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Genotype x Environment x Management Interaction of Common bean (*Phaseolus Vulgaris* L.) on Acidic Soils of Western Ethiopia

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Soil acidity mainly constrained the production of common bean in western Ethiopia. The present study consisted of Fifteen common bean genotypes tested in 2016 cropping season at four acidic prone areas of western Ethiopia namely Nedjo, Mandi, Bambasi and Assosa using split plot design with lime treated and untreated as main factors and the genotypes as sub-factors with the aim to examine the effect of genotype x environment x management interaction on seed yield and yield related traits in common bean and to determine the stability of the genotypes across environment and managements. Data collected from each location were analyzed both for individual location as well as across locations. The result revealed that there were significant ($p \leq 0.05$) difference among genotypes, environment, management and genotypes by environment interaction for days to flowering, pod per plant, biomass yield and seed yield. There were also significant ($p \leq 0.05$) differences among genotypes, environment, and management for days to maturity, seed per plant and total number of nodules. Moreover, genotype by environment by management interaction had significant effect on yield which shows that the genotypes performed differently across environment upon the application of lime. AMMI stability model was used to identify stable genotype and genotypes with specific and wider adaptation. Accordingly, genotype ALB 207, BFS 39 and ALB 179 had higher yield and wider adaptation, while genotypes BFS 35 and ALB 212 had high mean yield but specific adaptation. Based on four stability models such as Lins and Bins cultivar superiority, Wricks'ecovalence, Nassar and Huehn's mean absolute rank difference and variance of ranks and AMMI stability value; genotype ALB 179 was found to be stable both on lime treated and untreated soil and ALB 209 was stable genotype on lime treated soil while BFS 39 on lime untreated soils. AMMI - biplot showed that Assosa was most discriminating environment while Mandi was the most favorable environment for the tested bean genotypes. Specific best performing genotypes were; at Assosa (ALB 163); Nedjo (ALB 209) and at Bambasi (BFS 24). Generally, genotypes ALB 207 and BFS 39 have performed best at Mandi, and this two can also be recommended for all the four testing sites and other areas with similar agro-ecology without lime application, while genotypes ALB 133, ALB 204 and BFS 39 for lime treated soils because of their wider adaptability.

Keywords: AMMI, Lime treated, Lime untreated, Soil acidity, Stability

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INTRODUCTION

Common bean (*Phaseolus vulagris* L), is locally known as ‘Boleqe’ in Ethiopia. It is seed-propagated, true diploids (2n =2x= 22) and have a relatively small genome (650 Mb) (Broughton *et al.,* 2003). It is an annual crop which belongs to the family Fabaceae. Common bean is thought to be introduced to Ethiopia by the Portuguese in the 16th century (Wortman, 1997). Nowadays, in addition to its subsistence value, common bean is an important commercial crop contributing significant incomes to the majority of the rural peasants in Sub-Saharan Africa (Wortman *et al*., 2004).

In Ethiopia, common bean is grown as 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). The current national production of common bean in Ethiopia is estimated at 323,317.99 hectares; with a total production of 513,724.807 tons and average productivity of 1.59 tons per hectare (CSA, 2015) in the main season only. Further, substantial amount of land is also covered at short rainy season (belg) cropping. The crop grows well at the altitude between 1400 and 2000m above sea level (Fikru, 2007) and in warm climate at temperature of 18 to 24^{o}C (Teshale *et al*., 2005).The wide range of growth habits of common bean enabled it to fit many growing situations (Kristin *et al*., 1997).

Evaluations of common bean lines should be conducted under environmental conditions that best represent the prevailing growth conditions (Ramalho *et al*., 1998 cited in Perreira *et al*., 2010) and this requires the implementation of a network of assessment tests, including the major producing states in the country. The demand for a variety with high productivity and high performance for agronomic traits over a range of production environments is very high among growers and development practitioners. Differential responses of crop varieties to variable environmental conditions limit accurate yield estimates and identification of high yielding stable varieties. This differential response of genotypes to changing environmental conditions is known as genotype x environment interaction (GEI).

Soil acidity is a significant problem that agricultural producers in tropical and subtropical regions are facing and limit legume productivity (Bordeleau and Prevost, 1994). This is aggravated by the inherent poor fertility and acidity in most tropical soils (Okalebo *et al*., 2006). Soil acidity occurs when there is a build-up of acid forming elements in the soil. This soil acidity is also a major problem affecting about 40% of the total land in Ethiopia (Mesfin, 2007), about 27.7% of which are dominated by moderate to weak acid soils (pH in KCl) of 4.5 to 5.5, and around 13.2% by strong acid soils (pH in KCl) <4.5). Acidic soils cause poor plant growth resulting from Aluminum (Al^{+3}) and Manganese toxicity (Mn^{+2}) or deficiency of essential nutrients like phosphorus, calcium and magnesium. Restoring, maintaining and improving fertility of this soil is major priority as a demand of food and raw materials are increasing rapidly. This can be achieved by adding limestone to the soil (Maheshwari, 2006). This use of lime is a potential option for soils sustainable management among the other options for restoring soil health and fertility.

Liming acid soil make the soil environment better for leguminous plants and associated microorganisms as well as increase concentration of essential nutrients by raising its pH and precipitating exchangeable aluminum (Kisinyo *et al*., 2012). The most important effect of soil acidity includes retardation of plant growth through toxicity of Aluminum (Al) and Hydrogen (H) ions, unavailability of other plant nutrients, mainly Nitrogen and Phosphorus, and reduction of microbial activity in the soil (Ano and Ubochi, 2007). Like many legumes, common beans prefer well aerated, sufficiently drained soil with a pH of 6.0 to 7.5, the critical pH thresholds being 5.0 and 8.1 (Lunze *et al*., 2007).

Although both national and regional variety trials of different bean types have been part of the bean breeding program in national research system for many years in Ethiopia, the relative magnitude of GEI and use of stability statistics in common beans have not been very much studied and documented in common bean growing areas of western Ethiopia. Similarly, although studying soil acidity problems and response to lime application estimation have been done in some part of the country, quantitative analysis using soil laboratory tests to acquire appropriate solution for the problem was very limited. Thus, evaluating bean genotypes over different representative environmental condition with appropriate management measures of acidic soil is very important to generate relevant information and to recommend stable and superior genotype for western Ethiopia

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Thus, this study was conducted with the following objectives:

1. To determine the effect of genotype x environment x management interaction on grain yield and yield related traits of common bean
2. To determine the stability of common bean genotypes across environment and management practices

MATERIALS AND METHODS

Experimental Sites

The experiment was conducted during the 2016 main cropping season at four locations representing acid affected areas of western Ethiopia where the crop is widely grown. The locations were Nedjo, Mandi, Bambasi and Assosa which are found along the main road side from Addis Ababa to Assosa with a distance of 490, 565, 616 and 661km from Addis Ababa, respectively. The descriptions of the locations are indicated in Table 1.

Experimental Materials and Design

Fifteen common bean genotypes (Table 2), which had been selected based on their background of adaptability to low soil fertility and acid soil were obtained from Melkassa Agricultural Research Center (MARC), Lowland Pulse Research program and were evaluated at the selected sites. The selected genotypes were assumed to be variable in their tolerance to soil acidity as sensitive, tolerant and mildly tolerant.

Triple Super Phosphate (46% P_2O_5), Urea and ground lime (85% calcium carbonate) with fineness of 25% were used as sources of Phosphorus, Nitrogen and as liming materials, respectively. The experiment was conducted by using both lime treated and untreated soils by using split plot design with three replications at the four locations by assigning liming as a main plot and genotypes as sub-plots. The size of the experimental plot was 9.6m^2 with 6 rows 4 of meters long and the net plot size was 4 rows x 0.4 m x 4 m= 6.4m^2. The spacing was 0.4m and 0.1m between rows and plants, respectively. The spacing between replications and blocks were 1.5m and 1m respectively.

Pre-planting composite soil sample from the experimental site was collected in a zigzag pattern from the depth of 0-30 cm before planting. Uniform volumes of soil were taken at each sub-sample by vertical insertion of an auger. The samples were air dried, ground using a pestle and a mortar and allowed to pass through a 2 mm sieve to remove the coarser materials. Working samples were obtained from each submitted samples and analyzed for organic carbon, total N, soil pH, available phosphorus, cation exchange capacity (CEC) and textural analysis using standard laboratory procedures.

Organic carbon content was determined by the volumetric method (Walkley and Black, 1934) as described in Food and Agriculture Organization of the United Nations (FAO) guide to laboratory establishment for plant nutrient analysis (FAO, 2008). Total nitrogen was analyzed by Micro-Kjeldhal digestion method with sulphuric acid (Jackson, 1962). The pH of the soil was determined according to FAO (2008) using 1:2.5 (weight/volume) soil sample to water ratio using a glass electrode attached to a digital pH meter. The total number of exchangeable cations a soil can hold, cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH4OAc) and displacing it with 1N NaOAc (Chapman, 1965). Available phosphorus was determined by the Olsen's method using a spectrophotometer (Olsen *et al.*, 1954). Particle size distribution was done by hydrometer method (differential settling within a water column) according to FAO (2008).

The land was ploughed, disked, and harrowed. All cultural practices such as weeding, cultivation, etc were applied uniformly to all plots. The common bean varieties were planted at inter-row spacing of 0.4m and intra row spacing 0.1m.

The lime was incorporated for the quickest and maximum effect; limestone was evenly spread and incorporated into the soil 20 cm deep by using hoe one month before planting of common bean. Urea (46% N) and TSP (46% P_2O_5) were used as the sources of N and P; respectively. Urea was applied (23 kg N ha^{-1}) as starter fertilizer to all treatments at planting whereas calcite limestone ($CaCO_3$) was used as the source of lime. The whole (recommended) doses of TSP were applied at planting time. All other necessary agronomic managements practices were carried out properly and equally for all treatments.

Data for days to flowering, days to maturity, plant height, total number of nodule, number of effective and non-effective nodules, number of pod per plant, seed per pod, seed per plant, aboveground biomass, hundred seed weight, seed yield and harvest index were collected following *Phaseolus vulgaris* L. descriptors (Debouck and Hidalgo, 1986).

SAS and different statistical software packages were used to analyze the data. Analysis of variance for each location, combined analysis of variance over locations and AMMI analysis were computed using the Genstat statistical software.

Four stability measures such as Lin and Binns cultivar superiority measure (Pi), Wricke's ecovalence Analysis (Wi), Nassar and Huehn's mean Absolute rank difference (Si1) and variance of ranks (Si2), and AMMI Stability Value (ASV) were computed using Gestat computer program to identify stable genotypes which had consistence yielding performance across the testing environments.

RESULT AND DISCUSSION

Phenological and Growth Parameters of Common bean

Soil acidity had a marked influence on common bean's flowering, maturity and growth. Analysis of variance showed that the main effect of Management, the interaction effect of Management by environment (M x E), Management by genotype (M x G), and genotype by environment by Management (G x E x M) had non-significant effect on days to 50% flowering but the main effect of genotypes and environment and the interaction of Genotype by environment (G x E), were found to have

Table 1 Description of the study sites for geographical positions and soil chemical properties

parameters	Testing Environments			
	Assosa	**Bambasi**	**Mandi**	**Nedjo**
Altitude	1553	1425	1601	1735
Temperature(min and max)	17 and 32	21 and 35	15 and 31	12 and 26
Rainfall	1275	1433	1674	1386
Latitude	$34^{0}34$'E	$34^{0}73$'E	$35^{0}06$'E	$35^{0}45$'E
Longitude	$10^{0}02$'N	$9^{0}75$'N	$9^{0}47$'N	$9^{0}3$'N
Soil type	Nitosols	Fluvisols	Inceptisols	Inceptisols
Soil Texture	Clay loam	Sandy loam	Sandy loam	Silt loam
Soil PH	4.9	5.3	5.1	4.6
Organic carbon (%)	1.73	2.57	2.01	1.89
Total Nitrogen (%)	0.155	0.327	0.213	0.326
Avaliable P(mg kg-1)	5.53	6.02	5.94	4.91
CEC [cmol (+) kg-1)	12.36	16.39	13.42	19.28

Table 2 Common bean genotypes used for the experiment

No	Genotype	Background information	Source
1	ALB 212	Acid soil tolerant segregating population	CIAT
2	ALB 133	Acid soil tolerant segregating population	CIAT
3	ALB 163	Acid soil tolerant segregating population	CIAT
4	ALB 204	Acid soil tolerant segregating population	CIAT
5	ALB 25	Acid soil tolerant segregating population	CIAT
6	ALB 149	Acid soil tolerant segregating population	CIAT
7	ALB 179	Acid soil tolerant segregating population	CIAT
8	ALB 209	Acid soil tolerant segregating population	CIAT
9	ALB 207	Acid soil tolerant segregating population	CIAT
10	BFS 320	Low soil fertility tolerant segregating population	CIAT
11	BFS 35	Low soil fertility tolerant segregating population	CIAT
12	BFS 24	Low soil fertility tolerant segregating population	CIAT
13	BFS 39	Low soil fertility tolerant segregating population	CIAT
14	ROBA	Released variety (Check)	CIAT
15	NASIR	Released variety (Check)	CIAT

significant ($P < 0.05$) effect on days to 50% flowering (Appendix Table 1). The highest days to 50% flowering (51 days) was recorded at Nedjo on lime treated (Roba) genotype. On the other hand the lowest days to 50% flowering (37 days) was recorded at Mandi on lime untreated (ALB 133) genotype (Table 3). The result indicates that the application of lime promote vegetative growth and lengthen the days taken to the plant to flower. Ganev and Arsova (1982) have also reported that the optimum application of lime and P has both direct and indirect effects on crop for the development of reproductive organs and absorption of mineral nutrients such as water, zinc and potassium which have influenced on flower development. Consequently, application of lime reduces Al/Fe toxicity and makes the soil media slight to neutral for the availability of most of nutrients and also improves the physical conditions of soil for good aeration and circulation of nutrient (Bassetti and Westgate, 1994).

Table 3. Table of Phenological trait, growth trait and Nodulation of fifteen common bean genotype

Treatment	Genotype	DTF		**DTM**		**PHT**		EN		NEN		TNN		HI	
		LT	**LUT**	LT	LUT	LT	LUT	**LT**	**LUT**	**LT**	**LUT**	**LT**	**LUT**	**LT**	**LUT**
1	ALB 212	40.08^{g-l}	40.5^{f-l}	77.33^{cde}	77.58^{bcde}	27.02^{abc}	29.42^{abc}	0.79^{ab}	0.69^{abc}	0.61	0.53	0.98^{abc}	0.88^{abc}	0.53^{abc}	0.45^{abc}
2	ALB 133	41.75^{c-k}	39.33^{kl}	76.17^{cde}	76.83^{cde}	29.6^{abc}	31.46^{abc}	0.78^{abc}	0.50^{bc}	0.60	0.47	1.00^{abc}	0.79^{abc}	0.55^{ab}	0.52^{abc}
3	ALB 163	42.58^{b-f}	42.5^{b-h}	79^{a-e}	77.92^{bcde}	28.7^{abc}	29.16^{abc}	0.67^{abc}	0.63^{abc}	0.62	0.54	0.93^{abc}	0.86^{abc}	0.55^{ab}	0.46^{abc}
4	ALB 204	40.75^{e-l}	41.42^{d-l}	78.92^{a-e}	78.25^{bcde}	26.45^{abc}	27.97^{abc}	0.74^{abc}	0.67^{abc}	0.69	0.58	1.00^{abc}	0.93^{abc}	0.47^{abc}	0.44^{abc}
5	ALB 25	41.5^{c-l}	41.92^{c-j}	77.25^{cde}	77^{cde}	25.15^{bc}	25.82^{abc}	0.82^{ab}	0.74^{abc}	0.63	0.38	1.00^{abc}	0.83^{abc}	0.52^{abc}	0.47^{abc}
6	ALB 149	40.08^{g-l}	39.08^{l}	76^{de}	75.75^{e}	28.3^{abc}	26.6^{abc}	0.74^{abc}	0.50^{bc}	0.51	0.47	0.9^{abc}	0.76^{bc}	0.61^{a}	0.60^{a}
7	ALB 179	40.33^{f-l}	39.58^{jkl}	78.75^{a-e}	77^{cde}	31.95^{abc}	25.78^{abc}	0.65^{abc}	0.64^{abc}	0.57	0.54	0.87^{bc}	0.85^{bc}	0.58^{a}	0.60^{a}
8	ALB 209	39.67^{jkl}	40.08^{g-l}	76.75^{cde}	$76d^{e}$	27.98^{abc}	27.07^{abc}	0.85^{b}	0.66^{abc}	0.68	0.57	1.06^{ab}	0.86^{bc}	0.54^{abc}	0.57^{a}
9	ALB 207	43^{bcde}	42.5^{b-g}	79.33^{a-d}	78.83^{a-e}	29.68^{abc}	31.4^{abc}	0.85^{abc}	0.64^{abc}	0.58	0.65	1.00^{abc}	0.92^{abc}	0.46^{abc}	0.57^{a}
10	BFS 320	41.08^{e-l}	40^{ijkl}	75.67^{e}	75.67^{e}	23.55^{c}	25.89^{abc}	0.52^{abc}	0.57^{bc}	0.54	0.51	0.79^{bc}	0.80^{bc}	0.52^{abc}	0.57^{a}
11	BFS 35	43.58^{bcd}	42.25^{c-i}	78.58^{a-e}	77.25^{cde}	27.95^{abc}	28.38^{abc}	0.52^{bc}	0.44^{c}	0.44	0.56	0.75^{bc}	0.83^{bc}	0.47^{abc}	0.50^{abc}
12	BFS 24	41.5^{c-l}	40.08^{g-l}	78.33^{bcde}	77.25^{cde}	26.03^{abc}	24.43^{bc}	0.85^{abc}	0.45^{bc}	0.81	0.61	1.12^{ab}	0.88^{abc}	0.43^{abc}	0.45^{abc}
13	BFS 39	44.58^{b}	43.83^{bc}	79.58abc	78.83^{a-e}	32.2^{abc}	35.78^{a}	0.75^{ab}	0.61^{abc}	0.63	0.56	0.97^{abc}	0.91^{abc}	0.47^{abc}	0.53^{abc}
14	Roba	47.5^{a}	47.67^{a}	81.75^{a}	80.83^{ab}	33.77^{ab}	30.5^{abc}	0.64^{bc}	0.64^{abc}	0.68	0.67	1.00^{abc}	0.90^{abc}	0.37^{c}	0.37^{bc}
15	Nasir	40.25^{f-l}	40.92^{e-l}	79.33^{abcd}	78.92^{a-e}	32.18^{abc}	30.93^{abc}	1.11^{a}	0.73^{ab}	0.83	0.79	1.31^{a}	1.02^{abc}	0.46^{abc}	0.48^{abc}
	EM	41.88	41.44	78.18	77.59	28.7	28.71	0.75	0.61	0.63	0.56	0.97	0.81	0.50	0.51
	SEM	0.71		1.0		2.8		0.2		0.2		0.2		0.05	
	CV	5.29		4.5		17.9		20.91		17.34		12.68		19.7	

DTF= Days to flowering, DTM=Days to maturity, PHT= Plant height, EN= Effective nodule, NEN=Non effective nodule, TNN= Total number of Nodule, HI= Harvest index, LT= Lime treated, LUT = Lime untreated, EM= Environmental mean, CV= Coefficient of variations. Means within the same letter are not significantly different from each other

In contrary to the finding of the present study, Hirpha (2013) found that the application of lime hastened flowering and maturity dates of the common bean plants.

Combined analysis of variance also showed that the main effect of Genotype, Environment and Management and the interaction effect of Genotype by Environment (G x E) had a significant ($P < 0.05$) effect on days to physiological maturity while the interaction effect of Genotype by Management (G x M), Management by Environment (M x E) and Genotype by environment by Management (G x E x M) had non-significant effect on days to physiological maturity **(**Appendix Table1). The highest days to physiological maturity (88 days) was recorded at Nedjo on lime treated (Roba) genotypes, while the lowest days to physiological maturity (73 days) was recorded at Mandi on both lime treated and lime untreated ALB 149 genotype (Table 3). All the genotypes took longer time (days) to reach physiological maturity at nedjo, 83 days on average, which is mainly due to the higher level of soil acidity at Nedjo which hinders the availability of essential nutrient for the bean plant and the minimum number of days to physiological maturity was at Mandi and Assosa, 75 days on average, which is supposed to be due to more or less favorable growing environment including less soil acidity and better availability of mineral nutrients in the environments in relation to other environments. The result of the experiment indicated that application of lime had propped up the vegetative growth of the crop plant and taken longer time to reach physiological maturity whereas crops planted on lime untreated soils had fasten their development and reached the physiological maturity earlier than those planted on lime treated soils across all locations to escape from stress imposed due to soil acidity. In contrary to this, Tesfaye (2015) reported that lime application did not significantly influence days to physiological maturity.

The analysis of variance indicated that the main effect of Environment, genotype and the interaction effect of Genotype by Environment (G x E), Genotype by Management (G x M) and Management by Environment (M x E) had a significant ($P < 0.05$) effect on plant height where as the main effect of Management and the interaction effect of Genotype by Environment by Management (G x E x M) had non-significant effect on plant height **(**Appendix Table1). The tallest (45.2cm) plant height was recorded at Mandi from lime treated (Roba) genotype and shortest (12.4cm) plant height was recorded at Nedjo from lime untreated (BFS 24) genotype (Table 3). The increase in plant height of the genotypes across environment in response to the application of lime indicates that the maximum vegetative growth of the plants under lime application is due to the availability of micronutrients such as Nitrogen, P, OC, and lower concentration of toxic Cations mainly $Al^{3+}$and Mn^{2+} ions. Similar result was obtained by Jessop *et al.* (1990) that the plant height of lupin was reduced on low lime depression soil. Haynes and Ludeck (1981) also reported that soil acidity will retard the growth of the crop because of root growth restriction and greater difficulty in nutrient accusation and access to water reserve in sub surface soil layers, especially when the top soils dries out.

Analysis of variance also revealed that only the main effect of Environment and Management had a significant ($P \leq 0.01$) effect on number of effective nodule where as the main effect of genotype and its interaction with other effects had non-significant effect on the number of effective nodules **(**Appendix Table 1). The highest number of effective nodule (31 and 30) was recorded at Assosa from lime treated Nasir and Roba genotypes respectively, whereas the lowest number of effective nodule (0) was recorded at Mandi from lime untreated (ALB 133 and BFS 320) genotypes. Generally, higher number of effective nodule was recorded from lime treated soil than lime untreated for most of the genotypes (Table 3). From the combined analysis result, genotype Nasir had the highest number of effective nodules (1.59) on lime treated soil whereas genotype BFS 35 had the least number of effective nodules (0.65) on lime untreated soil. Effective nodulation is essential for a functioning of legume/*Rhizobium* symbiosis. Plants which produce effective nodules should have greater potential to fix more atmospheric nitrogen. Nitrogen fixing ability of the legumes depends on the effectiveness and compatibility of the root nodule bacteria which nodulate it. In many soils, populations of natural root nodule bacteria are present in sufficient number to nodulate the sown legumes. In other situations, there may be only low numbers of root nodule bacteria in the soil or they may be entirely absent. The adverse effects of soil acidity on nodulation and nitrogen fixation were also reported by Bambara and Ndakidemi (2010).

On the contrary, analysis of variance indicated that the main effect of Genotype, Environment, the interaction effect of Environment by Management (E x M), Genotype by Management (G x M), Genotype by Environment (G x E) and Genotype by Environment by Management (G x E x M) had a significant ($P \leq 0.05$) effect on number of non-effective nodule where as the main effect of management, had non-significant effect on number of non-effective nodules **(**Appendix Table 1). The highest number of non-effective nodule (10) was recorded at Mandi from lime treated Nasir and BFS 24 genotypes respectively whereas the lowest number of non-effective nodule (0) was recorded at Assosa and Mandi from lime untreated and Nedjo from lime treated genotypes (Table 3).

Similarly, analysis of variance revealed that the main effect of Genotype, Environment and Management, and the interaction effect of Environment by Management (E x M) have a significant ($P \leq 0.05$) effect on total number of nodule whereas the interaction effect of Genotype by Management (G x M), Genotype by Environment (G x E) and Genotype by Environment by Management (G x E x M) had non-significant effect on total number of nodules **(**Appendix Table 1). The highest total number of nodule (37) was recorded at Assosa from lime treated Nasir and Roba genotypes while the lowest total number of nodule (1) was recorded at Mandi from lime untreated ALB 133 and BFS 320 genotypes(Table 3). According to the combined analysis result, genotype Nasir has the highest number of total nodule (1.91) on lime treated soil whereas genotype BFS 320 has smallest number of total nodule per plant (1.0) on lime untreated plots. Similar result was also obtained by Buerkert *et al.* (1990) confirming that liming acid soil significantly increased nodulation of beans and alfalfa. The reason for the increment of nodule at limed soil were due to the direct effect of lime on reducing the H^{+} concentration and toxic level of Al and Mn, and subsequently reducing the deficiencies of Ca, P, and Mg.

Yield and Yield Components of Common Bean

Yield Components

Analysis of variance showed that the main effect of environment, genotype and management and their interaction effects of Genotype by Environment (G x E) had a significant effect on the total number of pods per plant, while the interaction effect of Genotype by Management (G x M) and Genotype by Environment by management (G x E x M) had non-significant effect on total number of pod per plant (Appendix Table 1). The highest total number of pod per plant (14) was recorded at Bambasi and Mandi from some genotypes which were lime treated, while the lowest total number of pod per plant (2) was recorded at Nedjo (Table 4). According to the result of the combined analysis, genotype ALB 207 had the highest number of pods per plant (9.42) on lime treated plots, whereas genotype Roba had the lowest number of pods per plant (4.83) on lime untreated plots. Hence, application of lime promoted vegetative growth thereby enabled the plant to bear higher number of pods per plant than the untreated plot. In line with this result, Okpara and Muoneke (2007) reported as liming had significantly increased number of pod per plant on soybeans.

The result of analysis of variance also revealed that the main effect of Environment and Genotype and the interaction effect of Genotype by Management (G x M) had a significant effect on the number of seeds per pod, while the main effect of Management and the interaction effect of Genotype by Environment (G x E) and Genotype by Environment by Management (G x E x M) had non-significant effect on number of seed per pod *(*Appendix Table 1).

The highest number of seed per pod (6) was recorded at Bambasi and Mandi from some genotypes which were lime untreated while the lowest total number of seed per pod (2) was recorded at Nedjo also from lime untreated soil (Table 4). This shows as application of lime by itself had no significant effect on the number of seed per pod. In line with this result, Fageria and Santos (2008) reported that the number of seeds per pod of different common bean genotypes varied in the range of 3.1 to 6 and attributed the difference due to the genetic variation of cultivars. In contrary to this finding, Buerkert *et al*., (1990) reported from his experiment conducted at four locations on bean that liming increased seed number per pod by 18%.

The analysis of variance also showed that the main effect of Environment, Management and Genotype and the interaction effect of Genotype by Management (G x M) had a significant effect on number of seed per plant while the interaction effect of Genotype by Environment (G x E), Environment by Management (E x M) and Genotype by Environment by Management (G x E x M) had non-significantly affected the number of seeds per plant (Appendix Table 1). The highest number of seeds per plant (55) was recorded at Bambasi from lime treated ALB 207 genotype while the lowest total number of seed per plant (6) was recorded at Nedjo from lime untreated ALB 25 genotype which indicated the response of genotype across management had a significant influence on the total number of seed per plant (Table 4).

On the other hand, analysis of variance showed that the main effect of Environment and Genotype and the interaction effect of Genotype by Environment (G x E), and Environment by Management (E x M) had a significant effect on hundred seed weight whereas the main effect of Management and its interaction with genotype as well as the Genotype by Environment by Management (G x E x M) interaction had no significant influence on hundred seed weight (Appendix Table 1). The highest hundred seed weight (22.18gm) was recorded at Mandi from lime treated BFS 39 genotype while the lowest hundred seed weight (12.22gm) was recorded at Assosa from lime untreated Roba genotype (Table 4). The result of combined analysis revealed that genotype ALB 179 had the highest hundred seed weight (19.19gm) on lime treated plots, whereas genotype Roba had the lowest hundred seed weight (13.45gm) on lime untreated plots. In general, application of lime to acidic soil across environment had increased hundred seed weight. Similar results have been reported by Hirpha (2013); stating as lime application increased hundred seed weight of common bean genotypes by about 3.54%.

Analysis of variance also showed that the main effect of Environment, Management and Genotype and the interaction effect of Genotype by Environment (G x E) and Environment by management (E x M) had a significant effect on aboveground biomass yield while the other interactions had non- significant effect on aboveground biomass (Appendix Table 1). The highest aboveground biomass yield (3.24t/ha) was recorded at Bambasi from lime treated ALB 212 genotype while the lowest aboveground biomass yield (0.41t/ha) was recorded at Nedjo from lime untreated ALB 149 genotype (Table 4). This result showed that the addition of lime to acidic soil as well as its interaction with environment had a paramount influence on above ground biomass yield of common bean across all the testing sites. Adding lime to the soil increased the above ground biomass yield over lime untreated ones. In agreement with this result, Caddel *et al*. (2004) reported that significant increase in dry mass yield (DMY) of alfalfa by liming was due to a number of factors including decreasing Al or Mn toxicity, improved nodulation and increased availability of Ca, Mo and P. Additionally, Fageria *et al*., (1990) also reported that addition of lime resulted in 40% dry matter increase in common bean.

Seed Yield

Analysis of variance for each environment revealed the presence of highly significant ($P \leq 0.01$) difference in seed yield among common bean genotypes tested at Assosa, Bambasi, Mandi and Nedjo (Appendix Table 1). This indicated the presence of performance variation among the tested genotypes for yield, which is supported by the earlier works of Kassaye (2006), Yayis *et al*, (2011) and Nigussie (2012), who noticed a large variation in yield performance among different bean genotypes.

Table 4. Yield and yield parameters of Fifteen Common bean genotypes

Entry	Genotypes	YLD		AGBM		HSW		SPPt		SPPd		PPT	
		LT	LUT	LT	LUT	LT	LUT	LT	LUT	LT	LUT	LT	LUT
1	ALB 212	1.02^{ab}	0.70^{defg}	1.9	1.61	18.28^{abcde}	18.31^{abcde}	32.08	23.25	4.25^{a-e}	3.58^{ef}	9^{ab}	6.58^{abc}
2	ALB 133	0.73^{cdefg}	0.66^{defgh}	1.34	1.37	15.47^{ij}	15.03^{j}	29.50	27.92	4^{a-f}	4^{abcdef}	7.92^{abc}	7.58^{abc}
3	ALB 163	0.82^{bcdef}	0.60^{fgh}	1.91	1.36	15.32^{ij}	14.93^{j}	27.08	24.58	4.42^{abcd}	4.75^{a}	7.33^{abc}	6.58^{abc}
4	ALB 204	0.83^{bcdef}	0.70^{defg}	1.69	1.59	19.02^{ab}	18.11^{abcde}	25.67	25.83	3.75^{cdef}	3.83^{cdef}	7.25^{abc}	7.17^{abc}
5	ALB 25	0.83^{bcdef}	0.60^{fgh}	1.66	1.33	16.89^{efgh}	16.38^{hi}	26.42	26.58	3.83^{cdef}	3.42^{f}	8.5^{abc}	7.67^{abc}
6	ALB 149	0.84^{bcdef}	0.74^{cdef}	1.4	1.29	18.1^{abcde}	17.04^{defgh}	31.67	28.33	3.58^{ef}	3.67^{def}	9.08^{ab}	8.5^{abc}
7	ALB 179	1.10^{a}	0.84^{bcdef}	2.13	1.44	19.19^{a}	18.67^{abc}	32.67	23.67	3.92^{b-f}	4.17^{a-f}	8.58^{abc}	6.58^{abc}
8	ALB 209	0.86^{bcd}	0.76^{cdef}	1.56	1.49	$17.8^{abcdefg}$	17.51^{cdefgh}	31.58	25.58	3.92^{b-f}	3.83^{cdef}	8.67^{abc}	7.42^{abc}
9	ALB 207	1.03^{ab}	0.77^{cdef}	2.05	1.57	17.56^{cdefgh}	17.91^{abcdef}	35.08	30.25	3.75^{cdef}	4.67^{ab}	9.42^{a}	8^{abc}
10	BFS 320	0.71^{cdefg}	0.77^{cdef}	1.44	1.51	16.42^{ghi}	16.62^{fghi}	24.92	31.42	3.92^{b-f}	4.17^{a-f}	6.58^{abc}	8.33^{abc}
11	BFS 35	0.85^{bcde}	0.89^{abcd}	1.73	1.73	18.82^{abc}	19.16^{a}	22.25	24.50	4^{a-f}	3.83^{cdef}	6.42^{abc}	6.25^{abc}
12	BFS 24	0.82^{bcdef}	0.62^{efgh}	1.8	1.49	18.47^{abcd}	18.38^{abcd}	25.75	19.50	4.25^{a-e}	4.33^{a-e}	6.25^{abc}	5.08^{bc}
13	BFS 39	0.90abcd	0.84^{bcdef}	1.86	1.83	18.17^{abcde}	18.05^{abcde}	25.00	26.58	3.75^{cdef}	4.03^{a-f}	7.58^{abc}	7.25^{abc}
14	Roba	0.50^{gh}	0.46^{h}	1.57	1.26	13.45^{k}	13.67^{k}	25.25	20.00	4.5^{abc}	4.25^{a-e}	7^{abc}	4.83^{c}
15	Nasir	0.94^{abc}	0.76^{cdef}	2.06	1.61	$17.6^{bcdefgh}$	18.31^{abcde}	27.58	27.75	4.42^{abcd}	4.17^{a-f}	6.5^{abc}	6.58^{abc}
	EM	0.85	0.71	1.74	1.5	17.35	17.21	28.17	25.72	4.02	4.05	7.74	6.96
	SEM		126.5		2.65		0.42		4.74		0. 23		1.15
	CV (%)		15.5		20.3		8.5		21.5		17.28		16.4

YLD= yield, AGBM= above ground biomass, HSW= hundred seed weight, SPPt= Seed per plant, SPPd= Seed per pod, PPT= Pod per plant, LT= Lime treated, LUT = Lime untreated, EM= Environmental mean, CV= Coefficient of variation. Means within the same letters are not significantly different from each other.

The combined analysis of variance (Table 5) for seed yield showed significant different (P≤0.01) among all main factors as well as all their interactions (Appendix table1). 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 so that they showed rank difference. Consequently, application of lime had a paramount influence on the mean performance of the genotypes across different testing environment, whereas genotypes responded differently to lime application across environment. In line with this finding, Kang (1988) showed that corn genotypes had responded differently across environment. From the present result, the effect of lime application on bean genotypes' performance across environment had a significant effect. Genotype ALB 179 gave the highest yield (1.10 t/ha) from lime treated plots whereas genotype Roba gave lowest seed yield (0.46 t/ha) from lime untreated plots. This result showed that application of lime to acidic soil resulted in yield increment over lime untreated ones. In agreement with this result, Hirpha (2013) reported 25.7% yield increment due to addition of lime over lime untreated soil. Further, Fageria *et al.*, (1991) also reported the increase of common bean grain yield by 45% due to liming on Oxisols. In this study generally, genotypes showed inconsistent performance in terms of seed yield across environment under both management regimes which indicated the presence of environmental influence on the performance of the genotypes.

Almost all genotypes performed better at Bambasi and Mandi under both management practices which indicated that the agro ecological condition of the both sites was better for the development of bean plant than the other two areas. In contrary to this, the genotypes performed poorly at Assosa and Nedjo under both soil regimes when compared to the other sites which might be due to the sever effect of soil acidity at both locations. This high soil acidity might limit the growth and development of the crop through inhibition of different physiological processes in addition to the differential performance of the genotypes across environment

Table 5 Combined ANOVA of yield for fifteen common bean genotypes

Source of variation	DF	MS
Environment	3	12851470**
Replication	8	188898
Management	1	1732959**
Residual	2	12924
Genotype	14	321241**
Management x Genotype	14	78048**
Management x Environment	3	804686**
Genotype x Environment	42	111906**
Genotype x Environment x Management	42	44268**
Residual	56	18687
Total	112	48005.5

*=significant difference ($p \leq 0.05$) and **= highly significant difference ($p \leq 0.01$).
Management =Lime treated and Lime Untreated; Environment=Location

(Table 3). These findings were supported by the findings of many authors. Firew (2002), Perreira *et al*., (2009) and Perreira *et al*.(2010) who indicated that bean genotypes can have different response and interact highly to environmental change, which was in contrary to the finding of Ribeiro *et al*. (2003).

The analysis of variance revealed that only the main effect of Environment and Genotype had a significant effect on harvest index while the Management and all the interactions were non-significant (Appendix Table 1). The highest harvest index (0.86) was recorded at Nedjo from lime treated ALB 179 genotype while the lowest harvest index (0.16) was recorded at Assosa from lime untreated ALB 212 genotype (Table 4). Neither the main effect nor the interaction effect of lime had a significant influence on harvest index of common bean, which implied that addition of lime to the soil had statistically no significant effect on harvest index. In line with this work, Tesfaye (2015) reported that Harvest index was not significantly affected by the main effects of lime and P fertilizer application rates.

Stability Analysis

Additive Main effects and Multiplicative Interaction (AMMI) Analysis

AMMI model provided the relative magnitude and importance of the effects of GEI and its interaction terms related with genotype and environmental effects. In this model, genotype with least ASV or have smallest distance from the origin are considered as the most stable, where as those which have highest ASV are considered as unstable (Purchase, 1997). The finding in this research revealed that different genotypes were evaluated by using AMMI stability model and gave different stability results based on their ASV values for both different soil management regimes. Accordingly, genotypes ALB 133, BFS 39, and ALB 179 were those genotypes considered as the most stable genotypes due to their lower ASV value on lime treated soils. On the contrary, genotypes BFS 24, ALB 207 and BFS 39 were those genotypes with smaller ASV value and then considered as stable genotypes on lime untreated soil (Table 7). Previously, different researchers used AMMI stability value as stability parameter to study the stability of grain yield and quality of different crops genotypes across various environments (Mohammadi and Amri, 2008; Mohammed, 2009; Mut *et al*., 2010).

The main effects of environment and genotype accounted for **56.83**% and 8.39%, respectively while G x E interaction accounted for 10.02% of the total variation in G x E data for bean seed yield on lime treated soils which indicated the environment contributed larger portion of the variation while genotypes contributed lesser extent. Similarly, on lime untreated acid soil, environment and genotype accounted for **64.12**% and 7.86%, respectively while G x E interaction accounted for 8.71% of the total variation in G x E. From this result, the large sum of squares for environments in both soil management regimes indicated that the environments have a great influence on common bean production in bean growing areas of western Ethiopia. The current research indicated that bean yield of genotypes was found to be significantly affected by changes in the

Table 6 AMMI analysis of variance for yield (t/ha) across the testing environments

Source		MS		Total variation explained (%)		G x E explained (%)		Cumulative	
		LT	LUT	LT	LUT	LT	LUT	LT	LUT
Total	179	234098	149034						
Treatments	59	534377**	364860**	75.24	80.69				
Genotypes	14	251186**	149770**	8.39	7.86				
Environments	3	7937765**	5702045**	**56.83**	**64.12**				
Block	8	515421**	101106*	9.84	3.03				
Interactions	42	99961**	55330ns	10.02	8.71				
IPCA 1	16	140046**	105869**			**53.37**	**72.89**	53.37	72.89
IPCA 2	14	75101*	30378*			25.04	18.30	**78.42**	**91.19**
Residuals	12	75517ns	17054ns						
Error	112	55821	38764						

DF= Degree of freedom, MS= Mean square, LT=Lime treated, LUT= Lime untreated, ns=non-significant, *&**= significant at p<0.05 and p<0.01 respectively

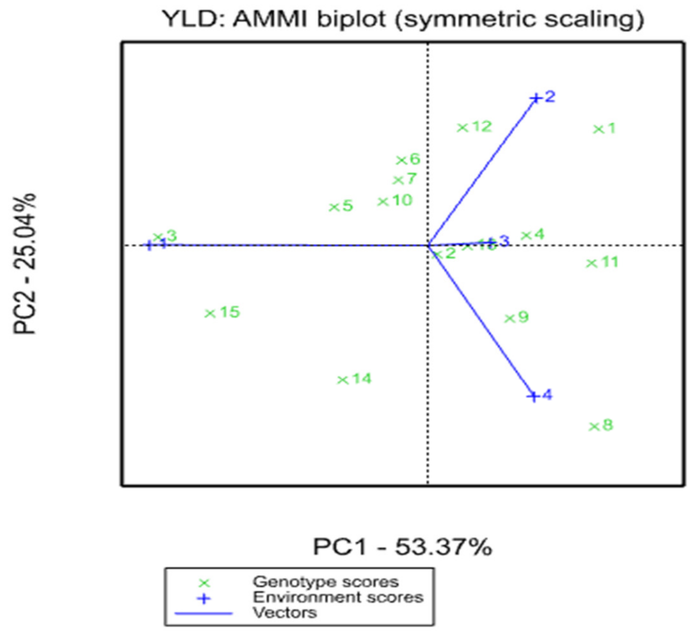
environment, followed by G×E interaction and genotypic effect. Thus, the large differences among environmental means causing most of the variation in bean yield were mainly due to environments.

The first two principal component axis of the interaction were significant for the model for both soil management regimes and the prediction assessment indicated that AMMI 2 with only two interaction principal component axes was the best predictive model (Zobel *et al*., 1988). The further interaction principal component axes captured mostly noisy and therefore do not help to predict valuable observations. Therefore, the interaction of fifteen genotypes with two different management measures across four locations was best predicted by the first two principal components of genotype and environments.

In AMMI 2 bi-plot, those genotypes which found closer to the origin were less sensitive to environmental change and are considered as stable genotypes across environment. On the other hand, those genotypes found far from the origin or center of the AMMI 2 bi-plot axis were more sensitive to environmental fluctuation and then considered as unstable. According to this, genotypes ALB 212, Roba, ALB 163, ALB 209, Nasir, ALB 209 and BFS 35 were found far from the origin of the AMMI 2 biplot of the lime treated soil and contributed considerably to the Genotype x Environment Interaction and then considered as unstable genotypes across testing environments when soil is treated with lime. On the other hand, genotypes ALB 133, ALB 204 and BFS 39 were those genotypes plotted relatively close to the origin and contributed less to the total GEI variance and then considered as stable across testing environments upon the application of lime (Fig.1). Similarly, genotypes ALB 207, ALB 209 and BFS 24 were those genotypes located closer to the origin of the AMMI 2 bi-plot and have contributed less to Genotype by Environment interaction and then considered as the most stable genotypes across all the testing environment on the soil with no lime application, whereas genotypes ALB 212, ALB 133, ALB 163 and Roba where those genotypes found far from the center of the biplot graph and then considered as unstable genotypes across all testing environments when the soil is not treated with lime (Fig.2). Based on the findings of this experiment, even though their yielding performance varies across both soil management regimes it could be possible to recommend genotypes ALB 179, ALB 207, ALB 209, BFS 35, BFS 39 and ALB 212 to be progressed to the next Variety trial for all environments with both management measures as they have wider adaptability. (Figure 1&2)

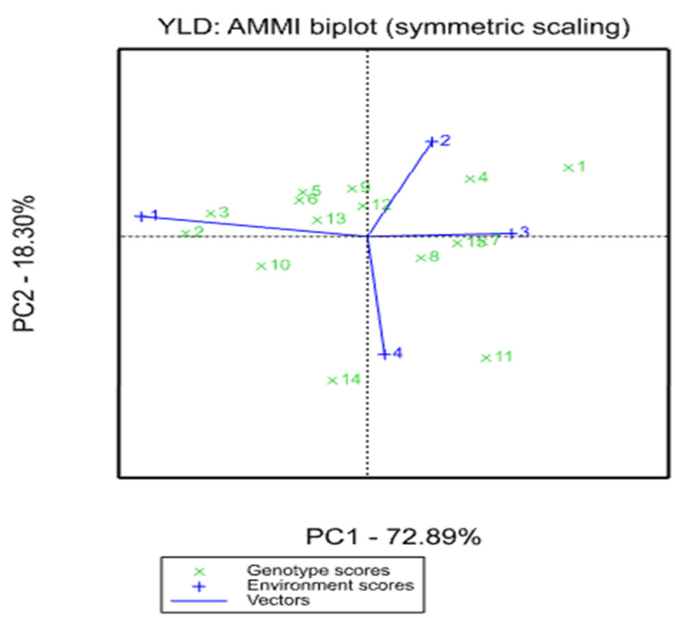
Lin and Binns Cultivar Superiority Measure (P*i*)

The superior genotype would be the one with the lowest P*i* value that the one which remained among the most productive in a given set of environments. Accordingly, the most stable genotypes with the lowest Pi value across all environments with treatment of acidic soil with lime ($CaCO_3$) were ALB 179, ALB 207 and ALB 212 which were ranked 1st, 2nd and 3rd in mean seed yield performance respectively (Table 7). Similarly, on the un limed plots genotypes BFS 35, BFS 39 and ALB 179 exhibited having lower cultivar superiority (pi) value and ranked 1st, 2nd and 3rd respectively on the mean seed



G1=ALB 212, G2= ALB133, G3= ALB 163, G4= ALB 204, G5= ALB 25, G6=ALB 149, G7=ALB 179, G8= ALB 209, G9= ALB 207, G10= BFS 320, G11= BFS 35, G12= BFS 24G13= BFS 39, G14= Roba, G15= Nasir

Figure 1. AMMI 2 biplot of IPCA1 Vs IPCA 2 Using seed yield data on lime treated soil.



G1=ALB 212, G2= ALB133, G3= ALB 163, G4= ALB 204, G5= ALB 25, G6=ALB 149, G7=ALB 179, G8= ALB 209, G9= ALB 207, G10= BFS 320, G11= BFS 35, G12= BFS 24G13= BFS 39, G14= Roba, G15= Nasir

Figure 2. AMMI 2 biplot of IPCA1 Vs IPCA 2 Using seed yield data on lime untreated soil

Table 7. Ranks of common bean varieties based on yield and various stability parameters

Genotypes	Yield		Rank		Wi		Rank		Pi		Rank	
	LT	LUT	LT	LUT	LT	LUT	LT	LUT	LT	LUT	LT	LUT
ALB 212	1.1	0.7	1	9	143105	146766	11	15	43952	55898	3	10
ALB 133	1.03	0.66	2	11	21375	120216	2	14	143710	70325	13	12
ALB 163	0.5	0.6	15	13	223941	100758	15	13	123999	84856	12	14
ALB 204	0.73	0.7	13	10	59669	58921	7	10	97951	48491	8	9
ALB 25	0.84	0.6	8	14	33822	19938	4	4	96626	75447	7	13
ALB 149	0.71	0.74	14	8	34741	21281	5	6	91856	34013	6	8
ALB 179	0.83	0.84	10	3	19818	44492	1	8	13627	13618	1	3
ALB 209	0.86	0.76	6	7	196835	20640	14	5	109342	23698	11	4
ALB 207	1.02	0.77	3	4	39134	7100	6	2	33134	25209	2	5
BFS 320	0.82	0.77	11	5	22421	45533	3	9	153877	29664	14	7
BFS 35	0.9	0.89	5	1	104140	87716	10	12	99714	7890	10	1
BFS 24	0.83	0.62	9	12	62684	3476	8	1	98714	64622	9	11
BFS 39	0.85	0.84	7	2	176322	9669	13	3	87672	13145	5	2
Roba	0.94	0.46	4	15	94021	61180	9	11	300908	134924	15	15
Nasir	0.82	0.76	12	6	167425	26929	12	7	72630	25267	4	6

Genotype	Si^1		Rank		Si^2		Rank		ASV		Rank	
	LT	LUT	LT	LUT	LT	LUT	L	LUT	LT	LUT	LT	LUT
ALB 212	4.17	7.5	8	15	10.9	38.25	8	15	23.42	53.39	12	15
ALB 133	2.83	6.5	4	14	4.92	27.58	4	14	1.39	47.99	1	14
ALB 163	6.5	5.67	14	12	32.3	25.67	14	13	34.29	41.39	15	13
ALB 204	5.17	5.67	10	13	18.9	20.67	11	12	12.57	27.57	9	9
ALB 25	3.67	3.67	7	7	8.67	9.67	7	7	12.25	17.42	8	6
ALB 149	3.17	2.67	5	5	6.92	4.67	5	5	7.23	18.2	5	7
ALB 179	0.67	4.5	1	10	0.33	17.58	1	11	6.19	30.53	3	11
ALB 209	7.17	3.33	15	6	24.3	6.67	13	6	25.22	14.3	13	4
ALB 207	1.5	1.17	2	2	32.9	0.92	15	1	11.81	5.74	7	2
BFS 320	3.5	4.33	6	9	1.58	12.67	2	9	6.6	28.1	4	10
BFS 35	5.67	4.83	12	11	7.58	15.58	6	10	20.91	33.01	11	12
BFS 24	5	1	9	1	23.3	1	12	2	9.93	2.86	6	1
BFS 39	5.33	2.5	11	4	16.3	4.25	9	4	5.06	13.35	2	3
Roba	1.83	2.17	3	3	18.7	3.58	10	3	14.85	15.31	10	5
Nasir	6.17	3.83	13	8	2.25	10.92	3	8	28.13	23.79	14	8

LT=Lime Treated, LUT=Lime Untreated, Wi=Wricke's ecovalence, Pi= Lin and Binns Cultivar superiority measure, Si1=mean absolute rank difference, Si2=variance of ranks, ASV=AMMI stability value

yield performance and thus considered as stable genotypes across all testing environment on acidic soils. These stable genotypes had least contribution to the total variation due to genotype by environment interaction. Similar result was reported by Lin and Binns (1988), Carbonell *et al.* (2004), Asrat *et al.* (2008), Pereira *et al.* (2009), Molla (2010).

Wricke's Ecovalence Analysis

According to this parameter, genotypes with lower ecovalence are less responsive to fluctuations across environments and contribute less to the GEI and thus are stable. Accordingly, the relatively stable genotypes across all testing environment on lime treated soil were ALB 179, ALB 133 and BFS 320 having lowest ecovalence value and ranked 1st, 13th and 14th in mean seed yield performance respectively. Whereas genotypes ALB 163, ALB 209 and BFS 39 were those genotypes that have the highest ecovalence value indicating that these genotypes contribute highest amount of variation to the total GEI variance and hence can be considered as unstable (Table 7). On lime untreated soils, genotypes BFS 24, ALB 207 and BFS 39 had lower ecovalence value and then contributed less to the total variation of the genotype by environment interaction being ranked 12th, 4th and 2nd in mean seed yield performance, whereas genotypes ALB 212, ALB 133 and ALB 163 were those genotypes with higher ecovalence value and considered as unstable. Dawit et al. (2012) also used this stability parameter to evaluate the stability of common bean genotypes.

Nassar and Huehn's mean Absolute Rank Difference and Variance of Ranks

According to this non-parametric stability analysis procedure genotypes ALB 179, ALB 207 and Roba were those genotypes with low estimates of mean absolute rank difference (Si^1) while genotypes ALB 209, ALB 163 and ALB 204 were those genotypes with higher mean absolute rank difference (Si^1) estimate from lime treated soil. Genotypes ALB 179 and ALB 207 were the genotypes with lower estimates of mean absolute rank difference (Si^1) as well as higher seed yield performance, therefore considered as the most desirable and stable genotypes across all testing environment with the application of lime to the acidic soils (Table7). Different researchers have reported similar results so far on bean genotypes (Dawit *et al*., 2012).

CONCLUSIONS

As per AMMI plot, genotypes ALB 207, BFS 39 and ALB 179 had higher yield and wider adaptation while genotypes BFS 35 and ALB 212 had high mean yield but specific adaptation to the specific environment. From the AMMI 2 biplot, Assosa was the most discriminating environment both for lime treated soil and lime untreated soil. Genotypes ALB 212, ALB 163, ALB 209, BFS 35, Nasir and Roba were the most responsive genotypes to change in environment on lime treated soil whereas genotypes ALB 12, BFS 35 and Roba were responsive genotypes on lime untreated soil. Genotypes ALB 179, ALB 207, ALB 209, BFS 35, BFS 39 and ALB 212 can be tested as National Variety trial and for future research stages for all environments with both management measures as they have wider adaptability.

REFERENCES

Ano, A. O. and Ubochi, C. I. 2007. Neutralization of soil acidity by animal manures: mechanism of reaction. *African Journal of Biotechnol*ogy, 6 (4): 364-368.

Bassetti, P. and Westgate M.E. 1994. Floral asynchrony and kernel set in maize quantified by image analysis. *Agronomy Journal*, 86:699-703.

Bordeleau LM, and Prevost D. 1994. Nodulation and nitrogen fixation in extreme environments. *Plant and Soil,* 161(1):115-125.

Broughton WJ, Hernández G, Blair M, Beebe S, Gepts P. and Vanderleyden J. 2003. Beans (*Phaseolus* spp.) - model food legumes. *Plant and Soil*. 252: 55-128.

Carbonell S.A.M., Azewdo F.J.A., Dias L.A.S., Garcia A.A.F. and Morais L.K. 2004.Common bean cultivar and line interaction with environments. *Scientia Agricola* 61(2):169-177.

Chapman, H. D. 1965. Cation exchange capacity by ammonium saturation. PP. 891-901. In: C. A. Black, L. E. Ensminger and F. E. Clark (Eds.). Method of soil analysis.m*American Society of Agronomy.* Madison Wisconsin, USA.

CSA (Central Statistical Agency), 2015. Agricultural Sample Survey 2014/15. Report on Area and Production of Crops (Privat3 Peasant Holdings, "Meher" Season), Vol. IV Statistical Bulletin 446, Addis Ababa

Debouck D.G. and Hidalgo R. 1986. Morphology of the Common Bean (*Phaseolus vulgaris L.*), Study Guide, CIAT, Cali, Colombia.

Fageria, N. K., Wright, R. G., Baligar V. C.and Carvalho, J. R. P., 1991. Response of upland rice and common bean to liming on an oxisol. Kluwer, Brazil.

FAO (Food and Agricultural Organization). 2008. Land and Plant Nutrition Management Service. Soil Problem Soils Database. Acid soils.

Fikru Mekonnen, 2007. Haricot ban (*Phaseolus Vulgaris* L.) variety development in the lowland areas of Wollo. Proceedings of the 2nd Annual Regional Conference on Completed Crops Research Activities 18 - 21 September 2007, Bahir Dar, Ethiopia, pp 86-93.

Firew Mekibib, 2002. Simultaneous selection for high yield and stability in common bean (*Phaseolus bulgaris*) genotypes. *Journal of Agricultural Science* 138: 249-253.

Girma Abebe. 2009. Effect of NP Fertilizer and Moisture Conservation on the Yield and Yield Components of Haricot Bean (*Phaseolus Vulgaris* L.) In the Semi-Arid Zones of the Central Rift Valley in Ethiopia. *Advances in Environmental Biology*, **3**: 302-307.

Haynes, R. J and Ludeck T. E., 1981. Effect of lime and phosphorus application on concentration of available nutrients and on P, Al and Mn uptake by two pasture legumes in an acid soil. *Plant and Soil*, 62: 117-128.

Hirpha, Legesse. 2013. Growth, Yield and Seed Quality of Common Bean (*Phaseolus Vulgaris* L.) Genotypes as influenced by Soil Acidity in Western Ethiopia. A PhD Dissertation Presented to the School of Graduate studies of Haramaya University.

Jackson, M. L. 1962. *Soil chemical analysis.* New Delhi, Prentice Hall of India Pvt. Ltd. 498p.

Kisinyo, P.O., Gudu S.O., Othieno C.O., Okalebo J.R. and Opala P.A. 2012. Effects of lime, phosphorus and rhizobia on Sesbania sesban performance in a Western Kenyan acid soil. *African Journal of Agricultural Research*, 7: 2800- 2809.

Kristin, A., Schneider, R., Rosales, S., Francisco, I., Benito, C., Jorge, A., Acosta-Gallegos, Porfirio., R, Nasrat, W and James, D.K. 1997. Improving Common Bean Performance under Drought Stress. *Crop Sci.,* **37**: 43-50.

Lin C. S. and Binns M. R. 1988. A superiority measure of cultivar performance for cultivar x location data. *Canadian Journal of Plant Science* 681:93-198.

Lunze L., Kimani P.M., Ngatoluwa, R., Rabary B., Rachier G.O., Ugen M.M., Ruganza V., and Awad Elkarim E.E. 2007. Bean improvement for low soil fertility in adaptation in Eastern and Central Africa. *In*: Bationo, A., Waswa, B., Kihara, J. & Kimetu J. (Eds.) Advances in integrated soil fertility management in sub-Saharan Africa: Challenges and Opportunities, pp. 325 – 332. Springer, Dordrecht, The Netherlands.

Maheshwari D. 2006. Soil acidity. Sandip patil: Department of Landscape architecture, CEPT University.

Mesfin Abebe. 2007. Nature and Management of Acid Soils in Ethiopia. Alamaya University of Agriculture.18 pp.

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

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

Nigussie Kefelegn, 2012. Genotype X Environment Interaction of Released Common Bean (*Phaseolus Vulgaris* L.) Varieties, in Eastern Amhara Region, Ethiopia. An MSc Thesis Presented to the School of Graduate studies of Haramaya University.

Okalebo, J. R., Othieno, C. O., Woomer, P. L., Karanja, N. K., Semoka, J. R. M., Bekunda, M. A., Mugendi, D. N., Muasya, R. M., Bationo, A. and Mukwana, E. J. 2006. Available technologies to replenish soil fertility in Eastern Africa. *Nutrient Cycling in Agro ecosystems*, 76: 153-170.

Okpara, D. and Muoneke C., 2007. Influence of lime on the performance of high-yielding soybean varieties in southern Nigeria. Agro-Science journal. ISSN:1119-7455

Olsen, S. R., Cole, C. W., Watanabe F. S., and Dean. L. A. 1954. Estimation of available phosphorous in soils by extraction with sodium bicarbonate. *Soil Sci*ence, 96: 308- 12.

Perreira H.S., Melo L.S., Faria L.C., Diaz J.L.C., Peloso D.M.J., Costa J.G.C. and Wendland A. 2009. Stablity and adaptablity of Carioca Common Bean Genotypes in States of Central South Region of Brazil. *Crop Breeding and Applied Biotechnology* 9:181-188.

Perreira H.S., Melo L.S., Faria L.C., Diaz J.L.C., Peloso D.M.J., Costa J.G.C. and Wendland A. 2009. Stablity and adaptablity of Carioca Common Bean Genotypes in States of Central South Region of Brazil. *Crop Breeding and Applied Biotechnology* 9:181-188.

Tesfaye, Dejene. 2015. Response of Common Bean (*Phaseolus Vulgaris* L.) to Application of Lime and Phosphorus on Acidic Soil of Areka, Southern Ethiopia. An MSc Thesis Presented to the School of Graduate studies of Haramaya University.

Teshale, Assefa, Girma, Abebe, Chemeda, Fininsa, Bulti, Tesso and Abdel-Rahman M. Al-Tawaha. 2005. Participatory Bean Breeding with Women and Small Holder Farmers in Eastern Ethiopia. *World Journal of Agricultural Sciences,* **1**: 28-35.

Walkley, A., and Black, I.C. 1934. An examination of the Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. Soil Science, 37: 29 -38.

Wortman, S. C., Kirkby, A. R., Eledu, A. C., and Allen, J. D. (Eds.). 2004. Atlas of common bean (Phasealus vulgaris L.) production in Africa. Cali, Colombia: International Centre for Tropical Agriculture, CIAT.

Wortmann, C.S. and C. A. Eledu. 1997. Distribution of bean types in Eastern Africa. *Annual Report of the Bean Improvement Cooperative,* 40: 30-31.

Yayis Rezene, Setegn Gebeyehu and Habtamu Zeleke. 2011. Genetic variability for drought resistance in small red seeded common bean genotypes. *African Crop Science Journal* 19(4):303 – 311

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