the citrus family (Rutaceae), along with other fruits such as mandarins, lemons, grapefruits and limes. Even though citrus is a genius that contains many important species, sweet orange (*Citrus sinensis*) is the most important of all citrus fruits in the world (Taylor, 2008). Globally, the leading producer of sweet oranges is Brazil followed by the European Union and China. In 2014, Brazil produced 17 340 MT followed by China [7 600 MT], United States [6291 MT], and European Union [6 075 MT]. In Africa, Egypt is leading with a production of 2570 MT followed by South Africa [1600 MT] and Morocco [1000 MT] (Anonymous, 2014). Similarly, in 2013 orange was one of the important fruits in Ethiopia with a total area coverage and total production of 3,000 ha and 36,000 tons respectively (FAO, 2015). Citrus has multiple advantages including food source, raw material for agro-industries, income generation and source of employment especially for the rural poor. The Government policy on the promotion of citrus production in Africa is quite encouraging as the sector has attractive and multiple social and economic advantages. In tropical Africa, particularly Sub-Saharan Africa production of citrus is seriously hampered by a fungal disease caused by *Phaeoramularia angolensis* (Seif *et al*., 1984: Mohammed, 2013). In many parts of the country, citrus productivity is threatened by a disease called *Phaeoramularia* leaf and fruit spot (Mohammed *et al*., 2007). This disease, caused by a fungus, *Phaeoramularia angolensis* (Covalho & Mendes) Kirk(1986), was first reported in Angola and Mozambique in 1952. Within a short period, the disease spread northwards to the south of the Sahara (Meyonga, 1971: Emechebe, 1981: Seif, 1984). Later it spread to the eastern part of Africa: Uganda (Kirk, 1986), Kenya (Seif, 1984) and Ethiopia (Eshetu, 1999). The disease has also been reported in Yemen (Kirk, 1986). Leaf and fruit spot disease of citrus is transmitted by airborne conidia or infected planting materials (Kuate, 1998: Seif, 1998). Currently, the disease is widespread and is becoming a major threat to citrus plantation in 20 African countries including Ethiopia. The disease causes heavy loss to the citrus industry in these areas. The most devastating effect of the disease on all citrus species is premature defoliation of young leaves and fruit drop, and sunken lesions on the fruit surface, which seriously affect their market value. Infected fruits became extremely hard, juiceless and unattractive (Mohammed, 2007). However, the management of sweet orange fruit and leaf spot disease through application of fungicides has not been studied so far in West and Kellem Wollega, Western Oromia region of Ethiopia. Therefore, this study was carried out to evaluate the fungicides for management of fruit and leaf spot disease of sweet orange under field condition and assess the economic benefit of using these fungicides.

Materials and Methods

Description of the study area

The field experiment was conducted at Haro Sabu Agricultural Research Center (HSARC), Mexi Sub-site in Sayo District, Western Oromia, Ethiopia during the main cropping season of 2016 and 2017. Sayo District is located at 652 km West of Addis Ababa and its geographic location is 8.5333°'N latitude and 34.80117°E longitude with an elevation of 1754 - 2200 m. a. s. l. The area receives high rainfall with minimum and maximum temperature of the site being 13°C and 27°C, respectively and characterized by wet and humid climatic conditions where the fruit and leaf spot is known to be consistently prevalent and severe on local cultivars. The soil of the experimental study site is vertisol with light black in color and sandy loam soil type with 6.5 PH value.

Experimental Materials

Sweet orange local cultivar planted before twenty years by Sayo district Agriculture experts for farmers training was used in this experimental study. Three fungicides (Trust-cymocop 439.5 WP, Benomyl 500 WP and Unizeb 80% WP and combination of the two each fungicide (Benomyl 500 WP +Trust-cymocop 439.5 WP, Unizeb 80% WP +Trust-cymocop 439.5 WP and Benomyl 500 WP + Unizeb 80% WP were used in this study. All the fungicides were obtained from local market.

Experimental design, treatments and applications

A total of 7 treatments were arranged in a randomized complete block design in three replications and unsprayed plot was used as untreated check. Plot size was 6m x 6m and an inter-row and intra-row spacing were 3ms each. which had four plants per plot. Disease assessments were carried out from 2 plants which were tagged from each plot. The fungicides were applied as per recommendation of the manufacturers using a manually-pumped knapsack sprayer of 15 liter capacity. The spraying was started soon after the first leaf spot disease lesion was observed on the foliage and continued depending on disease status. All fungicides were applied for two months at fourteen days interval.

Disease assessment

Disease incidence and severity

Disease assessment were made on two pre-tagged plants from each plot starting from the onset of the disease and continued every ten days till fruit maturity. Both diseased and healthy plants were counted from the pre-tagged plants and the percentage of disease incidence (PDI) was calculated according to the formula used by Wheeler (1969):

$$PDI(\%) = \frac{\text{Number of plsnt diseased}}{\text{Total number of plants inspected}} x\ 100$$

Severity on leaves was estimated using the percentage leaf area infected based on a one-to-five scoring scale where 1 = no symptoms, 2 = 1-25%, 3 = 26-50%, 4 = 51-75% and 5 = above 75% (Amadi, 2008; Ezeibekwe, 2011). A similar scoring system was used for fruit severity, where 1 = healthy, 2 = less than 5%, 3 = 5-20%, 4 = 21-50% and 5 = above 50% of fruit surface affected (Seif and Hillocks, 1999). The severity grades were converted into percentage severity index (PSI) according to the formula by Wheeler (1969).

$$PSI(\%) = \frac{\sum Individualnumericalratings}{(TotalnumberofplantsassessedxMaximumscoreinthescale)} x\ 100$$

Area under Disease Progress Curve (AUDPC)

The progress of leaf and fruit spot was plotted over time using mean percentage severity index for each chemical and control plot and the AUDPC values (%-day) were calculated for each variety according to the mid-point rule formula (Campbell and Madden, 1990).

AUDPC==$\sum_{i-1}^{n-1} 0.5(x_{i+1}+x_i)(t_{i+1}-t_i)$

Where Xi is the disease severity of leaf and fruit spot at I th assessment date, Ti is the time of the I th assessment in days from the first assessment date and n is the total number of disease assessments. Because severity was in percentage and time in days, AUDPC was express in proportion days.

Correlation between yield and disease parameters

The correlations among the disease parameters and with the yield were tested at 5% probability level. The reliable yield loss was estimated on the basis of the severity level by employing regression equations.

Cost benefit analysis

The prices of fruit sweet orange (birr/kg) were assessed from the local market and the total price of the commodity obtained from each treatment was computed on hectare basis. Input costs like fungicide and labor were converted into hectare basis used. Fungicides cost was estimated based on the price of company. Cost of the labor was in Birr per man-days; cost of spray and spray equipment to spray one week time four per hectare were calculated. Cost of spray equipment (knapsack sprayer) was in Birr per day assessed. Based on the obtained data from the above mentioned parameters, cost benefit analysis was performed using partial budget analysis. Partial budget analysis is a method of organizing data and information about the cost and benefit of various agricultural alternatives (CIMMYT, 1988). Partial budgeting is employed to assess profitability of any new technologies (practice) to be imposed to the agricultural business. Marginal analysis is concerned with the process of making choice between alternative factor product combinations considering small changes. Marginal rate of return is a criterion which measures the effect of additional capital invested on net returns using new managements compared with the previous one (CIMMYT,1988). It provides the value of benefit obtained per the amount of additional cost incurred percentage. The formula is as follows:

MRR=$\frac{\mathrm{DNI}}{\mathrm{DIC}}$X%

Where, MRR is marginal rate of returns, DNI, difference in net income compared with control, DIC, difference in input cost compared with control.

Data Analysis

The analysis of variance (ANOVA) was performed for the disease parameters (incidence, severity, AUDPC) and yields using GenStat software. Least significant difference (LSD) values were used to separate treatment means (P<0.05) among the treatments. Correlation coefficient (r) between yield and severity were determined through yield components correlation analysis using

GenStat 15th edition software, following analysis using the standard procedure (Gomez and Gomez, 1984).

Results and Discussions

Disease incidence

Phaeoramularia leaf and fruit spot disease of sweet orange was first observed at on experimental field at the beginning of august in both years (2016 and 2017) and it was recorded on the leaf of sweet orange in all treatments. There was no significant difference in disease incidence between treatments.

Figure 1 leaf and fruit spot disease of sweet Orange

Disease severity

The Percentage Severity index (PSI) data revealed that the severity of *Phaeoramularia* leaf spot on the control plot was higher than the treated plots (Table 1). Highly significant differences (P<0.05) was observed on Unizeb 80% WP sprayed plot on all dates of assessment. Next to Unizeb 80% WP plot treated Benomyl 500 WP and Benomyl 500 WP + Unizeb 80% WP fungicides treated showed significant difference from control plot (Table 1). Variation in the disease severity was 17.33% on Unizeb 80% sprayed plots on last day assessment. In two years (2016 and 2017) Unizeb 80% WP fungicide significantly reduced the severity of *haeoramularia* leaf spot disease at P<0.05. The highest disease severity (46.67%) was assessed on Control (no sprayed) (Table 1).

The Percentage Severity index (PSI) data revealed that the severity of *Phaeoramularia* fruit spot on the control plot was higher than the treated plots (Table 2). In Unizeb 80% WP sprayed plots, Significant differences in PSI (P<0.05) was obtained followed by Benomyl 500 WP and Benomyl 500 WP + Unizeb 80% WP fungicides treated plots.(Table 2). The lowest disease severity (18.17%) was recorded from Unizeb 80% sprayed sweet orange while the highest disease severity (45.83%) was recorded from control (unsprayed) plots. (Table 2).

Table 1: Percentage severity index of leaf spot of sweet orange treated with fungicides against leaf and fruit spot

Fungicides	Percentage diseases severity index (10 interval)				
	1st	2nd	3rd	4th	5th
Control (no sprayed)	16.67^{a}	23.33^{a}	33.83^{a}	42.17^{a}	46.67^{a}
Trust-cymocop 439.5 WP	15.0^{bc}	19.33^{b}	25.17^{b}	30.67^{b}	34.33^{b}
Benomyl 500 WP +Trust-cymocop 439.5 WP	12.33^{bc}	16.67^{cb}	22.5^{bc}	26.83^{bc}	30.33^{b}
Benomyl 500 WP	9.5^{d}	14.33^{c}	17.67^{c}	21.17^{ed}	22.67^{cd}
Unizeb 80% WP +Trust-cymocop 439.5 WP	10.83^{cd}	17.0^{cb}	22.5^{bc}	28.5^{bc}	30.67^{b}
Benomyl 500 WP + Unizeb 80% WP	9.5^{d}	14.83^{c}	19.83^{c}	24.17^{cd}	27.83^{bc}
Unizeb 80% WP	5.83^{e}	9.0^{d}	12.0^{d}	15.17^{e}	17.33^{d}
mean	11.38	16.36	21.93	26.95	29.98
LSD (0.05)	2.73	3.83	4.93	6.07	7.26
CV %	20.37	19.91	19.12	19.14	20.6

LSD= Least significant difference, CV= Coefficient of variations

Area under Disease Progress Curve (AUDPC)

There were highly significant differences ($P < 0.01$) on AUDPC of fungicide sprayed sweet orange. The analysis of variance showed that Unizeb 80% WP fungicide sprayed plotswere significantly different on both leaf and fruit spot in AUDPC from all treatments followed by Benomyl 500 WP and Unizeb 80% WP +Trust-cymocop 439.5 WP, but there was no significant difference between the two treatments (Table 3). The maximum AUDPC was calculated on control (unsprayed) plot; both leaf and fruit spot which were 1965 and 1863 (%-day), respectively (Table 3). AUDPC values varied among the fungicide sprayed treatments and it is known that AUDPC is directly related to the yield loss (Singh and Rao, 1989). Therefore, fungicide sprayed plots should have low AUDPC value for acceptable practical purposes. Moreover, Jerger (2004) indicated that comparisons of disease progress curves and AUDPC between treatments are the most commonly used tools for evaluating practical disease management strategies.

Table 2: Percentage severity index of fruit spot of sweet orange treated with fungicides against leaf and fruit spot

Fungicides	Percentage diseases severity index (10 interval)				
	1st	2nd	3rd	4th	5th
Control (no sprayed)	17.83^{a}	22.83^{a}	31.33^{a}	38.17^{a}	45.83^{a}
Trust-cymocop 439.5 WP	12.67^{bc}	18.67^{b}	22.67^{b}	28.17^{bc}	33.33^{bc}
Benomyl 500 WP +Trust-cymocop 439.5 WP	14.0^{b}	19.0^{ab}	24.67^{b}	30.17^{b}	34.17^{b}
Benomyl 500 WP	11.0^{cd}	15.83b	20.5^{b}	24.83^{c}	26.83^{cd}
Unizeb 80% WP +Trust-cymocop 439.5 WP	13.83^{b}	18.67^{b}	23.0^{b}	30.17^{b}	35.17^{b}
Benomyl 500 WP + Unizeb 80% WP	10.33^{cd}	15.33^{b}	19.5^{b}	23.67^{c}	25.83^{d}
Unizeb 80% WP	8.25^{d}	10.25^{c}	12.33^{c}	14.17^{d}	18.17^{e}
mean	12.56	17.15	22	27.05	31.33
LSD (0.05)	1.48	3.99	5.41	5.28	6.92
CV %	18.71	19.82	20.91	16.61	18.79

LSD= Least significant difference, CV= Coefficient of variations

Table 3: AUDPC of leaf and fruit spot of sweet orange treated with fungicides against leaf and fruit spot

Fungicides	AUDPC %-days	
	leaf spot	fruit spot
Control (no sprayed)	1965^{a}	1863^{a}
Trust-cymocop 439.5 WP	1489^{b}	1496^{b}
Benomyl 500 WP +Trust-cymocop 439.5 WP	1310^{bc}	1469^{b}
Benomyl 500 WP	1039^{d}	1201^{c}
Unizeb 80% WP +Trust-cymocop 439.5 WP	1340^{bc}	1329^{bc}
Benomyl 500 WP + Unizeb 80% WP	1162^{cd}	1149^{c}
Unizeb 80% WP	716^{e}	749^{d}
mean	1289	1322
LSD (0.05)	297.3**	342.1**
CV %	13.7	15.4

LSD= Least significant difference, CV= Coefficient of variations

Total fruit yield (ton/ha)

There were highly significant differences ($P < 0.01$) among treatments in total fruit yield. Plots treated with Unizeb 80% WP foliar spray fungicide gave the highest total fruit yield (ton/ha) followed by Benomyl 500 WP and Benomyl 500 WP + Unizeb 80% WP (Tables 4). The highest (6.14 t ha^{-1}) fruit yield was obtained from Unizeb 80% WP foliar spray fungicide, where as the lowest (3.42 t ha^{-1}) fruit yield was recorded from control (unsprayed) plot. (Table 4). Likewise, Benomyl 500 WP and Benomyl 500 WP + Unizeb 80% WPfungicide sprayed plots (5.94 t ha^{-1}) and (5.43 t ha^{-1}) next high yielders, respectively. This result is higher than average fruit yield of Kellem Wellega (4.6 t^{-1}ha) while less than average fruit yield of national level (around 7.88 t^{-1} ha) (CAS, 2017).

Table 4:Yield of sweet Orange treated with fungicides against leaf and fruit spot disease

Fungicides	yield (ton/ha)
Control (no sprayed)	3.42^{e}
Trust-cymocop 439.5 WP	4.85^{cd}
Benomyl 500 WP +Trust-cymocop 439.5 WP	4.24^{de}
Benomyl 500 WP	5.94^{ab}
Unizeb 80% WP +Trust-cymocop 439.5 WP	5.43^{bcd}
Benomyl 500 WP + Unizeb 80% WP	5.82^{abc}
Unizeb 80% WP	6.14^{a}
mean	5.16
LSD (0.05)	10.8
CV %	12

LSD= Least significant difference, CV= Coefficient of variations

Relative Yield loss

Yield losses were computed relative to the average yield from plots with the maximum protection against the disease (i.e. plots with highest yield and lowest disease severity in each cultivar). Nevertheless, the fruit yield losses were reduced by all fungicides sprayed plots as compared with the unsprayed control plots (Table 5). The yield loss was significantly different ($P < 0.05$) in all treatments. The highest i.e. 44.31% relative yield losses occurred on the unsprayed control treatment. The second and third highest 30.93% relative yield losses occurred on the Benomyl 500 WP +Trust-cymocop 439.5 WPand Trust-cymocop 439.5 WPfungicides sprayed plots. Relatively, lowest yield loss of 3.29% and 5.24% were recorded from plots sprayed with Benomyl 500 WPand Benomyl 500 WP + Unizeb 80% WP, respectively(table 5).

Table 5: Yield loss of sweet orangefruits due to leaf and fruit spot

Fungicides	Yield and Relative Loss			
	yield (ton/ha)	Yield (Kg/ha)	RYL (Kg/ha)	RYL (%)
Control (no sprayed)	3.42^{e}	3421.2	2722.3	44.31
Trust-cymocop 439.5 WP	4.85^{cd}	4847.5	1296	21.09
Benomyl 500 WP +Trust-cymocop 439.5 WP	4.24^{de}	4243.3	1900.2	30.93
Benomyl 500 WP	5.94^{ab}	5941.2	202.3	3.29
Unizeb 80% WP +Trust-cymocop 439.5 WP	5.43^{bcd}	5430.3	713.2	11.6
Benomyl 500 WP + Unizeb 80% WP	5.82^{abc}	5821.4	322.1	5.24
Unizeb 80% WP	6.14^{a}	6143.5	0.0	0.0

RYL=relative yield loss, $kgha^{-1}$= kilogram per hectare, ns=non-significant,LSD= least significant difference, CV= coefficient of variations, **= highly significant difference at ($P<0.01$), *= significant difference at ($P<0.05$).

Correlation between yield and disease parameters

Correlation analysis of severity, AUDPC and yield exhibited highly significant ($P<0.01$) association with different fungicides treatments (Table 5). The severity and AUDPC values were negative but significant correlation was found between fruit yields. Severity and AUDPC showed highly significant negative correlation coefficients of $r = -0.89$ and $r = -0.90$ with yield, respectively, while AUDPC and severity themselves were even highly and positively ($r = 0. 97$) correlated with each other. (Table 5). Consequently, the result of this study indicated that the yield of the sweet orange fruit was significantly affected by disease severity that also influenced the AUDPC. In most cases, the negative correlation of yield with disease development was found to be stronger with the terminal disease severity and AUDPC. This might indicate that the terminal disease severity and AUDPC were very important in determining the extent of losses in yield and the observed levels of the disease had a considerable adverse effect on friut yield of the crops (Su1 *et al.*, 2006).

The regression analysis of the final severity (5^{th}) as predictor of yield (dependent variable) showed a significant ($p \leq 0.05$) relationship. The regression equation of the yield (t/ ha) =79.8-0.79X, (r^2= 83%, $p = 0.00$) demonstrated reduction of about 0.79t/ha fruit yield with the increase of 1% severity index of leaf spot. (Figure 2).

Table 6: Coefficients (r) linear correlation between of disease parameters and yield under field conditions

Correlations			
parameters	disease severity %	AUDPC	Yield t/ha
Disease severity %	1		
AUDPC	0.97**	1	
Yield t/ha	-0.89**	-0.90**	1

AUDPC= area under disease progress curve, yield t/ha=yield tone per hectare,**, *, Correlation is significant at the (p<0.01) and (P<0.05) significance level, respectively and ns= nonsignificant;

Similarly, regression analysis of the final severity (5^{th}) as predictor with fruit weight (dependent variable) showed a significant ($P \leq 0.01$) relationship with severity of fruit spot. The regression equation of the fruit weight (t/ha) = 84.07-1.07X, (r^2 =88%, P = 0.00) demonstrated reduction of about 1.07tone with the increase of 1% severity (Figure 2). The values of coefficient of determination (r^2) explained that 88% of the losses in fruit yield were due to the effect of the sweet orange "leaf and fruit spot" disease infection of sweet orange estimated as the final severity on the yield loss (%). (The independent variable 'x' indicates the disease severity level in percentage).

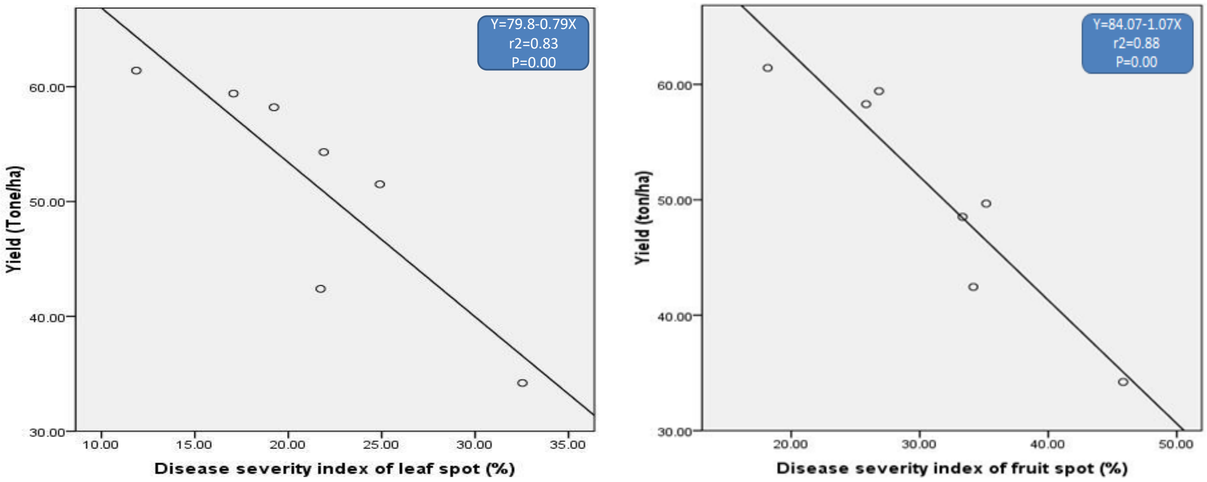

Figure 2: Linear regression of fruit yield and disease severity index leaf spot and fruit spot

Cost benefit analysis

The net benefit exhibited variation among fungicides treated plots. Partial budget analysis was calculated based on cost of variable inputs of the year 2016 and 2017 cropping season and net benefit was estimated based on mean of local market price and farmers supplied produce to the market. The application costs used were the average price for custom application (Muraro *et al.*, 1997) which should include not only the labor cost, but also capital expenditures and overhead. Unizeb 80% WP fungicide applied exhibited maximum partial cost benefit from all plots that means the highest (123970.00ETB ha^{-1}) was recorded (Table 6). Benomyl 500 WP and Benomyl 500 WP + Unizeb 80% WP applied fungicides plots also showed good results. The net benefit recorded on Benomyl 500 WP and Benomyl 500 WP + Unizeb 80% WP fungicide treated plots were (111520.00 ETB ha^{-1})and (111345.00 ETB ha^{-1}) (Table 6), respectively.

Table 7: Partial budget analysis for leaf and fruit spot management of sweet orange

Fungicides	General cost benefit						
	(A) adj. yield(t.ha-1)	(B) price (ETBt-1)	(C) sale revenue (A*B)	(D)marginal cost (ETBha-1)	(E)net profit (ETB) (C-D)	(F) marginal benefit (ETB)	MRR (F/D)(%)
Control (no sprayed)	3.42	20000	68400	0.0	68400	0.0	0.0
Trust-cymocop 439.5 WP	4.85	20000	97000	2880	94120	25720	108.93
Benomyl 500 WP +Trust-cymocop 439.5 WP	4.24	20000	84800	5080	79720	11320	102.23
Benomyl 500 WP	5.94	20000	118800	7280	111520	43120	105.92
Unizeb 80% WP +Trust-cymocop 439.5 WP	5.43	20000	108600	2855	105745	37345	113.08
Benomyl 500 WP + Unizeb 80% WP	5.82	20000	116400	5055	111345	42945	108.49
Unizeb 80% WP	6.34	20000	126800	2830	123970	55570	119.22

Adj. yield= adjusted yield, ETBt^{-1}= Ethiopian birr per tons, ETBha^{-1}= Ethiopian birr per hectare, MRR= marginal rate return.

Conclusions and Recommendations

The result of this study showed that disease incidence was 100% on all plots and fungicides affected disease severity. Unizeb 80% WP fungicides showed lower levels of disease severity over control(unsprayed). The lowest disease severities (17.33 and 18.83 %) were recorded on plots sprayed with Unizeb 80% WP, The maximum fruit yields 6.14 t/ha were obtained from Unizeb 80% WP sprayed plot with maximum net benefit from all plots (123970. 00 ETB ha-1) followed by Benomyl 500 WP(111520.00 ETB ha-1) and Benomyl 500 WP + Unizeb 80% WP(111345.00 ETB ha-1). The result of the present study revealed that using Unizeb foliar spray four times at the rate of 2.5 kg per hectare is effective in decreasing *Phaeoramularia* leaf and fruit spot disease on sweet orange fruit in Kellem Wollega, Western Oromia, Ethiopia and increased yield. it could be suggested that Benomyl foliar spray with 4 times at the rate of 2.3 kg/ha could be used in absence of Unizeb. Therefore, these fungicides are recommended in their order for the management the disease in the area.

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Adaptation of Orange Flesh Sweet potato varieties (*Ipomoea batatas* L) in West Hararghe Zone, Oromia, Ethiopia.

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Abstract

Orange Flesh Sweet potato (Ipomoea batatas (L.) Lam) is the seventh most important food crop in the world. In many developing countries, sweet potato is used as a staple food because of easy propagation, high yield and rich in nutrient and grows well under varied climatic conditions. The crop produces storage roots rich in β-carotene, a precursor of Vitamin A. Therefore, Orange fleshed sweet potato is a promising variety to address the Vitamin A deficiency needs of women and children and prevent malnutrition in poor and tribal areas. Orange fleshed sweet potato varieties are important in Africa and other developing countries like Ethiopia to reduce night blindness. Three Orange fleshed sweet potato varieties were tested for yield and adaptation in two different locations for one growing season in 2016. The total yield of the Orange Flesh Sweet potato Varieties was measured immediately after harvest and the data obtained from the two locations compared. Analysis of variance on the main effects of genotypes and environments as well as Interaction Principal Component Analysis (IPCA) for the residual multiplication interaction between genotypes and environments were conducted. Root yield result from two locations indicates that kulfo variety was superior over other varieties and standard check. Stability analysis found that kulfo was the most stable variety across the sites. It is obvious that in West Hararghe there is shortage of rainfall and even it was erratic in 2016. Varieties were tolerant to those harsh climate condition and give acceptable yield. This variety could be popularized among farmers as a source of Vitamin A.

Keywords: Orange fleshed Sweet potato, root yield and drought resistance Variety

Introduction

Orange fleshed sweet potato (*Ipomoea batatas* L.) is a dicotyledonous plant belonging to the family (Tortoe *et al*., 2010). Orange fleshed sweet potato plays a major role worldwide as a staple crop and is especially important in developing countries (Laurie *et al.*, 2015). Sweet potato is thought to have originated in Latin America (Davidson1999). Sweet potato yields are high per area (Nwankwo *et al*., 2012) per unit of time (Nedunchezhiyan *et al*., 2012). Sweet potato is adaptable to a broad range of agro-ecological conditions and fits into low-input agriculture. It is traditionally regarded as a 'poor man's crop as it is consumed by poor households. It gives satisfactory yield under adverse climatic and soil conditions, as well as under low or non-use of external inputs (Carey *et al.*, 1999; Ndolo *et al*., 2001; Githunguri and Migwa, 2004). The crop has a short growing period, stores well in the soil and performs well in marginal lands hence referred to as a food security crop (Kapinga *et al*, 2007). It is easily propagated and grows with no inputs on degraded soils under a range of rainfall patterns. As a rustic crop, it has frequently proven its value as a disaster recovery crop.

Sweet potato is a dry-land crop that is tolerant of a wide range of edaphic and climatic conditions. It is also more tolerant to cold than other tropical root and tuber crops and therefore it can be grown at altitudes as high as 2500 m (Luisa and Robert, 2000). Due to its higher productivity and drought tolerance, the crop can play vital role in achieving food self sufficiency of the region (Amare *et al*, 2014). This makes it an ideal sustainable crop for production in developing countries. Orange fleshed sweet potato varieties are believed to be the least expensive source of dietary vitamin A available to poor families (Stathers, 2005; Laurie *et. al*., 2013). There is a high correlation between color and values of orange-fleshed varieties , as measured using color difference meters, and their ß-carotene content (Simonne *et al.*, 1993; Takahata *et al*., 1993). In Ethiopia, sweet potato has been cultivated for many years and is important in diet where population growth is highest and land holding is the least (Habtu, 1995). Over 95% of the crop is produced in the Southwestern, Eastern and Southern parts where it has remained for centuries as one of the major subsistence crops especially in the periods of drought (Adhanom *et al*., 1985) and sweet potato is grown around a densely populated area in the South, Southwestern and Eastern parts of the country and is one of the most important crops for at least 20 million Ethiopians (Tofu *et al*., 2007). Vitamin A deficiency (VAD) is widespread and has severe consequences for young children in developing countries (Low *et al*., 2007) including Ethiopia. The orange fleshed sweet potato varieties are rich in beta carotene that the body uses to produce vitamin A (Wariboko and Ogidi, 2014). Choudhary *et al*. (2000), Tewe *et al*. (2003) and Muktar *et al*. (2010) had observed wide variation among Orange flesh sweet potatoes varieties in most of the parameters (number of branches per plant, vine length, fresh fodder weight, and saleable root yield) studied and attributed such differences to genetic composition. It is hardy, has low input requirements and is a versatile crop (Laurie *et al.*, 2015). The orange flesh sweet potato (OFSP) has significant antioxidant activity, and can potentially improve vitamin A status in children (Laurie *et al*., 2015; Hotz *et al*., 2012; Li and Mu, 2012; Burri, 2011). Emerging health benefits of the Orange flesh sweet potatoes are substantial, making it an even more important food especially for populations in danger of malnutrition (Aywa *et al*. 2013; Kaspar *et al*., 2013).

Sweet potato is widely grown in East, south and Central rift valley Ethiopia, where it is prized by the region’s resource-poor farmers both as a reliable, low input, food security crop, and increasingly, for its commercial potential. In low-land and mid-land agro-ecology of West Hararghe Zone horticultural and root crop are largely produced by small scale farmers for food stuff and local market. Farmers produced sweet potato and other drought tolerant root crop in small land as they have small land holdings and also in West Hararghe drought prone districts, food security and malnutrition are the main problem that exists in the area.

Deficiency of Vitamin A problem is minimized by identifying, adapting and promoting nutrient rich crop to the society. In West Hararghe, adaptability of the Orange flesh Sweet potato varieties are not evaluated. Evaluation of adaptability for these Orange flesh Sweet potato varieties is important in West Hararghe to solve food security problem at the same time combat Vitamin A Deficiency. Therefore, the objectives of this study was to investigate the performance and adaptation of orange fleshed sweet potato varieties in terms of yield and yield contributing parameters and hence could combat Vitamin A Deficiency (VAD).

Materials and Methods

Description of the study area

The experiment was conducted at two locations, Daro labu (Mechara Agricultural Research Center on station), and Habro districts (Balbaleti PA) West Hararghe zone, of Oromia Regional State, during the main cropping season, in 2016. Mechara Agriculture Research Center is located between 8.34 N latitude and 40.20' E longitude. The altitude of the area is about 1760 m.a.s.l. It has a warm climate with annual mean maximum and minimum temperatures 31.8°c and 14°c., respectively. The area receives mean annual rainfall of about 1100mm. The major soil of the area is well-drained slightly acidic Nitosol. Habro district is located at 404 km east of Addis Ababa, and 75 km south of Chiro. It is located at 8.51'N and 40. 39' E at an altitude of the district ranges between 1600-2400 meters above sea level. The mean maximum and minimum temperature are 20°c and 16°c, respectively. The district receives annual average rainfall of 650mm to 1000mm, Black sandy and loam soil types are the most dominant soil of Habro District.

Experimental Design and Treatments

Three Orange flesh Sweet potatoes (Beletech, Kulfo, Tulla) varieties were brought from Awassa Agricultural Research Center, and Barkume variety was used as standard check. The experiment was laid out in completed randomized block design (CRBD) with three replications. Cuttings were planted on the ridges (Anyaegbunam *et al*., 2008) with about three nodes buried in the soil uniformly for all treatments at the spacing of 50 cm between rows and 30 cm between plants (Nwankwo *et al*., 2012) on plots with the size of 3m×3m containing 3 rows and 10 plants per row resulting in 30 plants per plot. Weeding, Earthening up and other cultural practices were done according to the standard recommendation for Sweet potato uniformly for all Varieties.

Data Collection

Data were recorded from randomly sampled five plants from the middle rows of each plots by leaving the border rows. The trial was harvested at 5 and 1/2months after planting and data were on stand count at one month and half month, stand count at harvest, Number of branches per plant, Vine length, Average root no/plant, Root Diameter, Root Length, Number of Tuberous Roots per Plant, Marketable Tuberous Root Yield, Unmarketable Tuberous Root Yield and Total Tuberous Root Yield and root response to sweet potato nematodes were collected.

Data Analysis

All collected data were subjected to analysis of variance, for each of the locations and years and then combined, using SAS software version 9.1. Means that differed significantly were separated using the LSD procedures. Stability of the variety, the interaction of genotype and environment were analyzed by the GGE Biplot Model.

Results and Discussion

Yield and Yield Components

Vine length of the varieties was significantly different at $P \leq 0.05$ at Habro but non- significant at Mechara. Highest vine length (139.67 cm) at Habro district and lowest (83.3 cm) vine length at Daro labu was recorded on beletchi and kulfo variety, respectively. The present study is more or less in agreement with the findings of Siddique (1985) where the vine length ranged from 93.3 to 488.7 cm. Similarly, there was non-significant difference at $P \leq 0.05$ among varieties in number of vines per plant at both areas, but largest (7.33) and lowest (2.83) vine number was recorded in Tulla variety at Daro labu and Barkume variety at Habro, respectively. The result showed that there is significant variation between varieties at Habro and non-significant at Daro labu for root length parameter. The highest (15.66 cm) and lowest (10.2 cm) root length was recorded from standard check (barkume) at Daro labu and kulfo variety at Habro, respectively. The results are in agreement with the findings of Jahan *et al. (*2001) reported that the variety Daulatpuri produced the maximum root length (14.44 cm). There was non-significant difference at both locations at $P \leq 0.05$ in root diameter. The maximum (7.33cm) diameter was obtained from kulfo variety and minimum (4.3cm) from Beletech variety at Habro and Mechara, respectively. Significant difference was also observed among the varieties in tuber number per plant. The highest (9.33) and lowest (2) tubers per plant was recorded from kulfo variety at Habro and Tulla variety at Mechara, respectively. These results are closely related with those reported by Siddique (1985) where the number of tubers per plants varied from 1.73 to 6.03. Farooque and Husain (1973) also found the number of tubers per plant that varied from 4.70 to 11.76. The differences in tuber yield could be attributed to genetic variations among genotypes in partitioning photosynthesis. Differences in yield due to the genetic makeup among genotypes have also been reported in other sweet potato trials (Chipungu *et al.,* 1999; Nedunchezhiyan *et al.,* 2007).

The result of the analysis showed that there is significant variation between varieties for marketable yield at both sites. The maximum marketable yield (15.57 ton/ha) was recorded from kulfo variety at Habro, while the minimum marketable yield (7.74 ton/ha) was obtained at Mechara from Beletech variety. These results are in good agreement with those in other reports (Anonymous, 2011-12) where yield of tuberous root per hectare was about 19.44 tons/ha, Tesfaye T. *et.al* (2011), also reported significant variation between sweet potato genotypes in yield and other desirable traits in their adaptation trial in different agro ecologies of Ethiopia. The over location analysis also showed that there was non- significant difference at $P \leq 0.05$ among varieties in unmarketable yield. (Table 3). Similarly Nwankwo *et al*. (2012) also observed none significant differences in unmarketable tuberous root yield among Orange fleshed sweet potato varieties in their study. But, highest unmarketable yield (0.89 ton/ha) was recorded from Barkume variety (standard check). At Habro, there was significant difference at $P \leq 0.05$ among varieties on total yield. (Table.1). The maximum (16 ton/ha) and minimum (10 ton/ha) total yield was obtained from kulfo and Beletech, respectively. Similarly, at Mechara analysis of variance showed that the highest total yield was recorded from Barkume variety(standard check) with 16.29ton/ha and lowest total yield (7.87ton/ha) was obtained from Beletech variety (Table 2).

Choudhary et al. (2000), Tewe *et al*. (2003) and Muktar *et al.* (2010) had observed wide variation among sweet potato varieties in most of the parameters (number of branches per plant, vine length, fresh fodder weight, and saleable root yield). They studied and attributed such differences to genetic composition. Somda and Kays (1990) reported that during growth of sweet potato plant, substantial morphological changes occur and this influences the accumulation or distribution of the total dry matter among the major plant organs.

Genotype Performances and stability across environment: Results from the GGE bi-plot analysis explains the stability and performance component of the orange fleshed sweet potato varieties used in the study. In relation to this study, the GGE bi-plot depicted that kulfo Variety was high yielding and most stable and was considered as the best Variety. The bi-plot showed that kulfo was the most stable genotype across the locations in tuber yield since the most stable genotypes are located close to or along the zero line of IPCA ordinates (Mwale et al., 2008). Stable and high yielding traits are among the major agronomic characteristics required by farmers in sweet potato adoption as such varieties that can have both of these characteristics would likely be accepted by farmers (Mulema et al., 2008; Hassanpanah, 2010).Therefore, based on marketable root yield result from two locations, kulfo variety has good performance over other varieties and standard check (Figure 1 and 2). The which-won-where function is an extended use of pair wise comparison and an important visual tool in mega environment analysis (Yan *et al*., 2007). Therefore, kulfo was the vertex angle where Balbaleti fell and thus kulfo was the winning genotype for the Balbaleti location and barkume was the vertex angle where Mechara fell and thus barkume was the winning genotype for the Mechara location (figure 3).

Table 1.The mean of Growth and agronomic yield parameters for adaptation trial of Orange fleshed Sweet potato Habro District in West Hararghe zone of Oromia Regional state, during 2016 cropping season.

Varieties	AVL	ANVPP	ARL	ARD	ATNPP	MY	UNMY	TY
Tula	121.90ab	2.66	10.73b	5.43	5.33b	10.73bc	0.56	11.30ab
Kulfo	116.0ab	3.83	10.20b	7.30	9.33a	15.57a	0.43	16.0a
Beletech	139.67a	3.16	11.10b	4.40	6.00b	10.0c	0.50	10.5b
Barkume	91.17b	2.83	15.36a	6.33	6.66ba	14.5ab	0.03	14.53ab
MEAN	116.0133	3.23	12.10	6.22	6.83	13.23	0.68	13.95
CV (%)	16.22	37.66	18.87	35.89	25.09	19.568	42.12	21.47
LSD 5%	34.23	2.21	4.15	4.06	3.04	4.02	2.27	5.45

AVL=AverageVinelength(cm),ANVPP=AverageNumberofvineperPlant,ARL=AverageRootlength(cm),ARD=AverageRootdiameter(cm),ATNPP= Average of tuber number per plant, MY=Marketable yield ton/ha, UNMY=Unmarketable yield ton/ha, TY=Totally yield ton/ha.

Table 2. The mean of Growth and agronomic yield parameters for adaptation trial of Orange fleshed Sweet potato at Daro Labu District in West Hararghe zone of Oromia Regional state, during 2016 cropping season.

Varieties	AVL	ANVPP	ARL	ARD	ATNPP	MY	UNMY	TY
Tula	85.0	7.33	15.33	5.13	2.00b	9.80ba	0.19b	10.0ba
Kulfo	83.33	5.33	12.66	5.90	4.00a	14.83a	0.25b	15.08a
Beletech	88.66	4.33	13.0	4.30	4.33a	7.74b	0.12b	7.87b
Barkume	89.00	7.00	15.66	4.63	2.83ba	14.81a	1.48a	16.29a
MEAN	84.53	6.46	14.23	4.786	3.38	12.80	0.234	13.04
CV (%)	13.16	34.02	27.07	19.32	25.73	30.17	36.77	29.75
LSD 5%	20.24	4.00	7.01	1.68	1.58	7.03	0.15	7.06

AVL=Average Vine length(cm),ANVPA average Number of vine per Plant, ARL=Average Root length(cm), ARD= Average Root diameter(cm),ATNPP=Average of tuber number per plant, MY= Marketable yield ton/ha, UNMY=Unmarketable yield ton/ha, TY=Totally yield ton/ha.

Table 3. Daro labu and Habro Districts Over location mean of Growth and agronomic yield parameters analysis result of adaptation trial of Orange fleshed Sweet potato in West Hararghe zone of Oromia Regional state, during 2016 cropping season.

Variety	AVL	ANVPP	ARL	ARD	ANTPPT	MY	UMY	TY
Tula	103.4ab	5ab	11.7	5.28ab	3.67c	10.26b	0.38	10.64b
kulfo	99.67ab	4.58ab	12.77	6.6a	6.67a	15.2a	0.34	15.54a
Beletech	114.2a	3.75b	12.05	4.35b	5.17b	8.87b	0.31	9.18b
Barkume	90.08b	4.92ab	15.52	5.48ab	4.75bc	14.65a	0.75	15.4a
MEAN	100.27	4.85	13.17	5.51	5.03	12.25	0.48	10.7
CV(%)	15.22	37.46	24.29	30.47	20.99	23.95	58.5	33.88
LSD 5%	18.44	2.19	3.86	2.03	1.27	3.58	3	4.38

AVL=Average Vine length(cm),ANVPA average Number of vine per Plant, ARL=Average Root length(cm), ARD= Average Root diameter(cm),ATNPP=Average of tuber number per plant, MY= Marketable yield ton/ha, UNMY=Unmarketable yield ton/ha, TY=Totally yield ton/ha.

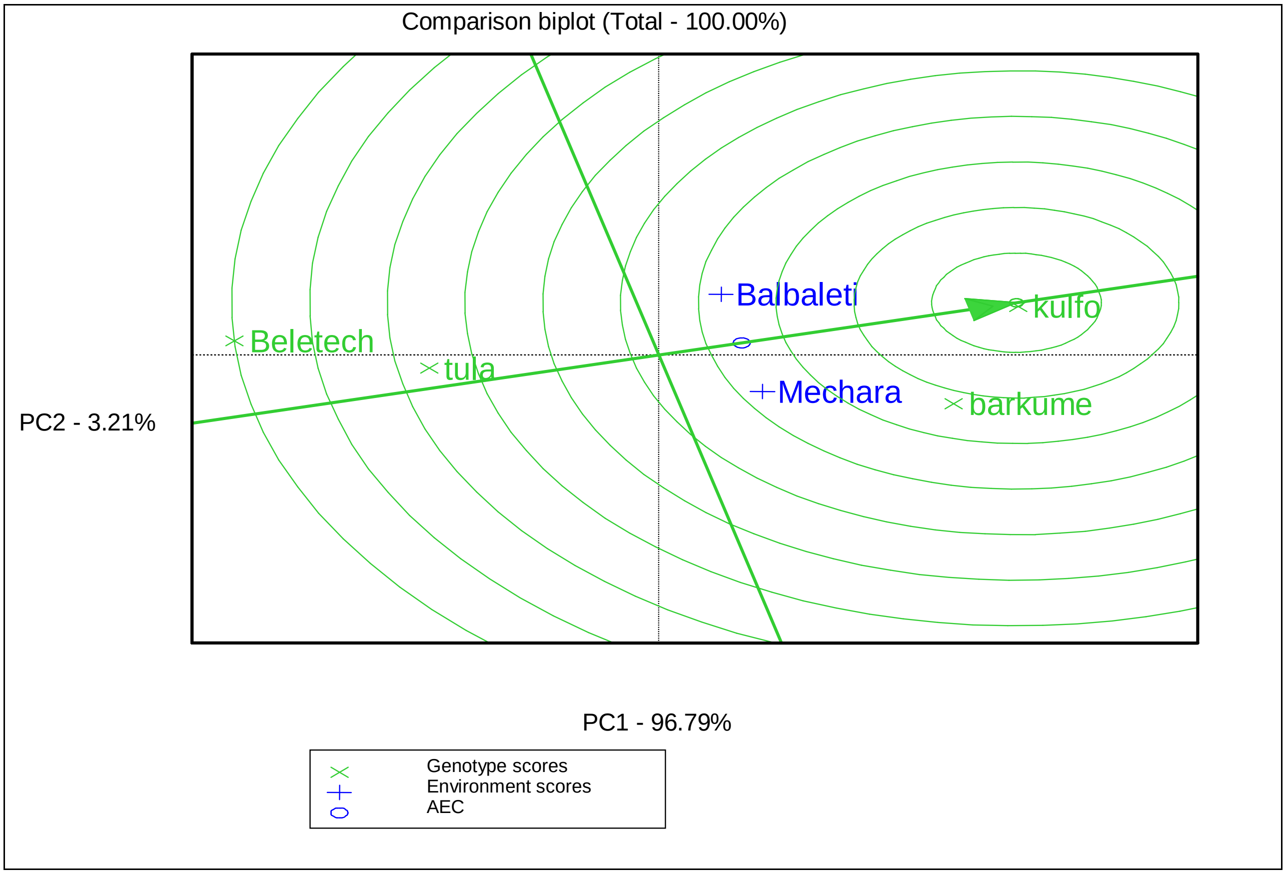

Figure 1**.** The stability view of GGE biplot based on *genotype by environment* yield data of Orange fleshed sweet potato Variety's evaluated at two locations in West Hararghe zone of Oromia Regional state, in the 2016 growing season.

Viewing from figure 1, which explains the performance and stability of the genotypes, it shows that kulfo was high yielding and most stable, tula was low yielding but stable and Beletech was low yielding and least stable.

From the result of the relationship among test environments (figure 2), the angles between the two locations Balbaleti, Mechara were less than 90^0 and imply that they are positively correlated to one another. Lines that connect the test environment to the bi-plot origin are called environment vectors. The angles between the vectors of the two environments approximate the correlation coefficient between them (Kroonenberg, 1995; Yan 2002).

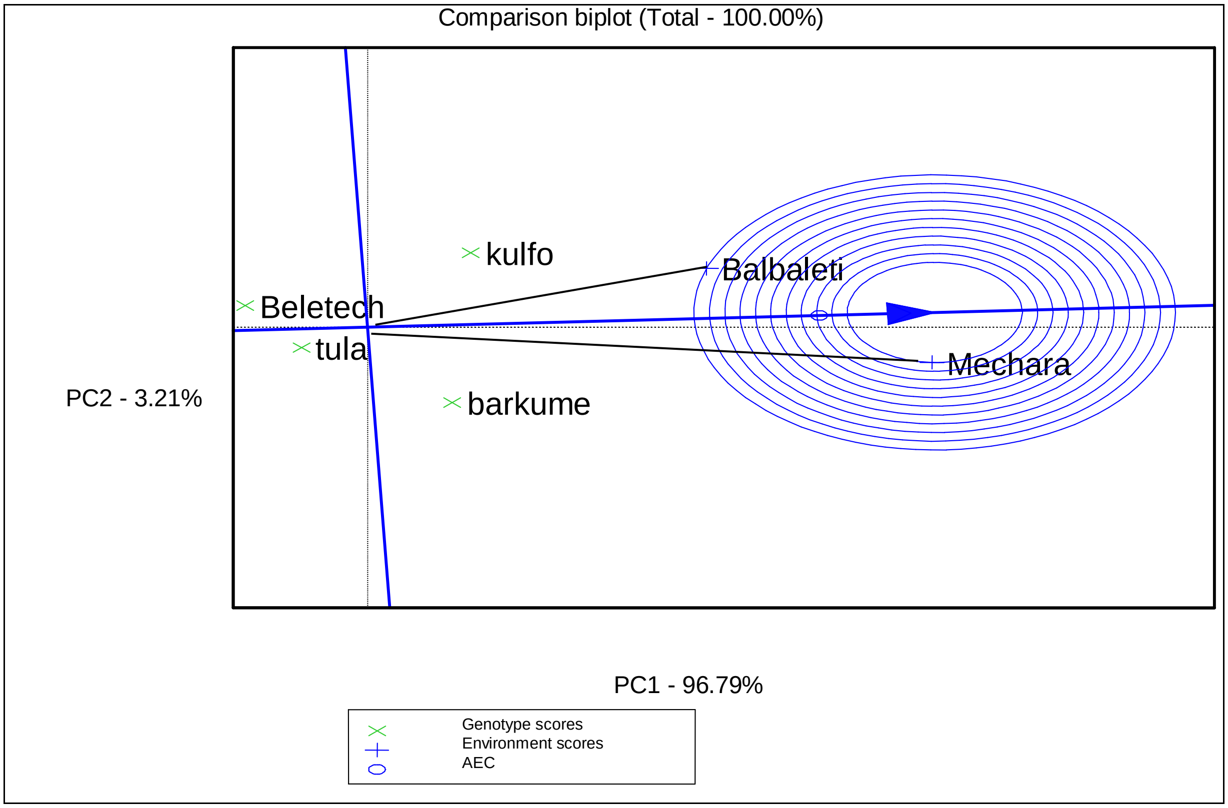

Figure 2**.** The GGE biplot view of the relationship among the *two environments* where the orange fleshed sweet potato were evaluated in West Hararghe zone of Oromia Regional state, in the 2016 croping season.

Conclusions and Recommendations

The current study showed that the most important yield and yield contributing parameters: root diameter, number of tuberous roots per plant, marketable tuberous root yield and total tuberous root yield were significantly varied among the orange fleshed sweet potato varieties evaluated. Kulfo variety produced the highest marketable yield across or over sites while beletech variety had consistently lowest marketable tuber yield. Based on over location analysis result of two location, kulfo varieties had good performance by root diameter, number of root per plant, marketable yield and total yields over other varieties and standard check. The maximum mean marketable yield of tested improved varieties was 15.2 ton/ha. Kulfo variety had 0.55 ton or 3.75% yield advantage over the standard check. Kulfo variety was identified as the highest tuber yielding genotype and most stable in the trial and can be beneficial to growers. It is obvious that in West Hararghe, there is shortage of rainfall and even it was erratic in 2016. Varieties were tolerant to this harsh climate condition and gave acceptable yield. Therefore, kulfo variety is superior in performance as compared to the other tested improved varieties and standard check. The farmers can produce kulfo variety until superior orange fleshed sweet potato variety will be obtained. Cultivar collection and screening activities can help in further development of superior varieties for this area.

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Additive Main Effects and Multiplicative Interactions (AMMI) Analysis of Grain yield in Small red bean genotypes in midlands of Bale zone, South-eastern Ethiopia.

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Abstract

Additive main effects and multiplicative interactions (AMMI) model analysis was performed to assess and to quantify the magnitude of genotype by environment interaction and yield stability of small red bean genotypes in midlands of Bale Zone. For this purpose, fifteen genotypes were planted in a randomized complete block design in four replications for two consecutive years (2016-2017) in the midlands of bale zone Ginir, Goro and Dellomena. The ANOVA combined over locations and years revealed highly significant variation among genotypes and Locations and significant variation for GE interaction. AMMI analysis of variance showed that the environment effect was a predominant source of variation (84.4% of the treatment SS) followed by GE interaction (9.82 %) and genotype effect (6.81%). The first two interaction principal component axes (IPCA) cumulatively explained 100%% of total interaction effects. A graphical interpretation of the AMMI analysis and GSI index incorporating the AMMI stability value (ASV) and the yield capacity of the different genotypes in a single non-parametric index were useful for discriminating genotypes with superior and stable grain yield. Accordingly, G2, G3, G4, G8, G9, G12 and G13 gave mean grain yield higher than the grand mean. Furthermore, the two genotypes G4 and G13 had the desirable characteristics of moderate stability with regression coefficient close to unity and the deviation from regression near zero with high grain yield with 19.5 % and 29.3% yield advantage over the check and thus, identified as candidate varieties to be verified in the coming cropping season for the midlands of Bale Zone.

Key words: AMMI, AMMI Stability Value, common bean, Genotype Selection Index stability

Introduction

Common bean (*Phaseolus vulgaris* L.) is a major staple food crop in eastern and southern Africa where it is recognized as the second most important source of human dietary protein and the third most important source of calories Pachico 1993). Beans also contribute as much as 30% of dietary energy in the widespread maize-based cropping systems of the mid-altitude areas of eastern and southern Africa. Part of the intercropped bean harvest may be exchanged by poorer rural families to make up for insufficiencies in production of the maize staple (Wandel and Holmboe-Ottesen 1992). Common bean is a well-established component of 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 to 700 kg/ha and yield from research station plots is in the range of 2000 to 3000 kg/ha (Mekbib, 1997). The most suitable bean production areas in Ethiopia are located in an altitude range of 1200 to 2200 masl, and characterized by mean maximum temperature of less than 32°C and well distributed annual rainfall of 350 to 500 mm throughout the growing season. Genotype-environment interactions are of major importance to the plant breeder in developing improved cultivars (Kang, 1993).

GEI is important for plant breeders and agronomists and the stability is mostly used to characterize a genotype, which indicates a comparatively stable yield and not affected by changing environmental conditions. In common bean improvement activities and in many aspects of its research, the analysis of GEI is of primary importance, as it is also for other crops (Ceccarelli 1996; Annicchiarico 2002; Voltas *et al.*, 2002). The AMMI model ensures a multivariate analytical parameter for interpreting GEI (Crossa *et al.*, 1990; Ebdon & Gauch 2002). When main effects and interaction are both important, AMMI is the model of first choice to improve accuracy of yield estimates (Zobel *et al.*, 1988). AMMI method combines ANOVA and principal component analysis (PCA) into a united approach. The most important feature of this analysis is that adjustment is carried out using information from other locations to refine the estimates within a given location (Sadeghi *et al.*, 2011). It removes residual or noise variation from GEI (Crossa *et al.*, 1990). It has no specific experimental design requirements, except for a two-way data structure (Zobel *et al.*, 1988). The effectiveness of AMMI procedure has been widely applied by many authors (Zobel *et al.*, 1988; Yan & Rajcan 2002; Yan *et al* 2001; Kaya *et al.*, 2002; Muhe & Assefa 2010; Wieslaw *et al.*, 2011; Mahalingam *et al.*, 2006; Ilker *et al.*, 2009; Banik *et al.*, 2010; Bantayehu 2009; Rodriguez et al 2007).

Therefore, the objective of the study was to explain GEI obtained by AMMI analysis of yield performances of fifteen small red bean genotypes over six environments in order to identify stable genotypes as candidate genotypes for possible release for midlands of Bale Zone and similar agro-ecologies.

Materials and Methods

Fifteen small red bean genotypes (Table 1) were used to find out the yield performance and stability across the testing environments during the main cropping season of 2016 and 2017 at the three midlands of Bale zone, *Viz* Ginir, Goro and Dellomena. In all the sites, randomized complete block design with four replications was used with plot size of 6.4m^2 (4 rows at 40cm spacing and 4m long). Data were collected from the two central rows. Combined analysis of variance least significant difference (LSD) multiple range test were done using Cropstat9 software. The 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 Cropsta9 program. AMMI stability value (ASV) was computed by the model suggested by Purchase *et al*. (2000):

$$ASV = \sqrt{\left[\frac{SSIPCA1}{SSIPCA2}(IPCA1)\right]^2 + [IPCA2]^2}$$

A =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) was 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. lists of small red bean genotypes used in the trial

SN	Genotpe Code	Genotype	SN		
1	G1	SCR 7	**9**	G9	SCR 9
2	G2	SCR 36	**10**	G10	SCR 29
3	G3	SCR 15	**11**	G11	SCR 2
4	G4	SCR 8	**12**	G12	SCR 17
5	G5	SCR 16	**13**	G13	SCR 28
6	G6	SCR 13	**14**	G14	SCR 1
7	G7	SCR 35	**15**	G15	Nasir
8	G8	SCR 18			

Results and Discussions

The combined analysis of variance revealed highly significant variation ($P<0.01$) for year, location, replication, genotypes for mean grain yield whereas the variation for genotypes x environment interaction and year x L x G showed significant variation for the mean grain yield (Table 2). Similarly, Tadele *et al., (*2017); 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. Peyman *et al.*, (2017) have also reported significant variation for genotypes by environment interaction in rice. Kadhem *et al., (*2016) also reported significant variation among genotypes, genotypes x environment interaction for wheat.

Table 2. ANOVA for grain yield of 15 small red bean genotypes

Source of Variation	**Degree of freedom**	**Sum of Squares**	**Mean Squares**
YEAR	1	65.6352	65.6352**
Location (L)	2	51.0564	25.5282**
Replication	3	1.16287	0.387623**
Genotype (G)	14	3.99933	0.285666**
L x G	28	5.82981	0.208207*
YEAR*L*G	42	6.03578	0.143709*
RESIDUAL	267	33.6162	0.125903
TOTAL	359	168.459	0.469246

**, * Significant at 1 % and 5% of probability level, respectively

The regression analysis (Table 3) revealed that the main effects of genotypes, and GE interaction were accounted only for 6.57% and 9.58% of the total sum of square (TSS), respectively. Tadele *et al.*, (2017) also reported 6.52% and 15.29% of the total sum squares of variation for genotypes, and genotypes by environment interaction in common bean.

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

Source of variation	D.F.	S.S.	M.S.	TSS%
Genotype (G)	14	0.499916	0.035708**	6.57
Location (L)	2	6.38205	3.19103**	83.86
G X L	28	0.728725	0.026026*	9.58
G X Site Reg	14	0.369038	0.02636*	50.64
Deviations	14	0.359688	0.025692	49.36
Total	44	7.61069		

AMMI Analysis

The AMMI analysis of variance of grain yield (t/ha) of the fifteen genotypes tested in six environments explained that 83.86% of the total sum square was attributed to environmental effects, only 6.57% to genotypic effects and 9.58% to GEI effects (Table 4). This implies environment effect play great role for the variation observed for grain yield followed by the interaction 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 one and half times higher than that of the genotype effect, suggesting that there were sustainable differences in genotypic response across environments. The AMMI analysis result also revealed the first AMMI1 component explained 72.34% of the interaction sum of squares in 53.57% of degrees of freedom (Table 4). Whereas the AMMI2 captured 27.66%of the interaction sum of squares. These two components jointly accounted for 100% of the total GEI. This indicates that the use of AMMI model fit the data well and justifies the use of AMMI2. Furthermore, the AMMI analysis revealed that highly significant difference for IPCA1, and IPCA2. According to Crossa *et al.* (1991) and Zobel *et al.* (1988) in AMMI the first two interaction principal component axis best predictive model explains the interaction sum of squares. This made it possible to construct the biplot and calculate genotypes and environment effects (Gauch and Zobel, 1996; Yan and Hunt, 2001; Kaya *et al.*, 2002).

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

Source of Variation	D.F	S.S.	M.S.	TSS%
Genotypes (G)	14	0.499916	0.035708**	6.57
Locations (L)	2	6.38205	3.19103**	83.86
G x L	28	0.728725	0.026026*	9.58
AMMI COMPONENT 1	15	0.52718	0.035145**	72.34
AMMI COMPONENT 2	13	0.201545	0.015504**	27.66
TOTAL	44	7.61069		

** Significant at 1% level of probability

The IPCA scores of genotypes provide indicators of stability of a genotype across environments (Purchase 1977). Further, interaction principal component beyond AMMI1 and AMMI2 captured mostly noise and did not help in prediction. In general, factors like type of crop, diversity of the germplasm and range of environmental conditions will affect the degree of complexity of the best predictive model (*Crossa et al.*, (1991). Mean grain yield (tha-1) of the 15 promising lines at 6 environments, their ranking orders and IPCA 1 and 2 are presented in Table 5.

AMMI stability Value (ASV)

AMMI stability value was also computed to determine stability of the genotypes (Table 5). In fact ASV is the distance from zero in a two dimensional scatter gram of IPCA1 (interaction principal component analysis axis 1) scores against IPCA2 scores. Since the IPCA1 score contributes more to GE sum of scores, 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 sum of squares. In ASV method, a genotype with least ASV score considered as the most stable. Accordingly, genotypes G11, G6, G1, G5, G4, G13 and G8 had general adaptation, while genotypes G12, G15, G10 and G9 were the most unstable. This was in agreement with Farshadfar (2008), Tadele *et al., (*2017) who has used ASV as one method of evaluating grain yield stability in their studies.

Genotype Selection Index (GSI)

Stability per se should however not be the only parameter for selection, because the most stable genotypes would not necessarily give the best yield performance (Mohammadi *et al.*, 2007), hence there is a need for approaches that incorporate both mean and stability in a single criteria. In this regard, as ASV takes into account both IPCA1 and IPCA2 that justify most of the variation of GE interaction, therefore the rank of ASVi and rank of mean are incorporated in a single selection index namely Genotype Selection Index (GSI). The least GSI is considered as the most stable (Table 5) , in that regard the G4, G13 and G10 were considered as most stable genotypes , whereas, G5, G7, G14, and G12 are the least stable genotypes. These results were in agreement with the result of biplots.

Table 5. Mean yield First and second IPCA and various yield-stability statistics investigated in small red common bean

Genotype code	Mean yield (t/ha)	Rank of yield	bi	MS-DEV (S^2di)	IPCA1	IPCA2	ASV	RASV	GSI
G1	1.3	10	0.944	0.03	-0.09	-0.04	0.22	3	13
G2	1.47	2	0.963	0.23	-0.15	-0.15	0.40	8	10
G3	1.45	4	1.254	0.25	0.16	-0.14	0.43	9	13
G4	1.47	2	1.04	0.18	0.21	-0.26	0.30	5	7
G5	1.26	11	0.883	0.28	-0.12	0.01	0.29	4	15
G6	1.31	9	1.045	0.01	-0.06	-0.14	0.2	2	11
G7	1.23	15	0.828	0.02	-0.2	-0.03	0.51	10	25
G8	1.39	7	0.955	0.02	-0.14	-0.13	0.39	**7**	14
G9	1.45	5	1.401	0.45	0.21	-0.22	0.56	12	17
G10	1.36	8	0.651	0.37	-0.23	0.18	0.6	13	21
G11	1.24	12	1.001	0.19	0.01	0.01	0.03	1	13
G12	1.43	6	1.026	0.13	0.3	0.37	0.84	15	21
G13	1.59	1	1.031	0.14	0.52	0.15	0.35	6	7
G14	1.24	12	0.699	0.29	-0.19	0.17	0.51	11	21
G15	1.23	14	0.631	0.31	-0.23	0.21	0.62	14	28

AMMI Biplot

The most important benefits of AMMI analysis is the construction of biplot graphs, through combining the analysis of variance with multivariate analysis through principle component analysis. In Figure 1, the IPCA scores for both genotypes and environments were plotted against the grain yield for the genotypes and the environments, and in Figure 2, the IPCA 1 scores for both genotypes and environments were plotted against the IPCA 2 scores. In Figure 1 the vertical line passing through the center of the biplot was the grand mean (1.36t/ha) of the experiment, and the horizontal line passed through the IPCA 1 axis score=0. The mean genotypes or environments in AMMI model 1 biplot located on the same parallel line, relative to the ordinate, have similar yield, while those located on the right side of the center of the axis have higher yields than on the left hand side (Banki *et al*., 2010). Therefore, according to Figure 1, seven small red bean genotypes, G8, G2, G3, G9, G12, G4 and G13 and one environment Goro located in the right side of the grand mean were considered as high yielding genotypes and environment whereas the other genotypes and environment located in the left side of the grand mean considered as low yielding genotypes and environment, respectively. The score and sign of IPCA1 reflect the magnitude of the contribution of both genotypes and environments to GEI, where scores near zero are characteristic of stability, whereas higher score (absolute value) considered as unstable and specifically adapted to certain environment (Gollob, 1968).

The characterization of each promising lines (genotypes) to mean grain yield and contribution to GEI by mean of IPCA1 (Fig.1) indicates that genotypes G9, G12, and G13 were specifically adapted to high yielding environment, Goro with grain yield more than grand average yield (Fig 1). And with respect to their contribution to GEI (i.e. stability) the IPCA1 score, G12 and G13 were the most unstable genotype and also adapted to higher yielding environments whereas G2 and G3 were more stable in comparison to G9, G12, and G13. However, G11, and G6 were low yielding genotypes and relatively stable. On the other hand, G5, G7, G10 and G15 were adapted to low yielding environment Ginir but not stable.

When IPCA1 was plotted against IPCA2 (Figure 2), genotypes; G1, G5 and G11 were found closer or at a lesser distance from the center of the biplot when compared with other genotypes and that would be considered as most stable genotype with regard to its lesser contribution to GEI. While G4, G7, G8 and G13 were found slightly far from the center implying as they were considered as moderately stable genotypes. The rest genotypes since they were found at a larger distance away from the center, they were considered as unstable genotypes indicating high contribution of these genotypes to GEI (i.e. unstable genotypes). The AMMI2 biplot also revealed that the environments were divers and exhibits longer vectors from origin and that imply their higher contribution to Environment Sum of Square. The longer vector of environments compared to genotypes explain the higher sum of square of environments as compared to Sum of squares of genotypes in the ANOVA (Table 2). The best genotypes with respect to Goro were G3 and G 9. Genotypes G2, G6, and G8 were best for Ginir whereas, G10, G14, G5, and G12 were best genotypes for Dellomena.

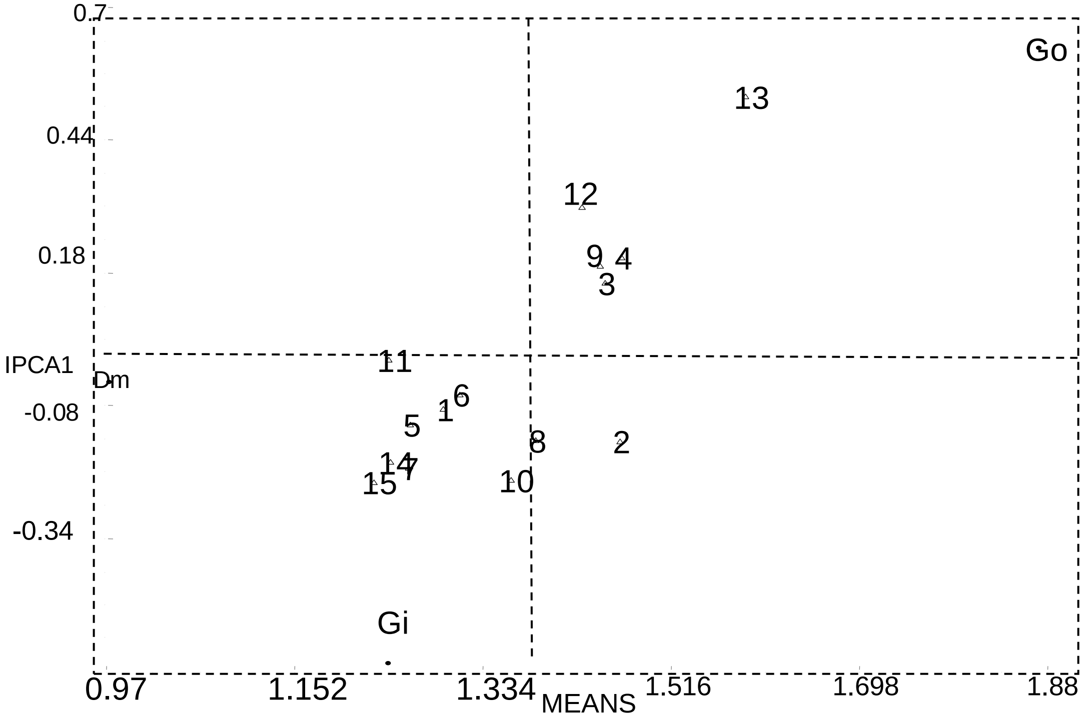

Figure 1 Biplot analysis of GEI based on AMMI 1 model for the PCA 1 scores and grain yield

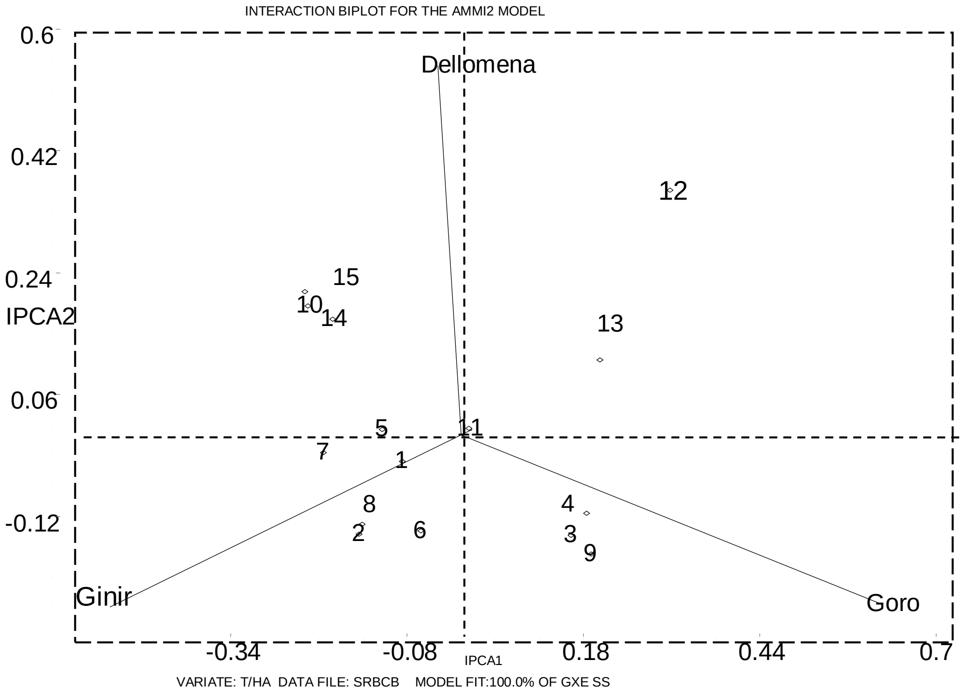

Figure 2. Biplot analysis of GEI based on AMMI 2 model for the first two IPCA scores

Conclusions

The results of this study confirm the importance of testing genotypes under representative environmental conditions to identify the best, stable and high yielding genotypes. Both yield and stability of performance should be considered simultaneously to reduce the effect of GE interaction and to make selection of genotypes more precise and refined. The analysis of variance for the AMMI model of grain yield showed that genotypes, environments, genotype x environments interaction and AMMI components 1 and 2 were significant. A graphical interpretation of the AMMI analysis and GSI index incorporating the ASV and the yield capacity of the different genotypes in a single non-parametric index were useful for discriminating genotypes with superior and stable grain yield. Based on ASV and GSI indices genotypes G4 and G13were considered as the most stable genotypes with higher grain yield. Furthermore, these two genotypes have yield advantage of 19.5% and 29.3% over the check and thus these two genotypes were identified as candidate varieties to be verified for the possible release in the tested environments.

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Adaptable Improved Teff *(Eragrostis teff)* Varieties for West Hararge Zone

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Abstract

An experiment was conducted in three districts of West Hararghe zone at Daro Lebu, Habro and Oda Bultum in 2016/2017 cropping season to identify and promote well adapted improved teff variety/ies. The experiment was laid out in randomized complete block design in three replications. Agronomic parameters and yield data of the trial like days to 50-% flowering, plant height, panicle length, maturity date, biomass harvest index and yield kg/ha were collected. The collected data were analyzed using Genstat statistical software and means were separated using least significance difference. Combined analysis of the data revealed that, varieties were significantly different at (P <0.05) in grain yield (kg/ha) and maturity date was highly significant at (P<0.01). Plant height, days to 50% flowering and the rest parameters showed non significant difference. Two varieties, Gimbichu and Boset, relatively gave better yield with a value of 1794 and 1789 kgha^{-1} respectively. Kena, Guduru and Dega varieties were less performing in terms of grain yield as compared to the standard check kuncho having a value of 1271, 1576, 1573 and 1731kgha^{-1}, respectively. As a whole the performance of the varieties was under their potential due to erratic rain fall during the growing period. Generally, Gimbichu and Boset were the two varieties showed better performance with their mean yield and other measured traits. Therefore, these two varieties were recommended to be used as alternative to the standard check (kuncho).

Key words*:* Tef Variety, Grain yield, adaptation,

Introduction

Teff is the most important cereal in terms of both production and consumption in Ethiopia, and is grown as food grain in only one other country, Eritrea (FAO, 2015). Teff (*Eragrostis Teff*) is a nutritious small grained cereal, related to millet, which originates in Ethiopia and is thought to have been domesticated by Ethiopian farmers between 3 and 6 millennia ago (Samuel and Sharp, 2008). East and West Gojam of Amhara and East and West Shoa of Oromiya are particularly known teff producing areas in the country (Demeke and Marcantonio, 2013).Teff is mostly produced by small holder farmers at the central, eastern and northern highlands of the country on fragmented lands with rain fed conditions in both, *Meher* and *Belg*, seasons (Engdawork, 2009). Teff production has increased by 24.5% between 2003/2004 and 2012/2013 cropping years. This growth was achieved mainly due to 37% expansion in area under cultivation and 64% increase in yield levels per hectare (CSA, 2015). Teff is one of the major cereal crops in Ethiopia which is mainly used for consumption as food. The composition of Teff shows that it has good mineral content and generally higher amount of the essential amino acids (Engdawork, 2009). Its grain flour is mainly used for preparing *injera,* which is the favorite national dish of most Ethiopians. Injera produced from teff flour is of good odor, flavor, texture, and keeping quality. The grains give higher returns both in flour upon milling (i.e. 99 percent compared to 60-80 percent from that of wheat) and in *injera* upon baking. The flour is also used for the preparation of porridge and *kita* (non-fermented unleavened bread). It is nutritionally rich with high levels of iron and calcium and has the highest amount of protein among cereals consumed in Ethiopia. It ranks low on the glycemic index (making it suitable for consumption by Type II diabetics), is gluten free and is high in fibre (FAO, 2015). Teff is the most nutritious of all grains grown in Ethiopia (Crymes, 2015). In term of caloric intake, cereals dominate the diets of Ethiopian households. Of the total calorie consumption, four major cereals (maize, teff, wheat, and sorghum) account for more than 60%, with maize and wheat representing 20% each. The low share of teff in calorie consumption often come as surprise to urban Ethiopians, as teff is the predominant staple in the diet of the middle- and high income households (Rashid, 2010). Similarly, FAO (2015) demonstrated that Teff is a major staple food for many Ethiopians. Most prefer teff to other grains but is in general more widely consumed by the economically better off urban residents than by rural households. Teff contributes up to 600 (28.5% of minimum requirement) kcal/day in urban areas, compared to only 200 (9.5% of minimum requirement) kcal/day in rural areas.

Teff is relatively resistant to many biotic and abiotic stresses and can be grown under different agro-ecological conditions, ranging from lowland to highland areas (FAO, 2015).The national average yield of teff is very low which is 1.3t/ha (CSA, 2016). Several factors were mentioned in different studies regarding the low productivity of the crop. Some of these constraints are lack of improved varieties adaptable to wider environment, limited access to improved crop variety, uneven and erratic distribution of rainfall and poor agronomic management practices. However, many research efforts have been made by many agricultural research centers to solve these problems by developing varieties adaptable to specific agro ecological conditions. In West Hararghe, there are potential districts well recognized by teff production but the production and productivity of this crop is very low due to dominant use of local varieties and poor agronomic management practices. As a result, identifying adaptable improved variety is immediate solution to increase productivity of the crop thereby improving the livelihood of teff farmers in West Hararghe. Therefore this activity was initiated with objective of evaluating and selecting the best adapted teff variety/ies for West Hararghe zone and similar agro ecologies.

Material and Methods

Description of the study area

The field experiment was conducted at Mechara Agricultural Research Center (MeARC) during the 2009/10 cropping season. The altitude of the center is 1700 m. a. s. l. It is located between 40° 19' N latitude and 08° 35' E longitude and 434 km east of Addis Ababa in Daro Labu district, West Hararghe, Ethiopia. The major soil type of the Center is sandy loam with reddish color (McARC, 2010). The ambient temperature of the district ranges from 14 to 26°C with average of 16°C and average annual rainfall is 963 mm/year. Oda Bultum is located at 08054, 3180N, 0400; 0210E.The annual rain fall is 900 mm-1100 mm. It has a mean maximum and mean minimum temperature of 28°C and 25°C; respectively. The maximum and minimum rainfalls are 1200mm and 900 mm, respectively. The district is characterized by sandy loam soil which is reddish in color. Habro district is found in West Hararghe zone of Oromia region with mean annual rainfall of 1010 mm and the annual temperature ranges from 25-32oC (HDoANRO, 2016) .The soil type of the district is black clay loam .

Experimental Material and Design

Six improved teff varieties including one standard check were brought from Debre Zeit (Boset Gimbichu, Dega-Tef) and Bako Agricultural research center (Kora, Guduru and Kena) and tested in randomized complete block design in three replications on plot area of 2.4m^2 with a plot length and width 2 m x1.2m. The spacing was 0.5m and1m between plots & blocks respectively.

Experimental Management

Land preparation was done using animal drawn conventional tillage implements 2-3 times was inverted and break down in to fine tilt to create suitable soil condition for uniform emergence and moisture conservation. Planting was done by drilling in the mid of August when the rain fall was well established with row spacing of 20cm and recommended seed rate of 25kg/ha. 100kg/ha each NPS and Urea were applied. Other agronomic practices were conducted as per the recommendation.

Data collected

The important data of the trial including days to 50% emergence, grain yield, and days to 50% heading, maturity date, plant height, panicle length and straw yield as well as harvest index were collected.

Data Analysis

The collected data were subjected and analyzed by Genstat software 16th edition. Mean separation was carried out using LSD test at 5% probability level.

Results and Discussions

Grain yield: There was no significant difference for grain yield at (P>0.05) Daro Lebu and Oda bultum (Table.1) but significant difference was observed at Habro. Combined analysis of variance for treatment means effect of location interaction showed significance difference on grain yield.(Table 2). The highest yield (1794 kg/ha) was recorded for variety **Gimbichu** while the lowest for Kena (1271 kg/ha)

Straw yield kg/ha: The analysis of variance shows no significant difference among individual location for straw yield (Table 1) and the combined analysis indicates variety and location interaction effect was also not significant for this trait. (Table 2). Variety Gimbichu showed better performance (4525 kg/ha) while kena was the lowest (3327kg/ha) straw yielder.

Plant height: At Daro Lebu the plant height was statistically significant at P<0.05 and non significant in other locations. The combined mean effect of plant height within variety and location showed highly significant difference at P<0.001, the highest (79.77cm) and lowest (66.67cm) recorded in Kora and Boset varieties, respectively. (Table 2).

Panicle length:-There was no significant difference for panicle length at each location as well as combined mean effect (Table 1, 2).

Days to 50% flowering:-This trait was significantly different at P<0.05 at Daro Lebu but non significant at Oda bultum and Habro. (Table.1). The performance of varieties for days of flowering in combined analysis among varieties and within location showed a highly significance difference at (P<0.001) (Table 2). The longest flowering days (46) were observed in kena while the shortest days (38) were observed in Gimbichu variety.

Maturity date: Analysis of variance showed that the individual location for days to maturity was non significant for mean effect of the varieties (Table 1), but the combined mean effects of varieties within locations showed a highly significant difference at P<0.001. Table 2). The interaction of location and varieties were showed no significance difference. However, overall days of maturity recorded for almost all varieties were very closer to each other as this trait is a very determinant character for selection.

Above ground biomass: -It is another important trait for this crop as it is economically a highly demanded plant part for many purposes including animal feed and mud house plastering services for low income farmers. Some varieties show proportional advantage with increasing biomass and increasing grain yield. Statistical analysis of variance showed that no significant difference was observed for mean effect of varieties for biomass yield where the highest above ground biomass (5759 kg/ha) was obtained from Gimbichu variety and lowest (4792 kg/ha) from Kena variety. But in combined analysis within locations there was a significant difference where the largest biomass was obtained at Oda Bultum.

The meta analysis indicated that variety Gimbichu (17.94 qt ha^{-1}) was highest grain yielder than other varieties while the lowest grain yielder was Kena variety (12.31 qt ha^{-1}). The principal component (PC1) explained 89.5% of the total variation; while the principal component (PC2) explained 10.4%. Finally, these two principal components summed up to 99.9% which accounted for the total variation in grain yield. The AMMI analysis of variance for grain yield of variety tested in three environments showed that the main effect of V and E account for 13.6% (Table 4). The analysis revealed that variance due to environment was highly significant and variety was significant while VxE interaction was not significant. Large difference among environment means causing most of the variation in grain yield, which is in line with the findings of (Molla *et.al*., 2013; Maqsood and Ali, 2007; Mahto *et.al.,* 2006) in finger millet production.

Table 3. Analysis of variance table from AMMI model showing the effect of variety, environments and their interaction on grain yield performance of teff varieties and interaction principal components in 2017 at three locations of West Hararghe, Ethiopia

Source	**D.F**	**S.S.**	**M.S.**	**% Explained**	**F.cal**	**F prob.**
Total	62	13230146	213389			
Treatments	20	7364394	368220	55.6	2.67	0.0051**
Genotypes	6	1908450	318075		2.30	0.0552
Environments	2	3658685	1829342		12.24	<0.001**
Block	6	896569	149428		1.08	0.3912
Interactions	12	1797259	149772	13.6	1.09	0.4008
IPCA 1	7	1611818	230260	89.5	1.67	0.1482
IPCA 2	5	185441	37088	10.4	0.27	0.9273
Residuals	0	0				
Error	36	4969184	138033			

Genotype 1 (G1)/ Boset and genotype 4 (G4) Gimbichu were the winning genotype in all locations .This pattern suggests that G1 and G4 being the winning genotypes , it would be selected for further demonstration and promotion in teff growing areas of West Hararghe zone. However, genotype 6 (Kena) was less responsive than Gimbichu. (Figure 3).

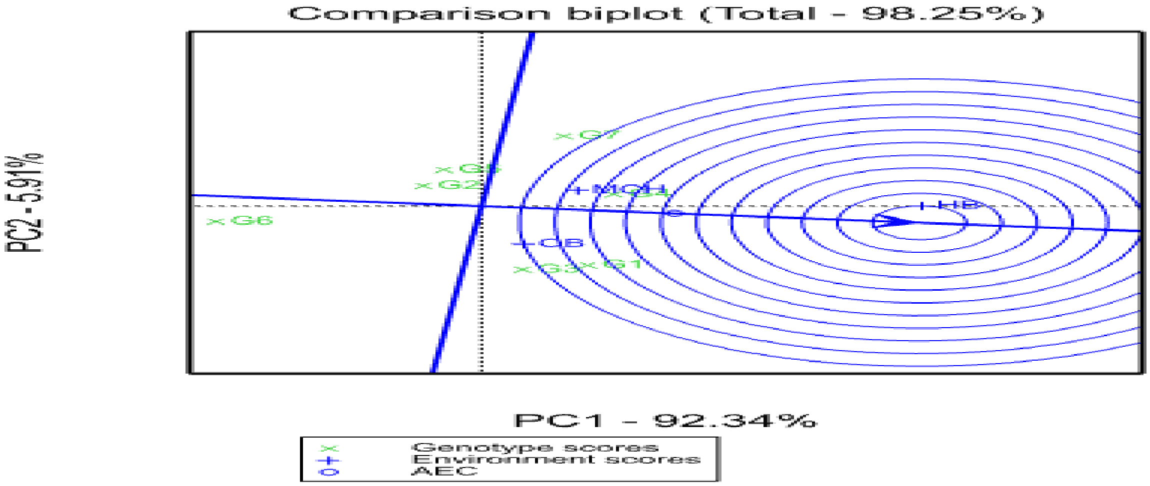

Figure 1. GGE Biplot of the relationship among three environments in grain yield of teff in West Hararghe.

Table.1 Mean effect of tef varieties on grain yield and yield components in each districts of western Hararghe Zone in 2009/2010 cropping season

	Daro Lebu (Mechara on station)						**Habro (Bareda on FTC)**						**Oda Bultum (Oda baso on FTC)**					
Varieties	Gy kg/ha	Stra yd kg/ha	Plan height (Cm	Panicle length (cm	Md	Df	Gy t/ha	Stra yd kg/ha	Plan Height (cm	Panicle length(cm)	Md	Df	Gy t/ha	Stra yd kg/ha	Plan height (cm	Panicle length(cm)	Md	Df
Boset	1281	4058	19.26	19.26	89	41	2.2	1764	30.47	30.47	64	43	1.9	5420	71.83	27.13	75	37
Dega-Tef	1340	3449	20.93	20.93	84	45	1.7	2572	32.2	32.2	68	40	1.7	4592	80.93	30.4	82	36
Kora	1367	3525	22.2	22.2	95	51	2.0	5183	37.1	37.1	73	45	1.9	4289	86.23	33.63	78	41
Gimbichu	1354	4305	20.14	20.14	86	27	2.3	4682	28.27	28.27	81	46	1.7	4588	77.33	30.3	84	41
Guduru	1319	4317	22.97	22.97	87	45	1.8	4481	36.33	36.33	68	41	1.6	4118	82.6	32.2	84	40
Kena	1076	2688	22.77	22.77	96	53	1.1	3320	28.57	28.57	82	44	1.7	3973	78.47	30.03	84	40
Kuncho	1444	3484	21.63	21.63	91	49	2.1	3224	31.47	31.47	69	42	1.6	4331	80.43	28.67	76	37
LSD 5%	406	1894	6.59	4.40	13	12	0.7	3318	13.1	11.2	16	4.5	0.8	2179	10.1	7.59	5.1	6.7
CV	17.4	10.5	5.8	11.6	8.3	15	2.0	51.8	9.4	19.8	12	5.8	26.7	27.4	7.1	14	4	9.7
P.value	NS	NS	*	NS	NS	*	*	NS	NS	NS	NS	NS	NS	NS	NS	NS	*	NS

* Significant at 0.05 level   LSD= Least significance difference NS = not significant CV= Coefficient variation Gy = grain yield Df= days 50% flowering Md= days to maturity Stra= straw yield

Table 2. Combined Mean effect of tef varieties and location on yield and yield components at Daro Lebu, Habro and Oda Bultum Districts in 2009/10 cropping season

Varieties	Grain yield kg/h	Straw yield kg/ha	Plant height(cm	Panicle length cm	Maturity date	lodging	Days 50% flowering	Disease (1-5)	Above Ground Biomass	Harvest index
Boset	1789	3747	66.67	25.62	76	1.5	40	1.2	5058	0.315
Dega-Tef	1573	3538	75.24	27.84	78	1.6	40	1.3	4958	0.341
Kora	1754	4332	79.77	30.98	82	1.3	46	1.6	5525	0.286
Gimbichu	1794	4525	69.47	26.24	84	2.1	38	1.3	5759	0.296
Guduru	1576	4306	78.89	30.5	80	2.1	42	1.3	5384	0.259
Kena	1271	3327	74.2	27.12	88	2.1	46	1.4	4792	0.352
kuncho(ch)	1731	3680	75.13	27.26	79	1.4	43	1.4	4935	0.301
LSD	423.2	1187	9.593	7.495	11.4	1	7.4	0.67	5058	0.1486
CV	22.3	37.1	7.8	16.3	8.6	35	10.6	29.2	23.5	29.3
P.Value	*	NS	**	NS	*	*	*	NS	NS	NS
Location Mean										
Locations	Grain yield kg/h	Straw yield kg/ha	Plant height(cm	Panicle length cm	Maturity date	lodging	Days 50% flowering	Disease (1-5)	Above Ground Biomass	Harvest index
Daro Lebu	1312	3690	64.18	21.41	72.1	2.143	44.4	1.21	4905	0.2917
Habro	1881	3604	78.72	32.06	80.62	1.238	43	1.81	4960	0.3256
Oda bultum	1731	4473	79.69	30.34	89.76	1.857	38.9	2.381	5740	0.3041
LSD %	228.7	907	3.36	2.83	4.3	0.38	2.8	0.25	763.6	0.05
P value	NS	NS	**	***	***	**	***	**	*	NS

Conclusions and Recommendations

The result of the experiment showedthat teff varieties showed lower performance than their potential .Genotypes were highly affected by environments which show the selective adaptation to specific location favoring their production. The mean performance of genotypes at Habro was relatively good showing the suitability of the area for this crop. Generally, Gimbich and Boset were good genotypes that performed better in mean grain yield. Therefore; these two varieties are adaptable and can be demonstrated to be used as improved varieties compared standard check (kuncho).

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Genetic variability, Heritability and Genetic Advance among Bread Wheat Genotypes at Southeastern Ethiopia

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Abstract

The knowledge of nature and magnitude of variation existing in available breeding materials is great importance for successful selection of varieties. This study was conducted to generate information on the extent of genetic variability in advanced bread wheat lines. Thirty bread wheat genotypes were tested at Sinana and Agarfa, Southeastern Ethiopia, in alpha lattice design with three replications. Combined over locations ANOVA was carried out for yield and yield related traits. There were highly significant differences among genotypes for all traits. Highly significant location effects at $P < 0.01$ *were observed for yield and yield related traits except for harvest index which showed significant effect at* $P < 0.05$ *and grain yield that showed non-significant location effect. This indicates the presence of variability for these characters among the tested genotypes. In combined analysis, grain yield had high phenotypic coefficient of variance (PCV) (27.1%) and moderate GCV was observed for biomass weight, grain yield and harvest index. PCV was moderate for biomass weight and harvest index. Heritability estimates in broad sense (*H^2*) was very high for most of the characters except for grain yield (52.3%) and number of kernel per spike (73.2%). However, low GAM was observed for most of the characters except for harvest index which was moderate (15.9%). Finally, the presence of variability among the genotypes, performance of heritability and GAM in the tested traits of the genotypes confirmed possibility to increase wheat productivity. Hence, selection and hybridization on those genotypes can be recommended for farther yield improvement of bread wheat.*

Keywords: Bread wheat; Variability; Heritability; Genetic advance; GCV; PCV

Introduction

Bread wheat, *Triticum aestivum* L. (2n = 6x = 42, AABBDD), belongs to the tribe *Triticeae* in the family *Poaceae*. Morphological, cytogenetic and molecular studies have shown that the genomic evolution of the segmental allohexaploid occurred through the hybridization of *Triticum turgidum* L tetraploid wheat (AABB) with wild relative (DD) - a grass *Triticum tauschii* followed by the doubling of chromosomes (Feuillet *et al.*, 2007; Marcussen *et al.*, 2014).

Ethiopia is leading wheat producer in Sub Saharan Africa and total production of 4.53 million tons (CSA, 2017). Accordingly, Oromia National Regional State contributes a total production of 2.66 million tons in the country. Among the wheat producing zones of Oromia, Arsi, West Arsi and Bale are considered as the wheat belts of eastern Africa. Although the productivity of wheat has increased in the last few years in the country, it is still very low as compared to other wheat producing countries in other parts of the world. The national average of wheat productivity is estimated to be 2.68 t ha^{-1} (CSA, 2017), which is below the world average of 3.0 t ha^{-1} (Hawkesford *et al.*, 2013).

For a successful breeding program, the presence of genetic variability plays a vital role. The knowledge of nature and magnitude of variation existing in available breeding materials, inter relationships between quantitatively inherited traits on grain yield is of great importance for successful selection of varieties for yield (Khan *et al.,* 2010; Kotal *et al.,* 2010). Reduction in the genetic variability makes the crops increasingly vulnerable to diseases and adverse climatic changes (Aremu, 2012). Therefore, precise information on the nature and degree of genetic variability present in wheat would help to select parents for evolving superior varieties.

High genetic advancement together with high heritability estimates offers the most suitable condition for selection (Johnson *et al*., 1955). The presence of variability, heritability and genetic advance in different yield related characters of bread wheat has been reported by different authors such as Obsa (2014), Alemu (2016), Kifle *et al*. (2016) and Birhanu *et al.* (2016). However, no variability studies have been conducted for recent genotypes in the study area. The current study was designed to assess the extent of genetic variability in advanced bread wheat lines.

Materials and Methods

Description of study Areas

The experiment was conducted at Sinana Agricultural Research Centre (SARC) and Agarfa district in 2017 main cropping season. SARC is located in Bale Zone of Oromia National Regional State, Southeastern Ethiopia. It is situated at a distance of about 463 km southeast of Addis Ababa, and 33 km from the nearby town, Robe-the capital city of the zone. Geographically, SARC is located at 07°07′N latitude and 40°10′ E longitude at 2400 meter above sea level (m.a.s.l). The area is characterized by bimodal rainfall pattern and receives annual total rainfall ranging from 750 to 1400 mm. The main season locally called ‘Bona’ season extends from August to December and receives 270 to 842 mm rainfall, while the short season ‘Ganna’ from March to June receives from 250 to 562 mm rainfall annually. Mean annual minimum and maximum temperatures are 9.6 and 20.7ºC, respectively. The soil texture of the area is clay loam having black color with pH ranges between 6.3-6.8 (SARC, 2006). Agarfa is located at 07°26′ N latitude and 39°87′ E longitude with an elevation of 2510 m.a.s.l. Its total annual rainfall ranges from 1000 to 1451 mm. The mean annual minimum and maximum temperatures are 7.3 and 22.8°C, respectively. The experiment at both locations was conducted during the main cropping season.

Experimental Materials and Design

The experimental materials comprised of thirty bread wheat genotypes including two released bread wheat varieties *viz.* Kingbird, Pavon-76 and 28 advanced bread wheat lines. These advanced lines are composed of materials introduced from CIMMYT, ICARDA and advanced genotypes generated from local crosses. The details of genotypes are summarized in Table1. The experiment was laid out in alpha lattice design with three replications having plot size of six rows of 0.2 m spacing and 2.5 m length (total area of the plot was 3m^2). Four central rows were harvested for grain yield computations. Seed rate of 150 kg ha^{-1} and fertilizer rates of 41/46

N/P_2O_5 were used. Planting was done by hand drilling; weed was controlled by using hand weeding as well as by using herbicide called Pallas 45OD (Pyroxsulam Triazolopyrimidine) at the recommended rate of 0.5 l ha^{-1} at stage of 21 days after planting.

Data Collected:

All yield and yield related data were recorded from the middle four rows of each experiment plot. The following agronomic traits were included in the investigation: Days to heading, days to maturity, grain filling period, plant height (cm), number of productive tillers, number of spikelets per spike, spike length (cm), number of kernels per spike, biomass yield (t ha^{-1}), grain yield at 12.5% moisture (t ha^{-1}), harvest index (%), thousand kernel weight (g) and hectoliter weight (kg hl^{-1})

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

S/N.	Genotype	Pedigree	Origin
1	ETBW 8252	SW895124*2/FASAN/3/ALTAR84/AESQ//2*OPATA/4/ARREHANE	CIMMYT
2	ETBW 8064	Line 1 Singh/ETBW4919	KARC
3	ETBW 8065	Line 1 Singh/ETBW4919	KARC
4	ETBW 8066	Line 1 Singh/ETBW4919	KARC
5	ETBW 8070	Line 1 Singh/ETBW4919	KARC
6	ETBW 8145	OPATA/RAYON//KAUZ/3/MILAN/DUCULA	ICARDA
7	ETBW 8163	SUDAN#3/SHUHA-6//FLAG-5	ICARDA
8	ETBW 8290	KACHU/KINDE	CIMMYT
9	ETBW 8310	ND643/2*WBLL1//ATTILA*2/PBW65/3/MUNAL	CIMMYT
10	ETBW 8336	PFAU/MILAN//ETBW 4921	ICARDA
11	ETBW 8342	N-AZRAQ-3/ETBW 4921	ICARDA
12	ETBW 8348	CMH82A1294/2*KAUZ//MUNIA/CHTO/3/MILAN/4/AMIR-2	CIMMYT
13	ETBW 8253	SOKOLL*2/ROLF07	CIMMYT
14	ETBW 8265	FRANCOLIN #1/4/2*BABAX/LR42//BABAX*2/3/KURUKU	CIMMYT
15	ETBW 8280	SNLG/3/EMB16/CBRD//CBRD/4/KA/NAC//TRCH	CIMMYT
16	ETBW 8283	KA/NAC//TRCH/3/DANPHE #1	CIMMYT
17	ETBW 8287	CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/HAR311	CIMMYT
18	ETBW 8292	KACHU/KIRITATI	CIMMYT
19	ETBW 8359	ALMAZ-11/3/PASTOR/FLORKWA-1//PASTOR	ICARDA
20	ETBW 8362	JAWAHIR-2//MILAN/DUCULA	CIMMYT
21	ETBW 8309	SUP152*2/KIRITATI	CIMMYT
22	ETBW 8206	FARIS-17//PFAU/MILAN	ICARDA
23	ETBW 8304	FRNCLN/4/WHEAR/KUKUNA/3/C80.1/3*BATAVIA//2*WBLL1	ICARDA
24	ETBW 8338	HUBARA-5/ETBW 4922	ICARDA
25	ETBW 8411	CHAM-4/MUBASHIIR-9	CIMMYT
26	ETBW 8445	HAAMA-16/MILAN	CIMMYT
27	ETBW 8441	TURACO/CHIL/6/SERI82/5/ALD'S/4/BB/GLL/CNO67/7C/3/KUZ/TI	ICARDA
28	ETBW 8451	FLAG-6/ICARDA-SRRL-6	ICARDA
29	Kingbird	THELIN # 2/TUKURU	KARC
30	Pavon 76	VCM/CNO/7C/3/KAL/BB	KARC

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

Statistical Data Analysis

All measured parameters including yield and yield related parameters were subjected to analysis of variance (ANOVA) following standard procedures using Proc Lattice and Proc GLM of SAS version 9.2 statistical software to estimate the prevailing variation among tested genotypes. Mean separation was carried out using Duncan's Multiple Range Test (DMRT) at 5 percent levels of significance depending on the significance of the analysis of variance for each traits.

Estimation of magnitude of variance component

The phenotypic and genotypic variation at each location was estimated according to the method suggested by Burton and De Vane (1953).

$$\sigma_g^2 = \frac{MS_g - M_e}{r}$$

For combined location $\sigma_g^2 = \frac{MS_{gl} - MS_e}{rl}$

$$\sigma_{gxe}^2 = \frac{MS_{gxe} - MS_e}{r}$$ (for genotype x location interaction)

Phenotypic variance $(\sigma_p^2) = \sigma_g^2 + \frac{\sigma_{gxe}^2}{l} + \frac{MSe}{rl}$

Where, σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

σ_{gxe}^2 = Genotypic by environment variance

MS_g = Mean square due to genotypes

M_e = Environmental variation (error mean square)

$\sigma^2_p = \sigma_g^2 + \sigma_e^2$

r = Number of replications

Coefficient of variation at phenotypic levels was estimated using the following formulae:

$$PCV = \frac{\sqrt{phenotypic\,variance}}{population\,mean\ for\ the\ character} \times 100$$

$$GCV = \frac{\sqrt{genotypic\,variance}}{population\,mean\ for\ the\ character} \times 100$$

Estimate of heritability and expected genetic advance

Heritability (H^2) in broad sense was computed for yield and yield related traits using the formula adopted from Allard (1960) as follow:

$$H^2 = [\sigma^2_g / \sigma^2_p] \times 100$$

Where: σ^2_g = genotypic variance

σ^2_p = phenotypic variance

σ^2_e = error variance

Genetic advance (GA) for each character was computed using the formula adopted from Johnson *et al*. (1955) and Allard (1960).

$GA = (k)(\sigma_p)(H^2)$

GA (as % of the mean) = $\frac{GA}{X} * 100$

Where, k = selection differential (k = 2.06 at 5% selection intensity)

σ_p = phenotypic standard deviation

H^2 = heritability (Broad sense)　　　　X = Grand mean

Results and discussions

Analysis of Variance

The relative efficiency of alpha lattice design for most of the character was greater and CV value less than RCBD, this indicating that alpha lattice has advantage in increasing experimental precision. Idrees and Khan (2009) and Alemu (2016) reported the same in that alpha lattice design was more efficient in reducing the experimental error and hence provided the efficient estimation of treatment effects. Test of homogeneity of error variance showed that the error mean squares were homogeneous for most traits except number of spiklet per spike and number of productive tiller. Hence, combined data analysis was done for homogeneous characters.

Combined ANOVA across locations were carried out for all characters of yield and yield related traits (Table 2). There was a highly significant difference at $P < 0.01$ for all traits among the test genotypes. This indicated the presence of sufficient genetic variability for yield and yield related traits among the genotypes tested. Similarly, variability among wheat genotypes for yield and yield related traits was reported by Alemu (2016), Kifle *et al.* (2016) and Tesfaye *et al.* (2016). However, Adhiena (2015) found non-significant differences among genotypes for plant height and number of tillers per plant.

Highly significant ($P < 0.01$) location effects were observed for all yield related traits except for grain yield. This might be due to differences in growth conditions exhibited at the two locations. The genotype x environment interaction showed highly significant ($P < 0.01$) differences among wheat genotypes for days to heading, days to maturity, biomass weight, grain yield, harvest index, and significant ($P < 0.05$) genotypic x environment interaction was found for grain filling period, plant height and number of kernel per spike (Table 2). Genotypes responded differently to varying environments for these traits. This suggested that the importance of assessment of genotypes under different environments in order to identify better performing genotypes that show better performance across locations. Hence analysis was done for individual location.

Performance of genotypes for yield and yield related traits

The combined analysis of range, mean and standard error of the mean values for 10 yield and yield related characters of 30 genotypes evaluated across locations were presented in Table 6. The detail mean performances of each genotypes for these characters based on combined over location analysis are presented in Table 3. Accordingly, the mean of days to heading, days to maturity and grain filling period ranged from 61 to 74, 125 to 137 and 51 to 61, respectively. Comparable ranges of results were also reported by Almaz (2017) for days to heading (54-69), days to mature (106-129) and grain filling period (49-64). However, the current results obtained here are in contrast with the wide variation reported by Obsa (2014) and Birhanu *et al.* (2016).

Plant height showed highly significant ($P < 0.01$) variability among the genotypes, which ranged from 77.9 to 97.2 cm (Table 3). The shortest plant height (77.9 cm) was observed from genotype ETBW 8163, while ETBW 8411 (97.2 cm) was the tallest genotype followed by ETBW 8283

(91.4 cm) and ETBW 8064 (91.2 cm), which is comparable to result reported by Obsa (2014). The magnitude of variability for spike length ranged from 6.4 to 9.1 cm with mean value of 7.9 cm. Maximum (9.1 cm) spike length was measured for genotype ETBW 8336, while minimum (6.4 cm) was from ETBW 8445.

Table 20. Combined analysis of yield and yield related traits in bread wheat genotypes tested at Sinana and Agarfa, Southeastern Ethiopia in 2017

Traits	Source of Variation						Mean	CV
	Loc [1]	Rep (Loc) [4]	Block (Loc x Rep)[30]	Genotype [29]	Genotype x Loc [29]	Error [86]		
DH	45.0**	8.98**	2.70*	56.81**	5.75**	1.45	68.72	1.75
DM	10672.2**	11.56*	7.04^{ns}	72.42**	10.48**	4.48	130.15	1.63
Gfp	12103.2**	5.77^{ns}	7.88*	45.54**	7.12*	4.36	61.43	3.40
Plh	932.07**	31.44*	31.71**	86.64**	18.00*	10.44	86.24	3.75
SPL	78.83**	0.91*	0.71**	2.30**	0.33^{ns}	0.34	7.93	7.32
NKPS	3853.09**	91.43**	15.64^{ns}	59.65**	18.21*	9.86	36.94	8.50
BMW	13.61**	7.06**	1.59^{ns}	17.77**	3.68**	1.24	11.46	9.73
GY	0.15^{ns}	0.11^{ns}	0.096^{ns}	5.25**	0.44**	2.44	3.49	10.38
HI	69.44*	17.13^{ns}	16.26^{ns}	187.18**	30.83**	12.83	30.02	11.93
Hlw	208.87**	10.13^{ns}	12.17^{ns}	64.99**	13.47^{ns}	10.85	79.18	4.16

DH = days to heading, DM = days to maturity, Gfp = grain filling period, Plh = plant height, SPL = spike length in centimeter, NKPS = number of kernel per spike, BMW = biomass weight ton per hectare, GY = grain yield in ton per hectare, HI = harvest index in percentage, Hlw = hectoliter weight, Loc = location, Rep = replication, Block = block with in replication, Error = error mean square, ** = highly significant at $P < 0.01$,* = significant at $P < 0.05$, ns = no significant difference, Numbers in square bracket indicates degree of freedom.

Combined analysis also showed highly significant variability among genotypes for grain yield t ha^{-1}, which ranged from 0.7 to 5.1 t ha^{-1} with the mean value of 3.5 t ha^{-1}. ETBW 8338 (5.1 t ha^{-1}) gave the highest overall grain yield, followed by ETBW 8304 (4.8 t ha^{-1}) and ETBW 8342 (4.7 t ha^{-1}). On the other hand genotype ETBW 8163 gave the lowest (0.7 t ha^{-1}) grain yield followed by genotype ETBW 8070 (1.37 t ha^{-1}) and genotype ETBW 8362 (1.67 t ha^{-1}) (Table 3). Highly significant difference ($P < 0.01$) was observed among the test genotypes for biomass weight per hectare with the values that ranged from 7.0 t ha^{-1} (ETBW 8163) to 14.8 t ha^{-1} (ETBW 8338) and mean value of 11.5 t ha^{-1}. The highest biomass weight was obtained from genotype ETBW 8338 followed by genotypes ETBW 8253 (14.4 t ha^{-1}) and ETBW 8283 (14.1 t ha^{-1}), whereas the second and third minimum was obtained from genotype ETBW 8070 and ETBW 8309 7.1 t ha^{-1} and 8.7 t ha^{-1}, respectively. Harvest index exhibited highly significant difference ($P < 0.01$) among genotypes with the value ranging from 9.2% (ETBW 8163) to 37.2% (ETBW 8304) with mean of 30.0%. Combined analysis over locations for hectoliter weight ranged from 66.8 for genotype ETBW 8163 to 83.5 for genotype ETBW 8441 with the mean value of 79.2.

Table 3. Mean performance of 30 bread wheat genotypes for different parameters across locations at Sinana and Agarafa, Southeastern Ethiopia in 2017

Treatment	DH	DM	Gfp	Plh	SPL	NKPS	BMW	GY	HI	HLw
ETBW 8280	70^{c-g}	130^{e-g}	60^{f-h}	85.2^{e-h}	8.8^{a-c}	38.5^{c-e}	11.8^{d-h}	3.7^{g-i}	31.5^{b-d}	81.2^{ab}
ETBW 8310	72^{bc}	135^{a-c}	63^{b-f}	83.9^{g-j}	9.1^{a}	35.2^{e-k}	12.5^{c-f}	3.4^{h}	27.4^{d-f}	75.1^{e-h}
ETBW 8064	70^{e-f}	127^{i-l}	57^{ij}	91.2^{bc}	8.6^{a-d}	35.3^{e-k}	10.0^{i-m}	2.8^{kl}	27.6^{d-f}	71.2^{hi}
ETBW 8252	73^{ab}	135^{a-c}	63^{b-f}	84.7^{e-h}	9.0^{a}	32.6^{kl}	12.6^{c-e}	3.3^{ij}	25.9^{ef}	76.3^{c-g}
ETBW 8163	74^{a}	130^{f-h}	56^{j}	77.9^{l}	7.4^{g-i}	28.9^{l}	7.0^{n}	0.7^{o}	9.2^{h}	73.0^{g-i}
ETBW 8451	71^{b-e}	127^{h-l}	56^{j}	82.7^{h-k}	7.4^{g-i}	35.6^{e-k}	11.0^{f-j}	2.9^{jk}	26.7^{ef}	77.9^{a-f}
ETBW 8309	69^{h-j}	133^{b-d}	65^{a-c}	86.2^{d-h}	7.6^{f-i}	34.5^{f-k}	8.7^{m}	2.4^{l}	28.9^{c-f}	75.5^{d-h}
Kingbird	61^{n}	125^{l}	64^{a-d}	86.0^{d-h}	6.9^{ij}	39.1^{b-e}	9.2^{lm}	3.0^{jk}	33.6^{a-c}	74.3^{f-i}
ETBW 8362	66^{kl}	127^{i-l}	60^{f-h}	87.1^{b-h}	7.6^{f-i}	36.3^{d-k}	9.3^{k-m}	1.6^{mn}	17.6^{g}	70.7^{i}
ETBW 8336	72^{b-d}	136^{ab}	64^{a-c}	86.5^{d-h}	9.1^{a}	35.9^{-k}	13.1^{b-d}	3.5^{g-i}	27.1^{d-f}	78.8^{a-f}
ETBW 8253	73^{ab}	136^{ab}	63^{a-f}	87.9^{b-g}	7.9^{d-h}	38.1^{b-g}	14.4^{ab}	4.6^{bc}	31.6^{cd}	80.0^{a-d}
ETBW 8265	73^{ab}	137^{a}	64^{a-c}	83.6^{g-j}	7.6^{f-i}	37.5^{d-i}	13.3^{b-d}	4.0^{d-g}	30.5^{b-e}	79.6^{a-e}
ETBW 8287	71^{b-f}	127^{h-l}	56^{j}	89.2^{b-e}	7.4^{g-i}	41.1^{bc}	12.2^{d-g}	4.0^{d-g}	33.0^{a-c}	80.4^{a-c}
ETBW 8342	71^{b-f}	129^{f-i}	58^{h-j}	87.4^{b-h}	7.3^{g-i}	35.6^{d-k}	13.3^{b-d}	4.7^{ab}	35.6^{ab}	79.3^{a-e}
ETBW 8445	70^{d-h}	127^{h-l}	57^{ij}	78.8^{kl}	6.4^{j}	33.1^{i-k}	12.2^{d-g}	4.0^{d-g}	33.2^{a-c}	82.1^{a}
ETBW 8065	68^{h-j}	133^{c-e}	64^{a-c}	83.7^{g-j}	8.6^{a-d}	38.4^{b-f}	9.7^{j-m}	2.4^{l}	25.3^{f}	76.3^{d-g}
ETBW 8348	62^{n}	125^{kl}	64^{a-d}	90.7^{b-d}	8.1^{b-g}	42.1^{b}	12.1^{d-h}	4.2^{c-f}	34.9^{ab}	78.3^{a-f}
ETBW 8145	69^{g-j}	131^{d-f}	62^{c-g}	88.1^{b-g}	8.9^{ab}	39.1^{b-e}	11.5^{e-i}	3.9^{e-g}	34.4^{ab}	79.3^{a-e}
Pavon-76	68^{jk}	126^{kl}	58^{h-j}	86.5^{c-g}	8.0^{c-h}	37.9^{c-h}	10.0^{i-m}	2.0^{m}	19.9^{g}	79.3^{a-e}
ETBW 8206	71^{c-g}	135^{a-c}	65^{a-c}	83.3^{g-j}	7.2^{hi}	41.1^{bc}	12.5^{c-e}	4.3^{b-e}	34.6^{ab}	79.1^{a-e}
ETBW 8411	63^{m}	126^{j-l}	63^{a-e}	97.2^{a}	8.0^{c-h}	35.6^{d-k}	13.0^{b-e}	4.4^{b-d}	34.9^{ab}	79.3^{a-f}
ETBW 8292	69^{g-j}	129^{f-i}	60^{e-h}	89.5^{b-e}	8.5^{a-e}	46.9^{a}	11.9^{d-h}	3.7^{gh}	31.7^{b-d}	81.2^{ab}
ETBW 8066	66^{l}	129^{f-i}	63^{a-e}	91.0^{bc}	7.7^{e-i}	37.6^{c-h}	12.6^{c-e}	4.4^{b-e}	34.8^{ab}	78.7^{a-f}
ETBW 8359	66^{l}	126^{kl}	60^{e-h}	79.9^{i-l}	7.7^{e-i}	33.6^{g-k}	9.7^{l-m}	3.3^{ij}	34.2^{ab}	75.6^{c-h}
ETBW 8070	68^{ij}	128^{g-k}	60^{e-h}	84.3f-i	7.3^{g-i}	33.0^{jk}	7.1^{n}	1.3^{n}	18.4^{g}	77.1^{b-g}
ETBW 8283	70^{e-i}	135^{a-c}	66^{ab}	91.4^{b}	8.0^{c-h}	37.3^{c-j}	14.1^{a-c}	4.6^{bc}	32.6^{a-c}	81.7^{ab}
ETBW 8290	61^{n}	125^{l}	64^{a-c}	88.8^{b-f}	8.4^{a-f}	40.1^{b-d}	10.8^{g-k}	3.9^{d-g}	36.8^{a}	81.2^{ab}
ETBW 8441	70^{f-j}	130^{e-g}	61^{d-h}	79.4^{j-l}	8.1^{c-h}	33.2^{h-k}	10.6^{h-k}	3.8^{f-h}	37.0^{a}	81.6^{ab}
ETBW 8304	69^{g-j}	132^{d-f}	63^{b-g}	90.2^{b-d}	8.8^{a-c}	33.6^{g-k}	12.9^{b-e}	4.8^{ba}	37.2^{a}	79.1^{a-f}
ETBW 8338	69^{h-j}	135^{a-c}	66^{a}	85.0^{e-h}	6.9^{ij}	41.3^{b}	14.8^{a}	5.1^{a}	34.7^{ab}	80.1^{a-d}
Mean	68.7	130.2	61.4	86.2	7.9	36.9	11.5	3.49	30.0	78.1
CV	1.95	1.67	3.68	4.02	7.81	8.73	10.25	10.03	12.1	3.15

DH = days to heading, DM = days to maturity, Gfp = grain filling period, Plh = plant height, SPL = spike length in centimeter, NKPS = number of kernel per spike, BMW = biomass weight ton per hectare, GY = grain yield in ton per hectare, HI= harvest index in percentage.

Phenotypic and genotypic variance of yield and yield related traits

The amounts of genotypic and phenotypic variability that exist in a species are very important in breeding to select better varieties and initiating a breeding program. Genotypic and phenotypic coefficients of variation are used to measure the variability that exists in a given genotypes. Estimated genotypic coefficient of variability (GCV) and phenotypic coefficient of variability (PCV), for combined locations are presented in Table 4.

The genotypic coefficient of variance (GCV) value for yield and yield related traits for combined location ranged from 2.6% for days to maturity to 19.6% for grain yield whereas the PCV values ranged from 2.8% for days to maturity to 27.1% for grain yield. Phenotypic coefficient of variance was generally higher than GCV for all traits studied at both location and combined locations, though the magnitude of the differences were small for most of the traits, indicating that the environmental effect on the expression of most characters was minimum. Navin *et al.* (2014), Gezahegn *et al.* (2015) and Alemu (2016) reported similar result for all studied character. According to Deshmukh *et al.* (1986), GCV and PCV can be categorized as high (>20%), moderate (10-20%) and low (<10%). As per this category, for combined location, grain yield had high PCV (27.1%). Moderate GCV was observed for biomass weight (14.5%), grain yield (19.6%) and harvest index (15.2%). Phenotypic coefficient of variance moderate for biomass weight (16.0%) and Harvest index (16.9%). Low GCV and PCV was observed for days to heading (4.4% and 4.6%), days to mature (2.6% and 2.8%), grain filling period (4.3% and 4.6%), plant height (4.1% and 4.6%), spike length (7.2% and 7.8%), number of kernel per spike (7.8% and 9.1%) and hectoliter (3.8% and 4.2%). The result agreed with the finding of Arati *et al.* (2015), Gezahegn *et al.* (2015) and Alemu (2016).

Estimates of Heritability in Broad Sense

Heritability estimates in broad sense (H^2) for yield and yield related traits are presented in Table 4. Pramoda and Gangaprasad (2007) categorized H^2 estimates as low (< 40%), medium (40-59%), moderately high (60-79%), and very high (≥ 80). For combined analysis estimated heritability values ranged from 52.3% for grain yield to 90.6% for days to heading. Very high heritability in broad sense was observed for days to heading (90.6%) followed by days to mature (86.6%), grain filling period (85.3%), spike length (84.8%), biomass weight (81.8%), plant height (80.9%), harvest index (80.1%) and hectoliter (80.1%). High heritability was obtained for number of kernel and medium heritability for grain yield. Very high heritability in broad implies the variation observed was mainly under genetic control and less influenced by the environment and the possibility of progress from selection. The obtained results agreed with results reported by Tesfaye *et al.* (2016), Berhanu *et al.* (2017) and Rajput (2018).

Estimates of Genetic Advance for Yield and Yield Related Traits

Genetic advance as percent mean (GAM) was categorized as low (0-10%), moderate (10-20%) and high 20% and above according to Johnson *et al.,* (1955). Accordingly, combined location GAM ranged from 0.9% spike length to 15.9% for harvest index (Table 4). Low GAM was observed for days to heading (2.9%), days to mature (1.9%), grain filling period (2.5%), plant height (3.4%), spike length (0.9%), number of kernel per spike (5.4%), biomass weight (5.5%), grain yield (3.8%) and hectoliter weight (2.6%) (Table 4). This finding agrees with the result of Alemu (2016) who reported low genetic advance as percent of mean for the characters days to mature, plant height, number of kernel per spike, grain yield and hectoliter weight. However, high GAM values were reported by Birhanu *et al.* (2016), Kifle *et al.* (2016) and Almaz (2017) for biomass, grain yield and total number of tillers per plant which contradict with the present finding. Johnson *et al.* (1955) suggested the importance of considering both the genetic advance and heritability of traits simultaneously rather than considering them separately in determining how much progress can be made through selection. In this study, for combined location high heritability accompanied with low genetic advance as percent of mean was observed for days to heading, days to mature, grain filling period, plant height, spike length, biomass weight and hectoliter weight (Table 6 and 7). This may be because of predominance of non-additive gene action in the expression of this character. The high heritability of these traits was due to favorable influence of environment rather than genotypic and selection for these traits may not be rewarding.

Summary and Recommendations

Thirty bread wheat genotypes were grown at Sinana and Agarfa to generate information on advanced bread wheat lines by assessing the extent of genetic variability. Combined over locations ANOVA was carried out for yield and yield related traits. There were highly significant differences among genotypes for all traits. Highly significant location effects at $P < 0.01$ were observed for yield and yield related except for harvest index which showed significant effect at $P < 0.05$ and grain yield non-significant location effect. This indicates the presence of variability for these characters among the tested genotypes and this would provide ample scope for selecting superior genotypes for further improvement of the traits in bread wheat. In combined analysis, grain yield had high PCV and moderate GCV was observed for biomass weight, grain yield and harvest index. Phenotypic coefficient of variance (PCV) was moderate for biomass weight and harvest index. Low GCV and PCV was observed for days to heading, days to mature, grain filling period, plant height, spike length, number of kernel per spike and hectoliter.The difference between GCV and PCV in this study were very small, implying the influence of environment on these characters were small.

Combined result over locations analysis of heritability estimates in broad sense (H^2) for yield and yield related traits revealed that, there was very high heritability estimate observed for days to heading, days to mature, grain filling period, spike length, biomass weight, plant height, harvest index and hectoliter. However, low genetic advance as percent of mean was observed for days to heading, days to mature, grain filling period, plant height, spike length, biomass weight and hectoliter weight. Finally, the presence of variability among the genotypes, performance of heritability and GAM in the tested traits of the genotypes confirmed possibility to increase wheat productivity. Hence, selection and hybridization on those genotypes can be recommended for farther yield improvement of bread wheat.

Table 4. Estimates of mean, standard error, range, genotypic, phenotypic coefficient of variability, heritability in broad sense, genetic advance and genetic advance as percent of mean of yield and yield related traits across locations, in 2017

Character	Mean ± SE	Range		σ^2g	σ^2ge	σ^2p	GCV (%)	PCV (%)	H^2	GA	GAM
		Min.	Max.								
DH	68.7 ± 0.28	61.0	74.2	9.2	1.4	10.2	4.4	4.6	90.6	2.0	2.9
DM	130.2 ± 0.67	125.0	137.0	11.3	2.0	13.1	2.6	2.8	86.6	2.5	1.9
Gfp	61.4 ± 0.68	55.5	66.0	6.9	0.9	8.1	4.3	4.6	85.3	1.5	2.5
Plh	86.2 ± 0.45	77.9	97.2	12.7	2.5	15.7	4.1	4.6	80.9	2.9	3.4
SPL	7.9 ± 0.09	6.4	9.1	0.3	0.003	0.4	7.2	7.8	84.8	0.1	0.9
NKPS	36.9 ± 0.51	28.9	46.9	8.3	2.8	11.3	7.8	9.1	73.2	2.0	5.4
BMW	11.5 ± 0.18	7.0	14.8	2.8	0.8	3.4	14.5	16.0	81.8	0.6	5.5
GY	3.5 ± 0.09	0.7	5.1	0.5	0.04	0.9	19.6	27.1	52.3	0.1	3.8
HI	30.0 ± 0.57	9.2	37.2	20.7	6.0	25.9	15.2	16.9	80.1	4.8	15.9
Hlw	79.2 ± 0.36	66.8	83.5	9.0	0.9	11.3	3.8	4.2	80.1	2.1	2.6

[a] DH = days to heading, DM = days to maturity, Gfp = grain filling period, Plh = plant height, Npt = number of productive tiller, NSPS = number of spiklet per spike, SPL = spike length in centimeter, NKPS = number of kernel per spike, BMW = biomass weight ton per hectare, GY = grain yield in ton per hectare, HI = harvest index in percentage, TKW= thousand kernel weight, Hlw = hectoliter weight, SE = standard error, σ^2p = phenotypic variance, σ^2g = genotypic variance, GCV = genotypic coefficient of variation, PCV = phenotypic coefficient of variation, H^2 = heritability in broad sense, GA = genetic advance and GAM = genetic advance as percent of mean.

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Adapted Market Type White Haricot Bean Varieties in West Hararghe

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Abstract

Haricot bean (Phaseolus vulgares L.) is the most important of the food legumes grown in tropics and sub-tropics.The objective of study was to select and recommend the best adapted market type white haricot bean varieties in the study areas. A field experiment was conducted at Mechara Agricultural Research Center on station and at Busoyitu FTC of Habro district in West Hararghe zone and at Fedis Agricultural Research Center on station in East Hararghe zone. Six improved Haricot bean varieties viz; Chercher, Awash-2, Chore, Nezarath-2, SAB-736 and LEHODE varieties and one standard check (Awash-1) variety were used under rain fed condition in 2017cropping season. The experiment was carried out using a randomized complete block design in three replications. The findings revealed that, there were significant variations ($P \leq 0.05$)among the varieties for all the yield and yield components except days to flowering and disease reaction at Busoyitu site. At Mechara, the result showed that there was highly significant difference among varieties for days to flowering, plant height, days to maturity, pod per plant, seed per pod and hundred seed weight, while at Fedis significant difference was observed on pod per plant whereas non significant difference was obtained on grain yield and number of seed per pod. The combined mean revealed that grainyield, pod per plant and seed per pod were significantly ($P \leq 0.05$) different among evaluated varieties across three locations. Awash-2 was superior in grain yield (2.2ton/ha) followed by variety Chercher(2ton/ha) and Chore (2ton/ha). The combined mean grain yield of Awash-2, Chercher and Chore varieties had 16%, 7%and 6% yield advantages over the standard check (Awash-1), respectively. On the other hand, lowest grain yield was recorded by Nezarath-2(1.6 ton ha^{-1}). GGE bi-plot analysis shows that Awash-2 and chore identified as ideal varieties in terms of yielding ability and stability. Chore had only 7% yield advantage over the check less than 10% yield advantage required for the new variety to be accepted. Therefore, Variety Awash-2 is recommended for the study area and similar agro-ecologies.

Keywords: Adaptation trial, Common Bean, Phenological Parameters, improved Varieties, GGE bi-plot analysis

Introduction

Haricot bean (*Phaseolus vulgares* L.) is the most important of the food legumes grown in tropics and sub-tropics. The crop 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 varieties). It is one of the fast expanding legume crops that provide an essential part of the daily diet and foreign export earnings for the country (Girma, 2009). It is cultivated primarily for dry seeds, green pods (as snap beans), and green-shelled seed. Beans offer a low cost alternative to beef and milk because bean seed is rich in protein, iron, fibers, and complex carbohydrates (Mwale*et al.,* 2008). In Ethiopia, haricot bean have been cultivated for their grain which have high protein content (around 22% or higher, on dry matter bases (CIAT, 2002). Wide ranges of haricot bean types are grown in Ethiopia including mottled, red, white and black varieties (Ali et al., 2003).The most commercial varieties are pure red and pure white color beans and these are becoming the most commonly grown types with increasing market demand (Ferris and Kaganzi, 2008). The national average productivity of haricot bean is about 16.58 tons ha^{-1} (CSA, 2017). In Ethiopia, haricot bean is consumed as *Nifro*, *Shirowat*, Soup and Samusa. It is important export crop, especially the navy beans from the Central Rift Valley region and some parts of east and west Hararghe high lands.

Haricot bean is one of the major grain legumes widely cultivated and grown as food and cash crop by smallholder farmers in Hararghe. In addition, beans are important crop in farming systems and it is intercropped with sorghum, maize, coffee and chat in Hararghe. The zonal average productivity of haricot bean is about 1.6 tons ha^{-1} (CSA, 2016).The poor yield of adapted varieties and un recommended management practice applied for its production are the main causes of yield reduction in the target area.Therefore, there is a need to test the adaptability of the improved common bean varieties to the target areas and improve productivity and production in Hararghe. Therefore, this activity was initiated with the objective to select and recommend the best adapted market type white haricot bean varieties in the study area.

Materials and Methods

Description of the studyareas

The field experiment were conducted in west Hararghe zone at Mechara Agricultural Research Center (McARC) on station and Busoytu FTC in Habro district and in east Hararghe zone at Fedis Agricultural Research Center on station in 2017 cropping season. McARC is found at 430 km southeast of Addis Ababa with geographical location of $8^0$36'N latitude and longitude 40^0 18'E at altitude of 1760 m.a.s.l,. Its annual rainfall is 871 mm and has average annual minimum and maximum temperatures of 8.9 and 23.4^{o}C, respectively and Sandy loam soil type (McARC, 2010). Habro district is found in West Hararghe zone of Oromia regional stae. It has an altitude range from 1600-2400 m.a.s.l. The mean annual rainfall of the district is 1010 mm and the annual temperature ranges from 5-32^{o}C (HDoANRO, 2016). The rainfall pattern in the area is bi-modal with the larger amount of rainfall occurring during the main rainy season between June to September (Kiremt) and the short rainy season stretching from March to June (Belg). The highest rainfall is received in August. The agro ecology of the district comprises highland (19%), midaltitude (50%) and lowland (31%) areas (Mengistu*et al*., 2016). It occupies a total area of 725 km^2 i.e. about 4.2% of the zonal total area.

Fadis Agricultural Research Center (FARC) is located in Fedis district of east Haraghe zone. Fadis town is located at 539 km east of Addis Ababa and 24km to the south of Harar town, which is the capital city of East Hararghe zone. The altitude of the district ranges from 1,050 to 2,118 m.a.s.l. The livelihood of the population is 93.8% agro-pastoralist and the remaining 6.2% are urban dwellers. The district is both Meher and Belg dependent. Both rainy seasons are the ones which are very crucial in determining the production, water and pasture availability. Normally, Belg rains go from April to June and Meher rains go from May to August. Lack of improved varieties and agronomic practices, soil degradation, erratic rainfall and farmland fragmentation contribute to low crop productivity in the area.

Experimental Materials and Design

Six released common bean viz. Chercher, Awash-2, Chore, Nezarath-2, SAB-736, LEHODE and one standard check (Awash-1)varieties were used for these study. The varieties were selected based on their average yield performance and agro ecological adaptation. There were obtained from Melkasa and Sirinka Agricultural Research Centers and Haramaya University. The experiment was laid out in RCBD with 3 replications and the plot size was 2.4m X 2.5m. The spacing was 0.5m between plots and 1 m between adjacent blocks. Each variety was sown in row using recommended seed rate. Fertilizer rate 100 kgha^1 DAP was applied. All other field management activities were carried out as necessary.

Data collected

Phenological Parameters: phonological parameters such as days to flowering and days to maturity were recorded. Days to flowering was recorded by counting the number of days after emergence when 50% of the plants per plot had the first open flower. Days to maturity was recorded when 90% of pods matured per plot.

Grain Yield and Yield Components: Four central rows were harvested for determination of grain yield. Grain yield was adjusted to 12.5% moisture content. Five plants were randomly selected from the four central rows to determine yield and yield components, which consisted of number of pods per plant and number of seeds per pod. Pod number per plant was determined by counting pods of the five randomly selected plants.While number of seeds per pod was recorded by counting the total number of seeds in a pod from five randomly selected plants. Seed weight was determined by taking a random sample of 100 seeds.

Data Analysis

R computer softwarewas used to analyze the data for each location and combined analysis of variance over locations.GGE bi plot analysis was computed using the GenStat software. Means were separated using Fisher’s Protected Least Significant Difference (LSD) test.

Results and discussions

There was highly significant difference among varieties for all traits except days to 50%flowering and disease reaction at Busoyitu site (Table1). Superior grain yield (3.4ton ha-1) was obtained from Awash-2 followed by variety Chercher (3.1ton ha-^{1}) among tested varieties. On the other hand, lowest grain yield was recorded by Nezarath-2 (2.3ton ha^{-1}). The mean grain yields of Awash-2 and Chercher varieties showed 26% and 15% yield advantage over standard check (Awash-1), respectively. These results were confirms with the findings of Habte 2018) and Biru (2014).

At Mechara on station, the analysis of variance revealed that there was highly significant difference among varieties for days to flowering, plant height, days to maturity, pod per plant, seed per pod and hundred seed weight. Statistically non significant difference was observed on grain yield and disease reaction among tested varieties. Relatively higher yields were recorded in Awash-2 (2.22ton ha^{-1}) and Chore (2.26ton ha^{-1}) followed by variety Chercher (2.10ton ha–1) among the tested varieties (Table2).

At Fedis, significant variation was observed on pod per plant whereas there was non-significant difference in grain yield and number of seed per pod between varieties (Table 3). Low yield was recorded for all the varieties at Fadis compared to the other two sites (Busoytu and Mechara). This might be due to moisture stress occurred at grain filling stage at Fadis. Water stress during the flowering and grain filling periods reduced seed yield and seed weight and accelerated maturity of dry bean. Szilagyi (2003). Molin a*et al. (*2001) reported that water stress reduced grain yield of common bean cultivars, by approximately 50%. From the combined mean result, there was significant variations ($P<0.05$) observed among the varieties for all the yield and yield components across locations (Table 4).This indicated that the environments had different impact on the yield performance of the genotypes while the genotypes had different performance in the testing environments. Similar result was reported by Habtamu (2018) and Tekle (2014). Mean comparison for the tested varieties indicated that maximum grain yield was obtained from Awash-2 (2.2ton/ha) followed by Chercher (2ton/ha) and Chore (2.14ton/ha). In contrast, the lowest grain yield was recorded from variety Nezarath-2(1.6ton ha^{-1}). The combined mean grain yield of Awash-2 and Chercher varieties were 16% and7% yield advantage over standard check (Awash-1) respectively. Variety Chercher had the highest mean number of pod per plant (35) and seed per pod (7).

GGE bi-plot analysis Result

Genotypes obtained in the concentric (central circle) are considered as stable genotypes. Variety stability and mean yield are equally important (Ezatollah*et al.*, 2011).Variety Awash-2 which fell in to the center of concentric circle was ideal variety interims of yielding ability and stability when compared to the other varieties. Chore was located on the next concentric circle and was desirable variety.

Table1:Mean grain yield and agronomic traits of haricot bean varieties at Busoytu FTC in 2017cropping season

Variety	**DF**	**DM**	**PLH(cm)**	**LCBB**	**PCBB**	**IPS**	**NPPP**	**NSPP**	**HSW(g)**	**GYD**	**Yield adv. (%)**
Awash-2	39.00	93.00ab	108.46abc	1.66	1.00	1.00b	36.66abc	6.00a	23.21cd	34.00a	26.00
Chercher	40.33	93.66ab	95.13c	1.33	1.33	1.66ab	51.66a	6.00a	25.27c	31.00ab	14.97
SAB-736	35.33	84.00d	42.80d	2.00	1.33	1.33ab	26.00bc	6.33a	43.40b	28.58abc	5.93
Chore	41.33	95.33ab	97.60bc	1.33	1.00	1.66ab	48.00a	6.66a	21.16de	28.00abc	3.78
Awash-1	39.00	88.00cd	102.00bc	1.66	2.33	1.00b	44.00a	6.66a	21.15de	26.98bc	
LEHODE	38.66	97.66a	120.80a	1.00	1.00	1.00b	20.66c	5.00b	51.14a	25.83bc	
Nezarath-2	40.33	91.33bc	111.40ab	2.33	1.66	2.00a	39.66ab	6.00a	20.40e	23.32c	
Mean	**39.14**	**91.85**	**96.88**	**1.61**	**1.38**	**1.38**	**38.09**	**6.09**	**29.39**	**28.23**	
LSD (0.05)	**ns**	**4.76**	**15.79**	**ns**	**ns**	**0.67**	**16.39**	**0.67**	**2.1**	**6.67**	
CV%	**5.16**	**2.94**	**9.24**	**21.09**	**24.73**	**22.89**	**24.39**	**6.31**	**4.06**	**13.4**	

DF=days to flowering ,Days to maturity, PH= plant height (cm), LCBB=Leaf Common Bacteria score(1-5), PCBB= Pod Common Bacteria Blight score(1-5),IPS=Pest Score (1-5), NPPP= Number of Pod Per Plant, NSPP=Number of Seed Per Pod, HSW=Hundred Seed Weight (g) and GYD= Grain Yield(ton/ha)

Table2: Mean grain yield and agronomic traits of varieties at Mechara on station in 2017 cropping season

Variety	**DF**	**DM**	**PLH**	**LCBB**	**PCBB**	**IPS**	**NPP**	**NSP**	**HSW**	**GYD**	**Yield adv.%**
Chore	44.33a	86.00a	76.93c	1.00b	1.00b	1.00	37.00a	6.33a	20.76d	22.57	8.10
Awash-2	44.00a	84.00ab	84.93bc	1.66ab	1.33ab	1.33	22.66ab	5.33bc	21.10cd	22.20	6.32
Awash-1	43.66a	82.66b	77.33c	2.00ab	2.00a	1.66	30.33ab	6.00ab	19.23d	20.88	
Chercher	43.66a	84.66ab	72.13c	1.00b	1.00b	1.33	36.33a	5.66abc	23.13c	18.74	
SAB-736	41.33b	77.00d	35.53d	2.66a	1.33ab	1.33	17.00b	5.00c	43.03b	18.44	
Nezarath-2	44.00a	84.00ab	95.60ab	1.66ab	2.00a	2.00	33.00a	6.00ab	19.33d	17.57	
LEHODE	41.66b	79.33c	102.13a	1.66ab	1.00ab	1.33	16.66b	5.00c	48.00a	15.49	
Mean	**43.23**	**82.52**	**77.8**	**1.66**	**1.47**	**1.42**	**27.57**	**5.61**	**27.8**	**19.41**	
LSD (0.05)	**1.49**	**2.05**	**17.09**	**1.02**	**ns**	**ns**	**14.67**	**0.89**	**2.15**	**ns**	
CV%	**1.95**	**1.41**	**12.45**	**30.83**	**2.23**	**27.1**	**25.17**	**9.04**	**4.39**	**27.59**	

DF=days to flowering ,Days to maturity, PH= plant height (cm), LCBB=Leaf Common Bacteria score(1-5), PCBB= Pod Common Bacteria Blight score(1-5),IPS=Pest Score (1-5), NPPP= Number of Pod Per Plant, NSPP=Number of Seed Per Pod, HSW=Hundred Seed Weight (g) and GYD= Grain Yield(ton/ha)

Table3:Mean grain yield and agronomic traits of haricot bean varieties at Fedis in 2017cropping season

Variety	PPP	SPP	Grain yield (qt/ha)	Yield adv. (%)e
Chercher	17.44abc	5.11ab	11.25	23.35
Awash-2	20.67abc	5ab	9.51	4.27
Chore	15.33bc	4.77ab	9.82	7.67
Awash-1	22.22ab	5.22ab	9.12	
SAB-736	13.89c	4.44b	9.45	
LEHODE	17.5abc	5.66a	9.4	
Nezarath-2	24.78a	5.66a	8.21	
Mean	**18.83**	**5.12**	**9.53**	
LSD(0.05)	**7.84**	**ns**	**ns**	
CV%	**23.6**	**11.17**	**28.83**	

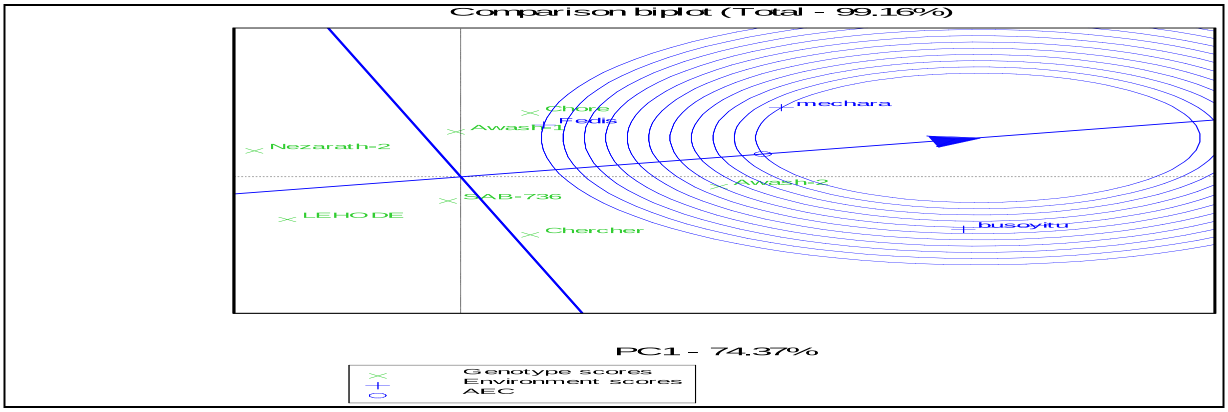
NPPP= Number of Pod Per Plant, NSPP=Number of Seed Per Pod, HSW=Hundred Seed Weight (g)

Table 4:The Combined means of varieties grain yield and yield components over three locations (Mechara, Busoyitu and Fedis) in 2017 cropping season

Variety	PPP	SPP	Grain yield (qt/ha)	Yieldadv. (%)e
Chercher	27bc	5c	2.20a	16
Awash-2	35a	7abc	2.034ab	7.10
Chore	33ab	6a	2.014ab	6.00
Awash-1	32ab	6a	1.90ab	
SAB-736	19cd	5c	1.90ab	
LEHODE	18d	5c	1.70b	
Nezarath-2	32.48ab	6ab	1.64b	
Mean	**28**	**6**	**1.91**	
LSD (0.05)	**7.80**	**0.47**	**0.40**	
CV%	29.22	8.9	22.26	

NPPP= Number of Pod per Plant, NSPP=Number of Seed per Pod, HSW=Hundred Seed Weight (g)

The environment obtained in the central circle is considered as ideal environments. Therefore, Mechara which fell in to the center of concentric circle was ideal environment interims of stability when compared to the other location. Busoyitu was located on the next concentric circle and was desirable location.



Conclusions and Recommendations

In this study, there were significant variations observed among the common bean varieties for yield and yield component parameters at single location and across locations. Grain yield was an important trait to be considered for variety selection to address the objective of the activity. GGE bi-plot analysis identified that Awash-2 and chore as ideal varieties interims of yielding ability and stability. The two varieties showed better performance for most of the studied traits including grain yield. But variety Chore's yield advantage was less than the minimum requirement (10%) over the standard check (Awash-1). Therefore, Awash-2 variety was recommended for the study area and similar agro-ecologies.

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Evaluation of Improved Maize (Zea mays L.) Varieties in the High Lands of Western Oromia, Ethiopia

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Abstract

The experiment was conducted on five improved maize varieties against local check at Belle and Badesso research sub-sites of Haro-Sabu Agricultural Research Center (HSARC) for two consecutive (2017-2018) years to identify and recommend high yielding, insect pest tolerant, and stable varieties for Kellem and West Wollega zones and similar agro-ecologies of Western Oromia. The seeds were planted in Randomized Completed Block Design (RCBD) with three replications in the net plot size of 9 m^2 using four harvestable rows at the spacing of 0.75mx 0.3m. Agronomic traits viz. days to flowering, days to silking, days to maturity, plant height, kernel per ear, ear position,grain yield, thousand kernel weight and disease reaction were collected and analyzed. Analysis of variance revealed significant difference among varieties for most observed traits. Significant difference was attained over years, locations and interaction. Jibat and Argane recorded medium days to heading, days to maturity, plant heat and ear height over locations and years. The genotype by environment interactions were significant for the studied traits. AMMI stability Value and GGE bi-plot analysis revealed that Jibat and Wenchi were stable and more yielder varieties and recommended int he zonesand with similar agro-ecologies.

Key words: Adaptability, maize (Zea mays L). Stability,Varieties

Background and Justification

Maize (*Zea mays L.*) is one of the most versatile crops having wider adaptability under different agro-climatic conditions. Globally, maize is known as queen of cereals because it has the highest genetic yield potential among the cereals. It is cultivated in 160 countries having wider diversity of soil, climate, biodiversity and management practices that contributes 36% inglobal grain production. Maize is also an important cereal crop for the smallholder farmers in sub-Saharan Africa in general and plays a critical role in food security in Ethiopia. Maize is ranked second to tef (*Eragrostistef Zucc*. in area coverage and first in production in Ethiopia (CSA 2017).The national average production is 36.75Qt/ha (CSA, 2017).Maize is an important major cereal crop in Wollega zones. The area coverage, production and yield (qt/ha) of maize in the zones were 135,807.03 hectares, 5,864,532.80 quintals and 43.18 qt/ha, respectively (CSA 2017).

In the current situations where the global warming and climatic changes wielded high pressure on the productivity of many crops around the world, considerable attention should be need to be given to exploit the effect of genotype by environment interactionin the plant breeding research. It is vital for plant breeders to detect specific genotypes adapted genotypes for specific recommendations and stable genotypes across growing environment(s) for wider production (Ariyo, 1989; Flores et al., 1998; Showemimo *et al.*, 2000; Mustapha *et al.*, 2001). GGE biplot and AMMI stability values were reported to be best approach to discriminate stabilities of varieties. Therefore, the current activity was conducted with objective of identifying adaptability and agronomic performance of released highland maize varieties.

Materials and Methods

Description of the study Area: Field experiment was conducted in Western Oromia, KellemWollega Zone, at Badesso and Belle research sub-sites of Haro Sabu Agricultural Research Center for two consecutive years (2017-2018). The geographical locations of the study sites were known with an elevation of 2050 m.a.s.l and 08° 37'N and 034° 42'E for Aleku Bellesub site whereas,2054 m.a.s.l and 08° 40' N and 034°47'E for Badeso sub site with uni-modal rain fall distribution pattern.

Five improved maize varieties introduced from Ambo plant protection and Holleta Agricultural Research Center (namely Jibat,Wenchi,Argane, Kuleni and Hora) were evaluated against with one local check.

Experimental Design: Randomized Completed Block Design (RCBD) with three replications having net plot size of 9 m^2 each consisting of four harvestable rows was used at the spacing of 0.75 m x 0.3 m between rows and plant respectively. The seeds were planted keeping spacing at the seed rate of 25 kg ha^{-1} whereas fertilizer NPS and UREA were applied at the rate of 1:2 ratios (100 $kgha^{-1}$ and 200 $kgha^{-1}$ respectively). NPS was used at sowing time while split application (50% at sowing and 50% at knee stage) was applied for UREA.

Plant based data collected: Like plant height (cm), ear height (cm) and number of seeds per earwere recorded from five randomly selected and tagged plants from the four harvestable rows.

Plot baseddata collected: Days to 50% heading, days to 50% slicking and days to 50% maturity, thousand kernel weight (gm) and grain yield (qt/ha).

Statistical analysis: The collected data were organized and subjected to analysis using SAS version 9.2 (SAS, 2008) computer software and Gestate 18 edition.

Results and Discussions

Analysis of Variance

Mean square of combined analysis of variance for all genotypes at different environmental conditions for grain yield and yield related traits are presented in Table1. Highly significant differences were detected among years ($P \leq 0.01$) for all parameters except plant height and number of seeds per ear. The combined analysis of variance indicated that year and location effects were significant for number of seeds per ear and grain yield. Varieties ×year and varieties ×location were significant for most studied traits; therefore, testing at more location and years are very important.

Table1: Combined analysis of variance (ANOVA) for grain yield and yield related traits of maize adaptation trial in 2017-2018 main cropping seasons.

Source	DF	DH	DS	DM	PH	EH	SPE	TKW	YLD qt/ha
Year	1	55.1**	76.1**	264.5**	313.8 ^{ns}	1770.2**	8813.5 ^{ns}	21390.**	7198817.9**
Location	1	2301**	3872**	624.2**	43833**	16314**	373.8 ^{ns}	38171**	128234961.1 **
Rep	2	54.6**	61.3**	145.2**	245.1 ^{ns}	957.4*	49.9 ^{ns}	6285.3 ^{ns}	71010.5 ^{ns}
Variety	5	272.3**	326.1**	1182**	14589**	9879.2**	7839.9 ^{ns}	21683.7* *	3155549.6**
Yr*Loc	1	3.1^{ns}	0.2 ^{ns}	0.5 ^{ns}	425.8 ^{ns}	96.2 ^{ns}	83691.* *	0.8 ^{ns}	25560023.**
Yr*Vrt	5	0.1 ^{ns}	6.9*	12.5**	180.9 ^{ns}	147.1 ^{ns}	1900.7 ^{ns}	803.5 ^{ns}	1868135.9**
Loc*Vrt	5	134.3**	168.2**	2.5 *	123.4 ^{ns}	240 ^{ns}	17493.* *	3700.3 ^{ns}	2154276.1**
Yr*Loc* Vrt	5	0.1 ^{ns}	0.8 ^{ns}	0.5 ^{ns}	183.1 ^{ns}	321.4 ^{ns}	3798.7 ^{ns}	1908.7 ^{ns}	1692755.3 ^{ns}

Key: Yr* Loc = year by location, Yr * Vrt = year by varieties, Loc *Vrt= location by varieties, Yr*Loc*Vrt = year by location by varieties, DF = degree of freedom,DH= days to heading, DS= days to slicking, DM= days to maturity, PH= plant height, EH =ear heightSPE= seed per ear, TKW= thousand kernel weight, YLD qt/ha= yield qt^{-h}

Grain Yield Performance of maize varieties over locations

The average grain yield ranged from 36.20 qt ha^{-1} at Belle-2017 site to 74.8 qt ha^{-1}at Bedesso site in the same year with grand mean of 52.34 qt ha^{-1}(Table2).The average grain yield across environments ranged from 44.05 qt ha^{-1}for Hora to 58.04 qt ha^{-1} for Jibat varieties (Table2). This variation might be due to the genetic potential of the varieties. Jibat was the top-ranking varieties at Badesso in 2017 and at Belle in 2018. Similarly, Wenchi variety ranked first at Badesso in both years. But, Argane perform well at Belle only in 2017cropping season. Generally, the combined over year analyzed data reveals that Jibat, Wenchi and Argane were high yielding varieties under different environmental conditions with yield advantage 13.21%, 9.05% o, 7.73% respectively over the local check (Table2).

Table 2: Mean performance of all maize varieties under different locationsand years for yield.

	Grain Yield in qt/ha				
	2017		2018		
Varieties	Badesso	Belle	Badesso	Belle	Comb. Mean
Jibat	84.385^{a}	32.65^{b}	65.31^{ab}	49.83a	58.04^{a}
Wenchi	79.64^{a}	34.85^{b}	65.99^{a}	43.50^{ab}	55.91^{ab}
Argane	73.597^{b}	57.82^{a}	51.40^{c}	38.13^{b}	55.24^{b}
Local	63.892^{c}	40.39^{b}	56.20^{bc}	44.61^{ab}	51.27^{c}
Kuleni	76.009^{ab}	32.97^{b}	52.27^{c}	36.81^{b}	49.51^{c}
Hora	71.323^{bc}	18.50^{c}	48.21^{c}	38.18^{b}	44.05^{d}
R-Square (%)	73%	92%	77%	62%	98%
CV%	7.09	13.83	8.87	11.69	5.20
Mean	74.80	36.20	56.56	41.84	52.34
LSD (5%)	9.64	9.10	9.12	8.89	2.23
F test	**	**	**	**	**

Key: CV =coefficient of variation, LSD =least significant different, DH= days to heading, DS= days to slicking, DM= days to maturity, PH= plant height, EH =ear heightSPE= seed per ear, TKW= thousand kernel weight, YLD qt/ha= yield qt^{-ha}

Agronomic performance of maize varieties over locations

Phonological traits: Kuleni and local check recorded late days to heading, days to silking and days to maturity over the years and locations while, Jibat, Argane and Hora recorded the medium days to heading over the years but Wenchi exhibited early days to heading. On the contrary, Jibat revealed significant medium days to maturity across the years and locations relative to the remaining varieties. However, Wenchi, Argane and Hora were recorded significant earlier for days to maturity over years and locations (Table 3).

Table 3: Combinedmeanfor grain yield and yield related traits of maize varieties over locations

Varieties	DH	DS	DM	PH	EH	SPE	TKW	YLD qt/ha	YLDA%
Jibat	88.0^{b}	92.9^{c}	181.2^{b}	221.4^{c}	110.2^{c}	433.3^{a}	369.1^{b}	58.05^{a}	13.21%
Wenchi	86.3^{c}	92.3^{c}	160.7^{e}	204.8^{de}	89.9^{d}	417.9^{ab}	347.1^{b}	55.91^{ab}	9.05%
Argane	88.0^{b}	95.3^{b}	165.5^{d}	209.8^{d}	104.4^{c}	369.2^{b}	354.5^{b}	55.24^{b}	7.73%
Local	96.4^{a}	103.2^{a}	181.2^{b}	286.8^{a}	169.8^{a}	371.2^{b}	456.3^{a}	51.27^{c}	0.00%
Kuleni	97.2^{a}	103.4^{a}	184.7^{a}	252.3^{b}	132.4^{b}	406.7^{ab}	359.8^{b}	49.51^{c}	-3.43%
Hora	88.8^{b}	93^{c}	168.8^{c}	194.6^{e}	104.2^{c}	403.8^{ab}	342.9^{b}	44.05^{d}	-14.08%
R-Square (%)	95%	91%	89%	90%	90%	60%	60%	98%	
CV%	1.3	1.7	0.6	6.9	12	15.3	14	5.2	
Mean	90.8	96.7	173.7	228.3	118.5	400.3	371.6	52.34	
LSD (5%)	0.99	1.33	0.81	12.9	11.7	50.4	42.9	2.23	
F test	**	**	**	**	**	**	**	**	

Key: CV =coefficient of variation, LSD =least significant different, DH= days to heading, DS= days to slicking, DM= days to maturity, PH= plant height, EH =ear heightSPE= seed per ear, TKW= thousand kernel weight, YLD qt/ha= yield qt^{-ha}, YLDA= yield advantage against local check.

Plant height (PH): The significant highest combined mean value of plant height was recorded by local check over the years and locations indicated susceptibility to lodging. Jibat and Kuleni were recorded medium plant height while, Wenchi and Argane recorded significant shorter mean value of plant height across the years and locations in relative to the others resulted resistance to lodging (Table 3).

Ear height (EH): Local check exhibited significant and larger mean value of ear position but Kuleni recorded the medium ear position. However, Jibat, Argane and Hora were observed with shortear position over years and locations (Table3).

Seeds per Ear (SPE): significantly high combined mean values for number of **seeds per ear** were obtained from Jibt, Wenchi, Kuleni and Hora. However, medium mean values were recorded by Argane and Local check over years (Table3).

Disease reaction with maize varieties across environments

Disease reaction: the result revealed that Jibat,Wenchi and Argane varieties are better tolerance to economically important gray leaf spot and common smut disease (Table 4)

Table 4: Analysis of major disease reactions of improved high maize verities at Kelam Wollega 2017-18

Varieties	Gray Leaf Spot	Leaf Blight	C.smut
Jibat	1.7^{c}	1.25^{b}	1.37^{c}
Wenchi	1.5^{c}	1.25^{b}	1.29^{c}
Argane	1.5^{c}	$1.3a^{b}$	1.37^{c}
Local	2.0^{a}	1.25^{b}	1.87^{a}
Kuleni	2.0^{a}	1.3^{a}	1.71^{ab}
Hora	2.1^{a}	1.25^{b}	1.42^{bc}
R-Square (%)	64%	93%	80%
CV%	26.01	6.70	24.77
Mean	1.82	1.27	1.51
LSD (5%)	0.39	0.07	0.31
F test	**	**	**

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

Additive Main Effects and Multiple Interaction (AMMI) model

The mean squares for all varieties grown under different environmental for grain yield are presented in Table (5). Result indicated that differences among all varieties were significant ($P \leq 0.01$). Variation due to genotypes by environments interaction was significant for the studied traits, indicated that genotypes differ genetically in their response to different environment. The GEI significant effect on the grain yield, which explained 12.98% of the total variation while the genotypes contributed 7.21% of the variation. However, large portion (73.12%) of the total variation was attributed to the environmental effect (Table5).

Table 5: Partitioning of the Explained Sum of square (SS) and Mean of square (MS) from AMMI analysis for grain yield

Source of variations	DF	SS	EX. SS%	MS
Total	71	219896262	100.00	3097130
Treatments	23	205167109	93.30	8920309**
Genotypes	5	15849876	7.21	3169975**
Environments	3	160783247	73.12	53594416**
Block	8	4503531	2.05	562941*
Interactions (GxE)	15	28533987	12.98	1902266**
IPCA	7	23220192	83.37	3317170**
IPCA	5	3976742	13.93	795348*
Residuals	3	1337053	4.68	445684^{ns}
Error	40	10225622		255641

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

Substantial percentage of GxE interaction was explained by IPCA-1 (83.37%) followed by IPCA2 (13.93%) and consequently used to create a 2-dimensional AMMI biplot. Gauch and Zobel (1996) recommends AMMI model that holds most of variation of genotype by environment interaction in its first two PCAs. The G × E interaction components were larger relative than to the genotypic components and if they were related to predictable environment factor (such as geographic areas, major pest problems,) the breeder searches for agenotypes to must the specific requirements of that environment while the interaction is small and unpredictable (micro climatic or yearly variation in weather and management practices) the breeder searches for agenotypes that has general adaptability and unversed performance over the range environments.

Comparison plot for genotypes based on the concentric circle

Figure 1: shows the comparison plot for variety, and an ideal variety is one which is near or at the center of the concentric circle. Hence in this study, the plot reflected that Jibat and Wenchi are the most ideal varieties as shown by their position. This also reflects that; these varieties have high mean grain yield and more stable. Good varieties are those which are closer to the ideal varieties. However, Hora, Local and Kuleni are the worst varieties as their position in the plot are located far from the concentric circle.

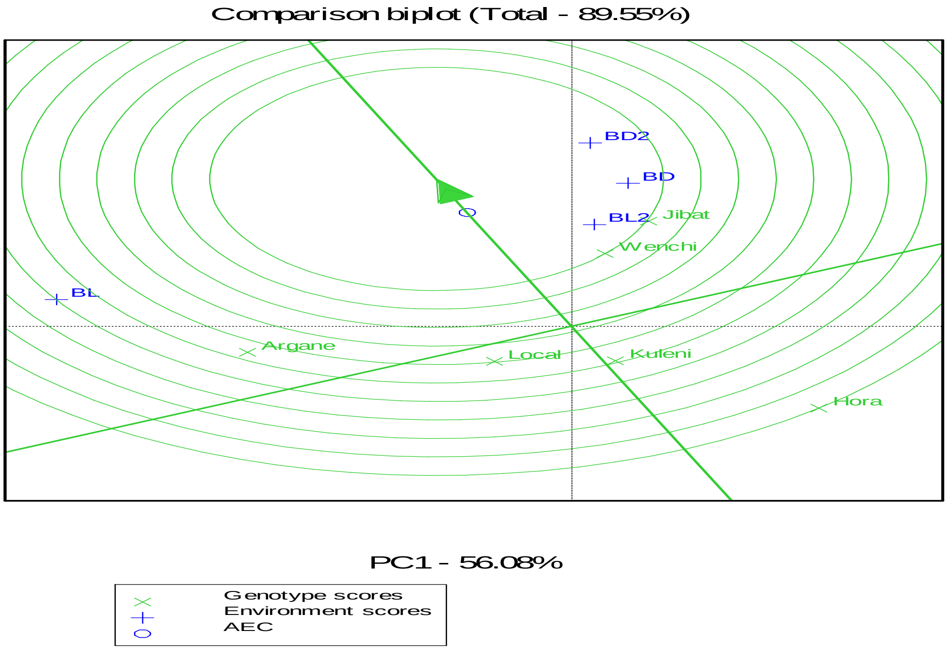

Figure 1: GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability.

Environment representativeness

Figure 2: presents the representativeness of the test environments. Bedeso 2 (BD2) indicated both good discriminating ability and representativeness, making it an ideal and best location for testing maize varieties. Environment like BL (Belle) and BL2(Belle2) are the least representative locations. An ideal environment is the one which is on the intrinsic circle (Figure 2). Therefore, Bedeso 2 (BD2) is found on the closer proximity or on the edge of the intrinsic circle (Figure 2). However, BL (Belle) and BL2 (Belle2) cannot be ideal test locations for selecting or discriminating cultivars which can be adaptable for the zones and similar agro-ecologies

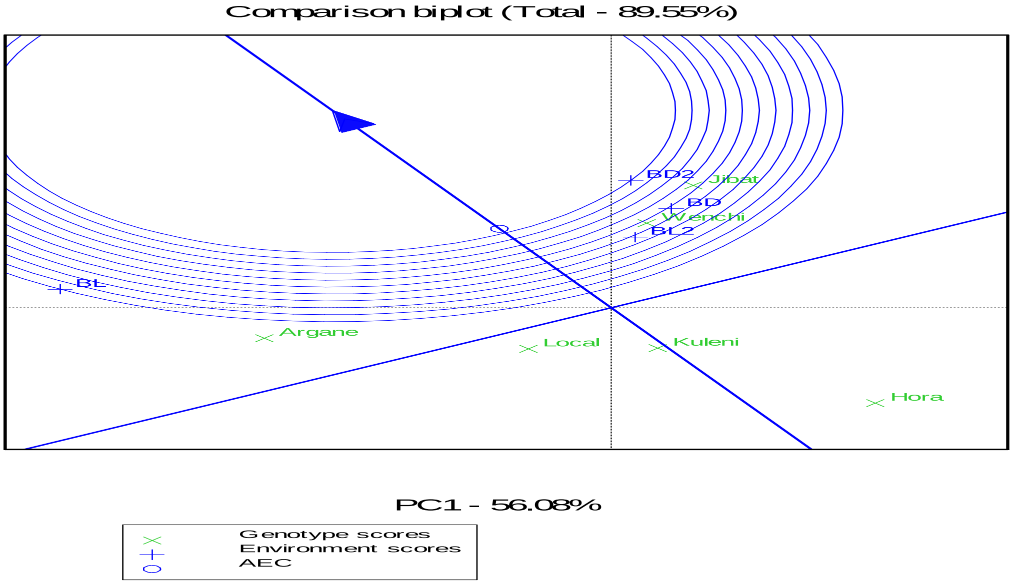

Figure: 2 GGE bi-plot based on tested environments-focused comparison for their relationships

The GGE bi-plot analysis showed that IPCA1 accounted for 56.08% and IPCA2 accounted for 33.47%, both accounted for a sum of 89.55% (Figure 2).The greater IPCA1 shows greater discriminating ability of an environment. This gives the importance of determining the discriminating ability to enhance separation through differences in performances of different genotypes. This showed similarity with study of Gasura *et al.* (2015) where PC1 and PC2 explained 36.8% and 29.5%, respectively. The bi-plot analysis identified the discriminating ability and representativeness of environment and genotype average performance (Sujay *et al.*, 2014).The result showed the importance of testing and comparing genotypes so as to select the one with specific and wide adaptation accordingly and environments which are representativeness to reduce experimental costs by discarding un-representative locations and those with poor discriminating abilities.

Conclusions and Recommendations

Combined analysis of variance (ANOVA) result detected significant difference of grain yield and most of yield contributing traits among evaluated maize varieties across locations, years and the interactions, indicating that the location and fluctuation of weather condition over the cropping season had affected performance of varieties. Jibat and Argane recorded medium days to heading, days to maturity, plant height and ear height over locations and years. Wenchi recorded earlier days to heading and days to maturity and shorter plant height and ear height. On the other hand, GGE bi-plot analysis detected that Jibat and Wenchi were better performed varieties in terms of grain yield and stability. Therefore, demonstration and popularization of these varieties were recommended in the study areas and other areas with similar agro-ecologies in that a waythat justify food security through enhancing productivity of maize.

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Multi-location evaluation of yield and yield related trait performance of sorghum(Sorghum bicolor L.) genotypes at western Oromia, Ethiopia

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Abstract

The field experiment was conducted on twelve sorghum genotypes in regional variety trial against checks at Haro-Sabu Agricultural Research Center (HSARC) sub site for three consecutive years (2016-2018) to evaluate high yielding, pest tolerant and to assess genotype by environmental interaction on grain yield and yield stability across four diverse environments. The seeds were sown in Randomized Completed Block Design (RCBD) with three replications in the net plot size of 9 m^2 *using four harvestable rows at the spacing of 0.75 m and 0.15 m. Eight agronomic traits and three economically important disease reaction were evaluated. Analysis of variance detected significant difference among genotypes for all observed traits both separated and combined analysis of variance. All observation attained significant differences over years except grain yield. Whereas, effect of locations had significantly affected all observed traits in combined analysis. On the other hand, varieties*location significantly affected all recorded traits excluding days to heading and thousand seed weight.Similarly,Year*variety had significantly differences for all recorded trait except days to maturity, head weight and lodging percentage while, varieties*year*location exhibited significant difference for plant height, head height, lodging* percentage *and* grain yield. *A pooled analysis of variance for grain yield across four different environments, the GxE interaction was significant (P<0.001), and this justified need for testing for GEI components using the GGE bi-plot analysis to enhance the understanding the effects of components. The results revealed that four environments were identifiable, which Hawa Galan had the most discriminating ability and good representativeness whereby Kombo had a poor discriminating ability as well as least representativeness. GGE bi-plot analysis revealed that G3,G11 and G12 were identified as ideal genotypes in terms of yielding ability and stability and were promoted to VVT for advancement, release and use as parents in future breeding programs.*

Key words: *Genotype x environment interaction, GGE, adaptation and yield stability.*

Background and Justification

Sorghum is the most known crop especially in Africa, central America and south Asia and Ethiopia in general and specifically a major cereal crop in west and Kellem Wollega zones.Sorghum is the most known crop in Ethiopia in general and specifically a major cereal crop in west and Kellem Wollega zones next to maize (CSA,2017). The national average production of sorghum is 25.25 qt/ha (CSA 2017).The area coverage, production and yield (qt/ha) of sorghum in the Wollega zones were 97,711.83 hectares, 2,989,883.74 quintals production and 30.60 qt/ha respectively (CSA 2017). It used as food, feed, beverage, and construction. Sorghum has in-built physiological characteristics such as dense and deep roots, ability to reduce transpiration through leaf rolling and stomatal closure which help the crop to survive the dry periods. Hence sorghum has become a strategic crop in the zones in the face of climate variability. Despite all this advantages over other cereals under different condition, the sorghum crop production is still very low. It is important to show the relationship between genotypes and environments for selected traits graphically by use of a genotype, genotype by environment interaction (GGE) biplot that allows visual assessment of genotype by environment interaction (GEI) pattern of multi-locational or multi-environment data (Yan *et al.,* 2000; Yan and Hunt, 2001). GGE is the most recent approach for analysis of GEI and increasingly being used in GEI studies in plant breeding research (Butran *et al*.,2004). The model was proposed by Yan *et al*. (2000), and has shown extensive usefulness and a more comprehensive tool in quantitative genetics and plant breeding (Yan *et al.,* 2001; Yan and Rajcan, 2002). The model covers very critical areas in the study of stability of multi-locational trials, like the which-won-where pattern, mean performance and stability of genotypes, discriminating ability and representativeness of environments.

The GGE method emphasizes on two concepts, whereby in the first concept, it clearly points out that even though the measured yield is a result of combination effect by Genotype (G), Environment (E) and genotype x environment interaction (GEI), only G and GEI are relevant and must be considered simultaneously when evaluating genotypes, thus the name GGE. The second concept is based on the bi-plot technique which is used to estimate and show the GGE of multi-environmental yield trial (MEYT). The GGE bi-plot is made by the first two principal components (PC), PC1 and PC2. This is resulting from subjecting the environment centered yield data (due to GGE) to singular value decomposition. This makes it very easy to identify which genotype won in which environments. This is facilitated in the form of a polygon to visualize the interaction patterns between genotypes and environments (Yan and Kang, 2003), whereby greatest genotypes are connected from the bi-plot origin such that all genotypes are contained in the polygon (Kaya *et al*., 2006). Some genotypes will be located on the vertices of the polygon and they are either the best or the poorest in one or more environments (Yan *et al.*, 2000; Yan and Rajcan, 2002; Yan and Tinker, 2006). The rays are drawn perpendicular to the sides of the polygon dividing it into sectors, such that the vertex genotypes in each sector is also the best genotype for sites whose markers fall into respective sector so that sites within the same sector share the same winning genotype (Yan, 2002; Yan *et al.,* 2000). GGE bi-plot is a visual display of the G + GE of multi-environmental data where groups of locations with similar cultivar responses are presented and it identifies the highest yielding varieties for each group. PC1 tend to correlate highly with the genotype means, the ideal cultivar is the one which possess large scores for PC1, thus indicating high average yield and small PC2 scores indicating less GEI and greater stability.

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

Materials and Methods

Study sites: The multi-location yield trial (MLYT) was conducted at four different locations in Kellem and west Wollega zones of Haro-Sebu agricultural research center at Kombo, Haro-sebu,Guliso and Hawa-Galan research sub-sites (Table1) to assess and confirm the effects of genotype, environment and genotype by environment interaction. The locations have different agro-climatic conditions.Hawa-Galan representing the high-potential area with good rains and soils, Guliso representing the intermediate potential area with average rainfall, Haro-Sabu and Kombo representing the low potential area. According to the 2016/7 season weather data collected at study sites, the low potential areas had an average of 1100 mm annual rainfall and temperature was 30°C, while the high potential areas received an average of 1600 mm and temperature of 22°C.The sites also characterized by different soil types, which range from the Light red Sandy Clayat Guliso, Brown sandy-loam soils at Hawa Galan and black clay loam at Kombo andlight red sandy atHaroSabu (Table 1).

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

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

NI=not identified

Breeding materials and experimental design: Twelve genotypes of sorghum including checks were evaluated sequentially for three (2016-2018) cropping season at four different locations (Table2). The trial was planted in randomized completed block design (RCBD) replicated three times. Each plot consists of six rows (with four harvestable rows), 3 m plot length with inter-row and intra-row spacing of 0.75 m and 0.15 m respectively and 2 m spacing between each block was used. A seed rate of 25 kg ha^{-1}and a combination of UREA and NPS fertilizer was applied at the recommend rate of 100 kg ha^{-1}(1:1 ratio).NPS fertilizer was applied uniformly for all treatments equally at the time of sowing and split application was carried out for UREA (half at planting time and halfafter six weeks from emergency). All other agronomic practices were performed as per the recommendation for the crop. The trial was raised under rain fed across all the test locations. The harvested panicles were sundried for two days before being tested for moisture content where 12% was the preferred average moisture content using moisture tester. Grain yield data was then obtained by weighing the dried grain using a digital scale.

Variety/line code	code	zone	woreda	village	altitude	Soil texture	Soil color	Sample	Genetic status
SLRC-010	G1	K/Wollega	d/sadi	Laku	1514	sandy	Light red	Pure line	Land race
SLRC-06	G8	W/Wollega	Guliso	d/guda	1708	Sandy Clay	Light red	Pure line	Land race
SLRC-027	G7	W/Wollega	Begi	Shelxa	1433	Clay loam	Black	Pure line	Land race
SLRC-028	G5	W/Wollega	Begi	Maganxaya	1584	Sandy loam	Brown	Pure line	Land race
SLRC-037	G4	K/Wollega	Gidam	Alchayajilo	1698	Sandy loam	Brown	Pure line	Land race
SLRC-043	G3	K/Wollega	Seyo	Minko	1690	Sandy loam	Brown	Pure line	Land race
SLRC-046	G12	K/Wollega	Arbigaba	Masarata	1482	Sandy loam	Brown	Pure line	Land race
SLRC-048	G6	K/Wollega	Hawa walal	Odamoti	1369	clay loam	Black	Pure line	Land race
SLRC-058	G11	K/Wollega	Yamalogiwalel	Hora maka	1429	Clay loam	Black	Pure line	Land race
local check	G9								

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

Statistical analysis: Multivariate method, Additive Main Effects and Multiplicative Interaction (AMMI) model was used to assess genotype by environment interaction (GEI) pattern. The AMMI model equation is: Yger =μ+αg+βe+Σnλnγgnδen+ εger+ρge; where, Yger is the observed yield of genotype (g) in environment (e) for replication (r);

Additive parameters: μ is the grand mean; αg is the deviation of genotype g from the grand mean, βe is the deviation of the environment e;

Multiplicative parameters: λn is the singular value for IPCA, γgn is the genotype eigenvector for axis n, and δen is the environment eigenvector; εger is error term and ρge is PCA residual. Accordingly, genotypes with low magnitude regardless of the sign of interaction principal component analysis scores have general or wider adaptability while genotypes with high magnitude of IPCA scores have specific adaptability (Gauch, 1992; Umma et al.,2014).

AMMI stability value of the 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):

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

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

$$GSIi = RASVi + RYi$$

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

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

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

Results and Discussions

Combined Analysis of Variance

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

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

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

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

Yield performance of sorghum genotypes Across Environments

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

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

Genotypes	Grain Yield in qt/ha								
	2016		2017			2018			
	KM-08A	HS-08A	HS-09A	GU-09A	HG-09A	HS-10A	GU-10A	HG-10A	Comb. Mean
SLRC-010	22.27fg	33.88cd	39.90c	35.61ef	39.61de	37.570d	38.250e	40.05bc	35.89d
Gamadi	28.880d	43.55a-c	42.99b	38.19d	41.21cd	43.990c	41.180d	42.94bc	40.37c
SLRC -043	45.160a	49.190a	51.83a	48.21b	52.800a	53.320a	48.980b	48.79ab	49.79a
SLRC-037	25.750e	28.29de	43.43b	43.95c	43.46bc	47.730b	46.93bc	44.58bc	40.52c
SLRC -028	33.950c	31.310d	36.82d	36.6ed	38.58de	38.300d	38.630e	38.080c	36.54d
SLRC -048	44.910a	31.680d	45.03b	43.45c	46.120b	46.26bc	45.310c	48.09ab	43.86b
SLRC -027	31.12cd	36.59b-d	35.53d	33.61f	36.870e	33.620e	34.610f	23.600d	33.19e
SLRC -06	20.860g	12.760f	28.86e	26.15g	24.750g	27.810f	25.770g	28.640d	24.45f
Local. Check	17.510h	16.870f	25.75f	26.36g	28.108f	25.860f	25.380g	27.280d	24.15f
Lalo	23.84ef	17.93ef	25.01f	23.88g	25.030g	26.440f	26.020g	27.770d	24.49f
SLRC -058	38.570b	38.17b-d	53.32a	50.08b	53.290a	55.640a	49.230b	54.780a	49.14a
SLRC-046	32.610c	44.59ab	54.63a	54.78a	53.770a	53.860a	52.540a	54.620a	50.18a
Mean	30.45	32.07	40.26	38.41	40.31	40.87	39.40	39.94	37.71
CV%	5.75	19.54	4.30	3.86	4.21	4.13	3.72	13.05	8.52
LSD(5%)	29.53	10.56	29.20	24.97	28.62	28.47	24.69	87.84	18.29
F test	**	**	**	**	**	**	**	**	**

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

Agronomic performance

Combined mean grain yield and other agronomic traits are presented in Table 5. High mean of days to heading and days to physiological maturity were recorded by genotypes SLRC-058 and SLRC-046. These offer great flexibility for developing improved varieties suitable for various agro-ecologies with variable length of growing period. However, genotypes SLRC-028 and

SLRC-048 were with short mean of days to heading and days to physiological maturity indicating that early maturing genotypes were desirable when moisture is the limiting factors for sorghum production. Similarly, genotypes SLRC-010, SLRC-037, SLRC-06, Local check and standard check(Lalo) were recorded high plant height indicating that, these genotypes might be susceptible to root and/or stem lodging butgenotypes like SLRC-043, SLRC-058 and SLRC-046 were with medium plant height indicating that, the possibility to develop resistant variety against lodging problems. Moreover, genotypes, SLRC-043, SLRC-058 and SLRC-046 were recorded the highest grain yield and they had 23.33%, 21.72% and 24.3% yield advantage over the best standard check (Gamadi)(Table5).

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

Genotypes	DH	DM	LDG	PH	HH	HW	TSW	YLD qt/ha	YAD (%) against best check (Gamadi)
SLRC-010	127.67d	172.8d	2.5b	420.7a	32.9a	99.82c	24.8e	35.89d	-11.09%
SLRC -043	130.4bc	174.0d	1.1h	349.8d	33.1a	114.75ab	32.6ab	49.79a	23.33%
SLRC-037	124.02e	165.6f	2.1d	407.9ab	31.7a	106.35bc	26.6c-e	40.52c	0.37%
SLRC -028	124.42e	169.2e	2.6b	388.8c	31.8a	118.88a	25.4e	36.54d	-9.47%
SLRC -048	122.71f	169.2e	1.7ef	353.3d	29.6b	99.32c	25.7de	43.86b	8.64%
SLRC -027	129.83c	175.8c	1.8e	344.0de	28.8bc	103.96bc	27.5c-e	33.19e	-17.77%
SLRC -06	120.02g	163.1g	2.3c	407.1ab	27.2cd	114.03ab	25.4e	24.45f	-39.43%
SLRC -058	132.58a	181.9b	1.3g	326.3f	25.2e	106.56a-c	33.5a	49.14a	21.72%
SLRC-046	131.04b	183.4a	1.1h	344.0de	29.4b	105.36bc	32.5ab	50.18a	24.3%
Gamadi	122.60f	172.9d	2.3cd	327.1ef	26.3de	101.50c	32.8ab	40.37c	0%
Lalo	1216.4h	163.1g	2.9a	403.3bc	27.1c-e	110.22c	29.4b-d	24.49f	-39.33%
Check	127.75d	166.17f	1.6f	394.7bc	33.5a	110.00a-c	29.8a-c	24.15f	-40.18%
Mean	125.78	171.44	1.93	372.26	29.71	106.81	28.83	37.71	
CV%	1.68	1.2	15.83	8.1	11.1	20.5	22.85	8.52	
LSD(5%)	120	1.17	0.17	17.19	1.89	12.47	3.75	18.29	
F test	**	**	**	**	**	**	**	**	

Key: SLRC=Sorghum Land Race Collection, DH=Days to heading, DM=Days to maturity, PH= Plant height, HH= Head height, LDG- Lodging percentage, HW-head weight, TSW- Thousand seed weight, YLD qt/ha- Yield in quintals per hectare, YAD- yield advantage, CV- Coefficient of variation, LSD- least significant difference.

Reaction to the major disease and insect pest of sorghum genotypes across environment

Most genotypes evaluated had significantly low scores with their corresponding economically important insect pest and disease reactions. However, some genotypes Gamadi (G2) and Lalo (G10) were less tolerance to stalk borer but genotypes SLRC-043(G3), SLR-058 (G11) andSLR-046 (G12) were better tolerance to stalk borer (Table 6). In this study, maximum Anthracnose disease reaction was recorded by genotypes Gamadi (G2) and SLRC-048(G6). Likewise, maximum leaf blight disease reaction observed by Gamadi (G2) and Lalo (G10). On the other hand, genotypes SLRC-043(G3), SLRC-058 (G11) and SLRC-046 (G12) were better tolerance to stalk borer, Anthracnose and Leaf blight(Table 6).

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

Genotypes	Stalk borer	Anthracnose	Leaf blight
SLRC-010 (G1)	1.0000e	1.36d	2.04e
Gamadi (G2)	1.1690a	2.50a	2.88a
SLRC -043(G3)	1.027de	1.40d	2.04e
SLRC-037 (G4)	1.022de	2.29b	2.04e
SLRC-028 (G5)	1.0000e	2.29b	2.54b
SLRC -048(G6)	1.078bc	2.41a	2.38c
SLRC -027(G7)	1.0000e	1.44d	1.88f
SLRC -06 (G8)	1.1100b	1.56c	2.21d
L.Check (G9)	1.056cd	1.08e	2.04e
Lalo (G10)	1.1670a	2.33b	2.88a
SLR-058 (G11)	1.0000e	1.63c	1.57g
SLR-046 (G12)	1.083bc	1.37d	1.29h
Mean	1.06	1.72	2.15
CV%	4.79	8.61	1.37
LSD(5%)	0.03	0.09	0.02
F test	**	**	**

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

Additive main effects and multiple interaction (AMMI) model

Combined analysis of variance revealed highly significant ($P \leq 0.01$) variations among environments, genotype x environment interaction, IPCA-1 and IPCA-2 (Table7). This result indicated there was a differential yield performance among sorghum genotypes across testing locations and strong GEI.Similar result was reported on wheat (Sial *et al.,* 2000) and rice (Panwar *et al.,*2008).The GEI significant effect on the grain yield of sorghum genotypes, which explained 7.0% of the total variation whereas the genotypes contributed 80.1% of the variation. However, merely 9.4% of the total variation is credited to the environmental effect (Table7).

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

Source of variation	D.F	S.S	EX.SS%	M.S
Total	287	31574	100.0	110
Treatments	95	30462	96.5	320.7**
Genotypes	11	25281	80.1	2298.3**
Environments	7	2961	9.4	423**
Block	16	120	0.4	7.5^{ns}
Interactions	77	2220	7.0	28.8**
IPCA 1	17	1528	4.8	89.9**
IPCA 2	15	407	1.3	27.1**
Residuals	45	285	0.9	6.3 ^{ns}
Error	176	992		5.6

This also indicated the existence of large amount of reverent response among the genotypes to changes in growing environments and the differential discriminating ability of the test environments. Considerable percentage of GxE interaction was explained by IPCA-1 (4.8%) followed by IPCA2(1.3%) and therefore used to create a 2-dimensional GGE bi-plot. Gauch and Zobel (1996) suggested that the most accurate model for AMMI can be predicted by using the first two PCAs. Moreover, several authors took the first and second IPCA for GGE bi-plot analysis and greater proportion of GEI were explained by the first IPCA for maize (Abera and Labuschagne, 2005), bread wheat (Yuksel *et al.*, 2002; Farshadfar, 2008; Worku *et al.*, 2013), common bean (Temesgen *et al.*, 2008) and field pea (Mengistu *et al*., 2011).

Yield Performance of sorghum genotypes per location and AMMI

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

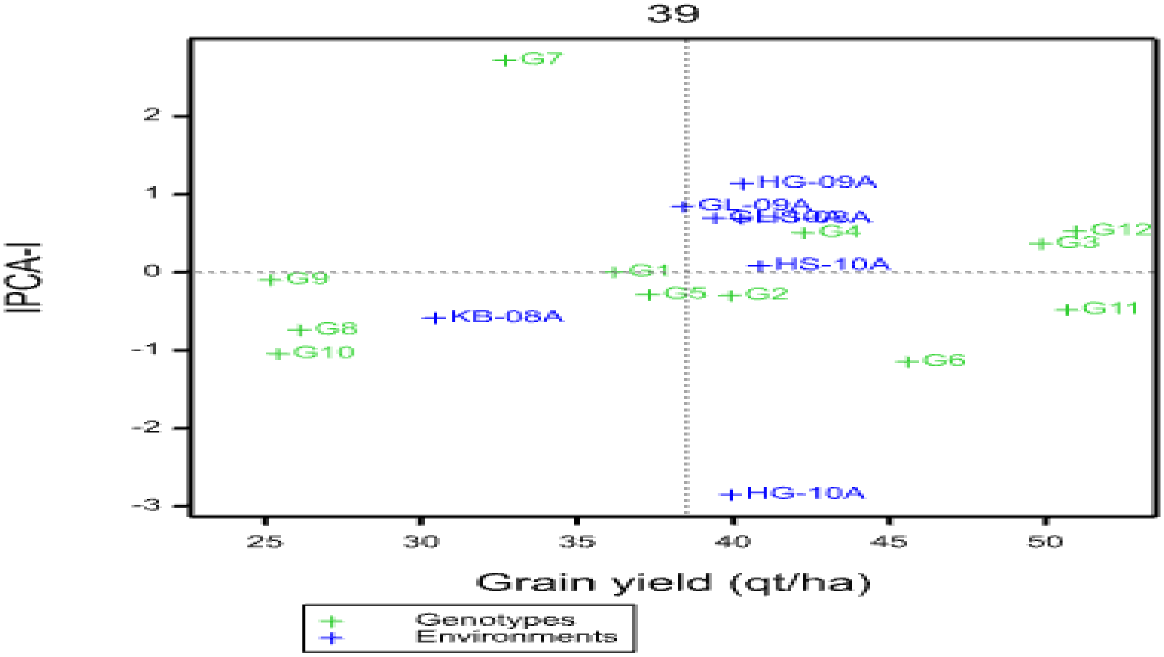

Fig.1 Matrix plot of environment and genotypes mean grain yield (qtha^{-1}) versus Interaction Principal Component Axis (IPCA-I) score. The reference line on the x-axis is the average grain yield (39 qtha^{-1}) and on the y-axis is the IPCA-I value indicating genotype stability (IPCA-I=0)

The result indicated most of the tested environments revealed fluctuating mean grain yields and IPCA scores (Table 8, Fig 1). For example, the overall mean grain yield at Haro-sebu during the 2016 growing season was 32.07qt ha^{-1} while the mean grain yield at the same location during the 2017 cropping season was 40.26q tha^{-1}(Table 8, Fig 1). This variation might be due to weather conditions, experimental plots and other soil factors at the tested environment. However, Hawa Galan is exhibited consistent mean grain yields than the rest test environments

Table 8. Mean grain yield (qt ha^{-1}) per location and AMMI

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

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

Relationship among test environments

The similarity between two environments is determined by both the length of their vectors and the cosine of the angle between them (Figure2). Haro-sebu and Hawa-Galan had good discriminating ability as shown by a long environmental vector, followed by Guliso site. However, Kombo had poor discriminating ability, as was indicated by its short environmental vector. The study shows Haro-sebu and Hawa-Galan were the most discriminating locations which means such sites gave more information on the performance of the genotypes, while Kombo was the least discriminating environment which means less information about the performance of the genotypes. This means if the study is carried out for several seasons and same site continue to be non-discriminating (less informative); such locations can be dropped and not to be used as test locations. Information on relationships among the test environments was also given (Figure 2) as is indicated by the cosine of the angles; acute angle indicates a positive correlation, right angle and obtuse angles indicate no correlation and negative correlation, respectively. Angles between any of the two environments; Hawa-Galan (HG-09A) and Haro-sebu (HS-09A); Kombo (KB-08A) and Haro-sebu(HS-08A); Guliso (GL-10A) and Hawa-Galan(HG-10A) were acute and hence showed positive correlations. Kombo (KB-08A) and Hawa-Galan(HG-10A); Haro-sebu (HS-08A) and Hawa-Galan (HG-10A) were obtuse and exhibited negative correlations. The close associations among test environments suggested that the same information in terms of performance can be obtained from fewer test locations and some may be dropped without losing any information about the cultivars under test, thus reducing experimental costs (Yan and Tinker, 2005). The results from the study indicated genotypes G7, G8, G9 and G10 performed below average in the four environments. However,G2, G4 and G6 performed above average in Kombo (KB-08A), Haro-sebu (HS-08A), Guliso (GL-09A), Guliso (GL-10A) and Hawa Galan(HG-10A) locations whereas G3, G11 and G12 were performed above average in all environmental condition(Table8, Fig2)

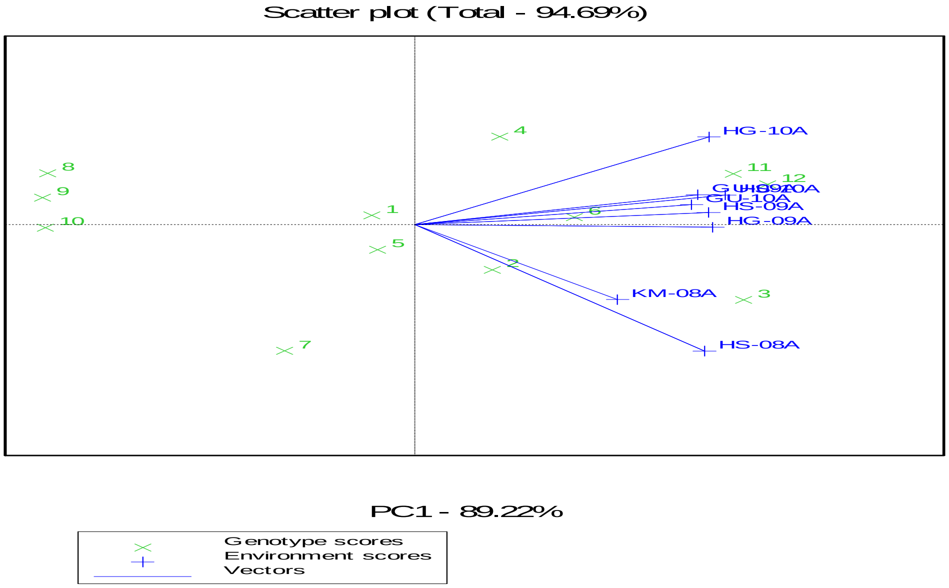

Figure 2: GGE bi-plot based on tested environments-focused comparison for their relationships

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

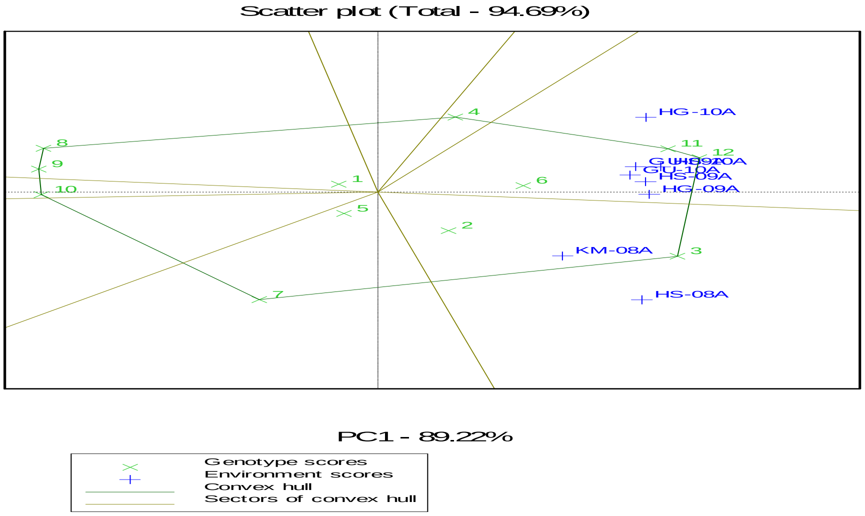

Figure 3. The which-won-where view of the GGE bi-plot to show which genotypes performed best in which environment

Discriminating ability of the test environment and genotype stability

The concentric circles on the bi-plot help to visualize the length of the environment vectors, which are comparative to the standard deviation within the particular environments and are a measure of the discriminating ability of the environments (Worku *et al*., 2013). Environments as well as genotypes that fall in the central (concentric) circle are considered as an ideal environments and stable genotypes, respectively (Yan and Rajcan, 2002).An environment is more desirable and discriminating when located closer to the central circle (Naroui *et al*., 2013). As a result, in the presentstudy, Hawa-Galan (HG) was more representative and discriminating environments but Kombo (KB) was non-discriminating and less representative site (Fig.2 and 4) Similarly, Odewale *et al*. (2013) reported that only one environment was stable, representative and discriminating among the nine environments for the performance of five coconut genotypes.

Ranking based on the genotype-focused scaling assumed that stability and mean grain yield were equally important (Yan and Rajcan, 2002). The best candidate genotypes were expected to have high mean grain yield with stable performance across all the tested locations. Consequently, high yielding and comparatively more stable genotypes can be considered as base line for genotype evaluation (Yan and Tinker, 2006). Both environments-focused bi-plot and genotype-focused comparison of genotypes shown that genotype SLRC-043 (G3) fell in the central circle indicating its high yield potential and comparatively stableto the other genotypes (Fig5). As well, genotypes such as SLRC-058 (G11) and SLRC-046 (G12) were fell close to the ideal genotype or around the center of concentric circle indicated these genotypes possessed specific adaptability with best grain yield potential. Therefore, genotypes SLRC-043 (G3),SLRC-058 (G11) and SLRC-046 (G12)were the best performing pipeline cultivars.

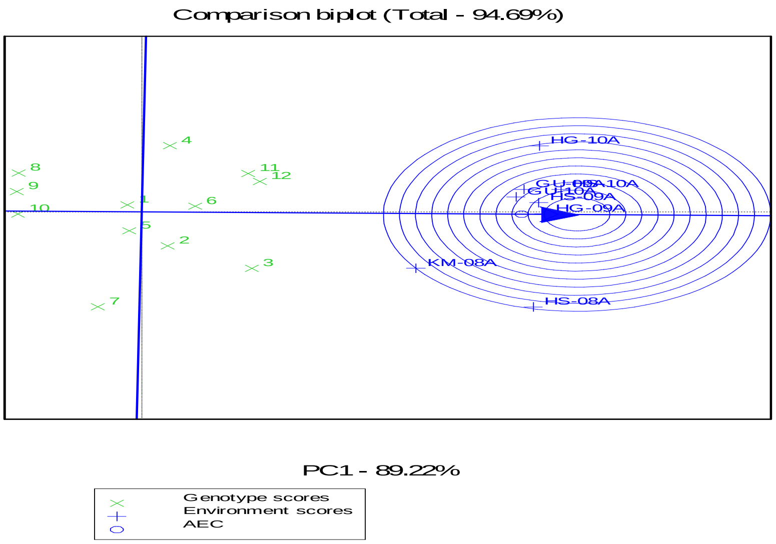

Figure 4 Ranking environments comparatively to ideal environment

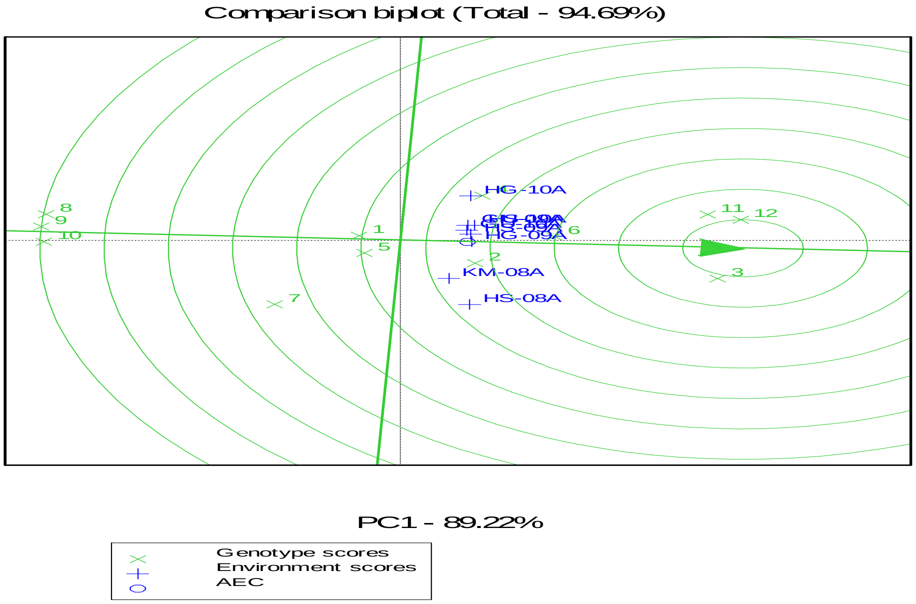

Figure 5: GGE bi-plot based on genotype-focused scaling for comparison of genotypes for their yield potential and stability.

Additive Main Effects and Multiple Interaction (AMMI) Stability Value (ASV)

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

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

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

G-genotype

Conclusions and Recommendations

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

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Multi-environmental Evaluation of Large Seed Red Mottled Common Bean (*Phaseolus vulgaris* L.) genotypes in West and Kelem Wollega Zones of Western Oromia

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Abstract

Multi-environmental evaluation of large seed red mottled bean was done on thirteen common bean genotypes at Haro-Sabu Agricultural Research Center main station and other sub-sites including Tole FTC, Sago FTC, Kure- gayib FTC and Shebel FTC during 2008-2010 E.C main cropping season. The main objective of the study was to evaluate, select and to release high yielding, stable and disease tolerant haricot bean variety/ies for West and Kellem Wollega Zones of West Oromia and area with similar agro-ecology. Field experiment was conducted by using randomized completed block design (RCBD) with three replications, having a net plot size of 1.6 m x 3 m. Combined ANOVA revealed significant variation of genotypes, environment and their interaction. Pooled ANOVA declared significant difference among evaluated genotypes for plant height, number of pods per plant, hundreds seed weight and grain yield. Environment had exerted significant variation on all agronomic traits considered across all environments, whereas the interaction effect of genotype by environment had imposed significant effect on days to flowering, days to maturity, plant height, number of branch/plant, seed/pod, Hundred seed weight and grain yield. Stability of genotypes were further tested and confirmed by AMMI stability value and Genotype Selection Index, and GGE biplot. From the total variation;11.03% (genotype), 52.86% (environment) and 13.17% (GXE), 2.68% (Block) and 20.26% (Error) were estimated. The higher mean value of grain yield 15.31 qt/ha (G3) and 14.41 qt/ha (G5) were obtained with a yield advantage of 9.05 % and 2.64% for genotype G3 and G5, respectively over the best standard check (ECAP-0056=14.04 qt/ha). ASV, GSI and GGE Biplot further confirmed that G3 and G5 were high yielder, more adapted and relativelystable genotypes. Thus, the identified genotypes (G3 and G5) were suggested for furtherreleasing as new varieties for West and Kelem Wollega Zones and areas with similar agro-ecology.

Keywords: Large red mottled bean, Stability, ASV, GSI, Yield

Introduction

Among major food crops, common bean (*Phaseolus vulgaris L.)* has one of the highest levels of variation in growth habit from determinate bush to indeterminate, extreme climbing types, seed characteristics (size, shape, and color), maturity, and adaptation. It also has a tremendous variability (> 40,000 varieties). Among which the bush type bean is the most predominant type grown in Africa (Buruchara, 2007). In Ethiopia, Common bean are grown from 1200-2200 meters above sea level under diverse climatic conditions. They are extensively grown in at least four climatic regions. These include the central rift valley and the Hararghe low lands representing the semi-arid areas, Hararghe highlands, Southern Ethiopia representing the mid altitude cooler areas and western and north-western Ethiopia representing the sub-humid climates.

Common bean varieties are classified into nine major classes according to colour and size as; pure large red, medium and small reds and red mottled, purple, yellow and tans, cream, navy/white and black (Wortmann*et al.,* 1998). Generally, special distribution of seed types in eastern and southern Africa (ESA) is a result of many factors but market forces and agro-ecological conditions are major. The red and red mottled beans are the most common types due to market preference. The majority of the farmers still lack access to improved high yielding varieties which has slowed down growth in national average yield figure15.59 16.94 (Legese *et al.,* 2006). Average national yield of 15.97 qt/ha (2015/16) and 16.94 qt/ha (CSA, 2016/17) was reported for red bean (CSA, 2016/17). On the other hands, averaged yield of 18.60 and 13.87 and 14.93 qt/ha was reported in Oromia, West Wollega and KellemWollega, respectively for 2016/17 main cropping season (CSA, 2016/17).The current market preferred varieties are less tolerant to biophysical constraints including drought, acidity, low soil fertility, disease such as anthracnose, common bacterial blight, angular leaf spot, rust, web blight and viruses, and the predicted effects of global warming on the climate (Wortmann *et al.,* 1998). It is necessary to alleviate some/ most of bean production constraints mentioned above through introduction and evaluation of germplasms in the area. Hence, the main objective of the study was to evaluate, identify and to release high yielding, stable and disease tolerant bean variety/ies for west and KellemWollega Zones and areas with similar-agro ecology.

Materials and Methods

Description of study area

A field experiment was conducted at Haro Sabu Agricultural Research Center main station and Farmer Training Center (FTC) of Tole, Sago, Kure-Gayib and Shebel during 2015-2017. The study areas were recognized with an elevation of 1450-2100 m.a.s.l with unimodal rain fall distribution pattern and sandy loam type soil textural class.

Testing genotypes

Thirteen large red mottle haricot bean genotypes originally introduced from Melkasa Agricultural Research Center were evaluated against local check for their mean performance on grain yield and other yield related agronomic traits including foliar disease reaction (anthracnoses).

Experimental design:

Randomized Complete Block Design (RCBD) with three replications, having a net plot size of 1.6 m x 3 m, each consisting of four harvestable rows. The spacing of 1.5 m, 1 m, 40 cm and 10 cm were used between replications, plots, plants and rows, respectively. The seed rate of 135 kg/ha was used in the experiment. Inorganic fertilizer DAP was applied at the rate of 100 kg/ha at sowing time. All agronomic practices were done as uniformly as required.

Table 1: Designation of genotype

Code	Genotype	Hosting Center
G1	RMBNVT2011(13)	Melkasa Agricultural Research Center
G2	RMBNVT2011(22)	Melkasa Agricultural Research Center
G3	RMBNVT2011(25)	Melkasa Agricultural Research Center
G4	RMBNVT2011(6)	Melkasa Agricultural Research Center
G5	RMBNVT2011(5)	Melkasa Agricultural Research Center
G6	RMBNVT2011(1)	Melkasa Agricultural Research Center
G7	RMBNVT2008(1)	Melkasa Agricultural Research Center
G8	RMBNVT2011(8)	Melkasa Agricultural Research Center
G9	RMBNVT2011(2)	Melkasa Agricultural Research Center
G10	RMBNVT2011(14)	Melkasa Agricultural Research Center
G11	RMBNVT2011(20)	Melkasaa Agricultural Research Center
G12	ECAP-0056 (standard check)	Melkasa Agricultural Research Center
G13	Local Check	Local Variety

Data collection

Agronomic data were collected on plot and plant basis. Some of the data taken were number of pods per plant (PPP), number of seeds per pod (SPP), plant height in centimeter (PHT), Branch per plant (BPP), days to 50% flowering (DF), days to physiological maturity (DM), thousand seed weight (TSW), grain yield (GY) and major haricot bean disease (Anthracnoses).

The collected data were organized and analyzed using SAS statistical package (SAS, 2006 version 9.03). The homogeneity of residual variance (MSE) was verified according to Cruz et *al*,. (2004), in which the ratio between the highest and the lowest residual mean square was less than 7. The significance of genotype, environment and interaction of genotype by environmental effect was determined by F-test. Combined analysis of grain yield and other yield contributing morphological traits were done using general linear model (Proc GLM) procedure. Thus, contribution of genotype, environment and their interaction towards total variation observed were estimated. Mean separation was done using least significant difference (LSD) employing the procedure developed by Gomez and Gomez (1984), whereas GGE biplot and AMMI stability analysis was done using GenStat computer software (2012). In AMMI stability method, the scores of the first principal component (IPCA1) of each genotype were used as a measure of stability. The magnitude of these scores reflects the contribution to the interaction (GEI). The lower the score, in absolute IPCA1 values, the more the stable the genotype.Moreover,stability parameters other than IPCA1 such as AMMI stability value, genotype selection index were considered in the study.

Results and Discussions

Analysis of variance

Analysis of Variance (ANOVA) was done for grain yield and other eight yield related traits mentioned above. Pooled analysis of variance showed significant difference among evaluated genotypes for PHT, PPP, HSW and GY. Environment had significant effect on all observed traits, whereas the interaction of genotype by environment had exerted significant ($p \leq 0.01$ or $P<0.05$) effect on DM, PHT, BPP, SPP, HSW and GY (Table 2). Occurrence of significant genotype by environment indicates presence of genetic variability and fluctuation of genotypic performance with environment. On the other terms, it becomes difficult to select superior genotypes across all environment (Hagos and Abay, 2013; Giovani Benin, 2013), requiring other specific statistical procedures to assist in the genotype selection. The same finding was also reported by (Asfawu *et al.*, 2008 and Tadele *et al.*, 2017). The effect of environment was more responsible for almost all of the total sum of squares (SS) for majority of the traits observed, the corroborating the finding of other study (Hagos and Abay, 2013; Roostaei *et al.*, 2014).

Table 2: Combined Mean square of yield and related agronomic traits of Large Red Mottled bean genotype

Source of Variation	**DF**	**Mean Square**							
		DF	DM	PH	BPP	PPP	SPP	HSW	GY
Geno	12.00	8.49	5.54	1176.68**	0.60	15.71**	0.69	377.81**	82.50**
Rep	2.00	12.70	9.37	380.47*	0.03	7.37	0.14	8.95	40.67
Env	6.00	134.90**	656.6**	3763.5**	129.1**	284.9**	2.1**	347.9**	791.0**
G*E	72.00	5.67	8.57**	145.59**	1.106*	5.04	0.44*	34.17**	16.42*
Error		6.36	4.90	68.07	0.80	4.63	0.30	17.26	10.99

Combined mean performance

Significantly higher mean value of grain yield (GY) was recorded from G3 (15.31 qt/ha) and followed by G5 (14.14 qt/ha). On the contrary, Local check had significantly lower (8.27qt/ha) mean value of GY and followed by G10 (9.82 qt/ha), G2 (12.4qt/ha), and G9 (12.91qt/ha) as presented below (Table 3).

Table 3: Combined mean performance of grain yield and yield related traits of large red mottled haricot bean genotypes

Genotype	DF	DM	PH	BPP	PPP	SPP	HSW	GY	YAD	DR
RMBNVT2011(13)	41.95a	76.43b	44.64c	4.30ab	8.84bc	2.55d	42.60a	13.9ab	-0.50	2.22f-g
RMBNVT2011(22)	41.4ab	76.29b	44.28c	4.660a	8.29bc	2.64cd	36d-g	12.40b	-11.68	3.440b
RMBNVT2011(25)	41.4ab	77.2ab	43.56c	4.20ab	8.34bc	2.9a-c	40.1a-c	15.31a	9.05	3.10b-d
RMBNVT2011(6)	42.14a	76.29b	47.28c	4.60ab	8.45bc	2.99ab	34.77g	13.7ab	-2.28	2.56c-f
RMBNVT2011(5)	42.48a	76.9ab	48.26c	4.35ab	8.54bc	3.16a	35e-g	14.4ab	2.64	1.89fg
RMBNVT2011(1)	41.67a	76.9ab	47.90c	4.56ab	9.290b	2.8b-d	37.6c-f	14.1ab	0.50	2.4d-g
RMBNVT2008(1)	41.81a	77.5ab	60.1ab	4.36ab	11.18a	2.7b-d	39b-d	14.3ab	2.07	2.11fg
RMBNVT201	39.95b	77.1ab	45.90c	4.37ab	8.50bc	2.61cd	41.2ab	13.5ab	-3.56	1.780g
RMBNVT201	41.1ab	77.1ab	45.89c	4.090b	8.13bc	2.8b-d	42.02a	12.91b	-8.05	2.4d-g
RMBNVT201	42.05a	76.7ab	64.20a	4.30ab	7.790c	3.00ab	28.00i	9.820c	-30.06	3.1b-d
RMBNVT201	41.90a	76.8ab	47.74c	4.30ab	7.840c	2.9a-c	35.2fg	14.2ab	0.93	2.89b-e
ECAP-0056	42.14a	78.05a	55.72b	4.27ab	8.71bc	3.02ab	38.0c-e	14.0ab	0.00	3.22bc

Local check	41.86a	76.38b	63.63a	4.61ab	8.25bc	2.8b-d	31.10h	8.270c	-41.1	4.22a
Mean	41.680	76.900	50.70	4.38	8.63	2.84	37.09	13.15		2.73
CV	6.0500	2.8800	16.27	20.34	24.93	19.38	11.20	25.21		43.06
Lsd	1.5400	1.3500	5.02	0.54	1.31	0.33	2.53	2.02		0.77

The yield advantage of 9.05% and 2.64 % were estimated for G3 and G5 over the best standard check ECAP-0056 (14.04 qt/ha), respectively (Table 3). On the other hand, the highest mean value of grain yield was obtained from Kur-010 (20.08qt/ha) and followed by SG-08 (16.20 qt/ha) and HS-08 (14.83 qt/ha). On the contrary, the lowest mean value was obtained from SH-010 (5.53 qt/ha) and TL-08 (10.67 qt/ha) as presented below in Table 4.

Code	**2008 E.C**			**2009 E.C**	**2010 E.C**			Combined	YAD
	TL-O8	SG-08	HS-08	SH-090	KU-010	HS-010	SH-010		
G1	10.83a	16.40abc	15.77abc	12.09b	21.57a	15.26ab	5.86abc	13.97ab	-0.50
G2	9.67a	14.300bc	12.33cde	11.70b	22.18a	11.506b	5.04abc	12.400b	-11.68
G3	11.97a	19.9000a	17.670ab	10.97b	22.02a	17.960a	6.74abc	15.310a	9.05
G4	9.98a	15.83a-c	16.400ac	12.9ab	22.31a	15.15ab	3.4500c	13.72ab	-2.28
G5	8.33a	19.4700a	18.0700a	12.41b	22.62a	15.16ab	4.77abc	14.41ab	2.64
G6	8.27a	19.5700a	15.07a-d	12.27b	20.81a	14.70ab	8.0700a	14.11ab	0.50
G7	11.73a	15.43a-c	16.000ac	17.04a	23.15a	11.77ab	5.210a-c	14.33ab	2.07
G8	8.50a	17.370ab	12.870dc	13.9ab	22.79a	13.20ab	6.140a-c	13.54ab	-3.56
G9	11.70a	12.1700c	13.30b-d	12.9ab	22.25a	13.95ab	4.0400c	12.910b	-8.05
G10	8.20a	12.0000c	10.830de	12.25b	11.99b	9.733bc	3.6903c	9.820c	-30.06
G11	14.4a	16.43a-c	16.27a-c	13.2ab	20.53a	11.083b	7.230ab	14.17ab	0.93
G12	14.47a	16.63a-c	16.37a-c	12.47b	20.40a	11.91ab	6.00abc	14.04ab	0.00
G13	10.13a	12.2300c	8.3e	11.55b	6.46c	4.41c	4.70a-c	8.270c	-41.1
Mean	10.67	16.2	14.83	12.53	20.08	12.76	5.53	13.15	
Cv	48.51	18.00	18.06	20.82	15.57	29.41	37.02	25.21	
Lsd	8.66	4.88	4.48	4.36	5.23	6.28	3.42	2.02	

Additive Main Effect and Multiplicative Interaction Effect (AMMI) Analysis

AMMI model analysis declared significant variation of main effect of genotypes, environments and the interaction effect of genotypes by environment for grain yield. From the total variation obtained for grain yield; 11.03% (genotype), 52.86% (environment) and 13.17% (GXE), 2.68% (Block) and 20.26% (Error) were estimated (Table 5). Significant interaction of genotype by environment illustrates presence of genetic variability and unstable response of genotypes towards environmental fluctuation. IPCA1 and IPCA2, attained 57.86% and 20.22% interaction sum square and contributed a total of 78.08% of total variation, where the remaining was due to residual effect. According to Kempton (1984) in AMMI model the first two interactions principal component axis was a best predictive model that explains the interaction sum of squares. The finding of the study supported Tadele *et al.* (2017) who reported highly significant ($p \leq 0.01$) difference of genotype, environment and their interaction for grain yield in Large red mottled bean genotypes evaluated in multi-location of Ethiopia.

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

Source	Df	SS	Explained (%)	MS
Total	272.00	8978.00	100.00	33.000
Treatments	90.00	6918.00	77.06	76.9**
Genotypes	12.00	990.00	11.03	82.5**
Environments	6.00	4746.00	52.86	791.0**
Block	14.00	241.00	2.68	17.200
Interactions	72.00	1182.00	13.17	16.4**
IPCA	17.00	684.00	57.86	40.2**
IPCA	15.00	239.00	20.22	15.900
Residuals	40.00	260.00	22.00	6.500
Error	168.00	1819.00	20.26	10.800

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

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

In AMMI model, the genotype with least AMMI stability value (ASV) score was considered as the most stable. According to AMMI stability value (ASV) G12 was most stable and followed by G7, G2, G1, G8 and G6. Most of genotypes identified for their better stability had lower mean value of grain yield which was undesirable. Stability of genotype is not only selection criteria and simultaneous consideration of grain yield and ASV in single non-parametric index is paramount important. Comparison of genotypes against to genotype selection index (GSI), which explains both mean value of grain yield and ASV is needed.Thus, G3 (15.31 qt/ha) followed by G5 (14.41 qt/ha) were identified for higher mean value of grain yield and relatively better GSI (Table 6), indicating higher mean value of grain yield and relative stability of genotypes across the studied environments. The same finding was reported by Tadele *et al.* (2017) at mid-altitude of Bale Zone, Southeastern Ethiopia.

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

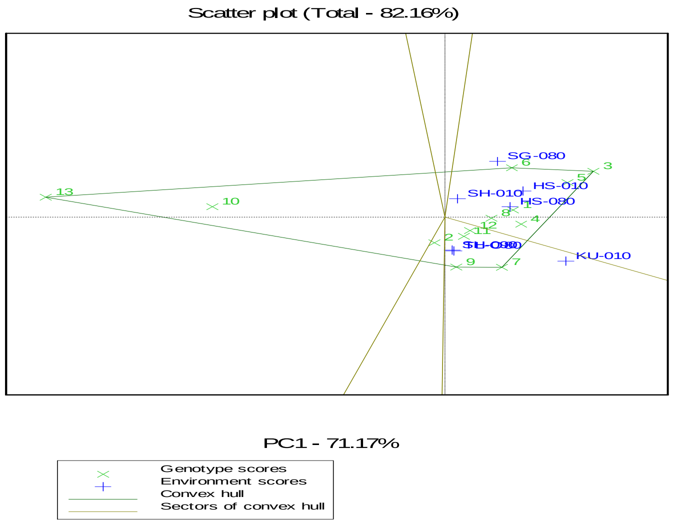
Genotype	Mean	Mean Rank	IPC1	1PC2	IPCAg[1]	IPCAg[2]	ASV	ASV R	GSI
G1	13.97	7.00	684.00	239.00	0.53	0.19	1.54	4.00	11.00
G2	12.40	11.00	684.00	239.00	0.47	-0.69	1.50	3.00	14.00
G3	15.31	1.00	684.00	239.00	0.80	1.22	2.59	10.00	11.00
G4	13.72	8.00	684.00	239.00	0.90	-0.19	2.58	9.00	17.00
G5	14.40	2.00	684.00	239.00	1.12	0.92	3.34	11.00	13.00
G6	14.11	5.00	684.00	239.00	0.42	1.32	1.78	6.00	11.00
G7	14.33	3.00	684.00	239.00	0.03	-1.34	1.34	2.00	5.00
G8	13.54	9.00	684.00	239.00	0.57	-0.03	1.63	5.00	14.00
G9	12.91	10.00	684.00	239.00	0.45	-1.34	1.86	8.00	18.00
G10	9.82	12.00	684.00	239.00	-1.27	0.28	3.65	12.00	24.00
G11	14.17	4.00	684.00	239.00	-0.62	-0.51	1.83	7.00	11.00
G12	14.04	6.00	684.00	239.00	-0.40	-0.35	1.19	1.00	7.00
G13	8.27	13.00	684.00	239.00	-3.00	0.53	8.62	13.00	26.00

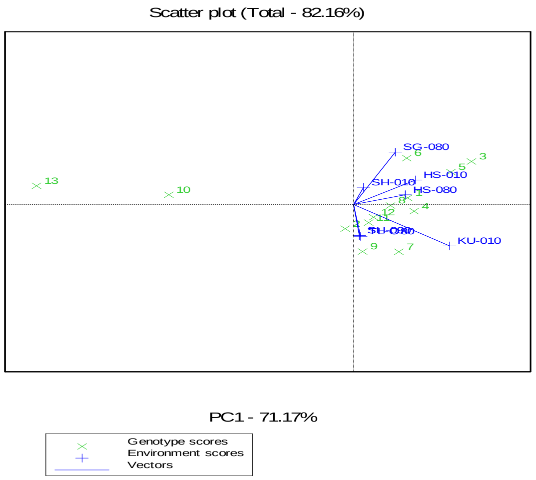
Keys; ASV= AMMI stability value, ASVR= Rank of AMMI stability value, GSI=genotype selection index, IPCA= principal component analysis, IPC= principal component

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

Graphic analysis of GGE biplot analysis of large red mottled haricot bean genotypes evaluated at seven locations was done in current study. The polygon dictated that G3, G7 and G13 were vertex genotypes, whereas the remaining genotypes lies inside the polygon. As a rule, the vertex cultivar is the highest-yielding in all test environments that share the sector with it and the sector with vertex genotype may be referred to as the sector of identified genotype. Accordingly, the sector G3 had four environments (HS-080 HS-010, SH-010 and SG-080), the sector of G7 had three environments (TL-080, SH-090 and KU-010). No environments fell in the sectors with G12, indicating that this vertex cultivar were not the best in any of the test environments, its poor performance in some or all test environments. Moreover, this indicates that these cultivars were the poorest in some or all of the environments.

Stable genotypes and environments were located near the origin of the biplot with the two IPCA scores of almost zero. Presently, G2, G11, G12 and G8 were slightly close to the origin, showed medium stability and had a mean value nearly close to grand mean of grain yield. Besides, G13, G10 and G3 were far from origin of polygon, exhibiting their more responsiveness to the environmental change and had specific environment adaptation (Fig 1). The line from the origin of the biplot to the genotype indicates the difference in yield of genotypes from the grand mean, and genotypes with long vectors could be of good or poor performance (Yan and Tinker, 2006). With this, G3 had best perforce for grain yield and had high contribution for the GEI. On the contrary, these genotypes were identified for specific adaptability because of their farness from the origin of biplot (Fig 1). Likewise, G13 and G10 were located far from origin, poor yield performance and contributing much to the GEI. Away from this, cultivar located at the origin would rank the same in all environments and is not at all responsive to the test environments. The result found supported Shitaye (2017).





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

The environments and genotypes obtained in the central circle are considered as ideal in GGE biplot (Yan, 2002). Besides, in GGE bi-plot based on genotype-focused scaling for comparison of genotype for grain yield stability (figure 2), assumes that stability and mean yield are equally important (Farshadfar *et al.*, 2011). Genotype G3 and G5 followed by G4 were lied relatively near to the center of concentric circles were ideal genotypes in terms of yield and stability (Figure 2). Similarly, superior genotypes with stable grain yield was reported previously by Tamane*et al*. (2015).

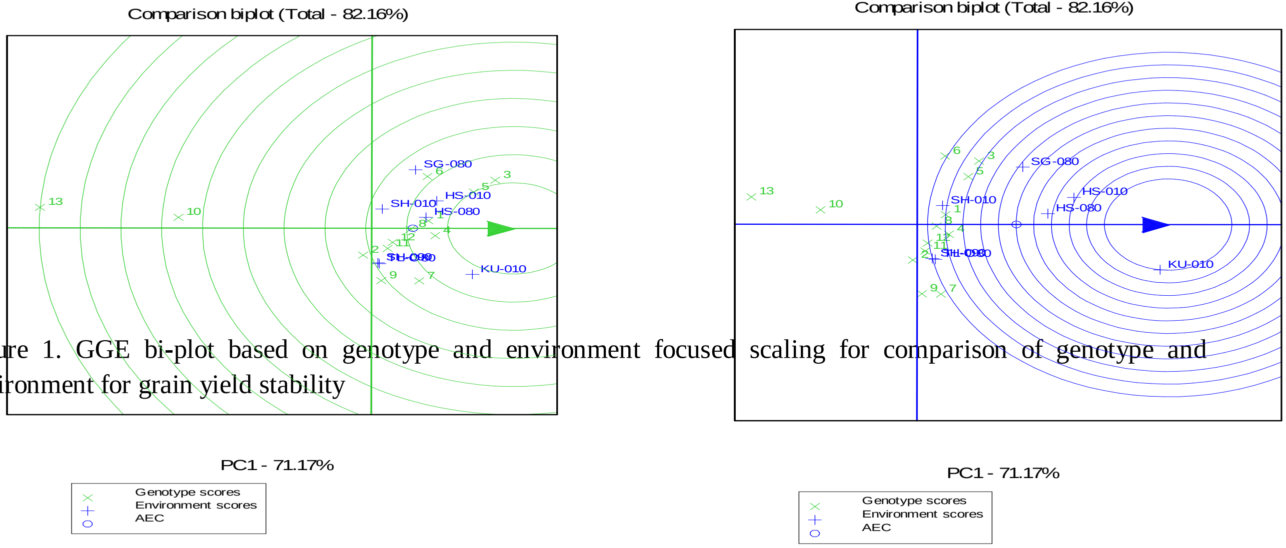


Figure 1. GGE bi-plot based on genotype and environment focused scaling for comparison of genotype and environment for grain yield stability

As environmental stability is concerned, KU-010 (20.08 qt/ha) was more stable and followed by HS-080 (14.83 qt/ha) and HS-010 (12.76 qt/ha). On the contrary, TL-080 and SH-090 were the most unstable environment and followed by SH-010 (Figure 1). Among the environments identified for their stability; KU-010 and HS-080 had the mean value above grand mean of grain yield which was 13.15qt/ha (Table 4).

Conclusions and recommendations

Pooled analysis of variance identified significant difference among evaluated genotypes, environments and their interaction, where significant interaction of genotype by environment declared variation of genotypic performance with fluctuation of environmental conditions. However, GGE biplot and some stability parameters including IPCA1, AMMI stability value and genotypic selection index analysis had further identified high yielding and relatively stable genotype. Hence, G3 and G5 were identified and selected as candidate large red mottled bean varieties and proposed for further releasing for West and KellemWollega Zones of Western Oromia and areas with similar agro-ecology.

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Genotype by Environment Interactions and Grain Yield Stability Analysis of Small Seed Red Bean (*Phaseolus Vulgaris* L.) Genotypes in West and Kelem Wollega Zones of Western Oromia

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Abstract

Twelve common bean genotypes were evaluated for their general performance and yield stability across the seven environments at Haro-Sabu Agricultural Research Center main station and sub-sites with the objective of identifying and selecting high yielding and stable candidate variety thereby suggesting for further releasing for West and Kellem Wollega Zones of West Oromia and for similar agro-ecology. Field experiment was done in Randomized Complete Block Design (RCBD) with three replications, consisting of 1.6 m x 3 m. Pooled analysis of variance exhibited significant main effect of genotype and environment, and their interaction effects.Combined ANOVA declared significant difference among evaluated genotypes for all agronomic traits excluding days to maturity, number of effective branch per plant, number of seed per pod. The main effects of environment exerted significant effects on all observed traits, while the interaction effect of environment by genotype had imposed significant effect on all observed traits excluding plant height, number of branch per plant, number of seed per plant and disease reaction, indicating genetic variability among evaluated genotypes and their unstable response towards fluctuation of environmental conditions. Stability of genotypes were further tested and confirmed by AMMI stability value and Genotype Selection Index, and GGE biplot. From the total variation; 17.48% (genotype), 43.68% (environment) and 17.31% (GXE), 3.13% (Block) and 18.39% (Error) were obtained. The higher mean value of 2.01 ton/ha (G3),1.99 ton/ha (G2), 1.94 ton/ha (G1) and 1.94 ton/ha (G7) were recorded for grain yield. On the other hands, the yield advantage of 24.07, 22.84, 19.75 and 19.75% were estimated for G3, G2, G1 and G7, respectively over standard check SER (119) which had the mean value of 1.62 ton/ha. ASV, GSI and GGE Biplot further confirmed that G3, G2, G1 and G7 were high yielder, more adapted and relatively stable genotypes. Thus, the identified genotypes) were suggested for further releasing as new varieties for West and Kelem Wollega Zones and areas with similar agro-ecology.

Keywords*:* Small red bean, Stability, ASV, GSI, Yield

Introduction

Phaseolus vulgaris L. belongs to family *fabaceae* commonly called bean, common bean, haricot bean, kidney bean and field beans. It is annual crop thrives in warm climate. The crop grown well between 1400 and 2000 meter above sea level (Vakali, 2009). Common bean is one of the cash crops next to faba beans accounting for the greatest portion of production in the world (Radish, 2010). It is one of the important cash crops in Ethiopia (Yitayal *et al.*, 2015). In the Ethiopian context, common bean has been one of the most important crops grown by small scale farmers in different parts of the region and, has significant role in food security owing to fast maturing characteristics that enable households to get cash income required to purchase food and other household needs when other crops have not yet matured (Legesse *et al,* 20016).

In Ethiopia, the national average yield of 15.59 qt/ha and 16.94 qt/ha were reported during 2015/15 and 2016/17 main cropping season, respectively for red bean. On the other hands, in Oromia the average grain yield is 18.60 qt/ha, but at Wollega it was reported 13.87qt/ha (West Wollega) and 16.14qt/ha (KellemWollega) (CSA, 2016/17), indicating the more proximity of crop productivity to the national average and the lower productivity of the western Oromia compared to the regional average. Before a decade common bean is not well distributed in west part of Ethiopia, although the area is potential for production. At the present time, the production and area coverage of common bean has been increasing from time to time because of the fact that the crop has immense potential for export and risk aversion in hot humid area. Although management practice can improve the productivity of common bean in such marginal areas; more progress in improving yield will be realized through genetic improvement (White *et al.*, 1994; Singh, 1995; Zelalem, 2013).

As improvement of common bean productivity is desirable in different farming including small scale farmers and commercial farms, introduction and evaluation of different kinds of small red common bean genotypes thereby identification of their performance, adaptability, stability were necessary. Therefore, present study was initiated to achieve the following objectives: To identify high yielding, stable and major disease tolerant candidate common bean genotype and to release the promising candidate as a new version of small red bean variety for the study area and area with similar agro-ecology.

Materials and Methods

Description of study area

A field experiment was conducted at Haro-Sabu Agricultural Research Center main station and Farmer Training Center (FTC) of Tole, Sago, Kure Gayib and Shebel and Gulliso during 2014/15-2016/17 (2008-2010). The study areas were recognized with an elevation of 1450-2100 m.a.s.l with unimodal rain fall distribution pattern and sandy loam type soil textural class.

Testing genotypes

Twelve small red bean genotypes originally introduced from Melkasa Agricultural Research Center were evaluated against local check for their mean performance on grain yield and other yield related agronomic traits including foliar disease reaction (anthracnoses).

Table 1: Designation of genotype

Code	Genotype	Hosting Center
G1	SRSB2011(8)	Melkasa Agricultural Research Center
G2	SER(9)	Melkasa Agricultural Research Center
G3	S&MRSB2011(24)	Melkasa Agricultural Research Center
G4	SRSB 2011(1)	Melkasa Agricultural Research Center
G5	SRSB 2011(3)	Melkasa Agricultural Research Center
G6	S&MRSBNV2011(8)	Melkasa Agricultural Research Center
G7	SRSBNVT2011(8)	Melkasa Agricultural Research Center
G8	SRSBNVT2011(11)	Melkasa Agricultural Research Center
G9	SRSBNVT2010(5)	Melkasa Agricultural Research Center
G10	S&MRSBNV2011(10)	Melkasa Agricultural Research Center
G11	SER(119)	Melkasa Agricultural Research Center
G12	Local check	Local cultivar

Experimental design:

Randomized Complete Block Design (RCBD) with three replications, having a net plot size of 1.6 m x3 m, each consisting of four harvestable rows was used. The spacing of 1.5 m, 1 m, 40 cm and 10 cm were used between replications, plots, plants and rows, respectively. The seed rate of 135 kg/ha was used in the experiment. Inorganic fertilizer DAP was applied at the rate of 100 kg/ha at sowing time. All agronomic practices were done as uniformly as required.

Data collection

Agronomic data were collected on plot and plant basis. Some of the data taken were number of pods per plant (PPP), number of seeds per pod (SPP), plant height in centimeter (PHT), Branch per plant (BPP), days to 50% flowering (DF), days to physiological maturity (DM), thousand seed weight (TSW), grain yield (GY) and major common bean disease like *Anthracnose.*

The collected data were organized and analyzed using SAS statistical package (SAS, 2006 version 9.03). The homogeneity of residual variance (MSE) was verified according to Cruz et *al.* (2004), in which the ratio between the highest and the lowest residual mean square was less than 7. The significance of genotype, environment and interaction of genotype by environmental effect was determined by F-test. Combined analysis of grain yield and other yield contributing morphological traits were done using general linear model (Proc GLM) procedure. Thus, contribution of genotype, environment and their interaction towards total variation observed were estimated. Mean separation was done using least significant difference (LSD) employing the procedure developed by Gomez and Gomez (1984), whereas GGE biplot and AMMI stability analysis was done using GenStat computer software (2012). In AMMI stability method, the scores of the first principal component (IPCA1) of each genotype were used as a measure of stability. The magnitude of these scores reflects the contribution to the interaction (GEI). The lower the score, in absolute IPCA1 values, the more the stable the genotype.Moreover,stability parameters other than IPCA1 such as AMMI stability value, genotype selection index were considered in the study.

Results and Discussions

Analysis of variance

Analysis of Variance (ANOVA) was done for grain yield and other eight yield related traits mentioned above. Pooled analysis of variance showed significant difference among evaluated genotypes for all considered agronomic traits excluding DM, BPP and SPP. ANOVA declared significant main effect of environment on all observation, while the interaction effect of environment by genotype had significant effect on all observed traits except for PH, BPP,SPP and DR, indicating genetic variability among evaluated genotypes and their unstable response towards fluctuation of environmental conditions (Table 2).Similar results were reported by different authors (Mekbib, 2003;Tamene*et al.*, 2014; Tadele et al., 2017). The wide occurrence of GXE is the basic cause of difference between genotypes in their yield stability, or in other words: ranking of genotype depends on the particular environmental conditions where it is grown (Huehn, 1990) as cited by Tadele*et al*. (2017).

Table 2: Combined Mean square of yield and related agronomic traits of small red bean genotypes

SV	DF	Mean square								
		DF	DM	PH	BPP	PPP	SPP	HSW	GY	DR
Environment	6.00	8.8**	316.6**	7207.6**	157.48**	633.0**	10.5**	62.0**	8.6**	9.26**
Rep	2.00	10.01	4.22	885.15*	7.99	0.05	0.24	19.26*	0.66	0.78
Genotype	11.0	5.69**	28.17	800.95**	9.11	26.76**	0.46	89.25**	1.8**	23.4**
Envt*Genotype	66.0	2.06**	29.05*	309.52	9.55	18.50**	0.58	6.63**	0.3**	2.18

Combined mean performance

Significantly higher mean value of grain yield (GY) was recorded from G3 (2.01 ton/ha) followed by G2 (1.99 ton/ha), G1 (1.94 ton/ha) and G7 (1.94 ton/ha). In the reverse, the lowest mean value of grain yield was obtained from G6(1.13 ton/ha) and followed by local check (1.25 tn/ha) and G9 (1.43ton/ha) as shown below (Table 3). So far, the mean value of 11.5qt/ha was reported by Zelalem (2013) at North western part of Ethiopia which was below grand mean.

Table 3: Combined mean of agronomic traits

entry code	DF	DM	PH	BPP	PPP	SPP	HSW	GY(tn/ha)	YAD(%)	DR
SRSB 2011 (8)	40.71c-e	76.76a-c	58.69de	5.67b	13.95ab	4.15ab	21.79a	1.94a	19.75	2.67
SER (9	40.67de	77.33ab	61.16b-e	5.42b	14.02ab	3.99ab	21.9a	1.99a	22.84	3.17
S&MRSB2011(24)	41.33b	76.52bc	70.58ab	5.83b	14.52a	4.29a	20.57b	2.01a	24.07	3.00
SRSB 2011(1)	40.33e	76.48bc	67.45a-d	6.04ab	13.69a-c	4.27a	21.11ab	1.91a	17.9	2.94
SRSB 2011(3)	40.52de	76.95a-c	73.88a	5.06b	12.01cd	4.09ab	20.39b	1.51b	-6.79	5.61
S&MRSBNV2011(8)	40.71c-e	76.57bc	60.49c-e	5.33b	11.45d	4ab	18.42cd	1.13d	-30.25	4.94
SRSBNVT2011(8)	41.29bc	77.81ab	64.19a-d	7.74a	13.28a-d	3.95ab	21.1ab	1.94a	19.75	3.61
SRSBNVT2011(11)	40.67de	77.1ab	58.45de	6.06ab	11.64d	4.23a	22.11a	1.59b	-1.85	4.67
SRSBNVT2011(5)	41.33b	76.57bc	51.59e	5.83b	12.18b-d	4.06ab	17.34d	1.43bc	-11.73	5.11
S&MRSBNV2011(10)	40.67de	76.48bc	64.78a-d	5.77b	12.1b-d	4.08ab	21.12ab	1.57b	-3.09	5.39
SER(119)	40.76b-e	74.29c	64.97a-d	5.91b	14.58a	4.08ab	18.77c	1.62b	0.00	4.28
L ocal check	40.95b-d	79.38a	69.72a-c	5.9b	13.2a-d	3.75ab	15.51e	1.25cd	-22.84	4.78
Mean	40.95	76.85	63.83	5.88	13.05	4.08	20.01	1.66		4.18
CV	2.35	5.81	25.51	48.56	24.21	16.43	9.74	22.96		39.24
Lsd	0.59	2.72	9.92	1.74	1.93	0.41	1.16	0.23		1.08

Values followed by different alphabet were significantly different (0.05)

KEY: DF= Days to flowering, DM= Days to maturity, PH= Plant height (cm), BPP= Number of branch per plant, PPP= Number of pod/plant, SPP= Number of seed/pod, HSW= Hundred seed weight (gm), GY=Weight of grain yield (ton/hectare), Dr= foliar disease reaction and YAD(%)= Percentage of yield advantage over the best standard check.

The yield advantage of 24.07, 22.84, 19.75 and 19.75 were estimated for G3, G2, G1 and G7, respectively over standard check SER (119) which had the mean value of 1.62ton/ha (Table 3).The highest mean value of grain yield was obtained from SG-008 (2.61 ton/ha) and followed by SG-008 (2.61ton/ha), TL-008 (1.81ton/ha) and SH-010 (1.8ton/ha). However, the lowest mean value was recorded at HS-010 (1.14 ton/ha) and GL-010 (1.45 ton/ha) as presented below (Table 4).

Table 4: Mean performance of grain yield (ton ha-1) over Locations and years

Genotype	2008 E.C		2009 E.C		2010 E.C			Comb.
	SG-008	**TL-008**	**HS-009**	**SH-010**	**GL-010**	**KU-010**	**HS-010**	
SRSB 2011 (8)	2.87a-c	1.94a	1.47a-d	2.16ab	1.59a-d	2.55a	0.97c-f	1.94a
SER (9)	3.02a	1.95a	1.61a-c	2.16ab	1.71a-c	2.07ab	1.43a-c	1.99a
S&MRSB2011(24)	2.6a-d	2.09a	2.17a	1.47ab	1.84a	2.1ab	1.77a	2.01a
SRSB 2011(1)	3.14c-e	1.67ab	1.87ab	1.91ab	1.77a	1.64bc	1.39a-d	1.91a
SRSB 2011(3)	2.34c-e	1.83a	1.07c-e	2.00ab	1.51a-d	0.8de	1.0c-f	1.51b
S&MRSBNV2011(8)	2.01e	1.89a	0.56e	1.22b	0.91e	0.70e	0.64fg	1.13d
SRSBNVT2011(8)	3.03a	1.11b	1.46b-d	2.33a	1.46a-d	2.49a	1.70a	1.94a
SRSBNVT2011(11)	2.88ab	1.75ab	1.04c-e	1.72ab	1.34b-e	1.25cd	1.17b-e	1.59b
SRSBNVT2011(5)	2.07e	1.93a	0.64e	1.33b	1.21de	1.34c	1.5ab	1.43bc
S&MRSBNV2011(10)	2.64a-d	2.01a	1.24b-e	1.72ab	1.31c-e	1.16c-e	0.92d-f	1.57b
SER(119)	2.43b-e	1.85a	1.19b-e	1.96ab	1.48a-d	1.59bc	0.89ef	1.62b
Local check	2.32de	1.73ab	0.83de	1.56ab	1.22de	0.8de	0.31g	1.25cd
Mean	2.61	1.81	1.26	1.8	1.45	1.54	1.14	1.66
CV	12.13	21.34	32.94	31.62	18.06	19.62	25.02	22.96
Lsd	0.54	0.66	0.7	0.96	0.44	0.51	0.48	0.2321
F-value	**	Ns	**	NS	*	**	**	**

Key: Whereas, SG, TL, HS, SH, GL and KU represent Sago, Tole, Haro Sabu, Shebel, Gulliso and Kure gayib, respectively.

Additive Main Effect and Multiplicative Interaction Effect (AMMI) Analysis

Additive main effects and multiplicative interaction (AMMI) analysis (Gauch, 1992) is one of stability parameters developed to investigate GEI and, particularly effective for depicting adaptive responses (Gauch, 1992; Cross,1990). AMMI model analysis declared significant variation of main effect of genotypes, environments and the interaction effect of genotypes by environment for grain yield. From the total variation obtained for grain yield; 17.48% (genotype), 43.68% (environment) and 17.31% (GXE), 3.13% (Block) and 18.39% (Error) were estimated (Table 5). Significant GEI exhibited genetic variability and unstable response of genotypes against environmental fluctuation. IPCA1 and IPCA2, attained 47.36% and 22.11% interaction sum square and contributed a total of 69.47% of total variation, where the remaining (30.53%) was due to residual effect. The first two interactions principal component axis of AMMI model were the best predictive model that explains the interaction sum of squares (Kempton, 1984). Hence, present study agrees with the finding of previous author (Tadele *et al.*, 2017).

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

As AMMI model is concerned, the genotype with lowest AMMI stability value (ASV) was the most stable. With this view, G11 was the most stable and followed by G8, G4, G2, G10 and G9. Most of genotypes identified for their better stability had lower mean value of grain yield, however, stability of genotype is not only selection criteria. Evaluation of average performance of grain yield with ASV is tremendously important. Comparison of genotypes against to genotype selection index (GSI) exhibits mean value of grain yield and ASV. Therefore, G11, G2, G4, G3, G8, G10 and G1 had better mean value of grain yield and were relatively stable genotypes overthe study environments (Table 6) and present finding supported Tadele *et al.* (2017).

Table 5: ANOVA table for AMMI model

Source	Df	SS	Explained (%)	MS
Total	251	118.11	100.0000	0.4710
Treatments	83	92.68	78.4692	1.12**
Genotypes	11	20.65	17.4837	1.88**
Environments	6	51.59	43.6796	8.60**
Block	14	3.70	3.13267	0.260*
Interactions	66	20.44	17.3059	0.31**
IPCA	16	9.68	47.3581	0.61**
IPCA	14	4.52	22.1135	0.32**
Residuals	36	6.24	30.5284	0.1730
Error	154	21.73	18.3981	0.1410

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

Genotype	Mean	Rank	IPCAg[1]	IPCAg[2]	IPCA1	IPCA2	ASV	ASV R	GSI
G1	1.94	3.00	-0.43	0.27	9.68	4.52	0.95	10.00	13.00
G2	1.99	2.00	-0.21	0.07	9.68	4.52	0.46	4.00	6.00
G3	2.01	1.00	-0.18	-0.78	9.68	4.52	0.87	7.00	8.00
G4	1.91	4.00	-0.17	0.02	9.68	4.52	0.36	3.00	7.00
G5	1.51	8.00	0.42	0.19	9.68	4.52	0.93	9.00	17.00
G6	1.13	11.00	0.49	-0.09	9.68	4.52	1.05	11.00	22.00
G7	1.94	3.00	-0.90	0.14	9.68	4.52	1.94	12.00	15.00
G8	1.59	6.00	0.09	0.11	9.68	4.52	0.23	2.00	8.00
G9	1.43	9.00	0.18	-0.55	9.68	4.52	0.67	6.00	15.00
G10	1.57	7.00	0.29	0.09	9.68	4.52	0.62	5.00	12.00
G11	1.62	5.00	0.03	0.18	9.68	4.52	0.19	1.00	6.00
G12	1.25	10.00	0.39	0.36	9.68	4.52	0.90	8.00	18.00

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

Graphic analysis of GGE biplot analysis of small red common bean genotypes evaluated at seven locations was done in current study. The polygon dictated that G3, G7, G12 and G8 were vertex genotypes, whereas the remaining genotypes lies inside the polygon. As a rule, the vertex cultivar is the highest-yielding in all test environments that share the sector with it and the sector with vertex cultivar may be referred to as the sector of identified genotype. Accordingly, the sector of G3 had three environments (HS-09, HS-010 and GL-010), the sector of G7 had three environments (SG-08, KU-010 and SH-010) and the sector of G8 had one environment (TL-08) and had higher mean value of grain yield.Stable genotypes and environments were located near the origin of the biplot with the two IPCA scores of almost zero. Presently, G11, G8 and G10 were slightly close to the origin, showed medium stability and had below grand mean (1.66ton/ha) value of grain yield, which was undesired. Besides, G3, G7, G12, G8 and G9 were far from origin of polygon, exhibiting their more responsiveness to the environmental change and had specific environment adaptation (Fig 1).

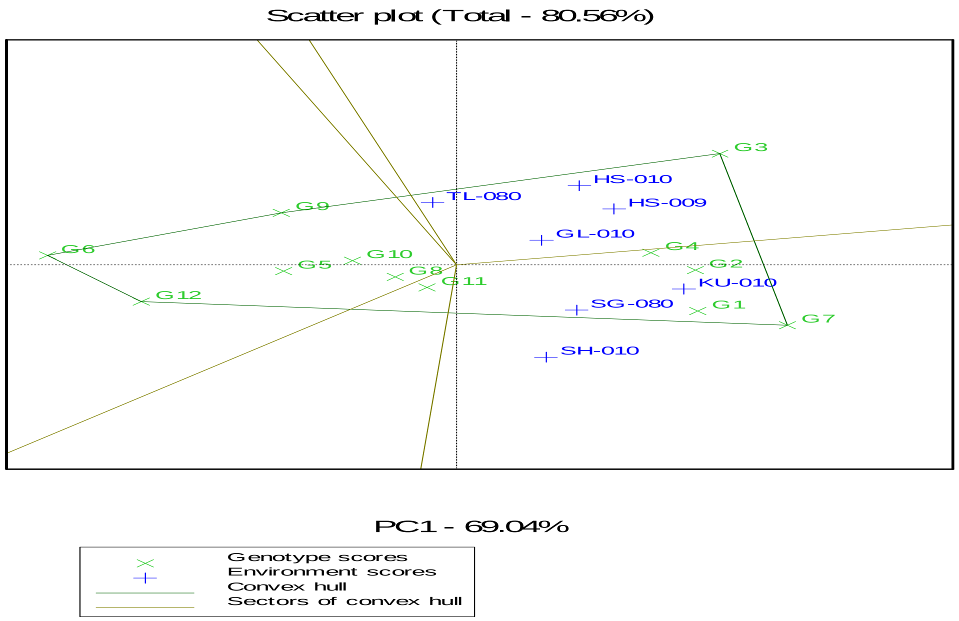

Figure 1. Scatter biplot ‘’Which won where’’ analysis, where G indicates genotyppes, GL= Gulliso, HS= Haro sabu, KU= Kure, SH= Shebel and TL= Tole

The line from the origin of the biplot to the genotype indicates the difference in yield of genotypes from the grand mean, and genotypes with long vectors could be of good or poor performance (Yan and Tinker, 2006). With this, G3 and G7 had best perforce for grain yield and had high contribution for the GEI. On the contrary, these genotypes were identified for specific adaptability because of their farness from the origin of biplot (Fig 1). No environments fell in the sectors with G12, indicating that this vertex cultivar were not the best in any of the test environments, its poor performance in some or all test environments. Moreover, this indicates that these cultivars were the poorest in some or all of the environments. Likewise, G8 and G12 were located far from origin, poor yield performance and contributing much to the GEI. Away from this, cultivar located at the origin would rank the same in all environments and is not at all responsive to the test environments. The result found supported Shitaye (2017). As “which won where pattern’’ of the biplot is concerned; the lines from the origin of the biplot perpendicular to the sides of the polygon divided the polygon in to 4 sectors (fig 1). The test locations fell in to 3 of the 4 sectors. Thus, HS-010, HS-009 and GL-010 fell in one sector and the vertex genotype for this sector was G3, indicating this genotype to be higher yielding at these three locations. KU-010, SG-080 and SH-010 fell in another sector and the vertex genotype was G7. Therefore, the current test locations could be grouped in to three mega environments; ME1 represented by G3 included three locations (HS-010, HS-009 and GL-010), whereas ME2 by G7 corresponded to KU-010, SG-080 and SH-010.

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

According to Yan (2002), the environments and genotypes obtained in the central circle are considered as ideal in GGE biplot. On the other hands, GGE bi-plot, assumes that stability and mean yield are equally important (Farshadfar *et al.*, 2011).

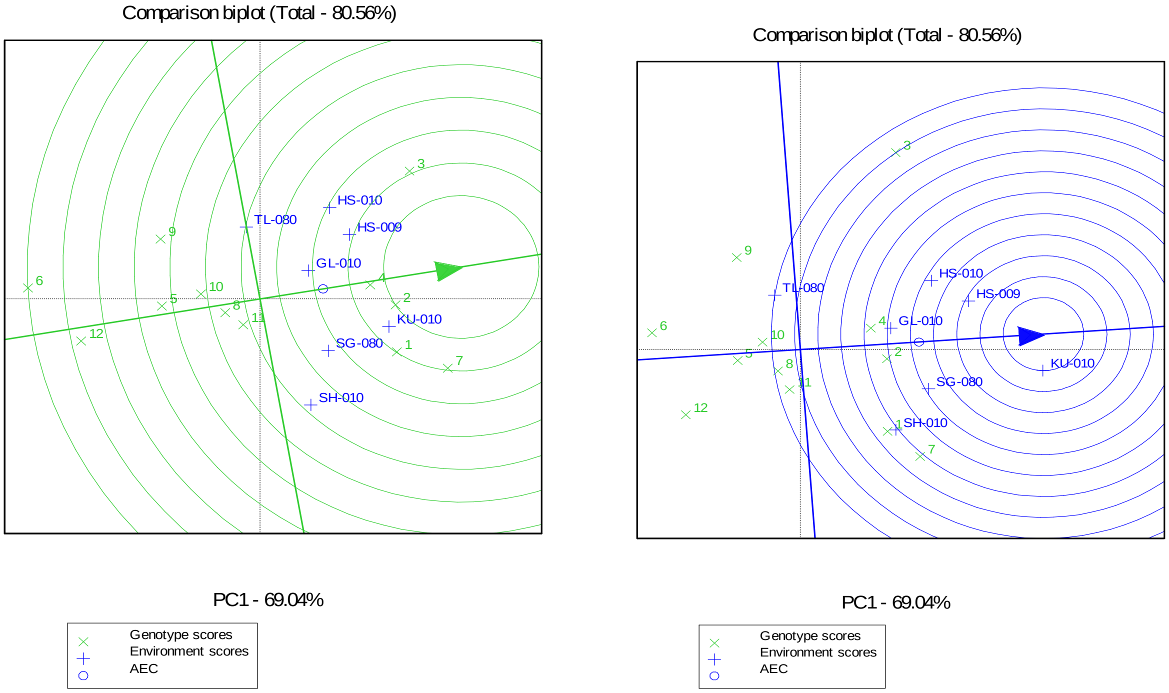

Figure 2. GGE bi-plot based on genotype and environment focused scaling for comparison of genotype and environment for grain yield stability

Genotype G2 and G4 followed by G3, G1 and G7 were lied near to the center of concentric circles and they are ideal genotypes in terms of yield and stability (Figure 2). Recently, superior and stable genotypes were reported for grain yield (Tamane *et al.*, 2015; Tadele *et al.*, 2017). Among the seven environments, Ku-010 (1.54 ton/ha) was more stable and followed by HS-009 (1.26 t/ha), and HS-010 (1.14 ton/ha) and SG-009 (2.61ton/ha), whereas TL-080 and SH-010 were the most unstable environment (Figure 2) on the contrary. Among the environments identified for their stability; SG-009 had the mean value above grand mean of grain yield which was 1.66 ton/ha (Table 4).

Conclusions and recommendation

Combined ANOVA illustrated significant variation of the main effect of genotype and environment, and their interaction effects. Significant GEI reveals difficult selection of superior genotype for all environments as their response become unstable with fluctuation of environmental conditions. Several stability parameters such as IPCA1, AMMI stability value, genotype selection index, and GGE biplot had confirmed high yielding and relatively stable genotype presently. Thus, G2, G3, G1 and G7 were identified and selected as candidate small red bean varieties and suggested for further releasing for West and KellemWollega Zones of Western Oromia and areas with similar agro-ecology.

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Genetic Inheritance in Sesame (*Sesamum Indicum* L.) Genotypes from Ethiopia

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Abstract

Knowledge on the nature and magnitude of gene action governing the inheritance of yield and its components is essential for formulating efficient breeding strategies of a crop. The aim of this study was to ascertain the type of gene action involved in the expression of yield and yield related traits in sesame. The present investigation on sesame comprised of a full-diallel set of 10 parents and their 90 F_1 *crosses. Seeds of all* F_1 *and their parents were planted in randomized complete block design, with three replications at Wama (1436 meters above level) experimental sites of Bako Agricultural Research Center on 14June 2012.Data for days to flowering, branches per plant, plant height, capsules per plant and seed yield per plant were recorded. Mean squares were highly significant among the parents and their hybrids for all the traits. The result of the study showed that both additive and dominant gene effects were important for all traits.*

Maternal effect (c) was observed for days to flowering, capsules per and yields while reciprocal effect (d) was important for all traits. For plant height and branches per plant medium narrow sense heritability was observed. In the present study over dominance is involved in all traits, hence for yield per plant parents can be best exploited by production of hybrids. Alternatively, recurrent selection in segregating material followed by conventional selection scheme is likely to lead to improvement of this crop for yield and yield related traits.

Key words: *Additive variance, Gene action, Inheritance, Segregating generations*

Introduction

Knowledge on the nature and magnitude of gene action governing the inheritance of yield and yield components is essential for formulating efficient breeding strategies for the improvement of a crop (Praveenkumar *et al*., 2012). The success of an improvement program for a crop essentially depends on the nature of action and degree of variability in the attribute of that crop (Sumathi and Muralidharan, 2010).The increase in yield and yield potential is always an ultimate goal for any crop-breeding program. Grain yield in sesame is a complex trait being the consequence of several genes and their interaction in a particular environment (Mahajan *et al*. 2011). The main effort of sesame breeder is the detection of favorable genes and to assemble them in a particular genotype using most suitable combination. As the sesame is predominantly a self-pollinated crop and due to its autogamous nature, it attains homozygosis at many loci (Weiss, 2000). So it is necessary to introduce different genes which are known to be yield contributor. The study of inheritance pattern and analysis of gene action is very important to make decision about selection of suitable parents. The diallel cross is a technique developed by Hayman (Hayman,1954a,b) provides information on genetic mechanism specially for quantitative traits involved in early generations and particularly suit to autogamous crops like sesame. The information derived would be effectively exploited to develop an appropriate breeding strategy for continued genetic improvement of this vital oil crop, aimed at evolving new varieties with desirable yield potential.

The diallel analysis techniques developed by Hayman (1954 a b) and Jinks (1954, 56) provide a fairly reliable mechanism to properly understand the genetic system and gene action involved in the expression of important plant attributes. The diallel cross procedures provides statistical approach of genetic study which is widely used by breeders for analyzing metric traits in different species. It furnishes logical information about the genetic architecture of the plant and heredity behavior of the parameters under study in early generation like F_1 and F_2. It also describes how to measure additive and dominance variation and the relative dominance properties of the parental lines.

The study on the genetic analysis of sesame would help the breeder to formulate appropriate selection procedure for screening of these inbred lines and the evaluation of their progenies for various purposes (Swain *et al*., 2001). It provides heritability estimates of the character, which helps to predict progress through selection. The character showing high heritability could be improved through direct selection. On the other hand, in the case of progenies involving a greater non-additive genetic variance including dominance, over dominance, epitasis and linkage selection of desirable genotypes is not straightforward procedure. There are number of biometrical approaches available to estimate genetic component of variations (Mather and Jinks 1971) but there have been very few attempts to apply them to the phenomenon of genetic analysis of sesame. The diallel crossing procedure and analysis (Hayman 1954a, b; Jinks 1954, 1956; Mather and Jinks 1971) also provides comprehensive information about the genetic basis of different parameters. This approach provides authentic information about the genetic architectures and mode of inheritance of traits in early generation like F_1 and F_2 .This statistical procedure of genetic analysis for analyzing quantitative traits in a wide variety of crops. These methods attempts to partition phenotypic variations into genotypic and environmental components and further subdivide genotypic variation into additive and dominance components. This method provides very important information about the nature of the genetic system and together more clearly resolve the mechanism of inheritance than do each alone. In Ethiopia, information on the inheritance of yield and yield component for sesame is lacking. The aim of this study, therefore, was to ascertain the type of gene action involved in the expression of yield and yield related traits.

Materials and Methods

Planting materials: Ten parental genotypes *viz*., EW002, BG006, EW023-2, EW006, EW003-1, EW019, Obsa, Dicho, Wama and EW010-1 were used in the study (Table 1). Parental lines, Obsa and Dicho are released varieties while others were elite breeding lines. Initially Bako Agricultural Research Center (BARC) identified the elite breeding lines among many sesame genotypes collected from western Ethiopia. For the crossing purpose, to establish the 10 parents as pure lines, seeds of a single plant from each genotype were collected during 2010 main season.

Table 1. Description of 10 sesame parental lines for selected agromorphology traits they exhibited variations

Genotype	Code	Collection zone	Collection altitude (masl)	Soil texture	Reaction to bacterial blight
EW002	P1	east Wellega	1470	Clay loam	R
BG006	P2	Benshangul-Gumuz	1000	Clay loam	R
EW023-2	P3	east Wellega	1580	Sandy	MR
EW006	P4	east Wellega	1400	Clay	R
EW003-1	P5	Horo-GuduruWellega	1346	Clay loam	R
EW019	P6	Benshangul Gumuz	1095	Clay loam	R
Obsa	P7	Horo-GuduruWellega	1395	Clay	R
Dicho	P8	east Wellega	1460	Clay	MR
Wama	P9	east Wellega	1430	Clay	MR
EW010-1	P10	east Wellega	1473	Sandy loam	R

R=resistant, MR=moderately resistant

Experimental Procedures

Ten parental lines were crossed in 10 x 10 full diallel mating design in 2011cropping season. Seeds of all 90 F_1s and their 10 parents was planted on 14 June 2012 at Wama (1436 m.s.l.) experimental sites of the BARC in a randomized complete block design with three replications. Each plot consisted of a single row of 5 m length with 50 cm and 25 cm inter and intra-row spacing, respectively. The seeds were drilled in each row at seeding rate of five kg ha^{-1}. Twenty days after planting, the plants were thinned out to adjust for optimum population per hectare. Nitrogen fertilizer at the rate of 50 kg ha^{-1}in the form of UEREA was applied as side dressing four weeks after emergence. Hand weeding was carried out four times at three weeks interval starting 20 days after planting. Observations were made on various characters of sesame genotypes (10 parental lines and 90 F_1s hybrids) but only five characters of interest in sesame breeding were selected viz., days to flowering, plant height, branches per plant, capsule per plant and yield per plant. Data for days to flowering (50%) was registered on a plot basis. Observations were made on ten randomly selected plants for the other four traits.

Statistical Analysis

Before subjecting the data to the diallel technique analysis of variance (ANOVA) was performed to determine whether significant genotypic differences are present for the traits among 100 genotypes. The analysis of data involved two distinct phases (Hayman 1954 a, b) and Jinks, 1954, 1956). In the first phase formal analysis of variance of the diallel table partitioning the family, mean effects into additive (a) and dominance (b) components. It also detects maternal (c) and reciprocal (d) effects. The dominance (b) component was further partitioned into directional dominance effects (b_1, the mean deviation of the crosses from the mid parent values); effect due to unequal contribution of the dominance alleles by parents (b_2) and the specific gene interaction (b_3) which is termed as specific combining ability (Griffing, 1956a) and refers to those cases in which certain parental combinations perform relatively superior or inferior than expectation based on the average potential of the genotypes involved. The analysis of variance (Hayman, 1954a) for F_1 generation is presented in Tables 2 and Table 3. Each main effect was tested against its own interaction over blocks. If 'c' maternal difference and 'd' reciprocal differences were, significant 'a' against 'c' and 'b' along its components against 'd' were tested. The second step of analysis was the computation of the variance of each array (Vr), the covariance of all the off-springs included in each parental array with the non-recurrent parents (Wr) and the variance of the parental means (V_0L_0) were computed. In addition, the means of the array variance (V_1L_1), the variance of the mean of array (V_0L_1) and the mean of the array covariance (W_0L_0) were also calculated. Before we proceed ahead with the numerical analysis the validity of the assumption regarding adequacy of additive dominance model was tested (Table 3).

The genetic parameters i.e E (environmental variance from ANOVA), D (estimate of additive and some portions of additive x additive genetic variance), F (estimate of relative frequency of dominant and recessive alleles in the parent), H_1 and H_2 (estimate of dominance and dominance x dominance interactions, respectively), h^2 (dominant effect as algebraic sum over all loci in heterozygous phase in all crosses provides the direction of dominance i.e. positive sign shows that direction of dominance being towards parents and the negative sign shows towards off-springs), $H_2/4H_1$ and $[(4DH_1)^{1/2} + F]/ [(4DH_1)^{1/2} - F]$ (KD/KR) provides the proportion of dominant and recessive genes in the parents, $(H_1/D)^{1/2}$, (as mean degree of dominance), and heritability in narrow sense were computed according to Mather and Jinks (1982). The correlation between parental order of dominance (Wr+Vr) and parental measurement (Yr) (r (Yr, Wr +Vr (the prediction for measurement of completely dominant and recessive parents) were also estimated as suggested by Mather and Jinks (1982). The minimum number of gene which exhibited some degrees of dominance (Hayman 1954) and Mather's (1949) and effective factor (k) Jinks (1956) were also computed.

Results and Discussion

The mean square for all genotypes was significant for all traits, signifying considerable genetic diversity among the parents and the crosses (Table 2). In addition, these genotypes seem to have different genes controlling the investigated traits. These results are confirmed by earlier reports (El-Bramawy, 2010; Pham *et al*., 2010). The estimates of components of variance from a diallel cross are unbiased, only if certain assumptions are met (Hayman, 1954). These assumptions are: Diploid segregation, no reciprocal differences, homozygous parents, no multiple allelism, uncorrelated gene distributions and absence of non allelic interaction. The adequacy of additive dominance model was tested to validate these assumptions. The Wr-Vr mean square was non-significant for only five traits viz.,days to flowering, plant height, branches per plant capsules per plant and yield per plant among ten tested traits (Table 3). Thus, values of Wr-Vr could be regarded as consistent over arrays that the additive-dominance model is satisfactory.

Table 2.Mean squares for different traits in sesame

Source of Variation	Df	Mean squares				
		DF	PH	BP	CP	YP
Rep	2	130.04**	668.84**	71.61**	25632.67**	261.34**
Genotype	99	9.84**	324.18**	5.23**	3299.79**	42.231**
Error	198	4.2000	199.3000	2.0800	1299.2600	15.2700

** Significant at $p \leq 0.01$ level; DF=days to flowering; PH=plant height; BP=branches per plant; CP=capsules per plant and YP=yield per plant

Table 3. ANOVA for (Wr-Vr)

		Mean square				
Source	DF	DF	PH	BP	CP	YP
Rep	2	2.0500	9779.4200	5.8700	36715554.900	93.300
Wr-Vr	9	2.29ns	5657.11ns	1.39ns	37003221.8ns	109.4ns
Error	18	3.0000	4673.8200	1.5100	39604250.000	64.900

ns=non significant, DF=days to flowering; PH=plant height; BP=branches per plant; CP=capsules per plant and YP=yield per plant

Hayman's ANOVA for all traits presented in Table 4.Additive variances (a) was significant for plant height, branches per plant and yield per plant, demonstrating the presence of additive gene effects. Praveenkumar *et al.* (2012) reported similar result for plant height, and seed yield per plant in sesame genotypes. For branches per plant and yield per plant after retest of ‘a’ against ‘c’ it remained unchanged for these two characters, indicating that there was no maternal effect on these traits. Item ‘b_1’ was non-significant for all traits, showing the absence of directional dominance for most of the studied traits. Dominance deviation due to the parents (b_2) was significant for days to flowering, plant height and branches per plant, demonstrating the asymmetrically distribution of dominant alleles in the parents. This unequal distribution of genes clearly suggests that some parents have considerably more dominant alleles than others for these traits.

Item b_3 was significant for all traits showing that there are differences between hybrids values due to the dominance effect. After retest of b_3 against ‘d’ it was non-significant for days to flowering, indicating that this trait was controlled by reciprocal effect. However, for capsules per plant and yield per plant it was kept significant, demonstrating that reciprocal effect had no control for these traits. Item ‘b’ was significant for all traits that were indicative of the presence of dominance genes effects. Aladji Abatchoua *et al.* (2014)) reported similar result for these traits in sesame. For days to flowering following the retest of item b_2, b_3 and b against that of ‘d’ it was reduced to non- significant, showing that the reciprocal effects had masked the dominant genes effects for this trait. For days to flowering, branches per plant and yield per plant item ‘c’ was significant, demonstrating that the presence of maternal effect for these traits. The ‘d’ item was significant for days to flowering, capsules per plant and yield per plant, indicating the presence of reciprocal effect for these traits. The choice of female parent is critical in a breeding program (Arunga *et al.*, 2010).

Table 4. Hayman’s analysis of variance for some traits in 10x10 diallel crosses of sesame evaluated at Wama

Item		Days to flowering			Plant height		Branches per plant		
	Df	MS	F- ratio	Retested against d	MS	F- ratio	MS	F- ratio	Retested against c
A	9	11.12	1.9000		812.20	3.84**	16.48	16.55**	3.82*
b_1	1	9.60	2.0900		98.61	1.4000	7.89	13.9400	
b_2	9	13.19	3.060*	1.37ns	728.35	4.79**	9.02	4.85**	
b_3	35	7.96	2.07**	0.83ns	282.50	1.860*	4.48	1.65**	
B	45	9.04	2.29**	0.94ns	367.59	2.49**	5.46	2.19**	
C	9	13.50	4.01**		232.00	0.6100	4.32	3.020*	
D	36	9.60	2.22**		170.95	0.7800	2.37	1.1800	
Total	99	9.84			324.18		5.23		
a x B	18	5.85			211.61		1.00		
b_1 x B	2	4.58			70.58		0.66		
b_2 x B	18	4.28			152.72		1.86		
b_3 x B	70	3.85			151.69		2.72		
b x B	90	3.96			150.09		2.50		
c x B	18	3.37			356.64		1.43		
d x B	72	4.32			218.39		2.00		
B x interaction	198	4.20					2.08		

ns= non significant *, ** = significant at $P \leq 0.05$ and $P \leq 0.01$, respectively, B= block, df: Degree of freedom, a = additive effects of genes; b =dominant effects of genes; b_1 = mean dominance effects; b_2 = additional dominance deviation due to the parents, b_3 = residual dominance effects; c=maternal effect; d=reciprocal difference

Table 4.Continued

		Capsules per plant			Yield per plant			
Item	Df	MS	F- ratio	Retested against d	MS	F-ratio	Tested against c	Tested against d
	9	4398.84	0.23ns		48.3	3.11**	16.1*	
b_1	1	2066.31	1.09ns		18.6	0.85ns		
b_2	9	2870.53	2.06ns		37.2	2.29ns		
b_3	35	3889.94	3.04**	3.59**	51.0	3.20**		2.9479**
b	45	3645.54	2.77**	3.36**	47.5	2.95**		2.7456**
c	9	2490.54	1.36ns		37.0	12.33**		
d	36	2795.15	2.58**		35.4	2.04**		
Total	99	3299.79			42.2			
a x B	18	18794.38			15.5			
b_1x B	2	1880.64			21.8			
b_2 x B	18	1390.00			16.2			
b_3 x d	70	1277.74			15.9			
bx B	90	1313.60			16.1			
c x B	18	1818.63			3.0			
d x B	72	1083.27			17.3			
B x interaction	198	610.85			159.2			

*, ** = significant at $P \leq 0.05$ and $P \leq 0.01$, respectively, B= block, df: Degree of freedom a = additive effects of genes; b =dominant effects of genes; b_1 = mean dominance effects; b_2 = additional dominance deviation due to the parents, b_3 = residual dominance effects; c=maternal effect; d=reciprocal difference

Table 5 shows the estimates of genetic parameters for yield and yield related traits. The additive variance (D) was significant for plant height, branches per plant and yield per plant, demonstrating that successful selection could be practiced for these traits. The dominance variance component (H_1) was significant for all traits except days to flowering, suggesting that the non-additive type of gene actions were involved in the inheritance of these traits. The expression of all traits was conditioned by both additive and dominant gene actions. However, dominant component (H_1) is more predominant than additive component (D), indicating greater contribution of non-additive variance. Days to flowering, branches per plant, capsules per plant and yield per plant are under the influence of dominant gene effects as shown by the significant value of non-additive genetic effects (H_2). The dominant effect (h^2) was significant and positive for yield per plant, and positive non-significant for plant height, branches per plant, and capsule per plant, indicating that the direction of dominance was towards the parents for these traits. On the other hand, h^2 was negative for days to flowering, demonstrating that the dominance was towards the off-springs.Dominant alleles are more frequent than recessive, irrespective of whether or not the dominant alleles have increasing or decreasing effects as revealed by the positive component of ‘F’ for plant height, branches per plant, capsules per plant and seed yield per plant. It was positive for the symmetry distribution of dominant and recessive alleles in parent as corroborated by the direction (sign) of ‘F’. As suggesting by a negative value of ‘F’ parameter, days to flowering may be under the influence of recessive genes.

The involvement of the environmental effects in the expression of all traits was revealed by the highly significant of environmental variance (E) for days to flowering, plant height, branches per plant, and capsules per plant and yield per plant. However, environmental variance was less than additive and dominant variances.

The over dominance for the expression of all traits was revealed by greater than unity value of the average degree of dominance $(H_1/D)^{1/2}$for all traits. This value suggested that the dominance component is relatively more important, so delayed selection in segregation generations should be preferred for the traits. Significant over dominance for plant height, days to 50% flowering, days to maturity, number of capsules per plant, number of seeds per capsule and seed yield per plant was earlier reported by Praveenkumar *et al*. (2012).When over dominance is involved, gene action can be best exploited by production of hybrids for commercial planting. The proportions of dominant genes with positive or negative effects in parents $(H_2/4H_1)$ were different from 0.25 for all traits; hence, dominant genes having increasing and decreasing effects in these traits are irregularly distributed in parents. The inferences drawn from the 'F' was also confirmed by the proportion of dominance to recessive alleles in the parents as measured by the value of KD/KR, which was more than unit for plant height, branches per plant, capsules per plant and yield per plant. Symmetry of dominant and recessive allele's distribution in parents is further established by relative sizes of H_1 and H_2.The value of H_1 and H_2 were not equal for all traits, indicating the asymmetric distribution of dominant and recessive genes.The value of K (h^2/H_2) was greater than one for yield per plant, suggesting that one group of genes exhibiting dominance governed that character. For the other traits, value of K was less than one. Thus, the value of K did not provide any valid interpretation for all the traits about the group of genes exhibiting dominance. The ratio could be under estimated when the dominance effects of all the genes concerned are not equal in size and distribution, when the distribution of genes is correlated (Jinks, 1954), or when the complementary gene interactions occur (Mather and Jinks, 1971). Among the parents, the correlation between standardized parental measurement (Yr) and parental order of dominance (Wr + Vr) was positive for days to flowering, branches per plant and capsule per plant, demonstrating that the parents containing the most increasing genes have the highest value of Wr +Vr and contain the least dominant genes for these characters. On the other hand ,the correlation was negative for plant height and seed yield per plant, indicating that parent containing the most increasing genes have the lowest value of Wr +Vr for these traits and thus contain the most dominant genes. Narrow sense heritability ranging 6.3 to 25% was observed for all traits, suggesting the need for population improvement or a good scope for the development of hybrids. According to Robinson 1966 (cited in Dabholker, 1999) heritability, estimates in cultivated plants can be placed in the following categories: (1) low heritability (5 to 10% e.g. grain yield) (2) medium heritability (10 to 30%, e.g. yield components (3) high heritability (30 to 60%, e.g. maturity traits, chemical composition of traits). Based on this classification low heritability was observed for seed yield per pant and days to flowering. Whereas medium heritability was observed for plant height and branches per plant, indicating that those genes, which are less, in controlling these traits due to influenced by environment. The present study indicated the both additive and dominant genes as well as environmental factors were important for the studied traits.

Table 5. Estimates of genetic parameters for yield and yield related traits

Genetic parameters	DF	PH	BP	CP	YP
D	2.207±3.96 ns	64.95 ± 31.13**	1.44±0.36**	562.6±520.12 ns	7.86±3.9**
H_1	10.68±8.43 ns	239±66.25**	3.453±0.77**	2417±1107**	25.054±8.3**
H_2	14.57±7.16**	107.84±56.31 ns	1.792±0.66**	2794. 92 ±940.94**	19.87 ± 7.02**
h^2	1.5±4.79ns	-12.60±37.68 ns	0.61 ns	126.08 629.64 ns	33.87 **
F	-2.42 9.13 ns	149.98 71.82**	2.194 0.84**	0.36 12.00 ns	11.008 ns
E	1.82 1.19 ns	58 9.38**	0.926 **	514.19 **	5.91 **
$(H_1/D)^{1/2}$	2.19	1.92	2.232	2.072	1.785
$H_2/4H_1$	0.341	0.112	0.129	0.289	0.198
KD/KR	0.63	4.008	2.931	1.003	2.290
K (d^2/H_2)	0.1029	-0.116	0.340	0.45	1.704
r(Yr,Wr +Vr)	0.16	-0.74*	0.20	0.20	-0.33
h^2ns (%)	6.3	21.40	25.0	7.1	9.0

ns, ** , non significant and significant at 0.01 levels, respectively; DF=days to flowering ,PH= plant height, BP=branches per plant, CP=capsules per plant, YP= yield per plant;

Conclusions and recommendations

The result of the study showed that additive and dominant gene effects were important with predominance of dominance variances for all traits. Maternal effect was significant for days to flowering, capsules per plant and yield per plant. For days to flowering, capsules per plant, and yield per plant were controlled by reciprocal effect. The residual dominance (b_3) for days to flowering, plant height, capsules per plant and yield per plant confirmed the presence of specific dominance or combining ability in some crosses. For plant height and branches per plant, medium narrow sense heritability was observed. In the present study, over dominance is involved in all traits, hence the parents can be best exploited by production of hybrids for commercial planting. Or else recurrent selection in segregating material followed by conventional selection scheme is likely to lead to improvement of the crop for yield and yield related traits.

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GGE-biplot analysis of Multi-Environment Yield Trial in Sesame (*Sesamum indicum* L.) genotypes

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Abstract

The development of high yielding cultivars with wide adaptability is the ultimate aim of plant breeders. The objective of this study was to evaluate sesame genotypes for stability. Ten genotypes were evaluated in year 2011/2012 main season at ten environments for grain yield performance. The experiment was laid out in a randomized complete block design with three replications. The seed yield data were analyzed using the genotype x environment interaction effect (GGE) biplot. The effect of environmental interaction on grain yield was high followed by GE interaction. Genotype Obsa (G8) was the best for its high yield but with specific adaptability. For their grain yield EW002 (G1), BG006 (G2), EW006 (G4), EW11-2 (G7), Obsa (G8) and Dicho (G9) are desirable. Test location, Haro-Sabu (E10) was the most desirable followed by Boneya (E6) and Arjo-Gudatu (E7).EW002 (G1) and BG006 (G2) were found to be the best two genotypes with both high yield and stability and they are recommended for production . These two genotypes can be used as parent in crossing program for their high per se grain yield performance.

Key words: Genotype × Environment Interaction, GGE biplot, Sesame, Stability

Introduction

The development of high yielding cultivars with wide adaptability is the ultimate aim of plant breeders. However, attaining this goal is made more complicated by (GEI) genotype-environment interactions (Gauch and Zobe, 1996). A genotype grown in different environments will frequently show significant fluctuations in yield performance. These changes are influenced by the different environmental conditions and are referred to as genotype-by-environment (GE) interaction (Allard and Bradshow, 1964). Genotype by environment interaction (GEI) reduces the genetic progress in plant breeding programs through minimizing the association between phenotypic and genotypic values (Comstock and Moll, 1963). Hence, GE interaction must be either exploited by selecting superior genotype for each specific target environment or avoided by selecting widely adapted and stable genotype across wide range of environments (Ceccarelli, 1989). Various authors have proved that stability indices are genetic and hence heritable (Lin and Binns, 1988; Lin and Binns, 1991; Farshadfar *et al.*, 1999).

Multi-environment trials (METs) are essential in estimation of genotype by environment (GE) interaction and identification of superior genotypes in the final selection cycles. Selection based on yield only, may not always be adequate when genotype by environment interaction is significant (Kang *et al.,* 1991). The presence of genotype by environment interaction (GEI) frequently changes the ranks in different environments due to cross interaction making their proper selection difficult. Therefore, it is essential to take in account the genotype by environment interaction, properly understood and analyzed. Consequently, METs are widely used by plant breeders to evaluate the relative performance of genotypes for target environments (Delacy *et al.*, 1996).Several researches identified plant breeders using GGE biplots for genotypic stability analysis (Farshadfar *et al.*, 2011a). GGE biplot is an effective method based on principal component analysis (PCA) to fully explore MET data. It allows visual examination of the relationships among the test environments, genotypes and the GE interactions. It is an effective tool for: (i) mega-environment analysis (e.g. "which-won-where" pattern), where by specific genotypes can be recommended to specific mega-environments (Yan and Kang, 2003; Yan and Tinker, 2006), (ii) genotype evaluation (the mean performance and stability), and (iii) environmental evaluation (the power to discriminate among genotypes in target environments) (Ding *et al*., 2007). The objective of this study was to evaluate sesame genotypes for stability.

Materials and Methods

Ten genotypes viz., EW002s, BG006, EW023-2, EW003-1, EW0011-4, EW008-1, EW011-2, Obsa, Dicho, and Wama) were used in the study. Among these, Obsa and Dicho were released for western Ethiopia, whereas the rest seven are elite breeding lines and a local check (Table 1). They were selected based on their high yield, good agronomic characters and disease resistance. The genotypes were also given codes for data analysis (Table 3). The experiments were carried-out in ten locations viz., Anger, Uke, Wama, Bako, Gambela-Tare, Boneya, Arjo-Gudatu, Lugama and Haro-sabu. The environments were also given codes for ease of data handling (Table 3).The experiment was laid out as a randomized complete block design with three replications. Sowing was done at all locations on June 13 to 20 in the main season of 2011/2012. The seed was drilled in each row at seeding rate of 5 kg ha^{-1} in plot consisting of 6 rows of 5 meter length each with the spacing of 40 cm. Nitrogen fertilizer in the form of UREA was applied at the rate of 46 kg N ha^{-1} at planting. Twenty days after planting, thinning was done to 5 cm spacing between plants. Hand weeding was done four times at two weeks interval starting 15 days after planting. The genotypes were harvested on October 14 to 20 in year 2012. Seed yield per plot of the middle four rows were taken and reported in kg ha^{-1}. The yield data was subjected to combined analysis of variance (ANOVA) to determine the effects of environment (E), genotype (G), and their interactions. The data was graphically analyzed for interpreting GE interaction using the GGE biplot software. GGE biplot methodology, which is composed of two concepts, the biplot concept (Gabriel, 1971) and the GGE concept (Yan *et al.,* 2000), was used to visually analyze the sesame genotypes MET data. This methodology uses a biplot to show the factors (G and GE) that are important in genotype evaluation and that are also the sources of variation in GE interaction analysis of MET data (Yan, 2001).

The graphs generated based on (i) ranking of genotypes based on yield and stability (ii)Which–Won–Where Pattern of Genotypes (iii) Evaluation of genotypes relative to an ideal genotype (iv) Relationships among Test Environments (v) Relationships between testing environments based on the angles between the vectors of the environments(iv)Ranking locations relative to the ideal location. The GGE-biplot shows the first two principal components (PC1 and PC2, also referred to as primary and secondary effects, respectively) derived from subjecting environmental centered yield data (yield variation due to GGE) to singular value decomposition (Yan *et al*., 2000). For raw data of seed yield biplots of the first two principal components were constructed using GenStat 15th edition and used to illustrate the relation among genotypes, environments and between the genotypes and environments. In the present study, genotype-focused scaling was used to compare genotypes, while environment focused; scaling was used to compare environments. Furthermore, symmetric scaling was preferred in visualizing the which–won-where pattern of the multi-environment trial yield data (Yan, 2002). Correlation coefficients between pairs of locations were computed by the use of SAS 9.0 software.

Table 1. Description of ten sesame genotypes evaluated in four locations in year 2012

Entry	Genotype	Category	DM	PH	BP	YP
1	EW002	Elite breeding line	124	140	9	17
2	BG006	Elite breeding line	123	138	7	16
3	EW023 -2	Elite breeding line	125	142	5	12
4	EW003-1	Elite breeding line	122	145	7	17
5	EW0011-4	Elite breeding line	124	140	8	14
6	EW008-1	Elite breeding line	121	137	7	16
7	EW011-2	Elite breeding line	124	139	7	16
8	Obsa	Released in 2010	119	135	7	14
9	Dicho	Released in 2010	120	140	8	16
10	Wama	Local	121	137	6	15

Note: DM = days to maturity, PH = plant height (cm), branches per plant and YP = yield per plant (g).

Table 2. Description of test locations used for evaluation of sesame genotypes.

Location	Soil type	Altitude (*m.a.s.l.*)	District	Zone
Angar	Humic nitosol	1355	Gida Ayana	East Wellega
Uke	Humic nitosol	1383	Guto Gida	East Wellega
Wama	Humic nitosol	1436	Wama Hagalo	East Wellega
Bako	Humic nitosol	1597	Gobu Sayo	East Wellega
Gambela -Tare	Nitosol	1645	Gobu Sayo	East Wellega
Bechera	Nitosol	1604	Bako Tibe	West Showa
Boneya	Nitosol	1624	Wayu Tuka	East Wellega
Lugama	Nitosol	1582	Jima Arjo	East Wellega
Arjo-Gudatu	Nitosol	1423	Diga	East Wellega
Haro-Sabu	Humic cambisol	1575	Dale -Sadi	Kelem Wellega

Table 3. Genotypes and environments and their codes

No	Genotype	Genotype code	No	Environments	Env. code
1	EW002	G1	1	Angar	E1
2	BG006	G2	2	Uke	E2
3	EW023- 2	G3	3	Wama	E3
4	EW003-1	G4	4	Bako	E4
5	EW0011-4	G5	5	Gambela-Tare	E5
6	EW008-1	G6	6	Bechera	E6
7	EW011-2	G7	7	Boneya	E7
8	Obsa	G8	8	Lugama	E8
9	Dicho	G9	9	Arjo-Gudatu	E9
10	Wama	G10	10	Haro-Sabu	E10

Results and Discussion

The results of combined analysis of variance showed highly significant variation among all sources of variation. The environments (E) and genotypes (G) justified 50.0% and 12.9% of the sum of squares, respectively (Table 4). Genotype × environment interaction (GEI) explained

37.1%, of the total variation and greater about three times than the G effect. The large GE interaction, relative to G effect, in this study suggests the possible existence of different mega-environments with different top-yielding genotypes (Yan and Kang, 2003; Farshadfar *et al.*,2012).This result revealed that there was a differential yield performance among the tested genotypes across testing environments due to the presence of GE interaction. The presence of GE interaction complicates the selection process as GE interaction reduces the usefulness of genotypes by confounding their yield performance through minimizing the association between genotypic and phenotypic values (Comstock and Moll, 1963). It is very common for multi-environment yield trials (MEYTs) data to embody a mixture of crossover and non-crossover types of GEI (Cravero *et al.*, 2010), the former indicate the change in yield ranking of genotypes across environments and the later term shows constant yield rankings of genotypes across environment (Yan and Hunt, 2001; Matus-Cadiz *et al.,* 2003). In normal, MEYTs were reported that E explained for about 80% of the total variation, while G plus GE explained for about 20% (Gauch and Zobel, 1997). On the other hand Farshadfar *et al.*(2012) reported in wheat the environment (E) effect that was accounted for 21.7 % of total sum of squares (TSS).

Table 4. The ANOVA of yield data of ten sesame genotypes tested ten environments in 2012

Source	Df	SS	MS	F	P	Model	SS%
Environment (E)	9	6290682.40	698964.7**	82.00	0.0001	Random	50.0
Rep(E)	20	575553.60	28777.6**	3.30	0.0001		
Genotype (G)	9	1627036.40	180781.8**	21.20	0.0001	Fixed	12.9
GEI	81	4660324.80	57534.8**	6.70	0.0001	Random	37.1
Error	180	1533251.00	8518.100				
Total	299						
CV% = 15.60		$R^2 =$ 0.89					

The mean seed yield of all sesame genotypes at ten locations was presented in Table 5. The grand mean performance of the tested genotypes across ten locations was 691 kg ha^{-1}.Genotype G1 was possessed the highest seed yield at three environments namely E2, E5 and E8.Genotype G2 in E6, G7 in E1, G9 in E9 showed maximum yield. The other genotype G8 was the best for its mean yield at E4, E7, and E10. Moreover, across all test environments, G8 was the best for grain yield with mean of 689 kg/ha. On the other hand, genotype G5 and G3 were low yielders with 479 and 483kg ha^{-1} respectively. The differential ranking of genotypes across test environments revealed that there exists possible crossover GEI. However, GEI is not always the case. Among the ten test environments, E2 was the best for its high yield followed by E3 and E1 while E4 was with the least yield.

GGE-Biplot Analysis

Ranking of Genotypes Based on Yield and Stability

The ranking of ten sesame varieties based on their mean yield and stability performance were shown in Figure 1. The line passing through the biplot origin is called the average tester coordinate (ATC), which is defined by the average PC1 and PC2 scores of all environments (Yan and Kang, 2003). The line, which passes through the origin and is perpendicular to the ATC, represents the stability of genotypes. Genotypes G3 and G5 were far away from the biplot origin, showing their greater GE interaction and reduced stability. A position in either direction away from the biplot origin indicated greater GEI and reducing stability (Yan, 2002).For selection, the ideal genotypes are those with both high mean yield and high stability. In the biplot, they are close to the origin and have the shortest vector from the ATC. The G1 and G2 can be considered as genotypes with both high yield and stability performance. The other genotypes on the right side of the line such as G4, G7, G8 and G9 have yield performance greater than grand mean yield (591kg) and the genotypes on the left side of this line had yields less than grand mean yield. The genotypes with highest yielding performance but low stability were G8 and G7, whereas the genotypes with low yield and low stability were G3 and G10.

Table 5. Mean seed yield (kgha^{-1}) of ten sesame genotypes (G1-G10) tested at ten locations (E1-E10) in 2012

Genotype	E1	E2	E3	E4	E5	E6	E7	E8	E9	E10	Mean
G1	662	1185	781	340	897	724	422	708	382	432	653
G2	774	748	695	409	625	786	341	646	372	625	602
G3	383	880	533	489	481	432	334	507	435	357	483
G4	867	909	690	621	689	713	601	434	439	625	659
G5	454	833	643	372	557	555	248	300	445	383	479
G6	774	821	714	372	697	276	590	531	353	373	550
G7	1266	808	896	245	689	503	421	502	606	525	646
G8	515	892	881	664	760	643	612	591	527	804	689
G9	512	964	838	307	517	638	567	584	794	628	635
G10	691	843	838	184	670	383	367	503	355	350	518
Site mean	690	888	751	400	658	565	450	531	471	510	

Which-Won-Where Pattern of Genotypes / Polygon view of GGE biplot analysis of MET

Figure 2 represents polygon view of genotype - environment interaction for sesame genotypes over the ten test environments. In this biplot, a polygon was formed by connecting the vertex genotypes with straight lines and the rest of the genotypes placed within the polygon. The polygon view of a biplot is the best way to visualize the interaction patterns between genotypes and environments (Yan and Kang, 2003) to show the presence or absence of cross over GE interaction, which is helpful in estimating the possible existence of different mega environments (Gauch and Zobel, 1997; Yan and Rajcan, 2002; Yan and Tinker, 2006). Visualization of the "which won where" pattern of MET data is necessary for studying the possible existence of different mega environments in the target environment (Gauch and Zobel, 1997; Yan et al., 2000).

The partitioning of GE interaction through GGE biplot analysis showed that PC1 and PC2 accounted for 32.75% and 26.95% of GGE sum of squares, respectively, explaining a total of 59.70% variation. The vertex genotypes in this study were G8, G7, G10 and G3. These genotypes were the best or the poorest genotypes in some or all of the environments because they were farthest from the origin of the biplot (Yan and Kang, 2003). From the polygon view of biplot analysis of MET data, the genotypes fell in four sections and the test environments fell in two sections. The first section contains the test environments EI, E3 and E5 which had the genotype G7 as the winner. The fourth section contains seven environments viz., E2, E4, E6, E7, E8, E9 and E10 with genotype G8. The falling of these environments into a single sector indicates that a single genotype (G8) has high yield in all environments. The falling of all environments into different sectors means that different genotypes win in different sectors (Yan *et al.,* 2007).The vertex genotype G3 and G10, were not the top-yielding genotypes in any environment. Actually, they were the poorest genotypes in some or most of the environments (see Table 5).

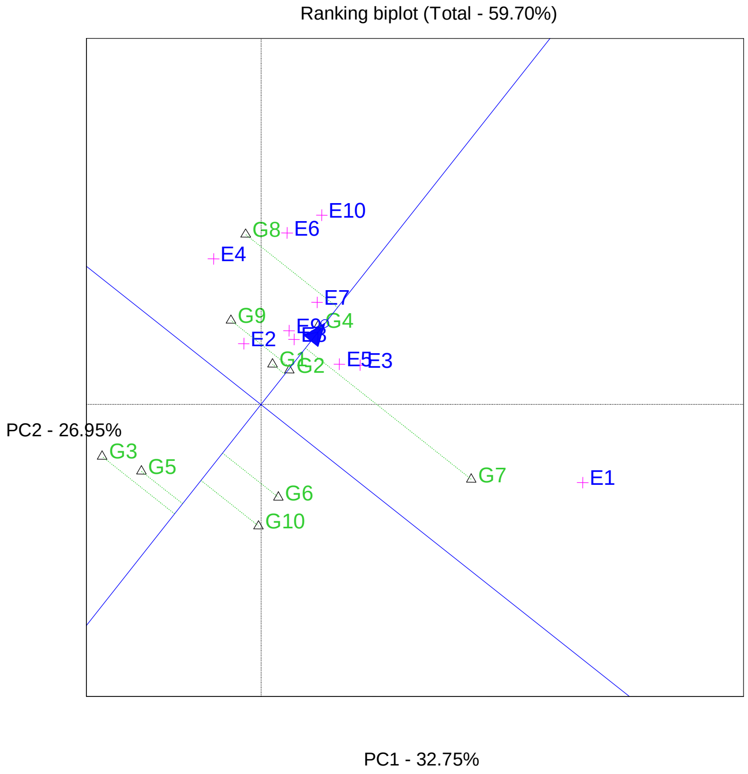

Figure.1.Ranking of genotypes

The vertex genotype in each sector is the best genotype at environments whose markers fall into the respective sector. Environments within the same sector share the same winning genotype, and environments in different sectors have different winning genotypes.

Evaluation of genotypes relative to an ideal genotype

An ideal genotype is defined by having the greatest vector length of the high-yielding genotypes and with zero GE (or highest stability), as represented by the dot with an arrow pointing to it (Figure. 3). An ideal genotype, which is located at the center of the concentric circles in Figure 3, is the one that has both high mean yield and high stability. An ideal genotype should have the highest mean performance and be absolutely stable (Yan and Kang, 2003).

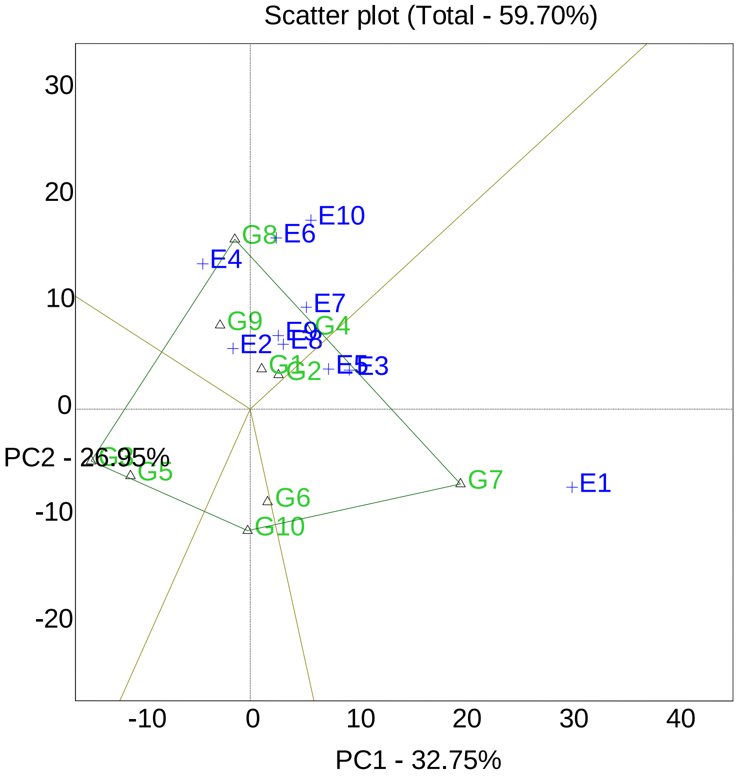

Figure 2. Polygon view of genotype –environment interaction for sesame genotypes over the test environments.

Ideal genotype projection on the ATC x-axis is designed to be equal to the longest vector of all the genotypes. The ideal genotype is stable because its projection on the ATC y-axis is near zero. A genotype is more favorable if it is closer to the ideal genotype. The G1 and G2 were the best two genotypes near to the ideal genotype. This study indicated that genotype G1, G2, G4, G7, G8 and G9 are desirable. A genotype is desirable if it is closer to the ideal genotype (Yan and Hunt, 2002; Kaya *et al.*, 2006). Ranking of other genotypes based on the ideal genotype was G6 > G10 > G5 > G3. In other words, the low yielding genotypes viz., G3, G5, G10 and G6 were undesirable because they are far from the ideal genotype. The relative contributions of stability and yield to the identification of desirable genotype found in this study by the ideal genotype procedure of the GGE biplot are similar to those found in other crop stability studies ((Farshadfar *et al.*, 2012).

Relationships among Test Environments

Figure 4 provides the summary of the interrelationships among the test environments. A GGE-biplot, which was based on environment scaling, is shown to estimate the pattern of environments. Environment PC1 scores were obtained in both positive and negative scores. This case exhibited that PC1 scores present proportional genotypic yield differences across environments, which were caused by both crossover and non-crossover GEI. Similar to PC1, PC2 had both positive and negative scores. It gives rise to the crossover GEI, leading to disproportionate genotypic yield differences across environments (Yan *et al.*, 2000). A genotype may, on one hand, have large positive interaction with some environments; it may, on the other hand, have large negative interaction with some other environments. Favorable test environments should have large PCA1 scores (more discriminating of genotypes) and near zero PC2 scores (more representative of an average environment) (Yan *et al.*, 2001).

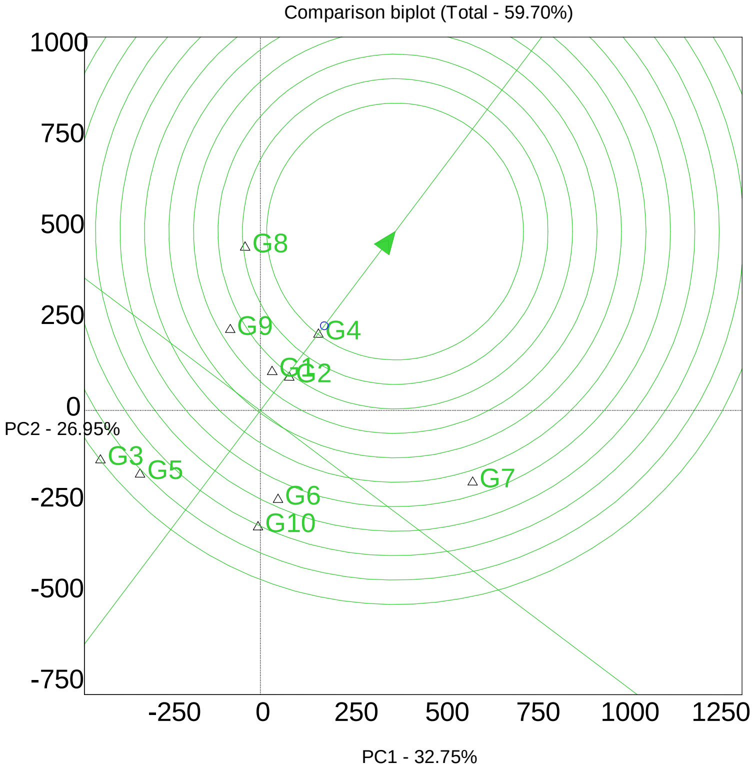

Figure 3. Ranking of genotypes relative to an ideal genotype. The ideal genotype can be used as a reference for genotype evaluation. Thus, using the ideal genotype as the center, concentric circles were drawn to help visualize the distance between each genotype and the ideal genotype.

The lines that connect the biplot origin and the markers for the environments are called environment vectors. Environment E2 had the shortest vector indicating that this test environment is not related to others environments. On the other hand, environment E1 was with larger vector demonstrating that it was more discriminating for the genotypes. This environment may be better test location under limited resources and whenever there is a need to conduct multi-environment yield trials in a limited number of locations. The angle between the vectors of two environments is related to the correlation coefficient between them. The cosine of the angle between the vectors of two environments approximates the correlation coefficient between them (Kroonenberg, 1995; Yan, 2002). Acute angles indicate a positive correlation, obtuse angles a negative correlation and right angles no correlation (Yan and Kang, 2003).

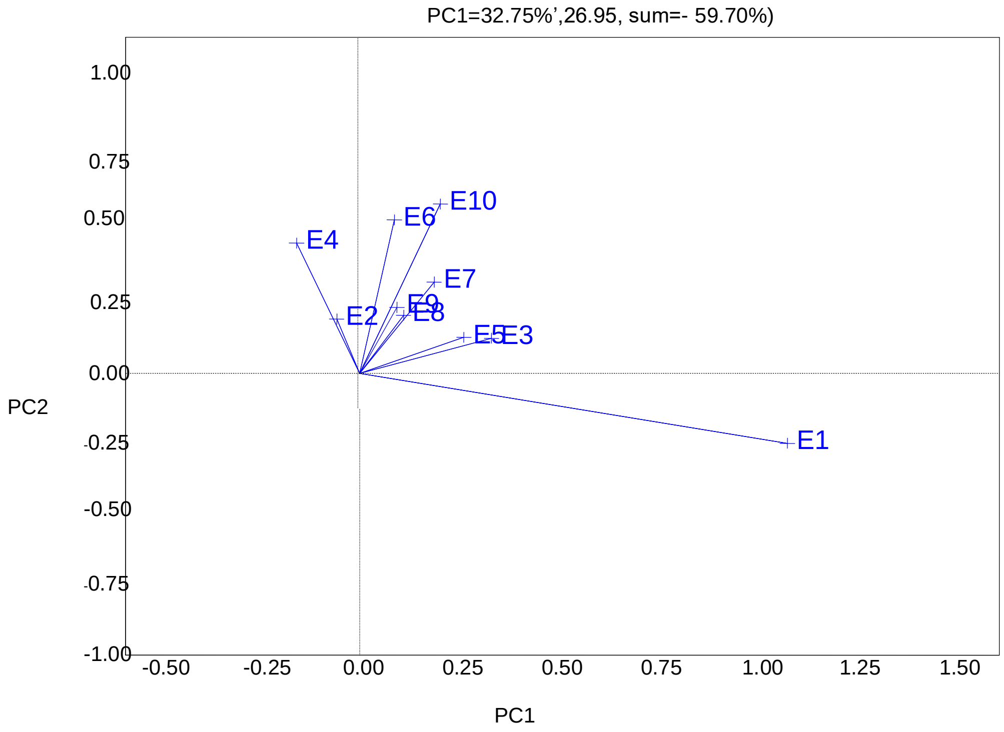

Figure 4. GGE-biplot based on environment-focused scaling for environments. PC and E stand for principal component and the environments, respectively.

Relationships between testing environments based on the angles between the vectors of the environments

The correlation coefficients among the ten test environments are presented in Table 6. The 45 correlation coefficients were calculated and five of which were significant. The correlation between E2 and E4, E2 and E10, E4 and E10 and E7 and E10 were positive and significant indicating that the environments were similar in their discrimination of the genotypes being tested. The presence of close association between test locations, suggests that the same information about the genotypes could be obtained from either of the test locations and hence the potential to reduce the testing costs. On the other hand, E3 and E4 was highly negatively correlated showing strong crossover type of genotype by environment interaction. The angle between the vectors of two environments is related to their correlation coefficient (Kaya, *et al*., 2006). The cosine of an angle between the vectors of two environments approximates the genetic correlation between them (Yan 2002) and allows visualization of similarity between environments in ranking genotypes (Yan, 2001). According to the theory, an acute angle indicates a positive correlation, an obtuse angle indicates a negative correlation and a right angle shows existence of no correlation (Kandus *et al.*, 2010).

Table 6. Correlation coefficient among the ten test environments

	. E1	E2	E3	E4	E5	E6	E7	. E8	E9
E1									
E2	-0.1428								
E3	-0.6659	-0.4903							
E4	0.3439	0.7059*	-0.8436**						
E5	-0.4116	0.4827	0.1578	0.1867					
E6	-0.1656	-0.1627	0.2484	0.0479	-0.1735				
E7	0.0319	0.5597	-0.2092	0.5703	0.5396	0.0349			
E8	0.4895	-0.3867	0.0194	-0.1889	-0.3610	-0.2255	0.2164		
E9	0.1510	-0.1162	0.1166	-0.0694	-0.5476	05435	0.1789	0.3993	
E10	0.0363	0.6887*	-0.3262	0.6992*	0.2875	0.4400	0.7911**	-0.0873	0.4298

Ranking locations relative to the ideal location

An arrow pointing to it (Figure 5) represents the ideal environment. Although such an ideal environment may not exist in reality, it can be used as a reference for genotype selection in the METs. An environment is more desirable if it is located closer to the ideal environment. Thus, using the ideal environment as the center, concentric circles were drawn to help visualize the distance between each environment and the ideal environment (Yan *et al.,*2000). The ideal location, represented by the small circle with an arrow pointing to it, is the most discriminating of genotypes and yet representativeness of the other tests locations. Environment E10 was the most desirable test locations followed by E6 and E7. The result of the study showed that almost all locations are important for growing sesame.

Conclusions and recommendations

Yield performance of sesame genotypes was highly influenced by the environment interaction effect followed by GE interaction. The tested genotypes showed high variation for grain yield. Genotype Obsa (G8) was the best for its mean grain yield performance and with specific adaptability. Test Genotypes EW002 (G1), BG006 (G2), EW006 (G4), EW11-2 (G7), Obsa (G8) and Dicho (G9) are desirable.

Environment Angar (E1) was the best for its discriminating ability for the genotypes. Location Haro-Sabu (E10) was the most desirable test locations followed by Boneya (E6) and Arjo-Gudatu (E7). Genotypes EW002 (G1) and BG006 (G2) were found to be the best two with both high yield and stability and they are recommended for production in western Ethiopia. These genotypes can also be used as parent in crossing program.

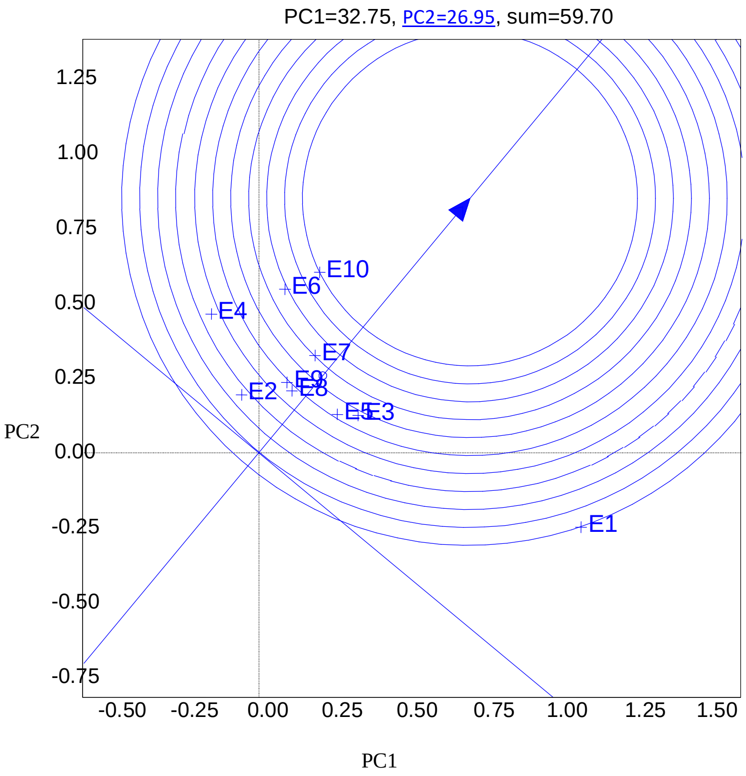

Figure 5.Comparison of environment

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Evaluation of the Effects of Intra and Inter Row Spacing on The Growth and Yield of Ground Nut (Arachis Hypogaea L.) at Haro Sabu, Western Ethiopia.

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Abstract

Planting density is one of the main factors that have an important role on growth, yield and quality of ground nut. The study was conducted in 2016 and 2017 during the main cropping season at Haro-Sabu Agricultural Research Center and Kombo sub-site of Kelem Wollega zone of Western Ethiopia to identify the effects of different spacing on growth parameters, yield and yield component of ground nut varieties. The experiment was laid out in Randomized complete Block design with three replications in factorial arrangement. The experiment was consisting of two factors. Nine levels of spacing were 50 cm x 5 cm, 50 cm x 10 cm, 50 cm x 15 cm, 60 cm x 5 cm, 60 cm x10 cm, 60 x 15 cm, 75 cm x 5 cm, 75 cm x 10 cm, 75 cm x 15 cm and two varieties (Manipinter and Sartu). According to two year average,the highest total number of pods per plant (21.36) was obtained from variety Manipinter. With regards to spacing, the highest number of pods per plant (25.00 and 22.45) was obtained from 75 cm X 10 cm followed by 75 cm X 15 cm respectively. The highest hundred seed (66.85 g) weight was recorded from Manipinter variety. The highest grain yield (21.05 quintal ha^{-1}) was obtained for variety Mainipinter while the lowest grain yield (13.73 quintal ha^{-1}) was obtained for variety 'Sartu'. Regarding to spacing, the highest grain yield (24.74 and 24.33 quintal^{-ha}) was obtained from 50 cm X 5 cm and 60 cm X 5 cm respectively. The highest net benefit (56450.00 ETB ha^{-1}) was recorded from 50 cm X 5 cm spacing followed by 60 cm X 5cm spacing (56324.90 ETB ha^{-1})). However the highest marginal rate return (236.11%) was recorded from spacing 60 cm x 5 cm followed by 50 cm x 5 cm (199.07%).

Keywords: Arachishypogaea L., grin yield, interaction effect,spacing

Introduction

Groundnut (*Arachishypogaea* L.) is an important monoecious annual legume used for oilseed, food and animal feed all over the world (Pande *et al.*, 2003; Upadhyaya *et al.*, 2006). It is the main source of food in various forms and used as a component of crop rotation in many countries (Gbèhounou and Adengo, 2003). Groundnut is grown on 26.4 million ha worldwide with a total production of 38.2 million metric tons (FAOSTAT, 2010). Developing countries account for 97% of the world's groundnut area and 94% of the total production. The lowland areas of Ethiopia have considerable potential for increased oil crop production including groundnut. The estimated production area and yield of groundnut in Ethiopia in 2016/2017 cropping season were 74861.37 hectares and 1296364.18 quintals, respectively(CSA, 2017). The seed yield is a function of interaction between genetic and environmental factors including soil type, sowing time and method, seed rate, fertilizers and time of irrigation among which, row spacing plays a vital role in getting higher yield (Hussain *et al.*, 2003). Proper spacing ensures adequate ventilation, reduces competition among plants for space and nutrients, and reduces transmission of diseases, facilitates weeding and movement in the farm and also reduces overcrowding and, therefore, allows interception of radiation by plant canopies.

The number of plant per unit area is one of the important yield determinants of field crops. So that planting density is one of the main factors that have an important role on growth, yield and quality of ground nut. It is important to accommodate the most appropriate number of plants per unit area to obtain better yield (Gulluoglu *et al.*, 2016b). The response of ground nut to plant density has been investigated in many areas of the world. Investigation of growth and yield performance of ground nut with special reference to arrangement has been conducted and the result showed that leaf area index, crop growth rate, pod growth rate, pod and kernel yield have increased by increasing plant density (Kiniry *et al.*, 2005). Cultivation of groundnut in narrow rows can lead to maintenance of a complete crop cover over the soil which inhibits weed seed germination and reduces the need to carry out weeding (Lee *et al.,* 1994). Early canopy closure by closely spaced groundnut crop has been shown to smother weeds hence reducing weed/crop competition, especially for soil nutrients and water.Such benefits are more evident under low input conditions as seen on most smallholder farms.

Some investigators concluded that narrow row spacing was superior in yield and more economicalthan broader rows (Pereira *et al*., 1988). Plants growing in too wide rows may not efficiently utilize the natural resources such as light, water and nutrients, whereas growing in too narrow rows may result in sever inter and intra-row spacing competition (Ali *et al*.,1999). Therefore, it is of crucially important to manipulate the row spacing in order to increase plant productivity. Production of groundnut is under progress since recently in west and Kellem Wollega zones. Intra and inter row spacing, fertilizer rate, appropriate sowing times and post-harvest management technologies are the most important and influential production packages. But the information of these agronomic practices is limited because it is produced at subsistence level by rural farmers and the farmer cultivate ground nut without consideration of the appropriate intra and inter row spacing.Research on manipulating plant density and their effects on growth and yield are crucial so as to generate enough information and data base for use by emerging farmers that would be interested in commercial production of this crop.

Objective:

- To determine the effects of intra and inter row spacing on growth , yield and yield component of ground nut varieties

Materials and Methods

Description of the Study Area: The study was conducted in 2016 and 2017 during the main cropping season at Haro-Sabu Agricultural Research Center (HARC) and Kombo subsite. HARC and Kombo were located in Kellem Wollega zone, western Ethiopia at 550 and 580 km away from Addis Ababa and 1530 m and 1510 m above sea level respectively. The rain periods covers from April to October at both site. The soil type of the experimental site was reddish brown and its pH is 5.82. The area were characterized by coffee dominant based farming system and crop livestock mixed farming system in which cultivation of maize, sorghum, finger millet, haricot bean, soybean, sesame, ground nut, banana, mango, sweet potato and coffee are the major crops grown in the area.

Treatments and Experimental Design

The experiments was consist of two factors. Nine levels of spacing 50 cm x 5 cm (400,000 plants ha^{-1}), 50 cm x 10 cm (200,000 plants ha^{-1}), 50 cm x 15 cm (133,333 plants ha^{-1}),60 cm x 5 cm (333,333 plants ha^{-1}), 60 cm x 10 cm (166,670 plants ha^{-1}), 60 cm x15 cm (111,113 plants ha^{-1}), 75 cm x 5 cm (266,666 plants ha^{-1}) ,75 cm x10 cm (133,330 plants ha^{-1}),75 cm x15 cm (88,887 plantsha^{-1}) and two varieties (Manipinter and Sartu). The experiment was laid out in Randomized complete Block design with three replications in factorial arrangement. Thus there was 18 treatments combinations. The gross plot area was 3 mx3.9 m and four, five and six rows were planted depending on the row spacing in each plot

Experimental Procedures

The experimental field was ploughed and harrowed by a tractor to get a fine seedbed and leveled manually before the field layout was made. Two seeds per hill were planted and thinned to one plant per hill one week after emergence. At planting full dose of DAP (18% N, 46% P_2O_5,) at the rate of 100 kg ha^{-1} was applied uniformly into all plots. It was harvested from the net plot after they attained their normal physiological maturity.

Partial budget analysis

Partial budget analysis was done using CIMMYT (1998) to identify the rewarding treatments. Actual yield from experimental plot were adjusted down ward by 10% to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. To find out the gross return the price of ground nut (sale price of 25birr kg^{-1})prevailing the local market at the time of harvest. The variable cost that vary was cost of seed.

Data Collection

Morphological and physiological data such as days to flower initiation, days to physiological maturity, number of primary branches, plant height (cm), number of pods plant^{-1}, number of seeds pod^{-1}, hundred grain weight (g) and grain yield (ton ha^{-1}) were recorded. Days to flower initiation were recorded as the number of days from planting to the time when 50% of the plants in each plot produced at least one flower. Days to physiological maturity was recorded as the number of days from planting to the time when 95% of pods reached maturity. Number of primary branches was determined by taking five randomly selected plants per plot at harvesting time. The average of five plants was taken as number of primary branches per plant. Plant height was measured from the base of plant to the tip of the main stem from five randomly selected plants at the stage of physiological maturity. Number of pods plant^{-1} was determined by counting total number of pods from five randomly selected plants from each net plot at the time of harvesting and expressed as number of pods per plant. Number of seeds per pod was determined by counting total seeds of counted pods from five randomly selected plants from each net plot and divided by the total number of pods and expressed as number of seeds per pod. Hundred grains were counted randomly from bulked grain of each net plot and weighted. The weight was adjusted to 10% moisture level.

Statistical Data Analysis

Analysis of variance was carried using General Linear Model of ANOVA using SAS version 9.1software (SAS Institute Inc. 2002). Mean separation was carried out using Least Significance Difference (LSD) test at 5% probability level.

Results and Discussion

The analysis of variance revealed that days to 50% flower initiation and days to physiological maturity were highly significantly ($P<0.01$) affected by varieties. Varieties 'Manipinter' reached to 50% flower initiation on average 50.48 days while variety Sartu took on the average 42.55 days. Similarly, the respective days to reach to 95% physiological maturity for variety Manipinter and Sartu were 173.76 and 164.28 days, respectively (Table 1). From this result, it is clear that variety 'Sartu' flowered and matured earlier than the Manipinter varieties. This difference observed in phenological parameters could be due to the inherent characteristics or genetic makeup of the varieties. In agreement with this result Kamara *et al.* (2011) reported that there were significant differences among varieties for days to flowering and maturity. Similarly, crop phenological development (emergence and flowering) significantly differed among the groundnut varieties were reported by (Arrison K. et al., 2014). The main effect of spacing and interaction of varieties and spacing showed statically no significant effect on days to flowering and days to physiological maturity. This result was in agreement with Arrison K.*et al.* (2014), reported thatspacing and the interaction effect of ground nut varieties and spacing had no significant effect on days to flowering and physiological maturity

Table 1: Main effects of varieties and spacing on phenological and growth parameters,2016 and 2017

Treatment	DF	DPM	PH	PBPP
		Variety		
Sartu	42.55b	164.28b	44	6.59
Manipinter	50.48a	173.76a	42	6.96
LSD (0.05)	0.17	0.25	NS	NS
		Spacing		
50 cm x 5 cm (400,000 plant ha^{-1})	46.75	169.25	43.75	6.65
50 cm x 10 cm (200,000 plant ha^{-1})	46.67	169.08	44.83	6.30
50 cm x 15 cm (133,333 plant ha^{-1})	46.58	168.75	40.77	7.13
60 cm x 5 cm (333,333 plant ha^{-1})	46.41	168.92	45.37	6.11
60 cm x 10 cm (166,670 plant ha^{-1})	46.58	169.17	44.82	7.22
60 cm x 15 cm (111,113 plant ha^{-1})	46.33	169.00	43.19	6.91
75 cm x 5 cm (266,666 plant ha^{-1})	46.33	169.33	43.80	6.93
75 cm x 10 cm (133,330 plant ha^{-1})	46.41	169.00	43.22	6.61
75 cm x15 cm (88,887plant ha^{-1})	46.58	168.67	43.13	7.09
LSD (0.05)	NS	NS	NS	NS
CV (%)	1.39	0.55	15.51	24.4

DF= Days to flowering; DPM= Days to physiological maturity; PH= plant height; PBPP= Primary branch per plant, LSD = Least Significant Difference ($P< 0.05$); CV = Coefficient of Variation; NS =Non Significant

The effect of main (variety and spacing) significant ($P<0.01$) effect number of pods per plant. But the interaction effect of variety and spacing was non-significant. The highest total number of pods per plant (21.36) was obtained from variety Manipinter (Table 2). The variations in the number of pods observed were probably largely attributable to the genotypes of the ground nut variety. This finding in agreement with Konlan *et al.* (2013) that the number of pods per plant were significantly differed between varieties.With regards to spacing, the highest number of pods per plant (25.00 and 22.45) was obtained from 75 x 10 followed by 75 x 15 respectively. The higher number of pods per plant recorded by wide spacing arrangements were probably because of lesser intra-specific competition for growth resources among the wide spacing compared to close spacing crop lower plant density and more available growth resource.Virk *et al*. (2005) and Abdullah *et al.* (2007) reported that, increased plant density decreased number of pods per plant and as plant density decreased, number of pods per plant increased. In general, total number of pods per plant was low in plots with the highest plant densities and high in plots containing lowest plant densities per plot.

The main effect of variety significantly ($P < 0.01$) affect number of seed per pod. while the main effect of spacing and interaction effect of variety and spacing was non- significant on number of seed per pod. Among the varieties, the highest number of seed per pod (1.70) was obtained for the variety Sartu. (Table 2).This might be attributed to number of seed per pod is a varietal difference which is largely controlled by plant genetic factors than agronomic practices. Hundred seed weight was significantly affected ($P<0.01$) by varieties but not by main effect of spacing and interaction effect. The highest hundred seed (66.85 g) weight was recorded from Manipinter variety. The varietal differences in hundred seed weight were mainly genotypic manifestation, since the seeds of Manipentar were generally larger and bigger (Table 2). Grain yield was highly significantly ($P < 0.01$) affected by main effect of variety and spacing. Whereas, the interaction effect of variety and spacing was non-significant effect on grin yield. The highest grain yield(21.05 quintal ha^{-1}) was obtained from variety Mainipinter while the lowest seed yield (13.73 quintal ha^{-1}) was obtained for variety ‘Sartu’ (Table 2). The highest seed yield produced by variety ‘Mainipintar’ could be attributed to its more hundred seed weight.

Regarding to spacing, the highest grain yield (24.74 and 24.33 quintal^{-1}ha) was obtained from 50 cm x 5 and 60 cm x 5cm respectively (Table 2). The grain yield at the higher plant densities might be efficient utilization of growth resources and the lowest grain yield at the lowest plant density might be attributed to the more luxurious growth because of the more resources at the lower plant density initiated more pod thickness than the grain yield. In line with this result, Bihter. *et al.*(2017) found that pod yield per hectare was increased when the plant density was increased; the highest pod yield (7511.9 kg ha^{-1}) was obtained from 75 cm x 10 cm and the lowest (5171 kg ha^{-1}) was from 75 cm x 25 cm planting density. Also Naeem *et, al.* (2007) reported that significant variation was observed on pod yield due to row spacing; the highest (3739 kg ha^{-1}) and the lowest (1903 kg ha^{-1}) pod yield was recorded from 30 cm and 60 cm row spacing respectively. Generally, decrease in spacing reduced the number of pods per plant but the additional plants per m^{-2} more than compensated for the reduction, resulting in higher pod yield. Such compensation effects have been reported by Ahmad *et al.* (2007), Norden and

Lipscomb (1974). Thus spacing arrangement that resulted in high plant population density was more efficient in the use of solar energy and other resources for pod production (Virk *et al.*, 2005).

Table 2: Main effects of varieties and spacing on yield and yield component during 2016 /17

Treatment	NPPP	NSPP	HGW	GY quintal^{-1}
Variety				
Sartu	19.33b	1.70a	41.27b	13.73b
Manipinter	21.96a	1.51b	66.85a	21.05a
LSD (0.05)	1.320	0.070	2.37	1.160
Spacing				
50 cm x 5 cm (400,000 plant ha^{-1})	18.250c	1.52	55.34	24.74a
50 cm x 10 cm (200,000 plant ha^{-1})	20.03bc	1.59	55.46	21.40b
50 cm x 15 cm (133,333 plant ha^{-1})	19.600c	1.63	53.79	13.23c
60 cm x 5 cm (333,333 plant ha^{-1})	18.730c	1.70	53.02	24.33a
60 cm x 10 cm (166,670 plant ha^{-1})	20.88bc	1.61	55.28	19.18b
60 cm x 15 cm (111,113 plant ha^{-1})	20.81bc	1.72	53.53	12.60c
75 cm x 5 cm (266,666 plant ha^{-1})	20.07bc	1.51	55.37	18.95b
75 cm x 10 cm (133,330 plant ha^{-1})	25.000a	1.59	52.98	12.58c
75 cm x15 cm (88,887 plant ha^{-1})	22.45ab	1.61	51.78	9.51d
LSD (0.05)	2.8100	NS	NS	24.80
CV (%)	23.900	17.05	16.37	2.45

Means within the same column followed by the same letter or by no letters of each factor do not differ significantly at 5% probability level; LSD = Least Significant Difference ($P< 0.05$); CV = Coefficient of Variation; NS =Non Significant; NPPP= Number of pod per plant; NSPP= Number of seed per pod; HGW= Hander grain weight; GY= grain yield

Partial budget analysis

Partial budget analysis was calculated based on cost of variable inputs of the year 2016 and 2017 cropping season and net benefit was estimated based on mean of local market price and farmers supplied produce to the market. Economic analysis of different spacing revealed that gave different economic return as compared to control (60 cm x 10 cm).The highest net benefit (50269.00 ETB ha^{-1}) was recorded from 50 cm x 5 cm spacing followed by 60 cm x 5 cm spacing (50245.00ETB ha^{-1}).However the highest marginal rate return (207.49%) was recorded from spacing 60 cm x 5 cm followed by 50 cm x 5 cm (173.35%) (Table 3).

Table 3. Economic and marginal analysis of different spacing

Treatment	(A) adj yield (t ha^{-1})	(B) price ETB Q^{-1}	(C) sale revenue (A*B)	(D) marginal cost(ETBha^{-1}	(E) net profit ETB (C-D)	(F) marginal benefit (ETB)	MRR= (F/D)x100%
50X5	22.27	2500	55675	5406.00	50269.00	9371.55	173.35
50X10	19.10	2500	47750	2703.00	45047.00	4149.55	153.52
50X15	11.90	2500	29750	1802.00	27948.00	-12949.45	-718.62
60X5	21.90	2500	54750	4505.00	50245.00	9347.55	207.49
60X10	17.26	2500	43150	2252.55	40897.45	0.00	0.00
60X15	11.34	2500	28350	1501.69	26848.31	-14049.14	-935.55
75X5	17.05	2500	42625	3603.99	39021.01	-1876.44	-52.06
75X10	11.32	2500	28300	1801.95	26498.05	-14399.40	-799.09
75X15	8.56	2500	21400	1201.31	20198.69	-20698.76	-1723.02

Adj. yield= adjusted yield, ETB= Ethiopian birr per quantal, ETB ha^{-1}= Ethiopian birr per hectare, MRR= marginal rate return

Conclusions and recommendations

Planting density is one of the main factors that have an important role on growth, yield and quality of ground nut. It is important to accommodate the most appropriate number of plants per unit area of land to obtain better yield. Establishment of optimum population per unit area of the field is essential to get maximum yield.Plants growing in too wide rows may not efficiently utilize the natural resources such as light, water and nutrients, whereas growing in too narrow rows may result in sever inter and intra-row spacing competition.In view of this, the experiment was conducted in 2016 and 2017 cropping season at Haro-Sabu Agricultural Research Center and Kombo sub site of Kelem Wollega zone of Western Ethiopiato determine the effects of intra and inter row spacing on growth parameters, yield and yield component of ground nut varieties.

The highest total number of pods per plant (21.36) was obtained from variety Manipinter. With regards to spacing, the highest number of pods per plant (25.00 and 22.45) was obtained from 75 cm x 10 cm followed by 75 cm x 15 cm respectively. The main effect of variety was significantly ($P < 0.01$) affect number of seed per pod.The highest number of seed per pod (1.70) was obtained for the variety Sartu. Hundred seed weight was significantly affected ($P < 0.01$) by varieties but not by main effect of spacing and interaction effect. The highest hundred seed (66.85g) weight was recorded from Manipinter variety.

Grain yield was highly significantly ($P < 0.01$) affected by main effect of variety and spacing. The highest grain yield (21.05 quintal ha^{-1}) was obtained for variety Mainipinter while the lowest grain yield (13.73 quintal ha^{-1}) was obtained for variety ‘Sartu’. Regarding to spacing, the highest grain yield (24.74 and 24.33 quintal^{-ha}) was obtained from 50 cm x 5 cm and 60 cm x 5 cm respectively. Generally, decrease in spacing reduced the number of pods plant^{-1}of ground nut, but the additional plants m^{-2} more than compensated for the reduction, resulting in higher grain yield. Economic analysis of different spacing revealed that economic return as compared to control (60 cm x10 cm). The highest net benefit (56450.00 ETB ha^{-1}) was recorded from 50 cm x 5 cm spacing followed by 60 cm x 5 cm spacing (56324.90 ETB ha^{-1}). However the highest marginal rate return (236.11%) was recorded from spacing 60 cm x 5 cm followed by 50 cm x 5 cm (199.07%). Therefore spacing of 50 cm x 5 cm and 60 cm x 5 cm was optimum plant population density for production of ground nut in KelemWollega zone of western Ethiopia.

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Evaluation of Maize-Common bean Relay Cropping Systems as Influenced by Bean Varieties and Spatial Management of Maize

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Abstract

Continuous maize-based mono-cropping has led to a rapid decline in soil fertility in western Ethiopia with corresponding low crop yields. Maize-common bean relay cropping is a recent practice in western Ethiopia and there is limited information on its productivity. Thus, a field experiment was conducted at Bako and Uke in western Oromia during 2016 and 2017 crop growing seasons to evaluate suitable common bean varieties for maize-based relay cropping systems, evaluate the effect of leaf defoliation at different time starting from time of dough stages on yield of common bean and maize components and to compare the yield performances of maize and common bean in relay cropping versus sole cropping systems. Treatments consisted of factorial combinations of two maize varieties (BH-546 and Gibe-3), two common bean varieties (Nasir and Anger) and five different leaf defoliation intensity of maize. A sole maize without leaf defoliation was used as a control treatment. The treatments were laid out in a randomized complete block design (RCBD) with three replications. Results indicated that maize grain yield was increased with decreasing leaf defoliation intensity and vice versa. The highest maize grain yield (9643 kg ha^{-1}) was recorded from maize relayed with Anger bean variety defoliated below ear placement and sole maize at Bako while the highest grain yield of maize (9598 and 9150 kg ha^{-1}) was recorded from relayed maize with beans with no leaf defoliation at Uke followed by defoliated maize below ear placement (8158.8 kg ha^{-1}). The partial budget analysis indicated that the highest net benefit was recorded from all maize removal as green cobs and Stover at time of dough stage and all leaves removal below ear placement resulted in higher net benefits respectively, at Bako whereas the highest net benefit recorded from all maize removal as green cobs and Stover at time of dough stage and all maize parts were not removed until harvest. maturity at Uke. Thus, it can be concluded that removal of all maize parts as green cobs and Maize defoliation below ear placement is more profitable and recommended for the farmers in the study areas and the crop residues can be used for livestock fattening especially in Chewaka areas.

Keywords: Cropping systems, defoliation, dough stage and growth stage

Introduction

The incorporation of grain legumes into cereal-based cropping systems can contribute to the replenishment of soil fertility through the fixation of atmospheric nitrogen (N_2) while supplying protein-rich grains for household food and nutrition (Giller, 2001). Because of rapid human population explosion, the size of cultivable land at the household level is gradually decreasing and most farmers own very small plots of land, especially in the developing countries of Asia and Africa. Hence, there is a need for increasing crops production per unit of cultivated land using various techniques including multiple cropping (Abate and Alemayehu, 2018). In Ethiopia, maize is the second next to Tef in the production area and the first in its productivity. Of the total cereal crop area, maize share 16.79% (2,128,948.91 ha) and its national productivity reaches up to 3.9 t ha^{-1}. In Oromia regional state maize accounts for about 23.9% of cereal production area and the productivity in this region is currently 4.1 t ha^{-1} (CSA, 2017). However, Western parts of sub-humid regions are dominantly producing maize crop and accounts for more than 60% of the total production of the region. Plant response to defoliation depends on more than just the total amount of leaf area that is lost. It is also known that defoliation intensity may vary along nutrient availability gradients and that defoliation may alter completion relationship among species ((Khaliliaqdam *et al*., 2012). Earlier study addressing the effect leaf removal on growth and yield. Moreover, the lower leaves of maize start senescence after complete tasseling and dry by the crop matures. It is proven fact that maize defoliation before tasselling delayed maturity and after tasselling hastens maturity (Rana *et al*., 2009). Farmers in western Ethiopia are producing both crops and livestock component for their livelihood. In western Ethiopia, the land being scarce resource reflects in fodder scarcity in general and particularly in Chewaka areas where Hararghe settlers are overpopulated.

Relay cropping is a sustainable approach that optimizes system productivity and compensates yield of two crops at a time and can solve time contravene among sowing of different crops. It possesses the capability to improve soil quality, to increase net return and land equivalent ratio, and to control the weeds and pest infestation, thereby decreasing chemical pest control measures (Tanveer *et al*., 2017). Relay cropping facilitates the farmers to cultivate two crops in one year especially in those areas/cropping systems where growing season is shrinking for sequential farming due to climate change (Jabbar *et al*. 2010). Other environmental benefits associated with relay cropping include improved soil, air, and water quality by reducing the leaching of nutrient compounds (Schepers *et al*. 2005). Relay cropping has still been recognized, especially by smallholder farmers, because of its potential to increase land use efficiency and reduce fertilizer consumption (Ayisi *et al*., 1997), enhance crop yield and nutrient accumulation, and improve biological activities (Ghosh *et al*. 2006). Relay cropping is proposed as a beneficial tool that results in better utilization of residual soil moisture from previous crops and reduces cost of production per unit area (Zhang *et al*., 2008a). However, majority of the studies pertaining to relay cropping have also highlighted several constraints including low germination problems and interspecific competition particularly in developing countries. Relay Cropping is one of the crop intensifications that vertically enhance production and productivity of a given crop per unit time and area. Selection of suitable crops, like early or medium maturity types can be used for relay cropping since both crops are able to mature within the given growing period. But, this relay cropping depends on the onset and session of rain fall amount and distribution in the growing seasons. Metrological information around Bako area in indicates that more than 185 growing days could receive rain fall even though the distribution and amount in each days vary, particularly in May and October. But, there is high probability of getting minimum effective rainfall starting from early to Mid-May that help us to plant the maize at early time. Some farmers, particularly Harar settlers, remove maize leaves at time of dough stage to feed their livestock, particularly for beef fattening.

Further, most of the farmers in Chewaka areas and even around Bako planted maize at early time (in May) and use as green cob in end of August. And planted early mature crops like the so called “Xaafii bunnisee (Tef)” or different varieties of common beans, mung beans as relay or double cropping. But, there is no information about these leaf defoliations whether it reduce maize yield and increases the yield of relayed bean crop. Particularly in Chewaka areas, some farmers practice maize defoliations when it reach dough stage and used for animal feeding (beef fattening). But, there is no information whether this defoliation reduce maize yield and enhance relayed beans. To study whether some of the lower maize leaves can be removed without reducing the yield of maize providing the additional benefit, the study were conducted to evaluate suitable common bean varieties for maize based relay cropping systems, evaluate the effect of leaf defoliation intensity at dough stages on yield of common bean and maize components and to compare the yield performances of maize and common bean in relay cropping versus sole cropping systems.

Materials and Methods

Description of Experimental site

Field experiment was conducted at two selected sites of western Oromia, located at Bako (09^{0} 6’00” N latitude and 37^{0} 09’00” E longitude at an altitude of 1650 a.s.l) and Uke (09^{0}25.082’N latitude and 036^{0}32.391’E longitude at an altitude of 1319 a.s.l) for two consecutive years (2016-2017). Figure 1 present climatic data on rainfall and temperature during 2016 and 2017 growing seasons. The area has a warm humid climate with an annual mean minimum and maximum temperature of 10.6 and 34.6°C, respectively. The area receives an annual rainfall of 1317 mm mainly from April to October with maximum precipitation in the month of May to September (Meteorological station of the center).

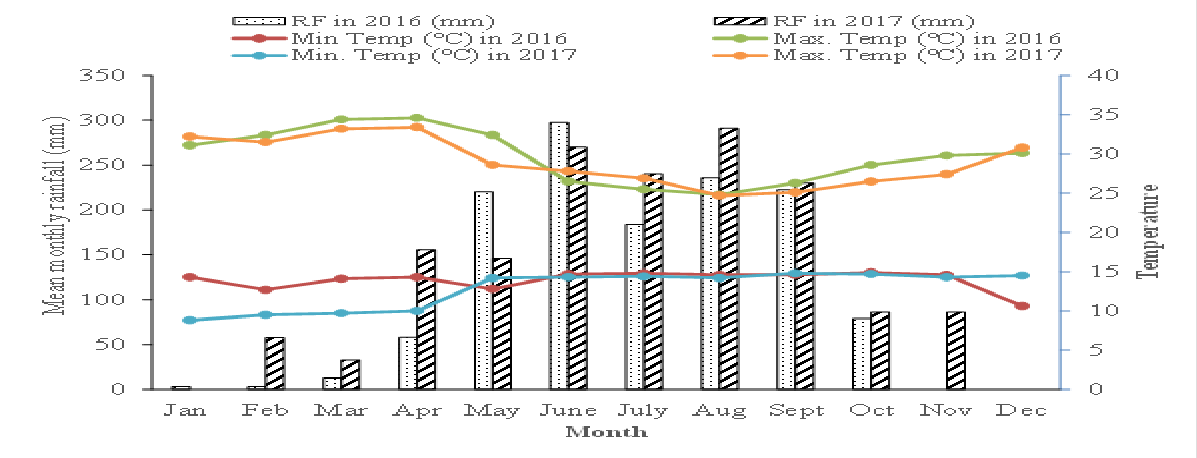

Figure 1. Monthly total rainfall (mm), mean minimum and maximum temperatures (°C) of experimental station in 2016 and 2017

Treatments and Experimental Design

Treatment comprised two maize and bean varieties and four different leaf defoliation intensity at dough stage of maize (all leaf removal except green cobs, all leaf removal except flag leaves, all leaf removal below ear placement, all maize removal as green cobs and Stover at time of dough stage and all maize parts were not removed until harvest maturity). A sole maize and common bean varieties were planted for comparison purposes. A factorial combination in a randomized complete block design with three replications was used. Two common bean (Nasir and Anger) and two maize varieties (BH546 and Gibe-3) were used for the study. BH546 and Gibe-3 maize varieties were used at Bako and Uke, respectively based on their adaptability.

Experimental procedures and Field managements

The land was ploughed by a tractor, disked and harrowed. Two common bean varieties were relayed in the maize just at the time of blister to milking stages of maize so that bean crops was established very well at the time of maize dough stage. Early/medium types of maize varieties (BH546 and Gibe-3) were planted at the onset of rainfall (mid-May). These varieties take 145 days from sowing to maturity. Maize was planted in 75 cm x 30 cm plant spacing and recommended inorganic fertilizer rates were applied, phosphorus sources at a time of planting and N sources was applied two times, half at planting and half at knee height. Nasir variety takes 91 days to mature while Anger variety takes 79 days to mature. The beans were planted in 37.5 cm x 10 cm plant spacing in maize and insoles so that plant populations for relayed and sole common beans were 266,666 plant populations per hectare. Bean rows were 17.5 cm far away from maize rows. At the time of dough stage (when maize was reached for green cob utilization) leaves were defoliated as per treatment arrangements. All defoliated leaves were measured as fresh and dry weight.

Data Collected

Maize part: data collected for maize part were leaf dry weight, biomass yield and grain yield. Leaf dry weight was defoliated as per the treatment and weighed after sun dried. Above ground dry biomass was recorded from harvestable plot at the time of harvest maturity.

Common bean part: At physiological maturity, the above ground dry biomass was measured at harvest maturity and the harvested produce was sun dried to measure at constant weight. This was used to calculate the harvest index. Grain yield was measured by harvesting the crop from the net plot area. The harvested produce was sun dried for seven days and threshed by hitting with sticks and winnowing was done. The moisture content of the grain was adjusted to 10%. Then the weight was converted to kg ha^{-1}.

Data Analysis

All collected parameters were subjected to analysis of variance using of Gen Stat 18th edition (GenStat, 2016). Whenever the effects of the treatments were found to be significant, the means were compared using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

Partial Budget Analysis

The economically acceptable treatment(s) were determined by partial budget analysis to estimate the gross value of the grain yield by using the adjusted yield (CIMMYT, 1988) at the market value of the grain and wage for maize leaf defoliation during the cropping period. Only total costs that varied (TCV) were used to compute costs. Wage for leaf defoliation, and guarding after the green cobs was harvested for selling to the market were considered as variable with their cost. Cost of land preparation, fertilizers, field management, harvest, transportation and storage were not included in the analysis as they were not variable. To equate the maize grain yield with what a farmer would get, the obtained yield was adjusted downward by 10%. Treatments net benefits (NB) and TCV were compared using dominance analysis. Treatments TCV were listed in increasing order in accordance with dominance analysis. All treatments which had NB less than or equal to treatment with lower TCV were marked with a letter “D” since they were dominated and eliminated from any further analysis. Un-dominated treatments were subjected to Marginal Rate of Return (MRR) analysis (CIMMYT, 1988) in stepwise manner, moving from lower TCV to the next as shown below:

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

Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCV_b = the next highest TCV.

Results and Discussion

Maize component

Table 1 indicated that the time of sowing, days to flowering and dough stage (used as green cob), and physiological maturity for maize components; and days to sowing, days to flowering to poding or grain filling stage, and days to physiological maturity for bean components. The phenological periods were took short period of time at Uke site compared to Bako site. This might be due to variability in environmental conditions between the two locations.

Table 1: Sowing time, days to flowering and maize dough stage (green cobs for maize), flowering to poding or grain filling stage (Haricot bean) and physiological maturity of component crops in relay cropping systems

Maize component					Haricot bean components		
Location	Sowing time	Days to flowering	Days to dough stage	Days to maturity	Date of sowing for relaying	Days to flowering	Days to phy. maturity
Bako	May 5-15	75-80	90-100	140-150	August 20-30	35-67	75-85
Uke	May 5-15	70-75	85-95	135-145	August 20-30	35-60	75-80

Figure 2 showed the history of onset of rainfall from May 1-31 of ten years and daily cumulative rainfall distribution of Bako areas. The rainfall distribution in the study areas indicated that there are some rainfall amount starting from early May (Figure 2). Thus, it is possible to plant early to medium maturity groups of maize varieties up to mid-May to use for relay cropping systems. As rainfall history in the study areas showed, the area is potential for early planting of maize to use for relay cropping and double cropping systems. But it depends on soil types and fertility.

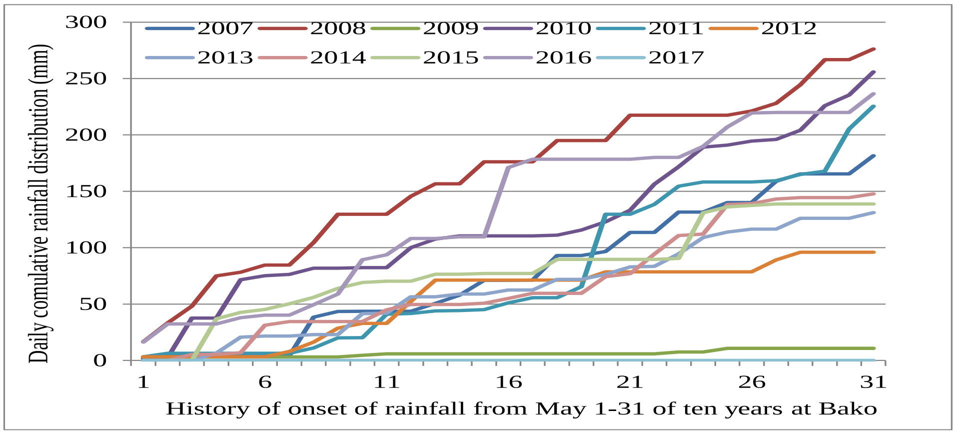

Figure 2: History of onset of rainfall from May 1-31 of ten years and daily cumulative rainfall distribution of Bako areas

Grain yield and leaf dry weight

Maize grain yield was significantly influenced by different leaf defoliation intensity of maize across the two locations. The highest maize grain yield (9643 kg ha^{-1}) was recorded from maize relayed with Anger bean variety defoliated below ear placement and sole maize at Bako (Figure 3). While the highest grain yield of maize (9598 and 9150 kg ha^{-1}) was recorded from relayed maize with beans with no leaf defoliation at Uke followed by defoliated maize below ear placement (8158.8 kg ha^{-1}). On the other hand, the lowest maize grain yield was recorded from maize all leaves removal except green cobs and all leaves removal except flag leaves at both locations, respectively (Figure 3). Dry matter production of crop plants depends on the source sink relations. Leaves and seeds are known as sources and sinks, respectively (Heidari, 2017). Maize yield is reported to be strongly depended on leaf area index (LAI) and leaf efficiency for absorption of solar radiation for photosynthesis process. Thus, defoliation treatments have been observed to decrease assimilates availability during grain filling (Iledun and Rufus, 2017). Maize plants under complete defoliation had the lowest seed yield, ear weight, row number per ear, cob weight and 100-seed weight, but had higher seed germination percentage, rate and vigor (Heidari, 2013). The leaf dry weight was increased with increasing leaf defoliation intensity and vice versa. The highest leaf dry weight was obtained from all leaves removal except green cobs, all leaves removal except flag leaves and all maize removal as green cobs and stover at time of dough stage (Figure 3). Leaf defoliation below ear placement gave the highest maize grain yield without affecting maize yield. Therefore, we can defoliate maize leaf for livestock feed without affecting maize yield. The defoliation of maize leaf up to 50% at the time of feed shortage did not have adverse effect on grain yield and stover yield of maize (Boogaard *et al*., 2001). In this study, severe defoliation at dough stage of maize had a much effect on yield. The maize leaf defoliation below ear placement had a slight influence on maize yield. Thus, leaf defoliation below ear placement especially after hard dough stage of maize has no significant influence on maize yield and yield components. The ability of a leaf to develop larger area after defoliation is due to a higher cell division or to cell enlargement. After defoliation, since plants are not able to initiate new leaf, a chance to improve growth is given by increasing single leaf area (Khaliliaqdam *et al*., 2012).

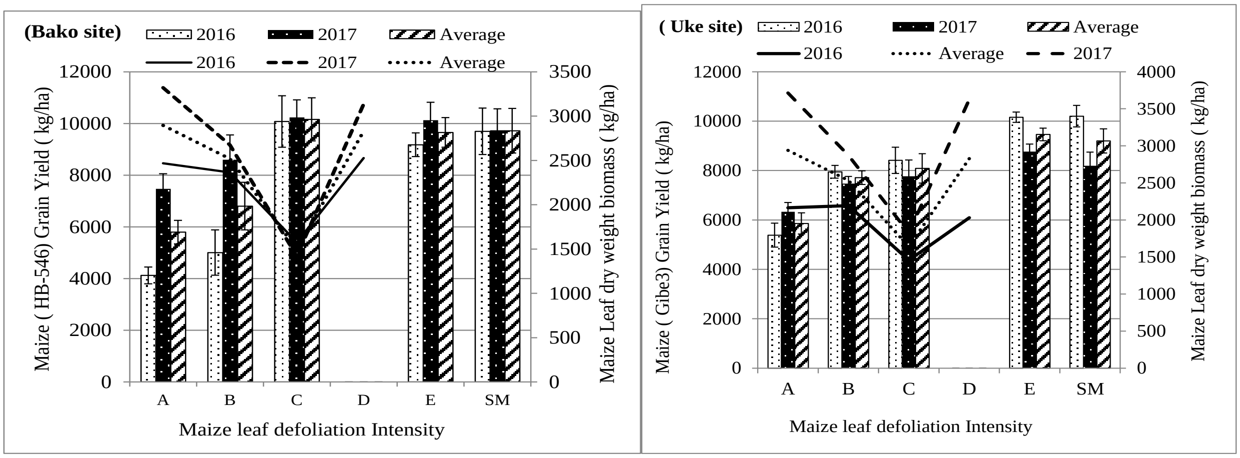

Figure 3. Mean grain yield and leaf dry weight of maize under different leaf defoliation intensity at Bako and Uke sites, respectively. Where, A= all leaves removal except green cobs, B= all leaves removal except flag leaves, C= all leaves removal below ear placement, D= all maize maize removal as green cobs and stover at time of dough stage, E= all maize parts was not be removed until maturity and SM= sole maize.

The result of correlation analysis also confirmed that there a strong and negative correlation between maize leaf defoliation intensity and grain yield of maize, indicated that as leaf defoliation intensity increases, the maize yield reduced. For example, an increase in one unit of leaf defoliation negatively decreased grain yield of maize (Figure 4A). In line with this result, Khaliliaqdam *et al*. (2012) reported negative interaction between maize seed yield and leaf defoliation intensity. On the other hand, the correlation analysis between above ground dry biomass and grain yield showed significant and positive relationship. This might be due to high partitioning of dry matter production in to grains (Figure 4B). The observation of positive correlation between grain yield and total above ground biomass shows that plants which produced more vigorous growth tend to produce high dry matter yield which results in increased grain yield.

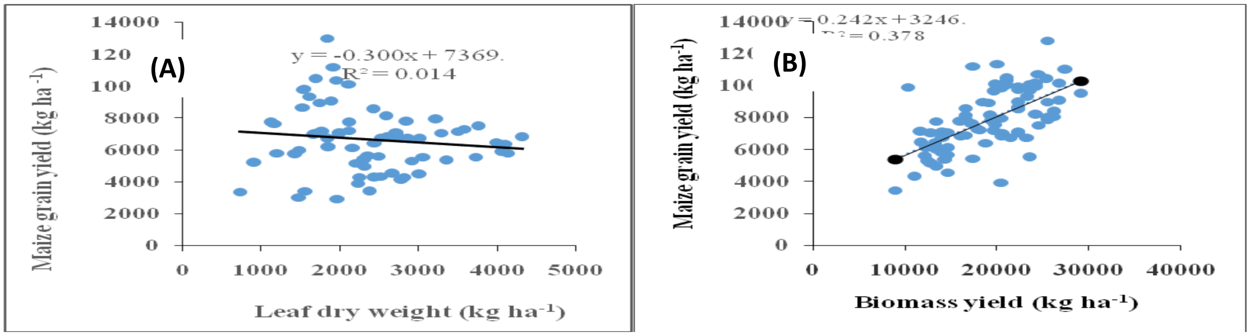

Figure 4: (A) Relationship between maize grain yield and leaf defoliation intensity of maize at hard dough stage and (B) relationship between above ground biomass yield and grain yield of maize

Bean components

Grain yield and above ground dry biomass: The biomass and grain yield of common bean varieties were significantly influenced under different leaf defoliation intensity (Figure 5). The highest common bean biomass yield was recorded from sole beans (Anger and Nasir) followed by relayed beans with maize leaf defoliation below ear placement and all leaf defoliation except green cobs at Bako and Uke, respectively. Also, the highest seed yield of common bean varieties was obtained from sole bean at both locations. The performance of common bean varieties was poor as compared to their potential average yield. The rain fall distribution during the growing period is enough for common bean growth according to meteorological data of the study areas. This low yield of common bean is might be due to the soil type of the study areas. The soil water holding capacity of the study areas are very low. Further, under these conditions the root of maize make the soil compact and block the root penetration of common bean plants into the soil. In agreement with this result, Kermah *et al*. (2018) reported poor performance of cowpea, soybean and groundnut in maize relay cropping due to insufficient rainfall amount.

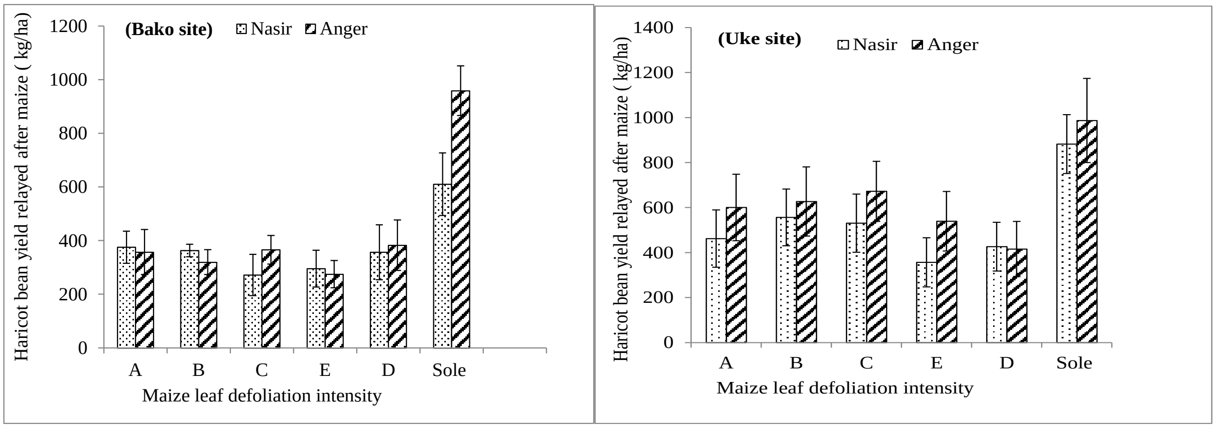

Figure 5. Grain yield of Haricot bean varieties relayed after maize at Bako and Uke sites, 2016-2017 cropping seasons. Where, A= all leaves removal except green cobs, B= all leaves removal except flag leaves, C= all leaves removal below ear placement, D= all maize removal as green cobs and Stover at time of dough stage and E= all maize parts was not be removed until harvest maturity.

Partial budget analysis

Analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 2. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation by farmers. The study assessed the economic benefits of the treatments to develop recommendation from the agronomic data. This enhances selection of the right combination of resources by farmers in the study area. The results indicated that all maize removal as green cobs and stover at time of dough stage and all leaves removal below ear placement resulted in higher net benefits respectively, at Bako whereas the highest net benefit recorded from all maize removal as green cobs and stover at time of dough stage and all maize parts was not removed until harvest maturity at Uke (Table 2). The partial budget analysis also showed that all maize removal as green cobs and stover at time of dough stage and all leaves removal below ear placement resulted in the highest marginal rate of return, respectively, at

Bako while the highest marginal rate of return was recorded from all maize removal as green cobs and stover at time of dough stage and maize harvested at harvest maturity at Uke (Table 2).

Table 2. Partial budget analysis of maize-common bean relay cropping at Bako

Factor A	Factor B	AMGY (kg ha^{-1})	CBGY (kg ha^{-1})	TVC	GFB (Birr)	NB (Birr)
BH546 + Anger	A	4210.0	392.0	1157.4	31534	30377
	B	4135.9	319.5	925.9	29928	29002
	C	**8679.1**	**365.7**	**555.6**	**57926**	**57371**
	D	-	382.8	2083.3	68348	66264
	E	7614.2	274.8	0.0	50082	50082
BH546 + Nasir	A	4320.6	375.4	1296.3	31931	30634
	B	5282.4	363.3	1157.4	37507	36349
	C	7185.2	292.2	694.4	47786	47092
	D	-	**387.7**	**1851.9**	**74775**	**72923**
	E	7798.4	295.5	0.0	51518	51518
	Sole Maize	7148.7		0.0	42892	42892

Partial budget analysis of maize-common bean relay cropping at Uke

Factor A	Factor B	AMGY (kg ha^{-1})	CBGY (kg ha^{-1})	TVC	GFB (Birr)	NB (Birr)
Gibe 3 + Anger	A	5394.6	600.2	2381	39570.5	37189.6
	B	6599.1	627.1	1984	47120.0	45135.9
	C	7210.0	672.2	1190	51326.1	50215.0
	D	-	539.4	3968	63615.8	**59647.6**
	E	8638.5	415.7	0	56819.9	**56819.9**
Gibe 3 + Nasir	A	5612.2	418.6	2381	38696.4	36394.8
	B	6837.3	556.2	1984	47697.9	45713.8
	C	7343.0	530.7	1190	50426.7	49236.3
	D	-	356.6	3571	70310.8	**66739.4**
	E	8235.9	426.2	0	54529.8	54529.8
	Sole Maize	8288.7	-	0	49732.3	49732.3

AMGY= Adjusted maize grain yield, CBGY= Common bean grain yield, TVC= Total variable cost, GFB= Gross field benefit, MRR= Marginal Rate of Return, Cost of maize= 6 birr/kg, Cost common bean= 12 birr/kg

Conclusion

Inclusion of legume crop as relay intercrop into maize-bean system could increase subsequent crop yields and enhances soil fertility. Defoliation of maize leaf below ear placement resulted in higher maize yields. In contrast, removal of all leaves (all leaves removal except green cobs and all leaves removal except flag leaves) resulted in lower maize grain yield due to a greater removal of leaves may be which are photo synthetically active. The partial budget analysis indicated that the highest net benefit were recorded from all maize removal as green cobs and stover at time of dough stage and all leaves removal below ear placement resulted in higher net benefits respectively. At Bako whereas the highest net benefit recorded from all maize removal as green cobs and stover at time of dough stage and all maize parts was not removed until harvest maturity at Uke. This implies that farmers would be better off remove all maize as green cobs and defoliating their maize below ear placement as these increase maize yields and thus increase farmer’s income. Thus, removal of all maize parts as green cobs and maize defoliation below ear placement are more profitable and recommended for the farmers in the study areas and other areas with similar agro-ecological conditions.

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Adaptability and Performance Evaluation of Irish Potato (Solanum tubersum L.) Varieties under Irrigation in West and Kellem Wollega Zones

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Abstract

The trial was conducted at Aleku Badesso and Nedjo sites of Haro-Sabu Agricultural Research Center (HSARC) during the 2016/2017-2018 Belg season under irrigation. Objective of the study was to identify the adaptable, high yielding, insect pest and disease tolerant varieties of Irish potato in mid-altitude potato producing areas of Western and Kelem Wollega Zones of Oromia Regional State. Seven improved Irish potato varieties introduced from Sinana, Holeta and Kulumsa Agricultural Research Center and one local check were evaluated using Randomized Complete Block Design (RCBD) with three replications. Inorganic fertilizer DAP was applied at rate of 195 kg/ha at planting while UREA at 165 kg/ha was split form (50% at planting and the remaining 50% early before flowering). Data were collected on seven observed traits and analysis of variance was done accordingly. The mean square indicated significant ($p<0.01$ or 0.05) varietal differences for all observed traits over year and locations. The highest number of main stem was recorded from variety Belete at Aleku-Badeso location in the first year and lowest was from Ararsa variety at Nedjo in the second year. The highest and the lowest number of tuber was recorded from Belete in the first year and Hunde in the second year respectively. Highest tuber size was recorded from Belete variety and the lowest was from local variety. The highest and the lowest total tuber yield was recorded from Belete and Ararsa varieties. The highest and the lowest total tuber yield were recorded from Belete and Ararsa. The highest and the lowest marketable yield was recorded Gudane variety at Nedjo and Ararsa variety at the same site. From the tested potato varieties Belete and Gudane showed better performances on desirable traits such as, number tuber per hill, tuber size, marketable yields and unmarketable yields which determine total tuber yield in t/ha. Therefore, Gudane and Belete were identified and selected as the best for different merits to be demonstrated and popularized in the studied areas.

Key words: marketable yield, tuber size,

Introduction

Potato *(Solanum tubersom L.)* is regarded as high-potential food security crop because of its ability to provide a high yield of high-quality product per unit input with a shorter crop cycle. It is considered to be one of the cheapest sources of energy and the production of protein per unit land and it is the highest among the four major food crops (rice, maize, wheat and potato) (CIP and FAO, 1995). In Ethiopia it is the fastest growing staple food crop and source of cash for small holder having high potential for food security due to its high yield potential and nutritional quality tuber, short growing period (mostly< 120 days),and wider adaptability (Tewodros *et al.*, 2014). Irish potato is the first tuber crops produced in Ethiopia next to Taro and sweet potato that accounts 66,923.33 ha in 2016/17Meher cropping season. The estimated potato production was 9,214,031.85 quintals with average yield of 137.68 quintals per hectare (CSA, 2017). The estimated producers of potatoes in both Belg and Meher season were accounted 3,705,879 (CSA, 2016). Most highlands with altitudes ranging from 1,500 - 3,000 meters above sea level (m.a.s.l) and annual precipitation of 600-1,200 millimeters (mm) are suitable for potato cultivation (FAO, 2010). In West and Kellem Wollega farmers produced potato under rain fed, irrigation and residual moisture to ensure food security and food self-sufficiency and income generation. However, due to lack of well adapted and improved variety farmers still depend on low yielder local varieties. Moreover, farmers are following poor agronomic and postharvest practices.

Objective of the study

To identify, select and recommend adaptable, high yielding, disease and insect pest resistant/tolerant potato varieties for Western and KelemWollega Zones.

Materials and Methods

The study was conducted at Aleku-Badeso of Sayo district in Kellem Wollega and Nedjo district of Western Wollega zones during the Belg season of 2016/17-2017/2018 from December to March. Seven improved potato varieties namely; Dagim, Belete, Gudane, Hunde, Ararsa, Jalane and Gera were introduced from Sinana, Holeta and Kulumsa Agricultural Research Center and one local check were evaluated using Randomized Complete Block Design (RCBD) with three replication. The gross plot size for the experiment was 13.5 m^2 (4.5 m × 3 m) with six rows of plants spaced at 75 cm and 30 cm between rows and plants, respectively, and the net plot size was 3 m × 3 m. A space of 1.5 m and 1m between blocks and plots was maintained, respectively. Inorganic fertilizer DAP at rate of 195 kg/ha at planting while UREA at rate of 165 kg/ha were applied in split form (50% at planting and the remaining 50% was applied early before flowering. Furrow irrigation was used and applied at interval of three days from land preparation till plant maturity.

Results and Discussions

Analysis of Variance

Analysis of variance revealed that the main effect of variety, location and year had highly significant ($p<0.01$) affect days to maturity and the main effect of variety had significant ($p<0.05$) affect total tuber yield and weight of marketable and unmarketable yield. Likewise, the interaction effect of variety and location revealed significant effect ($p<0.05$) on insect pest resistance, number of main stem, number of tuber per hill and weight of marketable yield. On the other hand, the other interactions were only revealed significant effect ($p<0.05$) for number of main stems (Table 1).

Table 1. Analysis of Variance (ANOVA) for performance evaluation of potato varieties

		Mean squares						
Source of variation	DF	DM	NMS	NTPH	TS (cm)	TYQ ha^{-1}	WMY (Kg)	WUMYK gpp
Replication	2	20.57	5.48	9.56	42.69	16501	0.5422	0.051
Variety	7	95.14**	3.39	60.914**	72.08*	25764*	5.0399**	0.119
Location	1	137.76**	0.27	14.714	4.78	71049*	1.4166	0.018
Year	1	1464.84**	96.25**	206.85**	1141.84**	1547	0.4323	0.050
Variety*Location	7	1.784	6.48*	17.098*	29.39	12582	1.895*	0.0366
Variety*Year	7	68.82**	5.098*	18.923*	56.21	5923	1.0708	0.068*
Location*Year	1	137.76**	34.79**	119.44**	30.28	390	7.4195*	0.201*
Variety*Location *Year	7	1.784	6.514*	9.448	18.52	11473	0.889	0.0362
Error	62	3.637	2.023	7.756	26.77	7206	0.7648	0.039

DF = Degree freedom of error, DM = Days to 90% maturity, DR=disease reaction, NMS = Number of main stem, NTPH = Number of tuber per hill, TS= tuber size in centimeter, TYtha^{-1}=total tuber yield in tone per hectare, WMY=weight of marketable yield, WUMYH= Weight of marketable yield.

Phenology and growth parameters of potato

The interaction effect of variety and year revealed highly significant effect ($p<0.01$) on days to maturity, where Belete variety was earlier than others in the first year and late matured in the second year (T able 2). This might be due the varietal effect and environmental conditions such as light and soils which influence crop maturity.

Table 21. Interaction effect of variety and year on days to maturity

	Year	
Variety	2016	2018
Dagim	103.30g	110.300a
Belete	97.70h	109.80ab
Hunde	104.3fg	109.2abc
Gudane	107.7b-e	108.2a-d
Jalane	93.700j	107.7b-e
Gera	95.30ij	107.0c-e
Local	97.0hi	106.3def
Ararsa	102.70g	105.70ef
LSD(0.05)	2.200	
CV (%)	1.800	

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

The interaction effect of variety, location and year showed significant different ($p<0.05$) on number of main stem per plant (Table 3). The highest number of main stem was recorded from variety Belete at Aleku-Badeso location in the first year and lowest was from Ararsa variety at Nedjo in the second year. The differences might be due varietal effect and plant canopy which determine main stem to different locations.

Table 3. Interaction effect of variety, location and year on number of main stem

		Year	
Variety	Location	2016	2017
	Aleku-Badeso	9.660a	3.58f-m
Belete	Nedjo	5.11c-j	2.86j-m
	Aleku-Badeso	3.22h-m	3.41g-m
Ararsa	Nedjo	8.220ab	1.417m
	Aleku-Badeso	5.000c-j	4.83c-k
Local	Nedjo	7.111bc	3.91e-l
	Aleku-Badeso	3.889e-l	3.66f-m
Jalane	Nedjo	6.77bcd	3.62f-m
	Aleku-Badeso	4.000e-l	3.08i-m
Hunde	Nedjo	6.111b-e	2.52klm
	Aleku-Badeso	5.444c-h	4.58d-l
Dagim	Nedjo	5.778c-f	2.50lm
	Aleku-Badeso	5.222c-i	5.66c-g
Gudane	Nedjo	5.000c-j	2.91i-m
	Aleku-Badeso	3.44g-m	4.66d-l
Gera	Nedjo	4.556d-l	3.25h-m
LSD(0.05)	2.30		
CV (%)	31.40		

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

Yield parameters of potato

The interaction effect of variety and location as well as variety and year revealed significant ($p<0.05$) effect on number of tuber per hill; whereas, the interaction effect of location and year showed highly significant ($p<0.01$) effect. The highest (16.44) and the lowest (6.75) number of tuber per plat was recorded from Belete in the first year and Hunde varieties in the second year respectively (Table 4). On the other hand, the highest and the lowest number of tuber per hill was recorded from Gudane (16.1) at Nedjo site and Gera (8.44) varieties at Aeku-Badesso site respectively (Table 5). These differences might be due to soil fertility effect since it varies from time to time and number and size of tubers basically depends on varietal character and edaphic factors. Similarly, Asfew *et al* (2017) reported that the highest number of tuber per hill was recorded from Gudane variety.

Table 22. The interaction effect of variety and year on number of tuber per hill

	Year	
Variety	2016	2018
Belete	16.4400a	11.62def
Gudane	15.00abc	16.170ab
Local	15.28a-c	12.23 c-f
Gera	13.2 bcd	10.08d-g
Hunde	13.10bcd	6.750h
Jalane	12.56cde	7.69gh
Dagim	11.40def	9.2fgh
Ararsa	9.89e-h	9.7e-h
LSD(0.05)	2.30	
CV(%)	31.40	

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

Table 5. The interaction effect of variety and location on number of tuber per hill

	Location	
Variety	Aleku-Badeso	Nedjo
Gudane	11.97 b	16.1 a
Belete	15.79 a	15.38 a
Jalane	11.86 b	15.65 a
Hunde	11.92 b	11.39 bc
Local	10.01 bc	9.85 bc
Dagim	10.89 bc	9.35 bc
Ararsa	11.18 bc	9.43 bc
Gera	8.44 c	11.19 bc
LSD(0.05)	3.20	
CV(%)	23.40	

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

The main effect of variety and year revealed significant ($p<0.05$) and highlysignificant ($p<0.01$) effect on tubersize (cm) where the highest tuber size(27.95cm)was recorded from Belete variety and the lowest(19.83cm) was from local variety. This might be due varietal character; numbers of tuber per hill and tuber size are mostly influenced by genetic and environmental factors (sunlight). The main effect of variety and location showed significant ($p<0.05$) different on total tuber yield t/ha (TYt/ha). The highest and the lowest total tuber yield (TYt/ha) was recorded from Belete (38.59 t/ha) and Ararsa (23.16 t/ha). On the other hand the highest (35.15 t/ha) and the lowest (30.47 t/ha) total tuber yield was recorded at Aleku-Badeso site and Nedjo sites respectively (Table 7). This might be due to performance adaptability of different varieties of the same crop to different environments. On the other hand, Gudane, Gera, Local, Jalane, Hunde and Dagim varieties showed non-significant from each other. Singh and Singh (1973) indicated that yield per unit area is the end product of components of several yield contributing characters which are highly influenced by the environment (Elfinesh, 2008 and Asmamawu, 2007).

Table 6. Main effect of variety and year on tuber size of potato varieties

Variety	Tuber size(cm)
Belete	27.90a
Dagim	25.64ab
Gera	24.93ab
Ararsa	24.71ab
Hunde	24.21ab
Jalane	22.52bc
Gudane	22.35bc
Local	19.830c
LSD(0.05)	4.223
	Year
2016	27.47a
2017	20.57b
LSD(0.05)	4.223
CV (%)	21.50

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

Table 7. Main effect of variety and year on total tuber yield t/ha (TYt/ha) of potato varieties

Variety	Total tuber yield(t/ha)
Belete	38.590a
Gudane	35.54ab
Gera	34.82ab
Local	34.11ab
Jalane	34.02ab
Hunde	31.180b
Dagim	31.080b
Ararsa	23.160c
LSD(0.05)	64.832
Location	
AlekuBadeso	35.15a
Nedjo	30.47b
LSD(0.05)	32.460
CV(%)	24.200

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

Similarly Habtamu *et al* (2016) reported that Gudane and Belete varieties were produced the highest marketable and total average tuber weight which directly determine total tuber yield per hectare. In addition to this Addis *et al* (2017) reported the highest yield (55.12 t/ha) was recorded from Gudanie variety at Bule-Hora District of Borena Zone. Similarly, Dembi and Basha (2017) reported that Gudanie yielded 26.69 t/ha at on farm evaluation at Guji highlands of Oromia region. The result of different authors who reported at different locations indicates the yield of different potato varieties affected by environment. The current investigation also agreed with these different scholars findings. The variation in total yield of potato genotypes at different location may be due to a response of the genotypes to growing environmental factors. This suggestion is in agreement with other authors who reported that yield differences among genotypes were attributed both by the inherent yield potential of genotypes and growing environment as well as the interaction of genotype x environment.

Table 8. Interaction effect of variety and location on weigh of marketable yield

	Location	
Variety	Aleku-Badeso	Nedjo
Gudane	3.365abc	4.3210a
Belete	3.702ab	3.34abc
Dagim	3.20bcd	1.690fg
Hunde	2.914b-e	2.924b-e
Gera	2.652c-f	2.705b-e
Ararsa	2.603c-f	1.3940g
Jalane	2.161e-g	2.457c-f
Local	2.33d-g	2.145efg
LSD(0.05)	1.009	
CV (%)	31.70	

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

The interaction effect of variety and location as well as the interaction effect of location and year had a significant ($p<0.05$) effect on weight of marketable yield. The highest (4.32) and the lowest

(1.39) marketable yield was recorded Gudane variety at Nedjo and Ararsa variety at the same site (Table 8). The differences among varieties might be due to potential adaptability of varieties to different locations. Likewise Habtamu *et al* (2016) was reported that Belete variety produced the highest total tuber yield per hectare in the eastern parts of Ethiopia. On the other hand tuber size is among desirable traits (desirable tuber size, color, shapes) which determine market quality and key for variety adoption (Semagn *et al*, 2015). Similarly, other researchers also investigated that marketable yield was significantly varied by variety, location and genotypes x environment interaction (Elfinesh, 2008, Pandey *et al*. 2004, Kumar *et al*., 2007). The interaction effect of variety and year revealed significant ($p<0.05$) effect on the unmarketable yield. Except variety Dagim all varieties had no significant difference. This might be due high deterioration of Dagim variety. The variation in unmarketable yield of the genotypes may be due to adaptability, crop maturity, and inherent ability of potato genotypes in producing unmarketable tubers per plant. The result was in line with the findings of Habtamu *et al* (2016), who reported that the interaction effects of growing environment and genotype; significantly influence unmarketable tuber yield.

Table 9. Interaction effect of variety and year on unmarketable yield of potato verities

	Year	
Variety	2016	2017
Dagim	0.37a	0.07b
Hunde	0.00b	0.17b
Ararsa	0.17b	0.12b
Local	0.12b	0.00b
Belete	0.11b	0.07b
Gudane	0.07b	0.08b
Gera	0.06b	0.06b
Jalane	0.00b	0.05b
LSD(0.05)	0.19	
CV (%)	31.5	

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

Conclusions and Recommendations

Field experiment was conducted to identify the performance evaluation of potato varieties under irrigation in Kelem and West Wollega zone on Aleku-Badeso and Nedjo for two consecutive years. Seven improved varieties were evaluated with local variety. The result of the study revealed that Belete and Gudane showed better performances on desirable traits such as number tuber per hill, tuber size, marketable yields and unmarketable yields which determine total tuber yield in t/ha. The highest (38.59 t/ha) and the lowest (35.54 t/ha) total tuber yield was recorded from Belete and Gudane varieties. From the tested potato varieties Belete and Gudane showed better performances on desirable traits such as, number of tuber per hill, tuber size, marketable yields and unmarketable yields which determine total tuber yield. Belete and Gudane were selected for their adaptability and higher tuber yield/ha in the study area. Therefore, Gudane and Belete were identified and selected due to their agronomic and economic merits to be demonstrated and popularized in the studied areas.

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Predition and Postdiction of Heterosis in Sesame (Sesamum Indicum L.)

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Abstract

Exploitation of hybrid vigor is one of the methods of plant breeding to develop cultivars with high yield potential. The objective of this study was to assess the reliability of prediction methods. The present investigation on sesame comprised a full-diallel set of 10 parents and their F_1 direct crosses. Seeds of all F_1 and their parents were planted in randomized complete block design, with three replications at two experimental sites namely Uke (1383 meters above sea level) and Wama (1436 meters above sea level) of Bako Agricultural Research Center on 12 and 14 June 2012, respectively. The data was recorded for five traits viz., days to flowering, branches per plant, yield per plan, oil content (%) and thousand seed weight. Seven crosses of F_1 showed significant and positive heterosis over both mid and better parents for seed yield per plant. These crosses could be utilized for hybrid development. These hybrids could also be utilized to develop potential pure line for seed yield. The result of this study showed that the effectiveness of the postdiction is better than that of prediction model.

Key words: Predition heterosis , Postdiction heterosis, *Sesamum indicum* L.

Introduction

Exploitation of hybrid vigor is one of the methods of plant breeding to develop cultivars with high yield potential (Kumar *et al*., 2003). To achieve higher yields in sesame, exploitation of heterosis is the most practical and achievable option. Shall (1948) explained that heterosis is the genetic expression of the beneficial effect of hybridization. A significant breakthrough in yield advances in sesame could made through the exploitation of heterosis at a commercial level (Sankar and Kumar, 2001). The magnitude of heterosis provides a basis for genetic diversity and a guide to the choice of parents for developing superior F_1 hybrids, so as to exploit hybrid vigor and/or for building better gene pools to be employed in population improvement. To achieve higher yields in sesame, exploitation of heterosis is the most practical and achievable option (Shobharani *et al*., 2015). Heterosis for seed yield in sesame is due to simultaneous heterotic effects of more than one component (Jatothu *et al*., 2013). Hence, it is important to measure the magnitude of heterosis in sesame hybrids with due emphasis on contribution of different morphological traits. The comprehensive review of heterosis in sesame indicated that there is a significant amount of heterosis over commercial cultivar indicating that the possibility of exploiting heterosis commercially in sesame. Yadav *et al*. (2005) has reported positive standard heterosis ranging 33.33 to 444.4% for grain yield in sesame. High levels of morphological genetic diversity do exist in sesame (Arriel *et al*., 2007) but this has not been fully harnessed for genetic improvement of the existing cultivars through heterosis breeding.

Heterosis for seed yield is due to simultaneous manifestation of allelic and inter-allelic interactions of innumerable number of genes controlling important morpho-economic component traits under certain environmental conditions. Hybrid vigor of even a small magnitude for individual components may have an additive or synergistic effect on the product. Thus, extent of heterotic response of F_1 hybrids largely depends on the breeding value and genetic diversity of the parents involved in the crosses (Young and Virmani, 1990). Heterosis over better parent (heterobeltiosis: Hb) is relatively more important than relative heterosis for commercial exploitation of hybrids. Heterobeltiosis for seed yield and yield components in sesame has been reported by many workers (Saravannan and Nadarajan, 2002, Prajapati *et al.*, 2010, Padmasundari and Kamala, 2012). Besides, heterotic crosses may be amenable for selection of high yielding transgressive segregants in F_2 and follow up selfing generations. Production and testing of a relatively large number of cross combination is the only way to trace a desirable hybrid. In cross pollinated crops like maize, the method predicting three way and double cross performance has been widely used to identify combinations of inbred lines that are worth evaluating and field trials. However, such methods are not available of self pollinating crops like sesame . Panter and Allen (1995) and Brandle and McVetty (1989) proposed methods of prediction and postdiction of heterosis of self-pollinating crops. Therefore, this study was undertaken to predict the heterosis for yield and yield related traits and to assess the reliability of prediction methods and to assess the performance of hybrid.

Materials and Methods

The experimental material comprised ten lines selected for yield viz., EW002, BG006, EW023-2, EW006, EW003-1, EW019, Obsa, Dicho, Wama and EW010-1. Genotypes EW002, BG006, EW023-2, EW006, EW003-1, EW019 and Wama were elite breeding lines while Obsa and Dicho are released cultivars. All these genotypes were collected from Western Ethiopia. Ten parental lines were crossed in the main growing season of 2011in 10 x 10 in full diallel mating design. Seed of all F_1s and their parents was planted on 12 June 2012 at Uke (1383 meters above seas level) and 14 June 2012 at Wama (1436 meters above sea level) testing sites of the Bako Agricultural Research Center in a randomized complete block design with three replications. In the study, the heterosis of the direct cross was considered. Each plot consisted of a single row of 5 m long with 50 cm and 25 cm inter and intra row spacing, respectively. The seeds were drilled in each row at seeding rate of five kg ha^{-1}. Twenty days after planting, the plants were thinned out to adjust for optimum population per hectare. Nitrogen fertilizer in the form of UREA was applied as side dressing four weeks after emergence at the rate of 50 kg ha^{-1}. Hand weeding was carried out four times at three weeks interval starting 20 days after planting. Maturity data was recorded on a plot basis. Observations were made on ten randomly selected plants for branches per plant, plant height, capsules per plant, seed yield per plant. Sampled seed from plot harvest was used for oil content analysis. Oil content was estimated at Holetta Research Center using Nuclear Magnetic Resonance method (Robbelen *et al.*, 1989).

Statistical analysis

Analysis of variance was performed using SAS Software to determine the existence of variability among parents and crosses for all the traits. The performance of the hybrids is estimated in terms of the percentage increase or decrease of their performance over the mid-parent (heterosis) and better parent (heterobeltiosis) (Hochholdinger and Hoecker, 2007). Mid parent heterosis, and heterobeltiosis were estimated following procedure developed by Fonesca and Patterson (1968).Heterosis over mid parent value (H_m was estimated as:

$$Hmp = \left(\frac{F1 - m}{mp}\right) x100$$

Where Hmp is heterosis over the mid parent value; F_1 is mean performance of F_1 ; m is mean value of the two parental lines involved in producing that particular F_1. .

Heterosis over the better parent (also known as heterobeltiosis) is estimated as:

$$Hbp = \left(\frac{F1 - bp}{bp}\right) x100$$

Where Hbp is heterosis over the better parent value; F_1 is mean performance of F_1; bp is mean value of the better parent value involved in producing that particular F_1.

The significance of mid parent heterosis was tested as per the method proposed by Panse and Sukhatme (1961) where critical difference is calculated for mid parent heterosis as:

CD=t $(3EMS/2r)^{1/2}$ at error degree of freedom.

Where CD =Critical difference for better parents heterosis = $t(3EMS/r)^{1/2}$ at error degree of freedom, r is the number of replications, EMS is error mean square and t is the table value of t at error degree freedom at 5% and 1% probability level.

Combining ability (GCA) effects of the parents were estimated following Griffing's Method I and Model I (fixed) of diallel analysis (Griffing, 1956a) using a modification of the DIALLEL-SAS program (Zhang and Kang, 1997).Expected hybrid performance was estimated from observed parental performance using a predictive method and postdictive method. The predictive method was based on calculation of mid parent value (Panter and Allen, 1995) as follows:

$$H_{ij}=(P_i + P_j)/2$$

where H_{ij}= is the expected performance from parent I and j with respective phenotypic value of Pi and Pj. The postdictive method was based on parental GCA value (Brandle and McVett, 1989) and expected hybrid performance was calculated as follows.

H_{ij}=H. +GCAi +GCAj

Where H_{ij} is the expected performance of hybrid derived from the i^{th} and j^{th} parents.

H. is the population mean; GCAi and GCAj are the GCA values of the the i^{th} and j^{th} parents

Pearson's simple correlation coefficient between expected and observed hybrid performance and regression coefficient of expected performance on observed data was calculated to assess the relative effectiveness of the two methods as described of hybrid performance.

Results and Discussion

The mean square for all traits was significant, indicating the existence of variability among the genotypes for these traits. This is consistent with the results of studies in sesame (Sumathi and Murlidharan, 2010). The study revealed that all traits showed in variable crosses depicted heterosis in both positive and negative directions, indicating that genes with negative as well as positive effects were important.

Table -1. Mean square of sesame genotypes evaluated in 2012 at Uke and Wama testing sites

S.V.	DF	YP	DF	BP	OC	TSW
Location	1	164.0**	20.5*	3.68	164.0**	5.5**
Reps	2	187.1**	61.3**	44.8**	187.1**	0.1*
Genotypes	99	51.8**	19.4**	7.5**	51.8**	0.2*
Genotype x Loc	99	48.4**	7.5**	4.5**	48.4**	0.1*
Error	398	15.7	4.4	2.3	15.7	0.04

*, ** significant at P< 0.05 and P< 0.01probability level, respectively; YP= yield per plant, DF= days to flowering; BP=branches per plant; OC=oil content and TSW= thousand seed weight

Evaluation of parental lines for general combining ability (GCA)

The estimates of GCA effects for different traits are presented in Table 2. For seed yield per plant EW002, BG006, EW003-1, Obsa and Dicho, demonstrated positive GCA effect indicating that these parents exhibited above average combiners for these traits. These parents should be chosen as parents for sesame-breeding program in view of their positive GCA effects for seed yield. On the other hand, EW019 and EW010-1 showed significant negative GCA effect for seed yield. Parental line EW023-2 was the best combiner for lateness. Quite the opposite, EW010-1 exhibited highly significant negative GCA effect for days to flowering, implying that this parent is good combiners for earliness. For branches per plant, EW023-2 had the most desirable GCA effects. Conversely, significant and negative GCA value for branches per plant was observed in EW019, Wama, and EW010-1. For oil, content BG006 illustrated highly significant positive GCA effect. In contrast, EW002 demonstrated highly significant negative GCA effect for this trait. For thousand seed weight, EW002, BG006 and Wama exhibited significant positive GCA effects.

Table 2. Estimates of GCA effects for F1 generation in five traits of sesame in a 10x10 crosses across Uke and Wama locations in year 2012

Inbred line	YP	DF	BP	OC	TSW
EW002	0.56	-0.33	0.05	-0.54**	0.07**
BG006	0.47	-0.38	-0.15	0.35**	0.03*
EW023-2	0.05	0.98**	1.21**	-0.24	0.01
EW006	0.04	0.24	0.14	-0.13	-0.08**
EW003-1	0.40	-0.18	0.09	0.10	-0.05*
EW019	-1.15*	-0.10	-0.35*	-0.07	0.00
Obsa	0.43	-0.12	-0.07	0.18	-0.03
Dicho	0.64	-0.07	-0.14	0.10	0.03
Wama	-0.01	0.53*	-0.31 *	0.13	0.05*
EW010-1	-1.47**	-0.56**	-0.47 **	0.10	-0.03
SE(gi)	0.41	0.2	0.14	0.12	0.02
SE (gi-gj)	0.75	0.22	0.21	0.19	0.5

Heterosis

The results related to mid and better parent heterosis for six traits in 45 direct crosses have been presented in table 3. In the present investigation, a medium level of heterosis in the desired direction was observed in several hybrids for seed yield and yield related traits including oil content. Positive and negative heterosis was observed for all the growth and yield attributing traits. Out of 45 F_1 hybrids, tested seven hybrids viz., BG006 xEW023-2,BG006 x EW03-1,BG006 xEW010-1, EW023-2 x Dicho , EW023-2 x Wama, EW023-2 X EW010-1,Dicho x Wama exhibited significant and positive heterosis over mid and better parents. These cross combinations offer a greater scope for exploitation of hybrid vigor in sesame. Chaudhari *et al.* (2015) and Prajapati *et al*. (2010) also reported better parent heterosis for seed yield in sesame. A positive estimate of heterobeltiosis would truly reflect “hybrid vigor” for important favorable yield related traits and seed yield per se which are meant for improvement in positive direction (Tripathy *et al.*, 2016). Seed yield per plant is a multiplicative product of several basic components of yield. The increased seed yield is definitely because of increase in one or more than one yield component. In the above crosses the superiority of hybrids in seed yield was due to genetic divergent characters of parents viz. number of productive branches per plant, number of seeds per capsule and 1000 seed weight. Virmani *et al.* (1982) reported that high heterosis was due to genetic divergence in the parents and dominant nature of gene action.

Early flowering hybrids are desirable as they produce more yields per day and fit well in multiple cropping systems. Among the 45 hybrids, 12 hybrids exhibited significant negative mid and 13 heterobeltiosis over their respective better parents for this trait. This indicates that there is ample scope for recovery of transgressive segregants in F_2 and onwards towards negative direction for earliness. This revealed significant negative better parents heterosis indicating tendency of large number of crosses for early and synchronous flowering. Early flowering in hybrids has been reported earlier (Jatothu *et al.,* 2013). Some of the traits related with flowering and maturity; and also plant height are favored in negative direction where a negative estimate that referred as negative heterobeltiosis would be appropriate (Tripathy *et al*.,2016). For number of branches per plant, eleven crosses showed significant and positive mid parent heterosis. Among these crosses BG006-2 x EW006, BG006-2 x Wama, EW023-2 x Dicho and EW006 x Wama possessed highly significant and positive heterosis over both mid and better parents. On the other hand, large number of crosses showed significant and negative heterosis over better parents for branches per plant. Oil content is an important character for higher yield. It is the single economic product in sesame. Twenty-four crosses for mid parent and seventeen crosses showed heterosis over mid and better parent respectively. The present investigation revealed a high order of heterosis for oil content. Thousand seed weight of a genotype serves as an indicator to the end product i.e., seed yield. Low seed yields in sesame hybrids are attributed mainly to the 1000 seed weight. The extent of 1000 seed weight directly influences the ultimate product (seed yield). Most of the crosses showed significant mid parent heterosis. Only nine crosses exhibited positive significant mid parent heterosis for the trait, 1000 seed weight but positively associated with seed yield. Five crosses viz., demonstrated positive and significant heterosis over better parent for thousand seed weight. In most of the crosses it was observed that relatively high number of mid parent heterosis compared to better parent heterosis for seed yield and other traits.

Table 3. Heterosis (%) of YP, DF, BP,OC and TSW over mid and better parents in sesame (45 direct crosses)

No.	Cross	YP		DF		BP		OC		TSW	
		Hmp	Hbp	Hmp	Hbp	Hmp	Hbp	Hmp	Hbp	Hmp	Hbp
1	P1xP2	-4.200	-13.3**	-0.70	-2.90	0.00	-11.1**	0.9	0.0	-13.0**	-4.8**
2	P1x P3	0.500	-11.4**	0.00	-1.40	0.00	0.0	0.0	0.0	-17.4**	-9.5**
3	P1 xP4	-13.5**	-15.5**	0.70	-1.40	-17.6**	-22.2**	-3.8**	-5.6**	-11.6**	-9.5**
4	P1x P5	-40.5**	-41.8**	-7.1**	-7.1**	-17.6**	-22.2**	-1.0	-1.9*	-16.3**	-14.3**
5	P1xP6	-12.2**	-24.8**	-5.7**	-5.7**	-29.4**	-33.3**	-1.9*	-1.9*	-14.3**	-14.3**
6	P1 xP7	-8.1**	-16.9**	-1.40	-2.90	-15.8**	-20.0**	4.8**	3.8**	0.0	4.8**
7	P1x P8	-14.9**	-21.0**	-4.3*	-4.3*	-22.2**	-22.2**	0.0	-1.9*	-8.3**	4.8**
8	P1x P9	11.0**	5.7000	-4.3**	-4.3*	6.7**	-11.1**	1.9*	0.0	-8.7**	0.0
9	P1xP10	22.8**	5.200	-0.70	-4.3*	-12.5**	-22.2**	1.0	-1.9*	-11.6**	-9.5**
10	P2xP3	19.4**	15.9**	2.20	1.50	-12.5**	-22.2**	-0.9	-1.9*	-4.8**	-4.8**
11	P2 xP4	11.3**	-1.40	0.00	0.00	20.0**	12.5**	-2.8**	-3.7**	-12.8**	-19.0**
12	P2 x P5	24.6**	10.5**	2.20	0.00	-6.7**	-12.5**	0.0	-1.9*	-7.7**	-14.3**
13	P2 x P6	5.000	-1.200	3.6*	1.40	-6.7**	-12.5**	-2.8**	-3.7**	2.1**	9.5**
14	P2 xP7	-21.9**	-35.4**	-2.20	-2.90	-5.9**	-20.0**	-1.9*	-3.7**	-15.0**	-19.0**
15	P2 xP8	3.400	0.60	-0.70	-2.90	0.00	-11.1**	4.8**	1.9*	-4.5**	0.0
16	P2x P9	-5.60*	-10.5**	-5.1**	-7.1**	23.1**	14.3**	2.9**	0.0	-9.5**	-9.5**
17	P2x P10	15.0**	8.20*	-1.50	-3.00	0.00	0.0	3.8**	0.0	-7.7**	-14.3**
18	P3 x P4	1.600	-12.3**	0.70	0.00	-5.9**	-11.1**	0.0	-1.9*	2.6**	-4.8**
19	P3 x P5	12.1**	-3.20	-2.9*	-4.3*	17.6**	11.1**	-1.0	-1.9*	-7.7**	-14.3
20	P3 xP6	14.2**	4.10	1.40	0.00	-17.6**	-22.2**	0.0	0.0	0.0	-9.5**
21	P3 x P7	-4.300	-22.7**	5.9**	5.9**	5.3**	0.0	1.0	0.0	-5.0**	-9.5**
22	P3 xP8	30.6**	23.3**	1.40	0.00	11.1**	11.1**	1.9*	0.0	-18.2**	-14.3**
23	P3xP9	27.4**	17.4**	4.3**	2.90	6.7**	-11.1**	1.9*	0.0	0.0	0.0
24	P3 xP10	23.2**	12.4**	3.8**	1.50	0.00	-11.1**	4.9**	1.9*	7.7**	0.0
25	P4x P5	-1.400	-1.4	2.20	0.00	0.00	0.0	1.0	-1.9*	22.2**	4.8**
26	P4 xP6	3.200	13.2**	0.70	-1.40	0.00	0.0	5.7**	3.7**	2.9**	-14.3**
27	P4 x P7	37.9**	42.7**	5.2**	4.4*	-22.2**	30.0**	4.8**	1.9*	-2.7**	-14.3**
28	P4 xP8	15.5**	5.00	-0.70	-2.90	-5.9**	-	3.8**	0.0	-12.2**	-14.3**

							11.1**				
29	P4x P9	0.500	-6.40	0.70	-1.40	28.6**	12.5**	0.0	-3.7**	-2.6**	-9.5**
30	P4 x P10	-20.5**	-33.2**	4.5**	3.00	-6.7**	-12.5**	4.9**	0.0	-5.6**	-19.0**
31	P5 xP6	-1.10	-16.8**	-4.3**	-4.3*	-25.0**	-25.0**	4.8**	3.8**	14.3**	-4.8**
32	P5x P7	-36.3**	-41.2**	0.00	-1.40	-11.1**	-20.0**	3.8**	3.8**	-8.1**	-19.0**
33	P5 x P8	-24.5**	-31.4**	0.00	0.00	-29.4**	-33.3**	4.9**	3.8**	-7.3**	-9.5**
34	P5 xP9	-11.2**	-17.3**	0.00	0.00	14.3**	0.0	6.8**	5.8**	-7.7**	-14.3**
35	P5 x P10	14.6**	-3.60	-2.20	-5.7**	6.7**	0.0	7.8**	5.8**	0.0	-14.3**
36	P6x P7	3.400	-18.5**	-2.9*	-4.3*	-22.2**	-30.0**	1.0	0.0	0.0	-14.3**
37	P6 xP8	16.4**	6.70	-2.9*	-2.9	-17.6**	-22.2**	5.8**	3.8**	0.0	-4.8**
38	P6 x P9	-15.3**	-24.2**	-8.6**	-8.6**	0.00	-12.5**	3.8**	1.9*	15.8**	4.8**
39	P6X P10	6.00*	6.00	2.20	-1.40	-20.0**	-25.0**	4.9**	1.9*	8.6**	-9.5**
40	P7x P8	-23.2**	-35.0**	-7.2**	-8.6**	-36.8**	-40.0**	6.8**	5.8**	-4.8**	-4.8**
41	P7 x P9	-27.6**	-37.3**	-1.40	-2.90	-25.0**	-40.0**	1.0	0.0	0.0	-4.8**
42	P7xP10	-9.8**	-28.8**	3.8**	1.50	-17.6**	-30.0**	5.9**	3.8**	8.1**	-4.8**
43	P8 x P9	21.6**	18.4**	-5.7**	-5.7**	-20.0**	-33.3**	5.9**	5.9**	-13.6**	-9.5**
44	P8 xp10	9.10**	0.00	2.20	-1.40	0.0	-11.1**	1.0	0.0	-7.3**	-9.5**
45	P9xP10	7.100*	-4.20	0.70	-2.90	7.7**	0.0	5.0**	3.9**	7.7**	0.0

Prediction of heterosis

The simple correlation between actual and predicted means of forty-five crosses (prediction method, Panter and Allen, 1995) indicated no significant correlation for studied traits. On the contrary to the present result, Sarode *et al.*, (2008) observed significant correlation between actual and expected means for different traits such as days to maturity, plant height, number of seeds per capitulum, seed yield per plant in safflower. Therefore, mid parent is not much useful to be used as cost effective guide for selection of parents for evaluation in hybrid combination. The results of this study are contrary with the result of Brandle and McVetty (1989) and Sarode and Ghorpade (2006).

The regression of the expected hybrid yield on the actual hybrid yield resulted in significant regression for days to flowering, branches per plant and thousand seed weight. Therefore, this study indicated that the hybrid performance can be predicted more on the basis of per se than the mid parental value. The additive model based on the general combining ability was effective in describing hybrid yield. In agreement with the present result, Brandle and McVetty (1989) indicated that a general combining ability was more effective than the mid parent for describing hybrid yield. The result of this study showed that the effectiveness of the postdiction is better than that of prediction model.

Conclusions and recommendations

In conclusion seven hybrids viz., BG006 x EW023-2, BG006 x EW03-1, BG006 xEW010-1, EW023-2 x Dicho, EW023-2 x Wama, EW023-2 X EW010-1,Dicho x Wama were very promising for yield per plant. There were higher chances of producing heterotic sesame hybrids that combined the highest yield. On the other way, selection pressure can be applied in segregating generations to isolate pure lines having better performance for seed yield. The result of this study showed that general combining ability was more effective than the mid parent for describing hybrid yield.

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Effect of Weed Management Options on Direct Seeded Up-Land Rice (Oryza Sativa L.) at Bako, Western Ethiopia

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Abstract

Field experiment was conducted during the rainy season of 2016/17 and 2017/18 at Bako Agricultural Research Center (BARC) on Station, to develop appropriate weed management practices for dry direct- seeded rice. Herbicide and their rate of application were Stomp at 3 l ha^{-1} 2 DAS, 2, 4-D at 1 l ha^{-1}, hand weeding at 25 and 40 DAS, Stomp at 1.5 l ha^{-1} + 2,4-D at 0.5 L ha^{-1}, Stomp at 1.5 L ha^{-1} + hand weeding at 40 DAS, 2, 4-D at 0.5 L ha^{-1} + hand weeding at 40 DAS, weed free and weedy check. The trial was laid out in Randomized Complete Block three replications. The weed density (m^{-2}) was significantly influenced by integrated weed management practices. Low weed population density and highest percentage of weed reduction resulted by two hand weeding (7.4 m^{-2}) followed by Stomp at 1.5l ha^{-1} + one hand weeding at 40 DAS (9.3 m^{-2}) which were statistically at different level with weed free check.. In contrary, highest density (27.8 m^{-2}) was counted in weedy check. Highest grain yield (5.5 ton ha^{-1}) obtained from weed free plot followed by two hand weeding (4.37 ton ha^{-1}) and Stomp at 1.5l ha^{-1} + one hand weeding at 40 DAS (4.19 ton ha^{-1}). While, significantly the lowest yield (0.24 ton ha^{-1}) was recorded in weedy check plot. The net return per unit investment obtained from Stomp at 1.5 L ha^{-1} + one times hand weeding. Therefore, integration of Stomp at 1.5 L ha^{-1} with one times hand weeding at 40 days after emergence can be recommended based on current rice economy and weed flora.

Keywords*:* integration; grain yield; major weeds; rice; weed management

Introduction

Rice (*Oryza sativa* L.) is staple food of more than a half of the world population (Sinha and Talati, 2007; Ginigaddara and Ranamukhaarachi, 2009). It is the fourth most important cereal in Africa in terms of area harvested and second in terms of production after sorghum (*Sorghum bicolor*), maize (*Zea mays*) and millet (*Eleusine coracana*) (FAO, 2017). Africa produces an average of 26.4 million tones of rough rice (17.4 million tones, milled) in 2012 (FAO, 2013). However, the production and productivity of crop is constrained by different factors including lack of improved variety, recommended crop management practices, pre and post-harvest technology, other biotic and abiotic factors (Tesfaye *et al*., 2005). Weeds are cited among the main production constraints in any of the rice ecosystems (Adesina *et al*., 1994; Rodenburg, 2009). Worldwide, weeds are estimated to account for 32% potential and 9% actual yield losses in rice (Oerke and Dehne, 2004. Losses due to uncontrolled weed growth in both lowland and upland systems in Africa were within the range 28-100% (David Johnson, 2013). The nature and severity of weed problems, however, vary according to the rice ecosystem. Weed competition is one of the major factors responsible for low yield of rice.

The greatest loss caused by the weeds resulted from their competition with crop for growth factors viz., nutrients, soil moisture, light, space, etc. (Walia, 2006). Thus, it is important that they are controlled in time to avoid unproductive use of growth factors to enable the crop plant to express fully by utilizing these factors meant for them. Depending upon the weed species, different weed management options are given keeping in view their susceptibility when growing in a crop (Walia, 2006).This includes cultural, chemical, mechanical and integration of these methods. A number of studies Gill *et al*., 1992; Panwar *et al*., 1992) showed that weed control through both traditional and chemical methods influence crop growth and yield attributes of rice. Herbicides are considered to be an alternative/supplement to hand weeding. Both Pre and Post-emergence herbicides can be used in aerobic rice fields, which are effective, if properly used (De Datta and Baltzar, 1996). In Ethiopia in general and Western Oromia in particular, rice field is infested by both grass and broad weed species and are causing significant yield reduction. Despite of the importance of the crop in western Oromia, weeds cause significant losses. Farmers practiced two times hand weeding which is tedious and inapplicable for the large scale farms. The commercial herbicide 2, 4-D is not effective for all weed species in rice. For this reason, there is a need to look for the effective weed management technologies against major weed species. Therefore, this study was aimed to establish effective weed management options to reduce weed infestation and enhance the production and productivity of rice in Western Oromia farming community.

Materials and Methods

Description study site: A field experiment was conducted at Bako Agricultural Research Center on station for two consecutive years (2016/17 and 2017/18) during the main cropping season. The research center is found in the Western part of Ethiopia with about 258 km from Addis Ababa, the capital city of the country. The experimental site is located at 37° 03' 487' E longitude, 09° 09’ 701” N latitude and altitude of 1586 m.a.s.l. The soil is sandy clay loam in texture. It has a warm-humid climate with annual mean minimum and maximum temperature of 13.0° C and 29.5° C, respectively and receives average annual rainfall of 1286.4 mm.

Experimental design and treatments

The experiment comprised of eight treatments arranged in randomized complete block design with three replications. The treatments include of Stomp at 3 l ha^{-1} 2 DAS , 2,4-D at 1 l ha^{-1}, Hand weeding at 25 and 40 DAS, Stomp(pendimethalin) at 1.5 l ha^{-1} + Dical (2,4-D) 0.5 l ha^{-1}, Stomp at 1.5 l ha^{-1} + hand weeding at 40 DAS , 2, 4-D at 0.5 l ha^{-1} + hand weeding at 40 DAS, weed free (weeded at every 10 DAS interval) and weedy check (control). The name of herbicides mentioned in the braces is chemical name, while the one outside the braces is trade name. Rice variety “Chewaqa” was used as seed source with 80 kg ha^{-1} seeding rate. It was drilled in row of 20 cm apart from adjacent row on the plot size of 4 m x 5 m. There was also 0.5 m and 1.5 m path between the plots and the blocks, respectively. Management of non-treatment routines was similar for all experimental units including the control. Herbicides were emulsified in 200L of water and applied using manual knapsack sprayer at necessary time as detailed above.

Data collection and statistical analysis

Data was collected both on crop and weed parameters. The weed data including of weed flora composition found in the experimental field and density were recorded. Weed infestation was assessed and scored by number and species throwing quadrant of 50 cm x 50 cm area three times per plot at 70 DAS using method described by Cruz *et al*. (1986).

The counted weeds were separated in to species as broad and grass weed species. Likewise, the rice data including plant height, number of effective and ineffective tillers, panicle length, and thousand kernel weight, grain and biomass yield were recorded during experimentation. Analyses of variances for the data recorded were conducted using the SAS version 9.3. Least significant difference (LSD) test at 5% probability was used for mean separation if the analysis of variance indicated the presence of significant treatment differences.

Results and discussions

Weed community: Different weed compositions have been observed in experimental fields. The recorded data regarding to weed flora demonstrated that, associated weeds in experimental plots were categorized as broad leaved and grasses. The broad leaved contributed to higher percentage (77.8 %). Whereas, grass weeds and sedges were shared lower percentage 18.2% and 4%, respectively. A total of eighteen weed species were observed during the growing season. Irrespective of the years**,** the important weeds infesting the crop include *Agratum conyozoids, Agropyron repens, Bidens pachyloma, Com melina species, Elusina indica*, *Galinsoga parviflora, Guzotia scarba, Medicago latifolia, Nicandra physalodes, Oplismus hertilatus, Tritfolium latilofolia, Polygonum convolvulus, Polygonum nepalens* and *Xantium strumarium*.

Weed density as influenced by weed management practices

Analysis of variance regarding to weed density (m^{-2}) indicated that combined mean value of the two years (2016/17 and 2017/18) on both grass and broad weeds were statistically significantly affected by weed control treatments (Table 1). Accordingly, all weed control practices significantly reduced weed density over weedy check. Bhurer *et al*. (2013) also reported that, all treated plots were shown significant reduction of weed density (m^{-2}) and dry weight over weedy check at 30 and 60 days after sowing. The minimum total weeds density (7.4 m^{-2}) was counted in two times hand weeding which was statistically equal with Stomp at 1.5 l ha^{-1} + one times hand weeding at 40 DAS. From integrated weed management practices, pre-emergence application of Stomp at 1.5 lha^{-1} + one hand weeding at 40 DAS resulted in lowest total weeds density (9.3 m^{-2}) which was statistically similar with the rest of combinations. The reason of zero count of weed species in weed free plots is the continuous removal of weeds through manual hoeing. Likewise, application herbicides Stomp at 3 l ha^{-1} and 2, 4- D at 1 l ha^{-1} alone shown weed density reduction as compared to weedy check. However, combination of herbicides with one times hand weeding and/or each of them could provide better result than they did alone. The reduction of weed density in treated plots might be due to their suppression effect that had hindered or restricted weed germination and further growth during the cropping season.

This is in analogy with Bhurer *et al*. (2013) who reported that weed density, dry weed weight and weed control efficiency resulted significantly different as influenced by integrated weed management practices. The authors also pointed out that, low weed population density, low weed index and highest weed control efficiency has been resulted by Stomp at 1.5 l ha^{-1} and 2, 4- D at 1 l ha^{-1} each supplemented by one hand weeding there by providing effective weed control as equal as weed free check. On the other hand, Riaz *et al*. (2007) reported an encouraging results achieved by combination of two post-emergence herbicides like 2, 4-D and Ethoxysulfuron against all kinds of weeds viz., grasses, sedges and broad leaf weeds. In contrary, the maximum (27.8 m^{-2}) total weed density was noticed in the weedy check treatment where no herbicide was used. The maximum weed density in weedy check plots resulted in higher weed competition for resources by weed. This is in analogy with the work of Bhurer *et al*. (2013) and Riaz *et al*. (2007) those recorded significantly the highest weed intensity and dry biomass in weedy check plots.

Rice yield components as affected by weed management practices

Results shown that yield related parameters were significantly affected by weed management practices. Accordingly, irrespective of years, all weed control treatments boosted yield related parameters over the weedy check (table. 2). This reduction in yield components might be because in weedy plots rice suffered from nutritional deficiency which in turn reduced leaf area development and lowered yield attributes as well. This is in conformity with the results of Riaz *et al*. (2007) who pointed-out that paddy rice yield and its components were found higher in all weed management treatments as compared to weedy check.

Table 1. Effect of different herbicide treatments on weed density during 2016-18

Treatments	Total Grass weeds (m^{-2})	Total broad leaf weeds (m^{-2})	Total weeds (m^{-2})
Stomp at 3 L/ha 2DAS	(2.1) 2.5c	(3.7) 11.1b	(4.1) 13.6b
2,4-D at 1Ll/ha	(2.3) 3.4c	(3.2) 7.6c	(3.8) 11.1bc
Hand weeding 25and 40 DAS	(2.1) 2.5c	(2.5) 5.0d	(3.2) 7.4d
Stomp 1.5 L/ha+2,4-D 0.5 L/ha	(1.2) 0.9d	(3.5) 10.5b	(3.6) 11.3bc
Stomp 1.5 L/ha+ hand weeding 40 DAS	(1.2) 0.7d	(3.4) 8.7bc	(3.5) 9.3cd
2,4-D at 0.5 L/ha +hand weeding 40 DAS	(3.3) 8.9b	(1.7) 2.1e	(3.7) 11.0bc
Weed free	(0.5) 0.0d	(0.5) 0.0e	(0.5) 0.0e
Weedy check	(3.9) 11.8a	(4.5) 16.0a	(5.8) 27.8a
Cv (%)	25.4	28.5	11.7
Trt	**	**	**
Trt*year	Ns	Ns	Ns

*Means followed by the same letter within the column are not significantly different at p < 0.05 using LSD. ** , * = significance difference at (p<0.01) and (P < 0.05) respectively , ns = no significance difference, Cv (%) = Cofficient of variation, F-test (5%) = Probability value, Data were subjected to square* $\sqrt{\Box + 0.5}$ *transformation figure in the parentheses indicates , transformed values; while the one outside the parentheses is the original data.*

Data regarding to plant height showed that the highest plant height (148.1cm) was observed in a weed free plots which was statistically not different from all other treatments; except weedy plots that achieved the lowest plant height (136.0 cm) (table. 2). Likewise, it was noticed that, Stomp at 1.5 Lha^{-1} + hand weeding at 40 DAS treated plots produced maximum (102.9) number of grain per panicle followed by weed free plots (96.8) which was statistically at the same level with any other treatments, except weedy check which yielded minimum (62.60) number of grains per panicle representing intensive weed competition in this treatment. On the other hand, Stomp at 1.5 L ha^{-1} + hand weeding at 40 DAS recorded the highest (19.8 cm) panicle length followed by the plots treated with 2,4-D at 0.5 L ha^{-1} + hand weeding at 40 DAS (19.6); which was statistically similar with weed free treatment. In contrary, lowest (13.8 cm) panicle length was recorded in weedy check having statistical similarity with plots treated of Stomp at 3 L ha^{-1} 2 DAS, 2, 4-D at 1 L ha^{-1} and Stomp at 1.5 L ha^{-1} + 2, 4-D 0.5 L ha^{-1}. This is in accordance with the work of Riaz *et al*. (2007) who report, application of herbicides like 2,4-D and Pendimethalin along with hand weeding Plant height, panicle length and grains per panicle also followed similar trend. Application of 2, 4-1 l/ha, Stomp at 1.5 l/ha + 2, 4-D 0.5 l/ha and Stomp 1.5 l/ha + hand weeding gave the maximum thousand grain weight (26.6 g) followed by weed free (25.8 g). While the lowest (21.4 g) thousand grain weights were achieved from weedy check plots. The lowest thousand grain weight in weedy plots was due to weeds crop interference because weeds compete with plants for resources. In general, application of herbicides alone and in combination with hand weeding boosted the yield and yield attributes. This is might be due to the fact that in all treated plots rice crop wiped out the principal materials like nutrients, moisture, light and space there by competing over the weed plants. This is in accordance with the work of Bhurer *et al*. (2013) who reported the involvement of Pendimethalin followed by manual weeding or other herbicides indicates that Pendimethalin seems to be an effective pre-emergence herbicide for weed control in direct seeded rice. Except plant height (cm) and panicle length (cm) there were no variation over the year.

Table 2. Mean value of yield and yield parameters of rice under different weed management options

Treatments	Ph	No.ET/ plant	No.I ET	panicle length(cm)	No. of Grain per panicle	TKW
Stomp 3 l/ha 2 DAS	145.2ab	8.500c	1.08b	16.2cd	89.0ab	23.6ab
2,4-D 1L l/ha	141.3ab	9.1b0c	2.7ab	16.2cd	91.8ab	26.60a
Hand weeding 25and 40 DAS	148.00a	9.2b0c	1.08b	17.2bc	93.2ab	26.10a
Stomp 1.5 L/ha+ 2,4-D 0.5 L/ha	145.60a	9.6abc	3.4ab	16.1cd	87.8ab	26.60a
Stomp 1.5 L/ha+ Hand weeding	147.50a	11.200a	2.7ab	19.80a	102.9a	26.60a
2,4-D 0.5 L/ha +hand weeding	147.40a	11.500a	3.5ab	19.6ab	75.9bc	26.20a
Weed free(weeded at every 10	148.10a	10.70ab	1.5b	19.5ab	96.8ab	25.80a
Un weeded(control)	136.00b	8.300c	4.4a	13.80d	62.6c	21.40b
Lsd	9.500	1.9000	2.40	2.60	25.00	4.200
Cv (%)	5.600	16.9000	30.40	12.60	24.90	140.00
Trt	*	**	**	**	*	*
Trt*year	*	Ns	ns	**	Ns	Ns

Means followed by the same letter within the column are not significantly different at $p < 0.05$ using LSD. ** , ** = significance difference at ($p<0.01$) and ($P < 0.05$) respectively , ns = no significance difference, Cv (%) = Cofficient of variation, F-test (5%) = Probability value, Ph. (cm) = Plant height, No.ET/ plant = Number of effective tillers per plant, No.I ET/ plant = Number of ineffective tillers per plant TKW(gm)= Thousand kernel weight*

Yield and harvest index as affected by weed management practices

Analysis of variance depicted that grain yield, biological yield and harvest index was affected by applied treatments. All weed management practices were increased rice yield and harvest index over the weedy check plots (Table. 3). Highest grain yield 5.55 tons ha^{-1} was resulted from weed free plot followed by two hand weeding with 4.37 tons ha^{-1} yield. Among integrated treatments, pre-emergence application of Pendimethalin + one hand weeding at 40 DAS achieved the maximum (4.19 tons ha^{-1}) grain yield followed by post-emergence application of 2, 4-D + one times hand weeding at 40 DAS. Application Pendimethalin and/or 2, 4-D alone at recommended rate provided a lower yield than in combination with each other or one times hand weeding, which was due to less effectiveness of herbicides.

Significantly, the lowest grain yield (0.24 tons ha^{-1}) was obtained from weedy check plots. On the other hand, the maximum harvest index (32.8%) followed by two times hand weeding at 25 and 40 DAS (28.2 %) was recorded in weed free plots. In contrary, the minimum harvest index (5.1 %) was achieved from weedy check plots. This is in accordance with the work of Bhurer *et al*. (2013) who concluded that grain yield, straw yield, ration grain and straw ratio, and harvest index significantly affected due to integrated weed management practices where the highest grain and straw yield obtained in weed free check closely followed by Pendimethalin followed by 2, 4- D and one times hand weeding. In weedy plots, weed competition reduced the water use by the rice and also affected the dry matter production. This lowered the input response and caused yield reduction. Weeds absorbed mineral nutrients faster than the crop and accumulated them in their tissues in relatively larger amounts.

Table 3.The mean value of yield and harvest index of rice as affected by weed management options

Treatments	GY (t/ha)	Biol yield ton/ha	HI
Stomp 3 L/ha 2 DAS	2.06cd	11.500c	18.2b
2,4-D at 1 L/ha	1.37d	7.200d	17.7b
Hand weeding 25 and 40 DAS	4.37b	17.10ab	28.2a
Stomp 1.5 L/ha+ 2,4-D 0.5 L/ha	2.51c	13.50bc	20.1b
Stomp 1.5 L/ha + hand weeding at 40DAS	4.19b	15.1abc	27.7a
2,4-D 0.5 L/ha +hand weeding at 40DAS	3.99b	14.3abc	27.9a
Weed free	5.55a	17.800a	32.8a
Weedy check	0.24e	3.150e	5.10c
Lsd	1.26	3.9000	7.400
Cv(%)	3.56	27.0000	28.400
Trt	**	**	**
Trt*year	Ns	ns	Ns

Means followed by the same letter within the column are not significantly different at $p < 0.05$ using LSD. *** , * = significance difference at (p<0.01) and (P < 0.05) respectively , ns = no significance difference, Cv (%) = Cofficient of variation, F-test (5%) = Probability value, Biol yield (t ha-^{1})= Biological yield, GY (t/ha) = Yield per hectare, HI = harvest index*

Economic analysis

Economic analysis of various weed management treatments exposed that control of weeds grown in rice crop by the use of Stomp at 1.5 L/ha + hand one times weeding at 40 DAS gave more economic return as compared to all other treatments (Table-3). Application of Stomp at 1.5 L/ha + hand weeding at 40 DAS gave the maximum net returns of 22927.6 ETB ha^{-1}. Thus, according to the results the use of Stomp at 1.5 L/ha + one times hand weeding at 40 DAS (22927.6 ETB) is more economical than other weed Management options.

Table.4 partial economic analysis of different weed control treatments

Treatments	Av.Gy (t ha-^{1})	Adj.Gy (t ha-1)	TVC (ETB)	Gb (ETB)	Net b (ETB)	Cost benf. ratio	MRR(%)
Weedy check	0.24	0.216	0.0	1404.0	1404.00	-	
2,4-D at 1l/ha	1.37	1.233	552.1	8014.5	7462.40	13.5	1100.0
2,4-D at 0.5 L/ha +hand weeding	3.99	3.591	1306.8	23341.5	22034.70	16.9	1930 .0
Stomp 1.5 L/ha+ 2,4-D 0.5l/ha	2.51	2.259	1423.57	14683.5	13259.9D	9.3	
Stomp 1.5 L/ha +hand weeding	4.19	3.771	1583.9	24511.5	22927.60	14.5	320.0
Hand weeding @ 25and 40 DAS	4.37	3.933	3100.0	25564.5	22464.5D	7.2	
Stomp at 3 L/ha 2 DAS	2.06	1.854	5166.7	12051.0	6884.3D	1.3	
Weed free	5.55	4.995	5266.7	32467.5	27,300.80	5.2	120.0

Av.Gy= Average grain yield, Adj.Gy = Adjusted grain yield, TVC = Total variable cost, Gb= Gross benefit, MRR (%) = Marginal rate of return

Conclusions and Recommendations

From this study, it could be concluded that weeds are causing yield losses of rice indicating weed management as mandatory to attain potential yield. All treatments increased grain yield of rice over weedy plots there by reducing weed infestation. As manual weeding alone is difficult due to labor scarcity and also in applicability for large scale farms integrating options like Stomp 1.5 L/ha + hand weeding at 40 DAS was effective and economically feasible. Thus, spraying of pre-emergence herbicide Stomp at the rate of 1.5 L/ha by mixing with 200 L of water two days after sowing and supplementing with one times hand weeding at 40 days after sowing (40DAS) is found to be effective weed control at study area area and similar agro-ecology.

Acknowledgement

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Yield Performance of Introduced Soybean Varieties as Influenced by Bradyrhizobium Inoculation and NPS Fertilizer Rates at Bako, Western Oromia

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Abstract

Soil acidity and poor soil fertility are the major soil chemical constraints which limit crop productivity in western Ethiopia. Thus, study was carried out to determine the influence of Bradyrhizobium inoculation, varieties and NPS fertilizer rates on soybean nodulation, yield and oil content; and to identify economically acceptable treatments that can maximize the productivity of soybean. Combinations of three soybean varieties (Gizo, PM-12-56 *and Dhidhessa), two* Bradyrhizobium *strains (uninoculated and Legumefix) and four levels of NPS (0, 50, 100 and 150 kg NPS* ha^{-1}*) were laid out in Split-Plot Design with three replications. The results showed that the application of NPS rates significantly increased plant height (91.1 cm) and nodule dry weight (16.6 g* $plant^{-1}$*). Similarly, days to 50% flowering and hundred seed weight was considerably influenced by soybean varieties. The interaction of NPS rates and* Bradyrhizobium *inoculation, revealed that application of 150 kg NPS* ha^{-1} *with Legumefix inoculation significantly resulted in the highest above ground biomass yield (11654 kg* ha^{-1}*). On the other hand, three ways interaction of* Bradyrhizobium, *varieties and NPS rates significantly influences days to reach physiological maturity where the longest days to reach maturity (*132) *was recorded from Dhidhessa variety with application of 150 kg NPS* ha^{-1} *supplied with Legumefix strain. In conclusion, the highest marginal rate of return was recorded from application of 150 and 50 kg NPS* ha^{-1} *supplied with and without* Bradyrhizobium *inoculation respectively. Thus, it can be concluded that application of 50 kg NPS* ha^{-1} *with effective Bradyrhizobium strain is recommended for the farmers in the study areas.*

Keywords: Blended fertilizer, Low soil fertility, Nodulation, Yield

Introduction

Soybean (*Glycine max* [L.] Merr) is one of the most important oil grain legume crops in the world. In the international trade market, soybean ranks number one among the major oil crops with an average protein contents of 40% on dry matter basis. It has the highest protein contents of all field crops and is second only to groundnut in terms of oil content (20%) among the food legumes. Soybean is a promising pulse crop proposed for alleviation of acute shortage of protein and oil worldwide (Mahamood *et al.*, 2009). In Ethiopia, soybean is a multipurpose crop, which can be used for a variety of purposes including preparation of different kinds of soybean foods and feeds, soy milk and currently, there are also factories producing oil from soybean showing increasing importance of soybean in the country. It also counter effects depletion of plant nutrients especially nitrogen in the soil resulting from continuous mono-cropping of cereals, especially maize and sorghum, thereby contributing to increasing soil fertility (Mekonnen and Kaleb, 2014). According to CSA (2017) report soybean was produced on about 38,072.70 ha of land and 86,467.87 tons produced in 2017/18 main cropping season with the productivity of 2.2 t ha^{-1}; which is low as compared to world average of 2.6 t ha^{-1}. This low yield may be attributed to a combination of several production constraints among which low soil fertility, periodic moisture stress, diseases and insect-pests, weeds and poor crop management practices play a major role (Kidane *et al.*, 1990). Phosphorus is used in numerous molecular and biochemical plant processes, particularly in energy acquisition, storage and utilization. P plays an important role in N-fixing process, as adenosine tri-phosphate (ATP) is required in large quantities for legumes to undergo N_2 fixation (Mmbaga *et al*., 2014). The deficiency of phosphorous supply and availability remains a severe limitation on nitrogen fixation and symbiotic interactions. Availability of phosphorus in the soil influences the efficiency of *Rhizobium* that fixes atmospheric nitrogen in association with nodulating legumes as it is directly involved in BNF via legume-*Rhizobium* symbiosis (Mahamood *et al.*, 2009; Mmbaga *et al*., 2014). Phosphorus influences nodule development through its basic functions in plants as an energy source. Furthermore, P increases the number and sizes of nodules and the amount of nitrogen assimilated per unit weight of nodules. Its deficiency in legume plants results in reduced nodule mass, N fixation, and low yield. In western parts of Ethiopia, low soil P availability, due to soil acidity and its high fixation, is a limiting factor to crop production (Zerihun *et al*., 2015; Zerihun, 2017).

Sulfur (S) is one of the essential nutrients for plant growth and it accumulates 0.2 to 0.5% in plant tissue on dry matter basis. It is required in similar amount as that of phosphorus (Ali *et al*., 2008). Sulphur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through development of reproductive structure and production of assimilates to fill economically important sink. Sulphur nutrition of bean and other plants is important since its application not only increases growth rate but also improves the quality of the seed (Deressa, 2018).

Since indigenous rhizobia are not always in sufficient numbers, effective enough or compatible with the specific legume crop to stimulate biological nitrogen fixation (BNF) and increase yields, inoculation of legumes with rhizobia is an important option for enhancing BNF in crop production systems (Giller, 2001). The effectiveness of BNF is affected by agro-ecological factors. For instance poor nodulation and poor plant vigour in beans grown in soil with low extractable P led to a poor BNF (Rurangwa *et al*., 2017). However, if P fertilizer was added to beans, consistent responses to inoculation in BNF and grain yield were achieved. Other environmental stresses, such as high temperatures and dry soil can affect the symbiosis between common bean rhizobia, leading to a lack of responses to inoculation (Hungria *et al*., 2000).

Shiferaw (2014) reported that Ethiopian soils lack most of the macro and micronutrients that are required to sustain optimal growth and development of crops. To avert the situation the Ministry of Agriculture of Ethiopia has been recently introduced a new compound fertilizer (NPS) containing nitrogen, phosphorous and sulfur with the ratio of 19% N, 38% P_2O_5 and 7% S (Alemayehu and Jemberie, 2018). This fertilizer has been currently substituted DAP in Ethiopian crop production system as main source of phosphorous (MoANR, 2013). The situation is even more challenging for the researchers and smallholder farmers to understand the effects and identify the optimum rates of the newly introduced NPS fertilizer that contains sulfur for economical production of crops.

Soybean crop production has been promoted in western low lands of Oromia but the average yield is below the potential yield of the crop. Commercial soybean varieties were introduced from abroad by Pawe Agriculture Research Center and evaluated nationally to see their adaptability. Among the evaluated varieties two of them were the most promising and disease tolerant varieties. These varieties are very important since they may feet the minimum requirement of some factory for processing. It is obvious that Bako is one of the most soybean producing areas from western parts of the region. Some of the varieties except Dhidhessa are currently not respond to biofertilizer. But, improved variety is not only one of yield enhancing criteria; abiotic factors also contribute a great line share. Soil fertility problem like NP and other elements are the major constricting factors particularly in acidic areas. Due to this fact, evaluations of different fertilizer sources are very critical to enhance production and productivity of the crop. Therefore, the objectives of the study were to evaluate introduced soybean varieties against standard checks and to evaluate yield performance of soybean to inoculations and blended NPS rates.

Materials and Methods

Description of the Study Area: The experiment was carried out during the main rainy season (June to November) for two consecutive years (2016 and 2017) at Bako Agricultural Research Center (BARC) which is located in Oromia Regional State, West Shoa Zone, Bako Tibe district at about 250 km away from the capital city Addis Ababa on the way to Nekemte town. It is at about 8 km from Bako town and located at an altitude of 1650 m above sea level 09^0 6’00” N latitude and 37^0 09’00” E longitude. Figure 1 present climatic data of rain fall and temperature during 2016 and 2017 growing seasons. The area has a warm humid climate with annual mean minimum and maximum temperature of 10.6 and 34.6°C, respectively. The area receives an annual rainfall of 1317 mm mainly from April to October with maximum precipitation in the month of May to September (Meteorological station of the center).

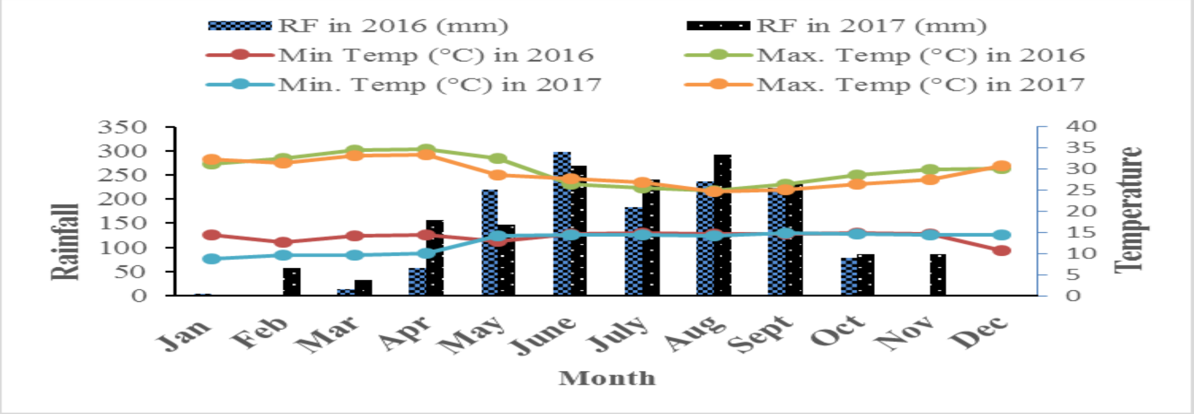

Figure 1. Monthly total rainfall (mm), mean minimum and maximum temperatures (°C) of experimental station in 2016 and 2017

Experimental Materials

Two introduced soybean varieties (Gizo and PM-12-56) and one standard checks (Dhidhessa) were evaluated under different rates of NPS rates containing (19% N, 38 P_2O_5 and 7% S) and *Bradyrhizobium* inoculation (Legumefix). These two introduced soybean varieties were selected based on their yield performances. Carrier based *Bradyrhizobium* strain (Legumefix) was obtained from Managasha Biotechnology Private Limited Company, Addis Ababa, Ethiopia.

Table 1. Characteristics of soybean varieties used for the study

Variety	Source centres	Adaptation Altitude (a.s.l)	Year of Release	Maturity (days)	Yield potential (Qt/ha)
Dhidhessa	BARC/OARI	1200-1900	2008	100-110	20-33
Gizo	PwARC/EIAR	520-1800	2010	100-120	20.6
PM-12-56	PwARC/EIAR	1300-1850	1974	90-100	-

Treatments and Experimental Design

The treatment comprised three factors namely three soybean varieties (Gizo, PM-12-56 and Dhidhessa), two levels of inoculation (Un-inoculated and Legume fix) and NPS fertilizer rates (0, 50, 100, 150 kg NPS ha^{-1}). The treatment was arranged as 2 x 3 x 4 in split-plot design with three replications. The gross plot comprised of seven rows of 3 m length (7 × 0.4 m × 3 m = 8.4 m^2) and one row each from both sides of the plot was left as a border row and one row following the border row was used for destructive sampling. Thus, the central four rows (4 × 0.4 m × 3 m = 4.8 m^2) were used for data collection as net plot.

Experimental Procedure and Field Management

The land was ploughed by tractor, disked and harrowed. The seeds were planted at spacing of 40 cm and 10 cm between rows and within rows, respectively. The spacing between blocks and plots were 1.5 m and 0.6 m, respectively. Two seeds were sown per hill and then thinned to one plant after seedling establishment. All other management practices were done as per the recommendations. Carrier based inoculants of each strain was applied at the rate of 10 g inoculants per kg of seed (Rice *et al*., 2001). To ensure that the applied inoculants stick to the seed, the required quantities of inoculants were suspended in 1:1 ratio in 10% sugar solution. The thick slurry of the inoculants was gently mixed with the dry seeds so that all the seeds received a thin coating of the inoculants. To maintain the viability of the cells, inoculation was done under the shade and allowed to air dry for 30 minutes and sown at the recommended spacing. Seeds were immediately covered with soil after sowing to avoid death of cells due to the sun's radiation. A plot with un-inoculated seeds was planted first to avoid contamination.

Data Collected

Days to 50% flowering: Number of days from sowing to the date on which 50% of plants on the net plot produced at least their first flower.

Days to physiological maturity: Days to physiological maturity was recorded as the number of days from sowing to the stage when 90% of the plants in a plot have reached physiological maturity, *i.e.* the stage at which pods lost their pigmentation and begin to dry.

Plant height: The height of five randomly taken plants from each of the four middle rows was measured in centimeter (cm) from the ground level to the tip of the plant at harvest maturity and expressed as an average of five plants per plot.

Number of primary branches: Number of primary branches was counted at physiological maturity by taking five randomly taken plants from four central rows and expressed as an average of five plants.

Nodule dry weight: The nodules collected from five plant samples from each plot were pooled including the dissected nodule for color determination, and their dry weight was measured by oven drying at 70°C for 24 hours. The dry weight was reported as g per plant.

Yield and yield components: The number of pods per plant was counted from ten randomly selected plants from four middle rows at maturity and expressed as an average of each plant. The weight of 100 seeds that were sampled from each plot was weighed using sensitive balance and the weight was adjusted at 10% standard moisture content. At physiological maturity, the above ground dry biomass of four middle rows was measured at harvest and the harvested produce was sun dried to measure at constant weight. This was used to calculate the harvest index. Grain yield was measured by harvesting the crop from the net plot area. The harvested produce was sun dried for seven days and threshed by hitting with sticks and winnowing was done. The moisture content of the grain was adjusted to 10%. Then the weight was converted to kg ha^{-1}. Harvest index was calculated by dividing grain yield per plot by the total above ground dry biomass yield per plot after the yield obtained from ten plants were converted to plot bases.

Data Analysis

All collected parameters were subjected to analysis of variance using of Gen Stat 18th edition (GenStat, 2016). Whenever the effects of the treatments were found to be significant, the means were compared using Fisher's protected Least Significant Difference (LSD) test at 5% level of significance.

Partial Budget Analysis

The economically acceptable treatment(s) were determined by partial budget analysis to estimate the gross value of the grain yield by using the adjusted yield (CIMMYT, 1988) at the market value of the grain and inputs during the cropping period. Only total costs that varied (TCV) were used to compute costs. Current prices of soybean, inoculants, NPS and application cost of inoculants and NPS were considered as variable with their cost. To estimate economic parameters, soybean yield was valued at an average open market price of 8.00 Birr/kg. Cost of land preparation, field management, harvest, transportation and storage were not included in the analysis as they were not variable. To equate the soybean grain yield with what a farmer would get, the obtained yield was adjusted downward by 10%. Treatments net benefits (NB) and TCV were compared using dominance analysis. Treatments TCV were listed in increasing order in accordance with dominance analysis. All treatments which had NB less than or equal to treatment with lower TCV were marked with a letter "D" since they were dominated and eliminated from any further analysis. Un-dominated treatments were subjected to Marginal Rate of Return (MRR) analysis (CIMMYT, 1988) in stepwise manner, moving from lower TCV to the next as shown below:

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

Where NB_a = NB with the immediate lower TCV, NB_b = NB with the next higher TCV, TCV_a = the immediate lower TCV and TCV_b = the next highest TCV.

Results and Discussion

Nodule dry weight

There were positively significant effects of the application of NPS rates alone. On the other hand, interaction of *Bradyrhizobium*, varieties and NPS rates had no significant influence on nodule dry weight (Table 2). Consequently, the highest nodule dry weight (16.6 g) was resulted from application of 150 kg NPS ha^{-1}, which was followed by application of 100 kg NPS ha^{-1} while the lowest nodule dry weight (10.9) was recorded in the control treatment (Table 2). Significantly higher nodule dry weight with increasing NPS rates indicates the positive role of P in initial nodule formation and development.

Phenological parameters and growth parameter

Days to 50% flowering: Analysis of variance showed highly significant effect of soybean varieties on days to 50% flowering while *Bradyrhizobium* inoculation and NPS fertilizer application did not show significant effect on days to 50% flowering. On the other hand, two and three way interaction effects of *Bradyrhizobium*, variety and NPS application rates did not significantly influence days to 50% flowering (Table 3). The variety Gizo was significantly earlier in attaining 50% flowering than variety Dhidhessa and PM-12-56 mainly due to their genetic difference in response to flowering.

Days to physiological maturity: Number of days taken by a crop to reach maturity is one of important factors in determining whether a certain cultivar can be successfully grown in a particular environment and cropping system.

Table 2. Main effects of Bradyrhizobium, varieties and NPS fertilizer rates on nodule dry weight of soybean

Treatment	Nodule dry weight (g)
Inoculation	
Un-inoculated	14.91
Inoculated	13.05
LSD (0.05)	NS
Variety	
Dhidhessa	14.7
Gizo	14.1
PM-12-56	13.2
LSD (0.05)	NS
NPS rate (kg ha^{-1})	
0	10.9^{c}
50	13.6^{b}
100	14.9^{ab}
150	16.6^{a}
LSD (0.05)	1.9
CV (%)	31.4

Means with the same factor and column followed by the same letter are not significantly different at 5% level of significance.

The interaction effect of *Bradyrhizobium* × variety × NPS rates showed significant effect on days to physiological maturity (Figure 2). The longest days (132) to reach physiological maturity was recorded from plants treated with 150 kg NPS ha^{-1} and inoculated with Legumefix without NPS application, respectively for Dhidhessa variety while the shortest days (120) to reach physiological maturity was observed in the application of 150 kg NPS ha^{-1} with Legumefix inoculation (Figure 2). The delayed maturity with inoculation under reduced NPS rates application is might be due to the fact that better nitrogen produced by N_2 fixation through inoculation promoted vegetative growth which in turn extended days to maturity while phosphorus found in highest rate of NPS fastens days to flowering which in turn shortens the days to reach physiological maturity of the plants. The results are supported by Tairo and Ndakidemi (2013) and Tesfaye *et al*. (2017) who reported that soybean inoculation with *Bradyrhizobium* showed extended phenological development compared to uninoculated plants.

Pooled over all *Bradyrihizobium* and NPS application rates, variety Dhidhessa took considerably longer period of time (132 days) to reach physiological maturity while variety PM-12-56 took 120 days indicating that PM-12-56 matured earlier than Dhidhessa by 12 days. PM-12-56 soybean varieties are short and early in maturity while Dhidhessa and Gizo varieties are strongly indeterminate, usually maturing in 110 to 120 days. This might be due to the fact that indeterminate varieties produce additional nodes after initial flowering as a result the physiological maturity become longer.

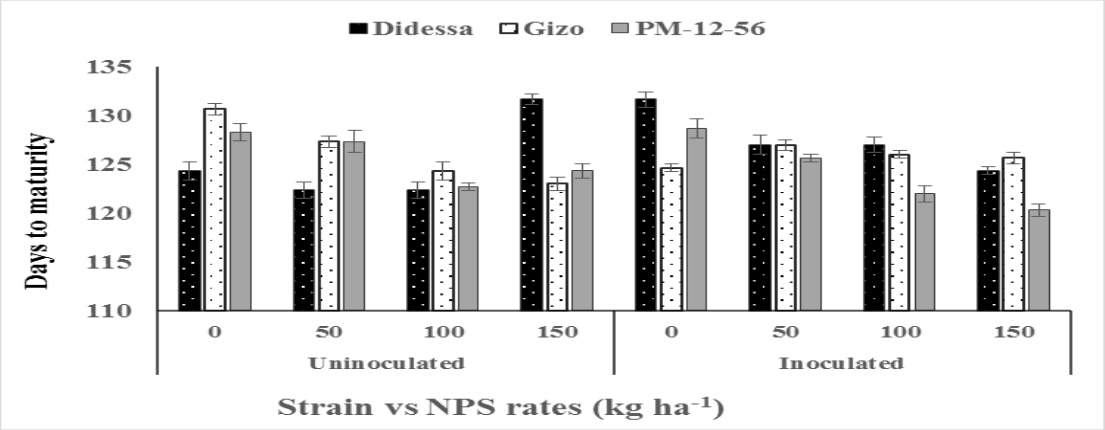

Figure 2. Interaction effect of Bradyrhizobium, varieties and NPS application on days to physiological maturity.

Plant height: As shown in Table 3, plant height was significantly affected by NPS application. However, there is no significant difference in terms of response to inoculation among the three varieties. The highest plant height (74.49 cm) was observed at the highest rate of NPS application (150 kg NPS ha^{-1}). The lowest plant height (64.1 cm) was recorded in control plots. Application of 150 kg NPS ha^{-1} increased plant height by 16.2% as compared to control (Table 3). The increase in plant height response to the increased NPS application rate indicates maximum vegetative growth of the plants under higher N availability in NPS rates. This result was in line with the findings of Amany (2007) and Caliskan *et al.* (2008) who reported that plant height increased with application of N fertilizer in chickpea and soybean, respectively.

Table 3. Main effects of Bradyrhizobium, varieties and NPS fertilizer rates on days to 50% flowering and plant height of soybean

Treatment	Days to 50% flowering	Plant height (cm)
Inoculation		
Un-inoculated	62.4	68.8
Inoculated	62.4	69.5
LSD (0.05)	NS	NS
Variety		
Dhidhessa	62.3^{b}	71.84
Gizo	60.8^{c}	68.02
PM-12-56	64.1^{a}	67.58
LSD (0.05)	0.9	NS
NPS rate (kg ha^{-1})		
0	62.6	64.11^{c}
50	62.1	68.68^{b}
100	62.2	69.31^{b}
150	62.5	74.49^{a}
LSD (0.05)	NS	3.3
CV (%)	2.2	13.1

Means with the same factor and column followed by the same letter are not significantly different at 5% level of significance.

Yield and yield components

Number of Pods per Plant and hundred Seed weight

The result showed no significant difference for the number of total pod production among soybean varieties in response to *Bradyrhizobium* inoculation by NPS rate interaction was absent. Even if the non-significant difference observed among NPS rates, pod numbers showed increasing trend (Table 4). The increase in number of total pods with the increased NPS levels might be possibly due to adequate availability of N and S which might have facilitated the production of primary branches; secondary branches and plant height which might in turn have contributed for the production of higher number of total pods. Hundred seed weight was significantly ($P< 0.01$) influenced by the main effect of varieties only. On the other hand, soybean varieties alone revealed significant influence on hundred seed weight (Table 4). Mean hundred seed weight of the varieties averaged over all NPS rates indicated that variety Dhidhessa produced significantly heavier seed weight which was about 9.8 and 20.9% higher than the weight of Gizo and PM-12-56, respectively indicating greater seed weight in the Dhidhessa variety (Table 4). Most probably number of seed per pod significantly varied between different genotypes, however, the seed weight is less affected by external factors like fertilization. This result was in conformity with Deressa (2018) who reported significant difference of hundred seed weight among common bean varieties.

Oil content (%)

There was no significant main or interaction effect of Bradyrhizobium inoculation, varieties and NPS fertilizers on the oil content of soybean (Table 4). It was observed that the oil content of soybean was increased with the application of NPS rates. The highest oil content was found in chemical fertilizer application compared with control plot. This might be due to the role of sulphur available in NPS fertilizer. Application of S promoted seed oil content due to increasing uptake of S elements by plants which brought to increase S bearing fatty acids. The present result was consistent with that of Babhulkar et al. (2000), who reported that increases in levels of S increased the oil content. Similar finding was also recorded by Khaim et al. (2013) in soybean.

Grain yield (kg ha^{-1}). Analysis of variance revealed that the main effect of varieties showed significant ($P< 0.01$) effect on grain yield of soybean (Table 4). The highest grain yield was recorded for variety Gizo (3265 kg ha^{-1}) which was followed by Dhidhessa variety (3111 kg ha^{-1}) while the lowest yield (2774 kg ha^{-1}) was observed for variety PM-12-56 (Table 4). Differences in grain yield among the soybean varieties might be related to the genotypic variations in P use efficiency. Hence, the cultivars which produced higher grain yield might have either better ability to absorb the applied P from the soil solution or translocate and use the absorbed P for grain formation than the low yielding cultivar. In agreement with the results of this study, Gobeze and Legese (2015) and Mourice and Tryphone (2012) observed significant variations in grain yield for common bean due to genotypic variations for P use efficiency which may arise from variation in P acquisition and translocation and use of absorbed P for grain formation in common bean. Analysis of variance also showed that there was significant ($P< 0.01$) effect of

NPS rates on grain yield. The maximum grain yield (3580 kg ha^{-1}) was recorded at rate of 150 kg NPS ha^{-1} while the lowest above grain yield (2534 kg ha^{-1}) was recorded at no application of NPS rates (Table 4). The increase in grain yield at the highest rate of NPS might be attributed to the enhanced availability of N, P and S for growth and development of the plants.

Table 4. Main effects of Bradyrhizobium, varieties and NPS fertilizer rates on number of pods per plant, hundred seed weight, oil content and grain yield of soybean

Treatment	NPP	HSW (g)	Oil content (%)	Grain yield (kg ha^{-1})
Inoculation				
Un-inoculated	51.7	15.4	19.97	3059
Inoculated	56.3	15.2	20.42	3042
LSD (0.05)	NS	NS	NS	NS
Variety				
Dhidhessa	52.8	16.8^{a}	20.76	3111^{a}
Gizo	58.4	15.3^{b}	19.76	3265^{a}
PM-12-56	50.9	13.9^{c}	20.07	2774^{b}
LSD (0.05)	NS	0.76	NS	260.0
NPS rate (kg ha^{-1})				
0	52.1	15.2	19.97	2534^{c}
50	50.6	15.1	20.4	2994^{b}
100	53.2	15.4	20.16	3094^{b}
150	60.1	15.6	20.27	3580^{a}
LSD (0.05)	NS	NS	NS	250.4
CV (%)		12.4	7.6	15.9

Where, HSW: Hundred seed weight, NPP: Number of pods per plant. Means with the same factor and column followed by the same letter are not significantly different at 5% level of significance.

Biomass yield as influenced by interaction effect of *Bradyrhizobium* and NPS

Analysis of variance revealed that interaction effect of *Bradyrhizobium* × NPS rates application had significant influence on above ground dry biomass yield of soybean (Figure 3). The highest above ground dry biomass yield (11654 kg ha^{-1}) was recorded from application of 150 kg NPS ha^{-1} inoculated with *Bradyrhizobium* strain while the lowest biomass yield was recorded from control treatment (7662 kg ha^{-1}) (Figure 3). The result indicated that N fixation by *Bradyrhizobium* enhanced the vegetative growth of soybean, which resulted in substantial increase in its biomass yield as well as the supply of N with P and S was responsible for the highest vegetative growth of soybean. In agreement with this result, Phiri *et al*. (2016) and Mrkovacki *et al*. (2008) reported that maximum results for biomass yield were seen by applying highest rate of N and P fertilizer to inoculated soybean.

Partial budget analysis

Analysis of the net benefits, total costs that vary and marginal rate of returns are presented in Table 5. Information on costs and benefits of treatments is a prerequisite for adoption of technical innovation by farmers. The study assessed the economic benefits of the treatments to help develop recommendation from the agronomic data. This enhances selection of the right combination of resources by farmers in the study area. The partial budget analysis was done on the basis of cost of NPS, inoculants and application cost of fertilizer and cost of mixing inoculants with seeds were considered.

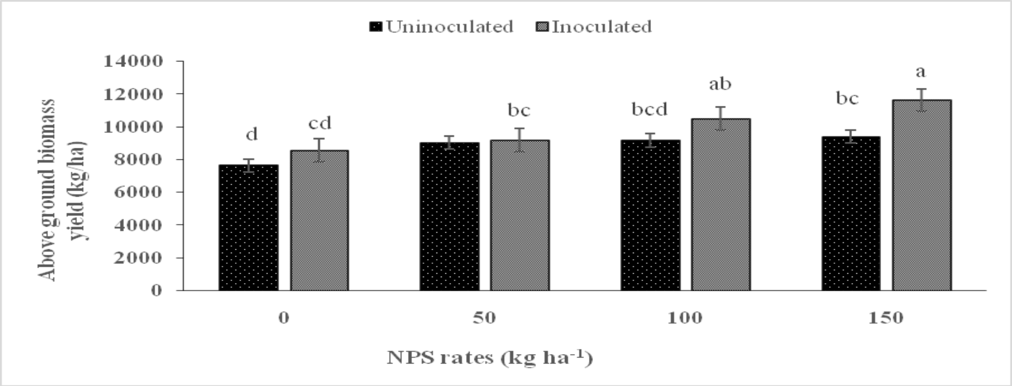

Figure 3. Interaction effect of Bradyrhizobium inoculation and NPS rates on soybean above ground dry biomass yield. Bars followed by similar letters are not significantly different to each other at LSD (0.05).

The partial budget analysis showed that application of 50 kg NPS ha^{-1} inoculated with *Bradyrhizobium* produced the highest net benefits. On the other hand, the control treatment produced the lowest net benefit. This implies that farmers would be better of inoculating their soybean in combination with application of 50 kg NPS ha^{-1} as these increase soybean yields and thus increase farmer's income. Thus, application of 50 kg NPS ha^{-1} inoculated with *Bradyrhizobium* is profitable and recommended for the farmers in the study areas and other areas with similar agro-ecological conditions. The grain yield was statistically nonsigniff icant among NPS rates. Thus, it is better to use minimum rate of NPS with rhizobium inoculation.

Conclusions and Recommendations

Soybean is one of the most economically important pulse crops cultivated in Ethiopia. However, its average yield reported at national level remains far below the potential yield to be attained. This is partly due to low soil fertility management, inappropriate agronomic packages and diseases and pest problems. Thus, it can be concluded that application of 50 kg NPS ha^{-1} with *Bradyrhizobium* inoculation proved to be superior with respect to grain yield as well as economic advantage. In conclusion, the highest marginal rate of return was recorded from application of 150 and 50 kg NPS ha^{-1} supplied with and without *Bradyrhizobium* inoculation respectively. Thus, it can be concluded that application of 50 kg NPS ha^{-1} with effective *Bradyrhizobium* strain is recommended for the farmers in the study areas.

Table 5. Partial budget analysis of the effects of varieties, rhizobium strains and NPS fertilizer rates on soybean yield

Main plot	Sub-plot	Sub-Sub-plot	GY (kg ha^{-1})	GFB (Birr)	TVC	NB (Birr)	Dominance	MRR (%)
Inoculation (+R)	Didessa	0	2684	18788	230	18558	D	
		50	3173	22211	1000	21211		405
		100	3138	21966	1700	20266	D	
		150	4016	28112	2400	25712		1440
Uninoculated (-R)	Didessa	0	2691	18837	0	18837		
		50	3007	21049	770	20279		318
		100	3029	21203	1470	19733	D	
		150	3508	24556	2170	22386		451
Inoculation (+R)	Gizo	0	2361	16527	230	16297	D	
		50	3239	22673	1000	21673		1.37
		100	3251	22757	1700	21057	D	
		150	3673	25711	2400	23311	D	
Uninoculated (-R)	Gizo	0	2901	20307	0	20307		0
		50	3125	21875	770	21105		1.04
		100	3180	22260	1470	20790	D	
		150	4393	30751	2170	28581		380
Inoculation (+R)	PM-12-56	0	2465	17255	230	17025	D	
		50	2753	19271	1000	18271		1.086
		100	2853	19971	1700	18271	D	
		150	2898	20286	2400	17886	D	
Uninoculated (-R)	PM-12-56	0	2455	17185	0	17185		0
		50	2668	18676	770	17906		94
		100	3110	21770	1470	20300		212
		150	2992	20944	2170	18774	D	

Key: GY: Grain yield, GFB: Gross field benefit, TVC: Total variable cost, D: Dominance and MRR= Marginal rate of return

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Adaptability and Seed Yield Stability of Medium Matiring Groups of Soyabean (Glycine max (L.) Merrill] Varieties in Western Oromia

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Abstract

This study was aimed to identify high yielding and stable medium maturity soybean varieties across environment and examines the influence of GEI on grain yield of soybean varieties in western Oromia. Seven early soybean varieties were evaluated at five locations (Bako, Gute, Billo, Chewaka and Uke) using RCBD with three replication for two consecutive years (2016 and 2017). Combined analysis of variance showed that grain yield was significantly (P< 0.01) affected by environments, genotypes and GE interactions. The environment, genotype and genotype by environment interaction accounted 57.4, 20.9 and 19.8% variations, respectively. The first two principal components ($IPCA_1$ *and* $IPCA_2$*) were used to create a two-dimensional GGE biplot and explained 68.9 and 15.6% of the total sums of squares of GE interaction, respectively. According to the average environment coordination (AEC) views of the GGE-biplot, soybean variety Didhessa and Hawassa-04 were identified as the most stable and high yielding varieties. In addition, Didhessa and Hawassa-04 also showed better stability performance according to ASV, GSI, Wricke's ecovalence and cultivar superiority measure among the evaluated varieties whereas variety Davis and AFGAT were identified as the least stable and low yielding variety. Therefore, among medium maturing soybean varieties, Didhessa, Hawassa-04 and Cheri were recommended for further production in most soybean growing areas of western Oromia.*

Keywords: AMMI, ASV, cultivar superiority measure, genotype, GSI

Introduction

Soybean [*Glycine max* (L.) Merrill] is a legume native to East Asia perhaps in North and Central China (Laswai *et al.*, 2005) and it is grown for edible bean, oil and protein around the world. Soybean is found in family *Fabaceae* and species *Glycine max* (Shurtleff and Aoyagi, 2007). Soybean is one of the most important oil grain legume crops in the world. In the International trade market, soybean ranks number one among the major oil crops with an average protein contents of 40% on dry matter basis. It has the highest protein contents of all field crops and is second only to groundnut in terms of oil content (20%) among the food legumes. Dugje *et al.* (2009) reported that soybean is more protein rich than any of common vegetable or legume food sources in Africa. Soybean is a promising pulse crop proposed for alleviation of acute shortage of protein and oil worldwide (Mahamood *et al.*, 2009). It is used as a good source of unsaturated fatty acids, minerals (Ca and P) and vitamins A, B, C and D (Alam *et al.*, 2009). Zerihun *et al.* (2015) indicated that soybean in Ethiopia could be grown between 1300 and 1800 m altitude with annual rain fall of 900 - 1300mm, an average annual temperature between 20 - 25^0C and soil pH of 5.5. Soybean is classified in different groups such as early, medium and late maturing varieties. A variety is classified to a specific maturity groups according to the length of period from planting to maturity. This phenological attribute is determined by two abiotic factors: photoperiod and temperature (Mourtzinis and Conley, 2017), and these factors can dictate the most suitable maturity groups of soybean varieties for a particular geographical location. Therefore, identification of different maturity groups of soybean varieties that fit specific agro-ecologies of western Oromia is an alternative option to boost soybean productivities.

In Ethiopia, soybean is a multipurpose crop, which can be used for a variety of purposes including preparation of different kinds of soybean foods, animal feed, soy milk, raw material for the processing factories like tasty soya; fafa food factories. Currently, there are also factories producing oil from soybean showing increasing importance of soybean in the country. It also counter effects depletion of plant nutrients especially nitrogen in the soil resulting from continuous mono-cropping of cereals, especially maize and sorghum, thereby contributing to increasing soil fertility (Mekonnen and Kaleb, 2014). Its area of production is increasing and according to CSA (2016) report soybean was produced on about 38,166.04 ha of land and 81241.833 tons produced in 2015/16 main cropping season with the productivity of 2.1 t ha^{-1}; which is low as compared to world average of 2.6 t ha^{-1}. This low yield may be attributed to a combination of several production constraints among which low soil fertility, lack of high yielding varieties, periodic moisture stress, diseases and insect-pests, weeds and poor crop management practices play a major role (Kidane *et al*., 1990).

Genotypes exhibit fluctuating yields when grown in different environments or agro-climatic zones. This complicates demonstrating the superiority of a particular genotypes. Multi-environment yield trials are crucial to identify adaptable high yielding cultivars and discover sites that best represent the target environment (Dabessa *et al*., 2016). It was also reported by Yazici and Bilir (2017). Failure of genotypes to respond consistently to variable environmental conditions is attributed to genotype by environment interaction (GGE). Knowledge of GGE is advantageous to have cultivar that gives consistently high yield in wider range of environments and to increase efficiency of breeding program and selection of best genotypes. Genotype and genotype by environment interaction (GGE) biplot allows for assessing the performance of genotypes in the tested environments. Phenotypic variation of genotypes across environments resulted from environmental and genotypic variations and genotype by environment interaction. Environmental variation is the dominant source of phenotypic variation (Amare and Tamado, 2014; Funga *et al*., 2017). Therefore, multi-environment trials (MET) are required to identify specific and the general adaptability of genotypes. In western Oromia, where this study was conducted, the yield of medium soybean variety is very low due to different biotic and abiotic factors. This study is therefore, aimed to identify high yielding and stable medium maturity soybean varieties across environment and examines the influence of GEI on grain yield of soybean varieties.

Materials and methods

Seven medium maturity groups of released soybean varieties (Clark 63k, Davis, Cheri, AFGAT, Didhessa, Hawassa-04 and Wello) were evaluated at six locations for two consecutive years during 2016 and 2017 main cropping season. The experiment was conducted at Billo and Gute and Bako. The experimental land was ploughed, disked and harrowed by tractor. The first ploughing was done before on-set of rain. Plantings were done in mid-June at each location using a randomized complete block design with three replications. Each plot consisted of four rows of 4 m length with 40 cm and 10 cm spacing between rows and seeds, respectively. The two middle rows were used for data collection and harvested at maturity. Fertilizer was applied at the rate of 100 kg NPS ha^{-1} during planting time. All other management practices were applied as per the recommendations.

Table 1: Pedigree, origin, area of adaptation and year of release of soybean varieties used for the study

Varieties	Pedigree	Source of materials	Year of release	Adaptation altitude (m.a.s.l)	RF (mm)	Maturity date
Clark 63k	NI	HwARC/SARI	1981	1000-1700	520-1500	110-120
Davis	NI	HwARC/SARI	1981	1000-1700	400-700	115-125
Cheri	IBP-81EP7	BARC/OARI	2003	1300-1850	900-1300	110-120
Afgat	TGX-1892-10F	HwARC/SARI	2007	520-1800	750-1300	110-120
Didessa	PR-149-81-EP-7-2	BARC/OARI	2008	1200-1900	1000-1200	115-125
Hawassa-04	AGS-7-1	HwARC	2012	1200-1700	500-1300	110-120
Wello	TGX-1895-33F	SARI/ARARI	2012	520-1800	520-1200	115-125

NI: Not identified

Table 2: Environments used in the study and their main characteristics

Location	Year	Longitude	Latitude	Altitude (m.a.s.l)	RF (mm)	Soil type
Bako	2016 & 2017	37°09'E	09°06'N	1650	1431	Sandy-clay
Gute	2016	E:036^{0}38.196’	N:09^{0}01.061’	1915	NI	Clay
Billo	2016	E:037^{0}00.165’	N:09^{0}54.097’	1645	1500	Reddish brown
Chewaka	2017	036.11703E	09.98285N	1259	NI	Clay loam
Uke	2017	E:036^{0}32..391’	N:09^{0}25.082’	1319	NI	Sandy loam

NI = not identified

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:

$$Y_{ger} = \mu + ag + \text{ß}e + \sum n\lambda n\gamma gnden + eger + \rho ge$$

Where, Yger is the observed yield of genotype (g) in environment (e) for replication (r);

Additive parameters: µ is the grand mean; ag is the deviation of genotype g from the grand mean, ße is the deviation environment e;

Multiplicative parameters: λn is the singular value for IPCA, γgn is the genotype eigenvector for axis n, and den is environment eigenvector; eger is error term and ρge is PCA residual. Accordingly, genotypes with low magnitude regardless of the sign of interaction principal component analysis scores have general or wider adaptability while genotypes with high magnitude of IPCA scores have specific adaptability (Gauch, 1992; Umma *et al*, 2014).

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

$$GSI = RASV + RY$$

Wricke's ecovalence (Wi)

Wricke (1962) proposed using the contribution of each genotype to the GxE interaction sum of squares as a stability parameter.

$$Wi = \frac{P}{(P-2)(q-1}\sum_{j=1}^{q}(Xij - \bar{X}.\mathrm{i} - \bar{\mathrm{X}}.\mathrm{j} + \bar{\mathrm{X}}..)\,2$$

Where, x_{ij} is the mean performance of genotype i in the j^{th} environment, xi. and x.j are the marginal mean of genotype i and environment j respectively, and x.. is the overall mean. Thus, genotype with a low W_i value are stable.

Lin and Binns Cultivar Superiority Measure

In addition, a cultivar-superiority measure was used to compute stability coefficients for genotype by environment data of each genotype. It is computed as the sum of the squares of the differences between its mean in each environment and the mean of the best genotype there, divided by twice the number of environments (Lin and Binns, 1988).

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 (ANOVA) and 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 : Analysis of variance showed statistically significant differences ($P< 0.01$) among evaluated soybean varieties, environments and their interaction for seed yield (Table 3). This indicated the presence of genetic variation among the soybean varieties and possibility to select high yielding and stable variety (s), the environments are variable and the differential response of soybean varieties across the testing environments. Similar result was reported for common bean and groundnut varieties, linseed and Niger seed varieties, respectively by Zeleke *et al*. (2016), Dabessa *et al*. (2016) and Tamesgen *et al*. (2014).

Table-3. Combined Analysis of variance for grain yield of medium soybean varieties evaluated at six environments in western Oromia.

Source of variation	**Degree freedom**	**Mean square**
Environments	5	6389445**
Genotypes	6	1947323**
Block within environment	2	6355
Interaction	30	367131**
Error	82	12501
LSD (0.05)	181.6	
CV (%)	5	

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

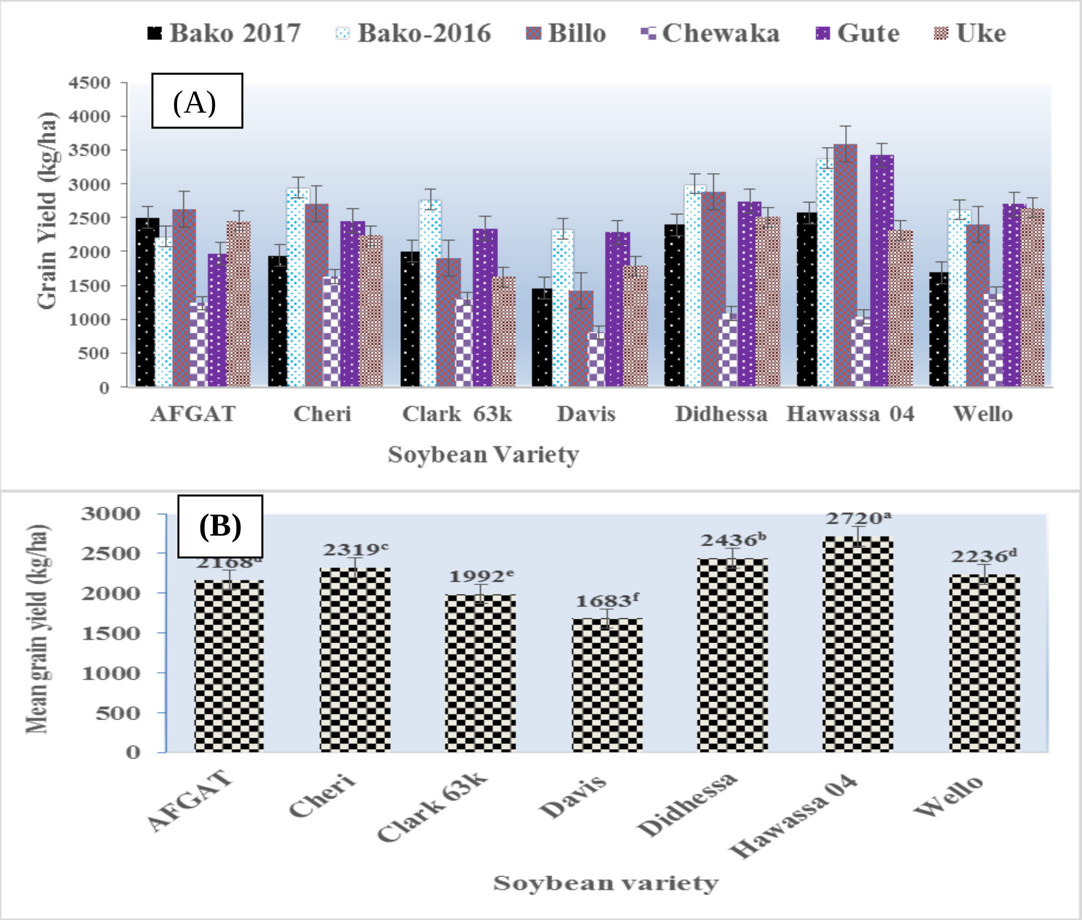

Fig-1. ***Performance of (A) medium maturity groups of soybean varieties at each environments, (B) mean performance of soybean varieties across environments. Bars followed by same letters are not significantly different from each other at LSD (0.05)*.**

Performance of soybean varieties across environments : Figure 1 (A and B) showed the performance of soybean varieties at each environments and average mean seed yield of soybean varieties evaluated across six environments in western Oromia, respectively. The pooled mean grain yield was ranged from 1683 to 2720 kg ha^{-1} (Fig- 1B). Among all varieties, Davis was the lowest yielder. The highest grain yield was obtained from Hawassa-04 variety (2720 kg ha^{-1}) followed by Didhessa (2436 kg ha^{-1}**)**. This difference could be due to their genetic potential. Hawassa-04 was the top ranking genotype at Bako (2016 and 2017) and Gute while Clark 63k, Cheri and Didhessa gave the highest yield at Billo, Chewaka and Uke, respectively (Fig- 1B). The difference in yield rank of medium soybean varieties across the test environments revealed the high crossover type of genotype by environment interaction.

AMMI Model Analysis

The AMMI model analysis of variance for grain yield is presented in Table 4. This analysis also revealed that presence of highly significant (P< 0.01) differences among medium soybean varieties for grain yield performance. From the total treatment sum of squares, the largest portion was due to environments main effect (57.4%) followed by varieties main effect (20.9%) and the effect of genotype by environment interaction (19.8%). This also indicated the existence of a considerable amount of deferential response among the evaluated soybean varieties to changes in growing environments and the differential discriminating ability of the test environments. Similar result was reported by Dabessa *et al.* (2016). Substantial percentage of G x E interaction was explained by IPCA$_1$ (8.6%) followed by IPCA$_2$ (6.3%) 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 4: Partitioning of the explained sum of square (SS) and mean square (MS) from AMMI analysis for grain yield of seven soybean varieties

Source of variation	DF	Sum of square	Explained SS (%)	Mean square
Total	125	55682927		445463
Treatments	41	54645104		1332807**
Genotypes	6	11683938	20.9	1947323**
Environments	5	31947226	57.4	6389445**
Block	12	251654	0.45	20971
Interactions	30	11013940	19.8	367131**
IPCA 1	10	4760206	8.6	476021**
IPCA 2	8	3486895	6.3	435862**
Residuals	12	2766840		230570
Error	72	786169		10919

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

In the AMMI selection of genotypes, Hawassa-04 took the first position in Bako, Gute and Billo while Didhessa took the second best position in Uke, Bako, Gute and Billo environments (Table 5). Accordingly, Hawassa-04 and Didhessa varieties showed dynamic stability, but its relative performance was consistent and predictable across environments, which is desirable characteristics for crop production at various levels of agricultural inputs. This narrow change of the differential response of Hawassa-04 and Didhessa varieties in different environments is an indication of its wide adaptability. AFGAT and Wello varieties took the first position at Chewaka and Uke indicating consistent and predictable dry pod yield performance in the specific environment (Table 5). The report indicated that the interaction pattern of some locations across crop species is consistent so that they are highly predictable in year to year interaction with genotypes (Ebdon and Gauch, 2002).

Table-5: First four AMMI selections per environment

		Genotype rank			
Environment	Mean yield (kg ha^{-1}	**1**	**2**	**3**	**4**
Chewaka	1209	Wello	Cheri	AFGAT	Didhessa
Uke	2224	AFGAT	Didhessa	Cheri	Hawassa-04
Bako-2016	2754	Hawassa-04	Didhessa	Cheri	Wello
Bako 2017	2081	Hawassa-04	AFGAT	Didhessa	Cheri
Gute	2559	Hawassa-04	Didhessa	Cheri	Wello
Billo	2505	Hawassa-04	Didhessa	AFGAT	Cheri

AMMI Biplot Analysis

AMMI biplot graph (Fig-2) with X-axis plotting $IPCA_1$ and Y-axis plotting $IPCA_2$ scores illustrate stability, adaptability and high yielding of soybean varieties to the testing environments. It has been reported that the $IPCA_1$ scores of a genotypes in AMMI analysis are an indication of the stability or adaptation over environments (Alberts, 2004). It is further stated that the greater the IPCA scores, negative or positive, the more specific adapted is a genotypes to certain environments. The more the IPCA scores approximate to zero, the more stable or adapted the genotypes is over all the environments sampled. According to AMMI biplot Environments Bako-2016 and Gute relatively showed high IPCA scores and contributed largely to GEI. These environments were favorable for high yielding soybean varieties based on mean grain yield as they had more than the grand mean. Environments Chewaka and Uke are the least favorable environment for most of the varieties with low yield and smaller $IPCA_1$ score (Fig-2). The variation of grain yield for each variety was significant at different environments. Varieties Davis, Clark 63k and Wello were specifically adapted to low yielding environments (Fig-2). Considering the IPCA score, AFGAT and Davis were the most unstable varieties and also adapted to lower yielding environments. Dhidhessa variety was more stable in comparison to other soybean varieties. Varieties Wello and Cheri were adapted to low yielding environments and also relatively stable (Fig-2). Dhidhessa and Hawaassa-04 varieties have relatively lower IPCA by which they had shown to have a higher stability for grain yield than other varieties (Fig-2). Hawassa-04 variety had highest grain yield followed by Dhidhessa variety.

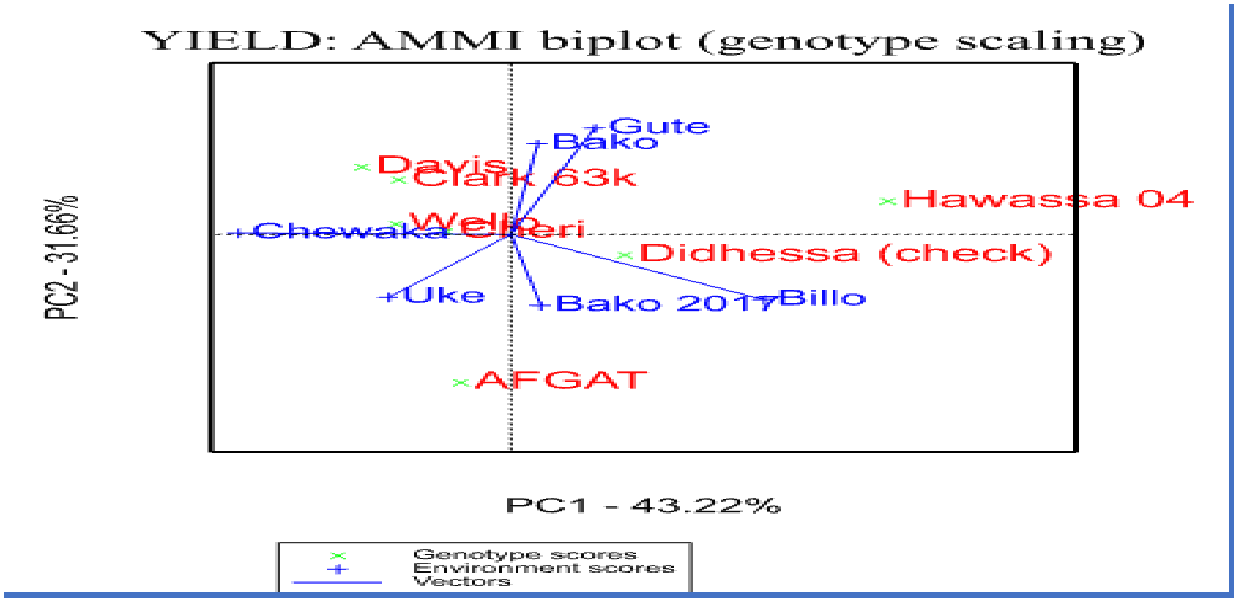

Fig-2. AMMI biplot showing "which won where" and stable soybean varieties evaluated at six environments in western Oromia.

AMMI stability value and genotype selection index

AMMI Stability Value (ASV) with its ranking for seven soybean varieties are presented in Table 6. In ASV method, genotype with least ASV score is the most stable (Purchase *et al.*, 2000). Accordingly, Hawassa-04, Didhessa and Cheri were the most stable, but Clark-63k and Davis were the most unstable. This measure is essential in order to quantify and rank of varieties according to their seed yield stability. The least Genotype Selection Index (GSI) is considered as the most stable with high grain yield (Dabessa *et al.*, 2016). Based on the GSI result, the most desirable variety for selection of both stability and high seed yield was Hawassa-04 followed by Cheri and Didhessa, which was in accordance with the result of AMMI biplot and with most estimation stability parameters.

Table-6: AMMI stability value, genotype selection index and ranks based on grain yield of seven medium soybean varieties evaluated at six locations during 2016 and 2017 seasons.

Variety	Yield	ASV	RY	RASV	GSI
AFGAT	2167.6	29.08	5	5	10
Cheri	2318.9	9.20	3	2	5
Clark-63k	1991.9	24.46	6	4	10
Davis	1683.4	3.31	7	1	8
Didhessa (check)	2436.3	40.62	2	6	8
Hawassa-04	2719.6	21.39	1	3	4
Wello	2236.3	42.62	4	7	11

Where, ASV= AMMI stability value, RY = Rank of yield, RASV = Rank of AMMI stability value and GSI = Genotype selection index

Stability analysis using Wricke's ecovalence (wi) and Cultivar superiority measure

Stability in performance of soybean varieties across environments using Wricke's ecovalence (Wi) was performed for grain yield. The result showed that Dhidhessa and Cheri were comparatively stable as their contribution to the GXE interaction sum of squares was least (Table 7). On the other hand, AFGAT and Hawassa-04 were unstable in grain yield performance because these genotypes had relatively highest Wricke's ecovalence (Wi). In line with this result, Gurmu *et al*. (2009) reported a significant Wricke's ecovalence of twenty soybean genotypes in southern Ethiopia. According to Lin and Binns (1988) for cultivar superiority measure analysis, the genotype with low or small cultivar superiority measure value is considered to be more stable. Among studied medium soybean varieties, Hawassa-04 and Didhessa had smallest cultivar superiority measure values, which showed their best yield performance and seed yield stability (Table 7).

Table-7: Stability analysis of Cultivar superiority index, static stability and wrikles ecovalence values of medium soybean varieties evaluated in western Oromia

Variety	Cultivar superiority	Rank	Wricke's Eco valence	Rank
AFGAT	382694	5	864972	6
Cheri	207273	3	230634	2
Clark-63k	489342	6	466509	5
Davis	813077	7	420541	4
Didhessa	121320	2	158038	1
Hawassa-04	38822	1	1120645	7
Wello	282916	4	409974	3

GGE biplot analysis

In GGE biplot (Figure 3), $IPCA_1$ and $IPCA_2$ explained 68.9 and 15.6%, respectively, of soybean varieties by environment interaction and made a total of 84.57%. The other studies conducted on groundnut by Amare and Tamado (2014) and white lupines by Atnaf *et al.* (2017) explained an interaction of 81.8 and 63.4% respectively, extracted from $IPCA_1$ and $IPCA_2$. An ideal genotype is defined as genotype which having the greatest IPCA1 score (mean performance) and with zero GEI, as represented by an arrow pointing to it (Fig 3). 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, Didhessa and Hawassa-04 varieties which fell closest to the ideal genotype was identified as the most desirable varieties as compared to the rest of the tested soybean varieties (Fig 3). Similarly, Dabessa *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.

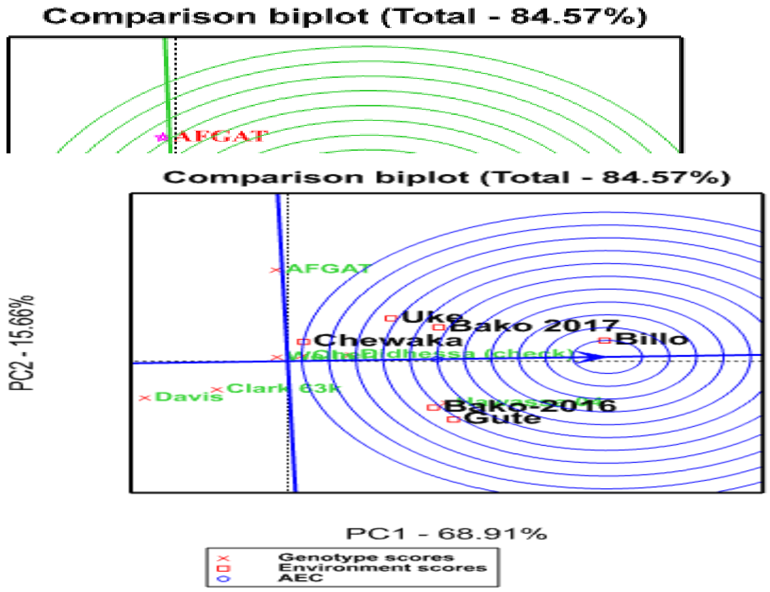

Fig-3. GGE bi-plot based on genotype-focused scaling for comparison of medium soybean varieties for their seed yield potential and stability.

Ideal test environment is an environment which has more power to discriminate genotypes in terms of the genotypic main effect as well as able to represent the overall environments. But such type of environment may not exist in real conditions. Therefore, by assuming a small circle which located in center of concentric circles and an arrow pointing on it as ideal environment (Fig. 5), it is possible to identify desirable environments which are found closer to the ideal environment (Yan and Rajcan, 2002). Hence, among the testing environments, Billo, which fell near to this ideal environment were identified as the best desirable testing environments in terms of being the most representative of the overall environments and powerful to discriminate soybean varieties.

Discriminating ability and representativeness of environments

Both discriminating ability and representativeness view of the GGE biplot are the most important measures of testing environment, which provide not only valuable but also unbiased information about the tested genotypes (Yan and Kang, 2003). Yan and Tinker (2006) also reported that the length of environmental vector is directly proportional to the standard deviation within the respective environments and help to know the discriminating ability of this target environment i.e. an environment with long environmental vector has high discriminating ability and vice versa. Thus, as shown in the (Fig 5), the test location (Billo and Gute) were identified as the most discriminating environment as compared to Bako and Uke that were identified as the least discriminating testing environments. Among the testing environments, Chewaka was identified as the least discriminating environment.

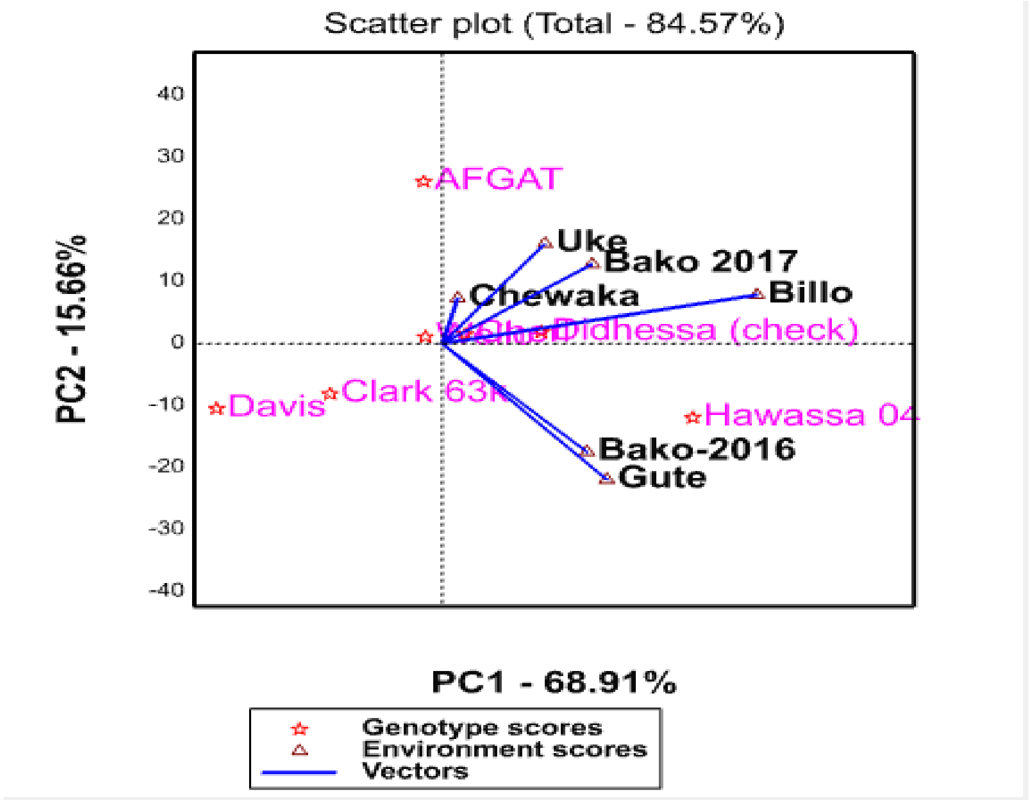

Fig 5. The vector view of GGE biplot which shows the interrelation ships among the test environments and their discriminating ability

Conclusions and Recommendations

Despite its potential and market demand, production of soybean is not yet popularized among farmers in western Ethiopia. These could be attributed to the lack of information on the effect of genotype, predictable and unpredictable environmental variations and their interaction on yield. Thus, seven medium soybean varieties were tested at six locations under rain fed conditions in western Oromia to determine the effect of genotype, environment, and their interaction and to identify stable ones in yield performance. The environment contributed most to the variability in grain yield. Genotypes Didhessa and Hawassa-04 were close to the ideal genotype and can thus be used as benchmarks for the evaluation of medium maturity groups of soybean genotypes in the western Oromia. Considering simultaneously mean yield and stability, Didhessa and Hawassa-04 were the best soybean varieties

Acknowledgements

Sincere gratitude to Oromia Agricultural Research Institute: Bako Agricultural Research Center for providing research facilities and financial support of this study. We would also like to thank pulse and oil crops research team members of Bako Agricultural Research Center for their kindly assistance in recording data at field condition.

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Yield Stability Analysis of Early Maturity Group Soyabean Varieties in Western Oromia, Ethiopia.

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Abstract

Over many years, there are a few early maturity soybean varieties developed and released through intensive breeding and genetics research program in Ethiopia. However, whether these varieties are stable, adaptable to the environments of Western Ethiopia and similar agro-ecologies are not clear. The objective of this study was to identify high yielding and stable early maturity soybean varieties across environment and examines the influence of genotype by environment interaction on grain yield of soybean varieties in western Oromia. Seven early soybean varieties were evaluated at five locations (Bako, Gute, Billo, Chewaka and Uke) for two consecutive years (2016 and 2017). Combined analysis of variance showed that grain yield was significantly ($P< 0.01$) affected by environments, genotypes and GE interactions; accounting for 51.1, 35.9 and 12.2% variations, respectively. The first two principal components ($IPCA_1$ and $IPCA_2$) were used to create a two-dimensional GGE biplot and explained 84.49 and 9.1% of the total sums of squares of GE interaction, respectively. According to the average environment coordination (AEC) views of the GGE-biplot, soybean variety Nyala was identified as the most stable and high yielding genotype. In addition, Boshe and Coker-204 also showed better stability performance among the high yielding varieties whereas variety Nova was identified as the least stable and low yielding variety. Therefore, among early soybean varieties, Boshe, Nyala and Coker-204 were recommended for further production in most soybean growing areas of western Oromia.

Keywords: AMMI, Genotype, Glycine max, Maturity

Introduction

Soybean [*Glycine max* (L.) Merrill] is one of the most important oil grain legume crops in the world (Laswai *et al.,* 2005). Soybean is rich in nutritional value due to its high protein and oil content as well as aspects of its functional composition, such as isoflavones (Liu *et al*., 2017). In Ethiopia, soybean is a multipurpose crop, used for a variety of purposes including preparation of different kinds of soybean dishs, animal feed and soy milk (Hailu and Kelemu, 2014). Soybean is classified in different groups such as early, medium and late maturing varieties. A variety is classified to a specific maturity groups according to the length of period from planting to maturity. This phenological attribute is determined by two abiotic factors: photoperiod and temperature (Mourtzinis and Conley, 2017), and these factors can dictate the most suitable maturity groups of soybean varieties for a particular geographical location (Liu *et al*., 2017). Therefore, identification of different maturity groups of soybean varieties that fit specific agro-ecologies of western Oromia is an alternative option to boost soybean productivities.

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 soybean breeding in Ethiopia, special focuses have been paid 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 (Tolessa and Gela, 2014). In such cases, genotype × environment (GE) interaction effect is expected to be greater. Genotypes exhibit fluctuating yields when grown in different agro-climatic zones. This complicates demonstration of the superiority of particular genotypes. Multi-environment yield trials are crucial to identify adaptable high yielding cultivars and discover sites that best represent the target environment (Tolessa and Gela, 2014; Dabessa *et al*., 2016). Failure of genotypes to respond consistently to variable environmental conditions is attributed to genotype by environment interaction (EI). Knowledge of genotype and genotype by environment interaction (GGE) is advantageous to have cultivar that gives consistently high yield in wider range of environments and to increase efficiency of breeding program and selection of best genotypes.

Genotype and genotype by environment interaction (GGE) biplot allows for assessing the performance of genotypes in the tested environments. Phenotypic variation of genotypes across environments results from environmental and genotypic variations and genotype by environment interaction. Environmental variation is the dominant source of phenotypic variation (Amare and Tamado, 2014; Funga *et al*., 2017). Therefore, multi-environment trials (MET) are required to identify specific and the general adaptability of genotypes. In western Oromia, where this study was conducted, the yield of early soybean varieties is very low due to different biotic and abiotic factors. This study was therefore, aimed at identifying high yielding and stable early maturity soybean varieties across environments and examining the influence of GEI on grain yield of soybean varieties.

Materials and Methods

Seven early maturity soybean varieties (Table 1) were evaluated at six locations for two consecutive years during 2016 and 2017 main cropping seasons. The study sites were Billo and Gute during 2016, Chewaka and Uke during 2017 main season and at Bako during 2016 and 2017 (Table 2). Each plot consisted of four rows of 4 meter length, with 40 cm and 10 cm spacing between rows and seeds, respectively. NPS fertiliser was applied at the rate of 100 kg ha^{-1} at planting time. All other management practices were applied as routinely used in the study areas.

Table. 1 Pedigree, origin, area of adaptation and year of release of soybean varieties used for the study

Variety	Pedigree	Source center	Adaptation Altitude (m.a.s.l)	Year of Release	Maturity (days)
Boshe	(IAC-13-1)	BARC/OARI	1200-1900	2008	100-110
Coker-204	NI	HwARC/SARI	700-1700	1981	100-110
Crawford	NI	HwARC/SARI	1300-1850	1974	90-100
Jalale	AGS-217	BARC/OARI	1300-1850	2003	100-110
Nova	NI	HwARC/SARI	1200-1700	2012	90-100
Nyala	NI	HwARC/SARI	800-1700	1974	100-110
Williams	NI	HwARC/SARI	1000-1700	1974	90-100

NI = not identified

Table 2: Environments used in the study and their main characteristics in Ethiopia

Location	Year	Longitude	Latitude	Altitude (m.a.s.l)	RF (mm)	Soil type
Bako	2016 & 2017	37°09'E	09°06'N	1650	1431	Sandy-clay
Gute	2016	E:036^{0}38.196’	N:09^{0}01.061’	1915	NI	Clay
Billo	2016	E:037^{0}00.165’	N:09^{0}54.097’	1645	1500	Reddish brown
Chewaka	2017	036.11703E	09.98285N	1259	NI	Clay loam
Uke	2017	E:036^{0}32..391’	N:09^{0}25.082’	1319	NI	Sandy loam

NI = not identified RF= Rainfall

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:

$$Y_{ger} = \mu + ag + \text{ß}e + \sum n \lambda n \gamma gnden + eger + \rho ge \text{ ……………………………Equation 1}$$

Where: Yger is the observed yield of genotype (g) in environment (e) for replication (r);

Additive parameters: µ is the grand mean; ag is the deviation of genotype g from the grand mean, ße is the deviation environment e;

Multiplicative parameters: λn is the singular value for IPCA, γgn is the genotype eigenvector for axis n, and den is environment eigenvector; eger is error term and ρge is PCA residual.

Accordingly, genotypes with low magnitude regardless of the sign of interaction principal component analysis scores have general or wider adaptability while genotypes with high magnitude of IPCA scores have specific adaptability (Gauch, 1992; Umma *et al.*, 2014).

AMMI stability value of the 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):

$$ASV_i = \sqrt{\left[\frac{SS_{IPCA1}}{SS_{IPCA2}}[IPCA1_{score}]\right]^2 + [IPCA2_{score}]^2}$$ ……………………………….Equation 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 (RY) across environments and rank of AMMI stability value (RASV), the Genotype Selection Index (GSI) was calculated for each genotype, which incorporate both mean grain yield (RY) and stability index in single criteria (GSI) (Purchase *et al*., 2000).

GSI = RASV + RY…………………………………………………………………… Equation 3

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 (ANOVA) and 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: There were statistically significant differences ($P< 0.01$) among soybean varieties, environments and their interaction for grain yield (Table 3). This indicates the presence of genetic variation among the soybean varieties and possibility to select high yielding and stable variety (s); the environments were variable and the response of soybean varieties across environments. Zeleke *et al*. (2016) and Dabessa *et al*. (2016) also reported statistically significant difference among common bean and groundnut genotypes, respectively.

Table-3. Combined Analysis of variance for grain yield of early soybean varieties evaluated at six environments for two consecutive years in Ethiopia

Source of variation	Degree freedom	Mean square
Environments	5	5591561**
Genotypes	6	3280014**
Block within environment	2	90706^{ns}
Interaction	30	223462**
Error	82	21356
CV (%)	8.5	

**= significant at P = 0.01, ns = non-significant

Performance of genotypes across environments

Table 4 shows the average mean grain yield of seven soybean varieties evaluated across six environments in western Oromia. The pooled mean grain yield ranged from 894.5 to 2189.6 kg ha^{-1}. Among all varieties, Nova was the lowest yielder (895.5 kg ha^{-1}). The highest grain yield was obtained from Coker-204 variety (2189.6 kg ha^{-1}) followed by Nyala (2008.6 kg ha^{-1}**)** and

Jalale (1708 kg ha^{-1}). This difference could be due to their genetic potential. Coker-204 was the top ranking genotype at Bako-2016, Bako-2017, Gute and Chewaka while Nyala and Boshe ranked first at Billo and Uke, respectively. The difference in yield rank of early maturity soybean varieties across the test environments revealed high genotype by environment interaction.

AMMI model analysis

An output of the AMMI model analysis of variance for grain yield is presented in Table 5. This analysis also revealed presence of highly significant ($P< 0.01$) differences among soybean varieties for grain yield performance. From the total treatment sum of squares, the largest portion was due to environments main effect (51.1%) followed by varieties main effect (35.9%) and the effect of genotype by environment interaction was 12.2%.

Table-4. Mean grain yield (kg ha^{-1}) of seven soybean varieties evaluated at six environments in Ethiopia

Varieties	Locations						
	Bako-2016	Bako-2017	Gute	Billo	Chewaka	Uke	Mean
Williams	1870.	1471	2353	1318	565	1377	1542
Crawford	2227	1629	2389	1839	957	975	1669
Nyala	2425	2390	2363	2463	1089	1319	2008
Nova	1458	897	7716	915.7	598.6	724.8	894
Boshe	2485	2546	2230	2254	1096	13391	19923
Coker-204	26559	2723	2511	2453	14729	13213	21896
Jalale	2214	2335	2080	1474	969	1174	1708
LSD (0.05)	206.9	199	188.3	489.5	116.4	191.9	116.4
CV (%)	5.3	5.6	5.0	14.8	6.8	9.2	10.2

A large yield variation explained by environments indicated that the existence of both spatial and temporal diversity in test-environments, with large differences among environmental means causing most of the variation in grain yield. In line with this result, Tolessa and Gela (2014) reported large yield variation of common bean genotypes due to environments. This also indicates the existence of a considerable amount of deferential response among the evaluated soybean varieties to changes in growing environments and the differential discriminating ability of the test environments. Substantial percentage of G x E interaction was explained by IPCA-1 (4.8%); followed by IPCA-2 (4.4%) and, therefore, used to plot a two dimensional GGE biplot. Amare and Tamado (2014) and Temesgen *et al.* (2014) suggested the most accurate model for AMMI could be predicted by using the first two IPCA.

AMMI biplot analysis

AMMI biplot graph with X-axis plotting $IPCA_1$ and Y-axis plotting $IPCA_2$ scores illustrate stability and adaptability of soybean varieties to tested environments (Fig. 1). The more the IPCA scores approximate to zero, the more stable or adapted the genotypes is over all the environments sampled. The variation of seed yield for each variety was significant at different environments. Varieties Jalale and Nyala were specifically adapted to high yielding environments (Fig. 1). Considering the $IPCA_1$ score, Nova, Crawford and Williams were the most unstable varieties and also adapted to low yielding environments. Boshe and Coker-204 were more stable in comparison to other varieties. Varieties, Nova, Crawford and Williams were adapted to low yielding environments and also not stable. Boshe and Coker-204 varieties were near to zero IPCA by which it were shown to have higher stability for seed yield than other soybean varieties (Fig. 1). Coker-204 had highest seed yield followed by Boshe variety. Boshe, Coker-204 and Jalale varieties had higher GEI at environments of Bako. It has been reported that the varieties that have the lowest IPCA score in AMMI biplot are an indication of the stability or adaptation over environments (Dolinassou *et al*., 2016). It is further stated that the greater the IPCA scores, negative or positive, the more specific adapted is a genotypes to certain environments.

Table 5: Partitioning of the explained sum of square (SS) and mean square (MS) from AMMI analysis for grain yield of seven soybean varieties used in a study of in Ethiopia

Source of variation	DF	Sum of square	Explained SS (%)	Mean square
Total	125	56274352		450195
Treatments	41	54341756		1325409**
Genotypes	6	19680083	35.9	3280014**
Environments	5	27957806	51.1	5591561**
Block	12	386230	0.7	32186^{ns}
Interactions	30	6703867	12.2	223462**
IPCA 1	10	2717387	4.8	271739**
IPCA 2	8	2480532	4.4	310067**
Residuals	12	1505948		125496
Error	72	1546366		21477

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

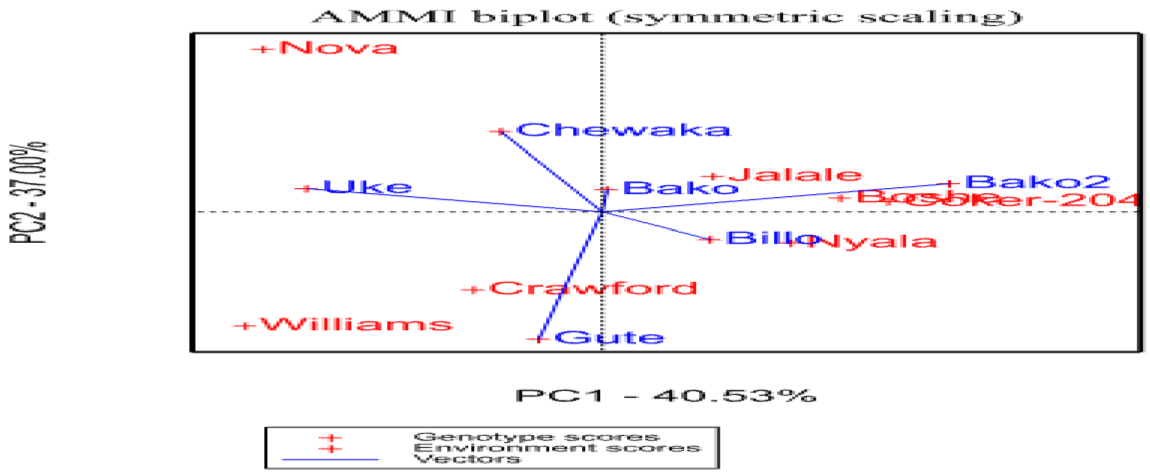

Fig-1. Biplot of interaction principal component axis ($IPCA_1$) against interaction principal component axis ($IPCA_2$) of early soybean varieties evaluated across six environments in Ethiopia.

AMMI stability value and genotype selection index

The IPCA$_1$ and IPCA$_2$ scores for each variety and also the AMMI Stability Value (ASV) with its ranking for seven early soybean varieties are presented in Table 6. In ASV method, a genotype/ variety with least ASV score is the most stable (Purchase *et al.*, 2000). Accordingly, Boshe, Jalale and Crawford were the most stable. On the other hand, Williams, Nyala and Nova varieties were the most unstable. This measure is essential in order to quantify and rank of varieties according to their seed yielding stability. The least Genotype Selection Index (GSI) is considered as the most stable with high seed yield (Farshadfar, 2008; Dabessa *et al.*, 2016). Based on the GSI result, the most desirable variety for selection of both stability and high grain yield were Boshe and Coker-204 (Table 6), which was in line with the result of AMMI and GGE biplot.

Table-6. AMMI stability value, genotype selection index and ranks based on grain yield of seven soybean varieties evaluated at six locations in Ethiopia

Varieties	Yield	ASV	RY	RASV	GSI
Boshe	**1992.27**	**13.92**	**3**	**2**	**5**
Coker-20	**2189.64**	**28.09**	**1**	**4**	**5**
Crawford	1669.47	12.19	5	1	6
Jalale	1708.06	25.02	4	3	7
Nova	894.50	34.04	7	5	12
Nyala	2008.60	43.69	2	6	8
Williams	1542.82	45.69	6	7	13

Where, ASV = AMMI stability value, RY = Rank of yield, RASV = Rank of AMMI stability value and GSI = Genotype selection index

GGE biplot analysis

In GGE biplot (Fig. 2), IPCA$_1$ and IPCA$_2$ explained 84.49 and 9.1%, respectively, of soybean varieties by environment interaction and made a total of 94.1%. Other studies conducted on groundnut by Amare and Tamado (2014) and white lupines by Atnaf *et al.* (2017) explained an interaction of 81.8 and 63.4% respectively, extracted from IPCA$_1$ and IPCA$_2$. An ideal genotype is defined as genotype having the greatest IPCA$_1$ score (mean performance) and with zero GEI, as represented by an arrow pointing to it (Fig. 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, Nyala, Coker-204 and Boshe varieties which fell closest to the ideal genotype was identified as the most desirable genotype as compared to the rest of the tested soybean varieties (Fig. 2). Similarly, Dabessa *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.

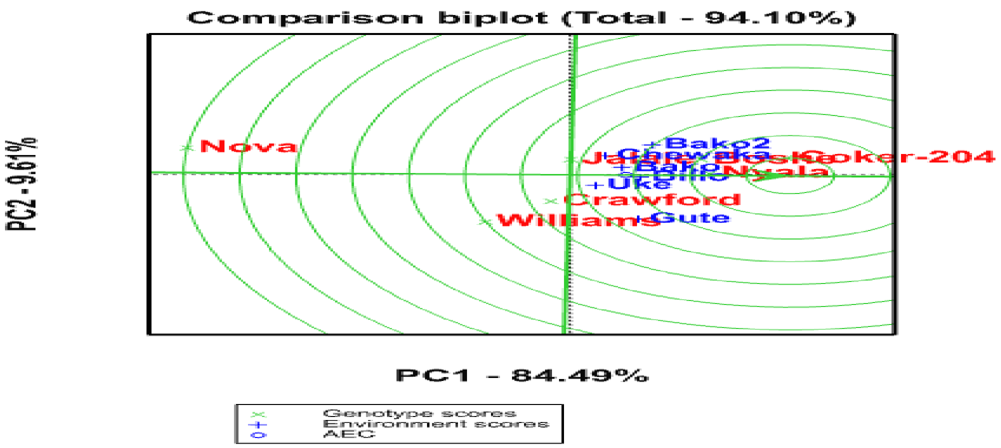

Fig 2. GGE-biplot based on genotype-focused scaling for comparison the genotypes with the ideal genotype.

Discriminating ability and representativeness of environments

Bako, Billo and Gute locations were identified as the most discriminating environment as compared to Chewaka and Uke that were identified as the least discriminating testing environments (Fig. 3). Thus, Bako and Billo were identified as the most conducive environments for soybean production. Both discriminating ability and representativeness view of the GGE biplot are the most important measures of testing environment, which provide not only valuable but also unbiased information about the tested genotypes (Yan and Kang, 2003). Yan and Tinker (2006) also reported that the length of environmental vector is directly proportional to the standard deviation within the respective environments and help to know the discriminating ability of this target environment i.e. an environment with long environmental vector has high discriminating ability and vice versa.

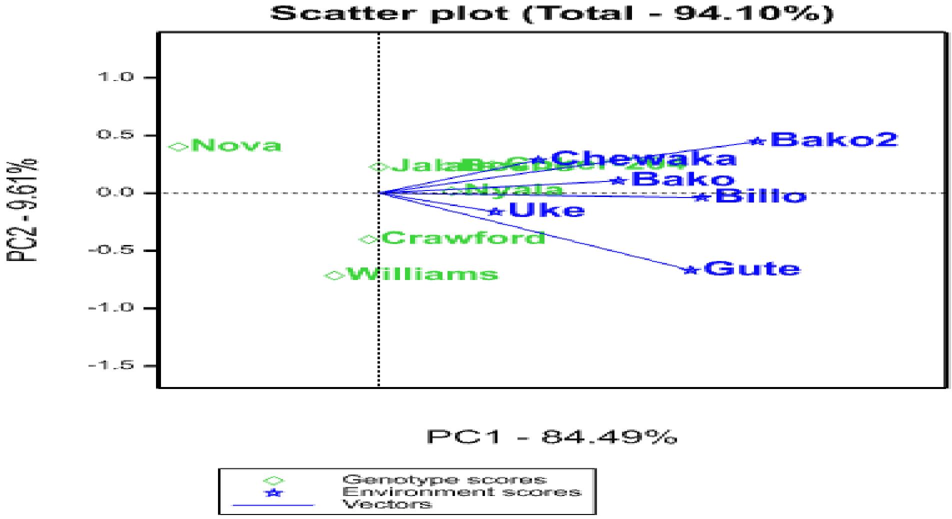

Fig 3. The vector view of GGE biplot which shows the interrelation ships among the test environments in Ethiopia.

Conclusions and Recommendations

Combined analysis of variance indicated that grain yield performance of the tested varieties was highly influenced by environment, varieties and GEI. This indicating that a particular variety does not exhibit uniform performance under different environmental conditions or different varieties may respond differently to a specific environment. The varieties and environment main effects and genotype-by-environment interaction effect were highly significant for early maturity soybean varieties. Environment contributed most to the variability in grain yield. Soybean varieties Nyala, Boshe and Coker-204 were close to the ideal genotype and can thus be used as bench marks for the evaluation of early soybean genotypes in western Oromia. Considering simultaneously mean yield and stability, Boshe and Coker-204 were the best early soybean varieties in the study area.

Acknowledgements

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