Evaluation of Released Improved Varieties of Common Bean for Acid Soils Tolerance at Mettu and Jimma, South Western Ethiopia

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Abstract

The study was conducted to identify common bean variety that tolerate acid soil or low pH soil. Fifteen (15) common bean varieties were grown in split plot design under four soil amendments with three replications at three locations in Western and South Western Ethiopia on strong acid soils. The results revealed that variety X amendments X locations X seasons interactions were significant (p<0.01) for both grain yield and plant height. Availability of varietal difference among common bean varieties under both amended and un-amended acid soil conditions was observed. The highest grain yield (1.043 t/ha) under control soil conditions obtained from this result is still below the national average (1.59t/ha), but more than the national average under lime and phosphorus treated plots (1.989t/ha), which showed that the selected variety is responded to lime and phosphorus than tolerant to acid soil. ER 119 variety showed similar performance across locations and years under recommended lime and phosphorus treated plots only. Generally, until tolerant variety is selected for resource poor farmers, SER 119 variety is selected for those farmers who have the capacity to apply lime with phosphorus based on the yield performance at both locations and also this variety is included in the future work of further selection trials. Also further study should be conducted by further introducing of additional varieties from abroad to determine their response to acid soil and to optimum lime and phosphorus fertilizers which can maximize the productivity of the crop and reduce soil acidity problem in the study area.

Keywords: Amendment, variety, soil Acidity, Lime, Phosphorus

Introduction

Common bean (*Phaseolus vulagris* ***L***), is locally known as Boleqe‘ also known as dry bean and haricot bean, is a very important legume crop grown worldwide and it is one of the most important and widely cultivated species of Phaseolus in Ethiopia. Its high protein content (20-25%) supplements diets of small holder farmers whose diet is based on cereals, root and tuber crops and banana; a balanced diet can be obtained if cereals and legumes are consumed in the ratio 2:1 (Broughton *et al*., 2003). 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).

The productivity of Common bean is very low, 1.69 tons/ha in Ethiopia (CSA, 2017). This low productivity of the crop is mostly due to lack of high yielding varieties adapted to diverse agro ecological conditions, low nutrients and adoption of better agronomic practices. 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, 2017) in the main season only. Differential responses of crop varieties to acidic soil conditions limit accurate yield estimates and identification of high yielding varieties.

Soil acidity is one of the most serious challenges to agricultural production worldwide, in general, and developing countries in particular. It is mostly distributed in developing countries, where population growth is fast and demand for food is increasing. According to Mesfin, (2007), about 40.9 % of the Ethiopian total land is affected by soil acidity. However, the recent study showed that about 43% of the Ethiopian arable land is affected by soil acidity (Ethiosis, 2014). In Ethiopia, vast areas of land in the Western, Southern, South-western, and North-western and even the central highlands of the country, which receive high rainfall, are thought to be affected by soil acidity (Mesfin, 2007) attributed to various factors including continuous cropping (in many areas mono-cropping) without the use of the required amount of inputs, and increasing use of ammonium based inorganic fertilizer, and; the problem of soil acidity in the country is apparently increasing both in area coverage and severity of the problem.

Increased soil acidity causes solubilization of Al^{3+}, which is the primary source of toxicity to plants at pH below 5.5, and deficiencies of P, Ca, Mg, N, K and micronutrients (Mesfin, 2007). Among these constraints, Al toxicity and Phosphorus deficiency are the most important ones, due to their ubiquitous existence and overwhelming impact on plant growth (Kochian *et al*., 2004), which limits crop growth and development that adversely affects crop production. Soil acidity is often an insidious soil degradation process, developing slowly, although indicators, such as falling yields, leaf discolorations in susceptible plants, lack of response to fertilizers may show that soil pH is falling to critical levels. The study areas are one of such areas with very strongly acidic soil. If it is not corrected, acidification can continue until irreparable damage takes in the soil. Therefore, the adjustment and maintenance of soil acidity is very important management of acidic soils to increase crop production using different mechanisms (approaches).

Lime and fertilizer management practices are primary importance for proper management of soil acidity. It is often not practicable for resource-poor farmers to apply high rates of lime, as well as, mineral fertilizers (Uguru *et al*., 2012).

Therefore, there is a need to develop practicable or the best alternative soil acidity mitigating strategy. For these reasons, development of common bean varieties adapted to acid soil is a promising alternative or supplement to liming and related agronomic practices. Low pH tolerance often coexists with tolerance to Al toxicity and low P (Liang *et al*., 2013). Tolerance levels have, however, been reported to be influenced by crop genetic background (Bona, 1994). Foy *et al*. (1993) reported the existence of wide genetic variability among and within the species in crops for tolerancetosoilacidity.AccordingtoRao(2001), the genetic improvement of crops fo r Al toxicity tolerance is a less costly complementary approach, for low fertility ag ricultural systems. Thus, selection of genotypes with high adaptability to acid soils is one of the best approaches to

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recommended (46 kg P2O5 $ha^{-1}$from Triple Super Phosphate) (Shahid *et al*., 2009) was applied at planting and mixed with the soil.

Statistical Analysis

The data was subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS Institute, 2012) 9.3 Version software using proc GLM procedure. List significant different(LSD) tests was used to separate significantly differing treatment means after treatment effects were found significant at $P \leq 0.05$.

Result and Discussion

Soil Sampling, Preparation and Analysis before Planting and After Harvesting

Prior to the field experimentation both undisturbed and disturbed samples were collected. Three undisturbed samples were taken by core sampler. Fresh weight and an oven dry weight at 105 ^{o}C, and used to determine bulk density (Baruah *et al*., 1997). Ten random disturbed composite soil samples (0-15 cm depth) were collected and a composite soil sample was made. The composite sample was used for soil chemical analysis, and for the determination of lime requirement of the soil. The disturbed soil samples were air dried, sieved to pass through 2 mm sieve, and placed in a labeled plastic bag and transported to Jimma Agricultural Research Center soil laboratory for analysis and the disturbed composite soil samples were analyzed for soil exchangeable acidity and soil pH. After harvesting, the soil samples were collected main plot-wise from each replication from the surface 0-15 cm depth, and composite samples were made for selected soil chemical analysis, and then the soil samples were air dried, sieved to pass through 2 mm sieve, and placed in a labeled plastic bags and submitted to JARC soil laboratory for soil chemical properties analysis. Exchangeable acidity was determined by saturating the soil samples with potassium chloride solution and titrates with sodium hydroxide as described by Mclean (1965).

Soil chemical Properties (pH and E.A) Prior to Planting at Mettu

Following the rating of pH of < 4.5 as extremely acidic, 4.5-5.0 very strongly acidic, 5.1-5.5 strongly acidic, 5.6-6.0 moderately acidic and 6.1-6.5 slightly acidic of soil status as indicated by (Foth and Ellis, 1997), the soil used for this study falls under the extremely acidic (pH 4.4) class indicating that the possibility of Al toxicity and deficiency of certain plant nutrients. The optimum pH range for legumes is generally reported to be between 6.6 and 7.5 (Johnston, 2004). Soybean and common bean has been found to do well in pH values of 5.5 – 7.0 and any pH below these values will affect its growth and needs amendments (Ferguson *et al*., 2006). This indicates that bean growth and yield is limited by low pH soil. Therefore, soil liming up to pH 6.5 to 7.0 is required for optimum yield and plant growth in bean (Havlin *et al*., 1999). Exchangeable acidity of the experimental soil was 2.72 cmol kg^{-1}, which indicates that the toxicity of some metal elements might affect growth of crops (Landon, 1991, Haynes and Mokolobate, 2001).

Performance of common bean varieties at individual location

There were highly significant differences among common bean varieties, seasons and amendments for grain yield and above ground biomass at Mettu. The interaction of amendments X variety X seasons was also highly significant for grain yield and above ground biomass at Mettu. At Mettu the highest grain yield (2703.7Kg/ha) was recorded with lime and phosphorus treated from SER 119 variety during the second year, and the lowest grain yield (242.2Kg/ha) was obtained from the control from Goberasha variety during the second year (Table 2). The result showed that application of lime with phosphorus to acidic soil resulted in yield increment over lime and phosphorus 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.

The highest aboveground biomass (6.44t/ha) was recorded from SER 119 variety under lime and phosphorus treated during the second year, while the lowest aboveground biomass (0.56t/ha) was recorded from Goberasha variety under control in the first year (Table 2). This result showed that addition of lime to acidic soil had a paramount influence on above ground biomass of common bean verities. In agreement with this result, Fageria *et al*., (1990) also reported that addition of lime resulted in 40% dry matter increase in common bean. Similar to Mettu at Jimma also, the variety, seasons and amendments were significantly different for grain yield and pod number per plant. The amendments X variety X season's interaction was also highly significant for number of pod per plant and grain yield at Jimma. Significantly higher grain yield (2073.4 and 2017.5 Kg/ha) was produced by variety SER 119 at Jimma under phosphorus treated alone and lime with phosphorus treated respectively during the second year(Table 3). Significantly higher pod per plant (18.47 and 17.8) was produced by variety SER 119 at Jimma under lime with phosphorus treated and phosphorus treated alone, respectively during the second year (Table 3).

Table 2: Mean values of grain yields and AGB as affected by interaction of amendments, varieties and season at Mettu

	Years	Yield Kg/ha				Agb t/ha			
Varieties		L	C	P	LP	L	C	P	LP
SER 119	Year 1	1181.7	396.3	1080.9	2159.5	2.22	0.69	1.82	4.12
	Year 2	1704.0	673.8	2257.5	2703.7	3.85	1.34	5.33	6.44
Naser	Year 1	1001.5	782.8	747.4	1637.1	2.08	1.22	1.53	2.68
	Year 2	1880.5	790.8	1648.7	2474.6	3.98	1.85	3.47	5.187
SER 125	Year 1	821.3	633.4	874.3	1604.7	1.29	1.29	1.77	3.01
	Year 2	1031.6	563.1	1977.8	2306.4	2.59	1.85	4.86	5.60
Gofat	Year 1	786.2	516.9	606.9	1529.3	1.20	0.93	0.93	2.36
	Year 2	1041.3	620.2	1632.6	2266.7	2.17	1.34	3.10	4.54
Roba	Year 1	579.2	239.7	501.9	1169.1	1.06	0.71	1.02	2.94
	Year 2	1526.1	730.3	1701.8	2235.4	3.33	1.57	3.89	5.74
Awash-1	Year 1	392.8	454.4	530.2	1038.3	0.74	1.44	1.16	2.50
	Year 2	1444.3	1864.4	2204.7	1963.2	3.05	4.17	3.98	5.69
Ayenew	Year 1	756.0	639.3	844.6	1277.8	1.94	1.29	1.48	2.13
	Year 2	1814.3	785.8	1730.1	2073.0	3.98	1.89	4.26	4.95
Melka	Year 1	1054.4	619.6	503.4	1090.1	1.75	1.22	1.02	2.13
	Year 2	1624.4	1322.7						

Performance of common bean varieties over amendments, seasons and locations

The analysis of variance showed that the main effect of location, amendment, seasons and Variety and the interaction effect of location X amendment X seasons X Variety had a significant effect on grain yield. The highest grain yield(2.73t/ha) was recorded at Mettu from combined lime with phosphorus treated SER 119 variety at second year of experiment (Table 4). The result of combined analysis revealed that variety SER 119 had the highest grain yield (1438 Kg/ha), whereas variety Awash Melka had the lowest grain yield (713.4 Kg/ha), and the result of combined analysis for individual amendment also revealed that variety SER 119 had the highest grain yield (1989.4Kg/ha) with lime and phosphorus treated, where as variety Goberasha had the lowest grain yield (541.2Kg/ha) without lime and P(control) soil condition. 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. In this study generally, common bean varieties showed inconsistent performance in terms of grain yield and pod per plant across location under both amended regimes which indicated the presence of environmental and amendment influence on the performance of the variety.

Table: 4 Over year combined mean value of grain yield (Kg/ha) of fifteen common bean varieties at individual location under different amendments.

Varieties	Mettu		Jimma		Combined	
	C	LP	C	LP	C	LP
SER 119	535.1	2431.6[a]	1238.1[abc]	1547.2[a]	886.6[abc]	1989.4[a]
SER 125	598.3[bc]	1955.5[bc]	1311.3[ab]	1405.6[abc]	954.8[abc]	1680.6[bc]
Naser	786.8[abc]	2055.8[ab]	965.2[cdef]	1352.2[abcd]	876.6[abc]	1704[b]
Ayenew	712.6[bc]	1675.4[cdef]	1211.3[abcd]	1509.5[ab]	962[abc]	1592.5[bcd]
Dimtu	714.7[bc]	1327.2[efg]	1371.9[a]	1329.9[abcd]	1043.3[a]	1328.6[efg]
Gofat	568.5[c]	1898.0[bcd]	947.2[cdef]	1232.1[bcd]	757.8[cde]	1565.1[bcde]
Melka	971.1[ab]	1491.8[defg]	1058.1[bcde]	1067.2[def]	1014.6[ab]	1279.5[fgh]
Roba	485[c]	1702.3[bcde]	1191.4[abcd]	1174.3[cde]	838.2[abc]	1438.3[cdef]
Bashbash	443.1[c]	1233.5[fgh]	1461.8[a]	1369.8[abc]	952.4[abc]	1301.7[fg]
GLP 2	689.8[bc]	1620.3[cdef]	918.9[def]	1238.9[bcd]	804.3[bcd]	1429.6[def]
Awash -1	1147.7[a]	1500.8[defg]	704.5[f]	781.8[f]	926.1[abc]	1141.3[ghi]
Dame	690.1[bc]	1121[gh]	992[cdef]	885.3[ef]	841.1[abc]	1003.1[ij]
Iboda	440.6[c]	1415.6[efg]	712.5[f]	857.6[f]	576.6[de]	1136.6[ghi]
Goberasha	391.8[c]	1228.3[fgh]	690.6[f]	872.9[f]	541.2[e]	1050.6[hij]
Awash Melka	397.6[c]	889[h]	779.3[ef]	787.6[f]	588.4[de]	838.3[j]
Mean	**638.25**	**1569.74**	**1036.94**	**1160.799**	**837.566**	**1365.38**
Level significant	*	**	*	**	**	**
LSD	**397.55**	**427.07**	**304.85**	**291.75**	**233.9**	**249.41**
CV	**37.246**	**16.266**	**17.577**	**15.027**	**16.77**	**10.9223**

Where, C=control, LP= Lime with phosphorus treated, CV= coefficient of variation, LSD= list significant different, Note: Means with the same letters are statistically not significant (p>0.05) different from each other

Table:7 Over year and amendment combined mean value of grain yield (Kg/ha) of fifteen common bean varieties at individual location.

Varieties	Mettu	Jimma	Combined
SER 119	1483.3[a]	1392.6[ab]	1438.0[a]
SER 125	1276.9[abc]	1358.4[abc]	1317.7[ab]
Naser	1421.3[ab]	1158.7[cd]	1290.0[ab]
Ayenew	1194.0[abcd]	1360.4[abc]	1277.2[ab]
Dimtu	1021[cdef]	1350.9[abc]	1185.9[bc]
Gofat	1233.3[abcd]	1089.6[de]	1161.5[bc]
Melka	1231.4[abcd]	1062.6[de]	1147.0[bc]
Roba	1093.6[bcdef]	1182.8[bcd]	1138.2[bc]
Bashbash	838.3[efg]	1415.8[a]	1127.1[bc]
GLP 2	1155.1[abcde]	1078.9[de]	1117.0[bcd]
Awash -1	1324.2[abc]	743.2[f]	1033.7[cde]
Dame	905.6[defg]	938.6[ef]	922.1[efg]
Iboda	928.1[defg]	785.1[f]	856.6[efg]
Goberasha	810[fg]	781.7[f]	795.9[fg]
Awash Melka	643.3[g]	783.4[f]	713.4[g]
Mean	**1103.956**	**1098.872**	**1101.414**
Level significant	**	**	**
LSD	**331.07**	**219.38**	**207.47**
CV	**17.93**	**11.94**	**11.26**

Where, CV= coefficient of variation, LSD= list significant different, Note: Means with the same letters are statistically not significant (p>0.05) different from each other

Tolerance and Susceptibility Index of Common bean Varieties to Acid Soils

Variability for soil acidity tolerance and susceptibility among common bean varieties has been observed in this study (Table 8). The tolerance and susceptibility rating of specific entries depended upon the particular criterion (based on observed characters) used to denote their tolerance and susceptibility. Compared with other varieties, variety SER 119 produced the highest tolerance values based on grain yield, which showed statistically non significant different with other some varieties i.e. Ayenew , Bashbash, Dimtu, Naser and SER 125(Table 8). In general, even if SER119 variety showed high tolerant value, this variety fail to reach national average under control soil condition, but more than national average under recommended lime and phosphorus treated soil condition, which showed this variety is well responded to lime and phosphorus than tolerant to acid soil condition.

Table 8. Tolerance and susceptibility index of common bean varieties for yield at individual locations and combined on acid soil

Locations	Jimma		Mettu	Combined	
Varieties	TI	SI	TI	TI	SI
Bashbash	1.853[a]	-0.070[ab]	1.353	1.77[a-d]	0.270[cd]
SER 119	1.777[ab]	0.1970[ab]	3.23[a-d]	2.513[a]	0.150[d]
Ayenew	1.74[ab]	0.210[ab]	3.17[a-d]	2.270[abc]	0.41[abc]
SER 125	1.693[ab]	0.020[ab]	2.97[a-d]	2.29[ab]	0.43[abc]
Dimtu	1.67[abc]	-0.063[ab]	2.42[a-e]	1.990[a-d]	0.203[d]
Roba	1.31[bcd]	-0.010[ab]	2.103[b-e]	1.750[bcd]	0.42[abc]
Naser	1.217[cde]	0.280[a]	4.017[ab]	2.123[abc]	0.483[ab]
Gofat	1.08[de]	0.270[ab]	2.81[a-e]	1.703[bcd]	0.527[a]
Melka	1.06[de]	0.013[ab]	3.527[abc]	1.85[a-d]	0.203[d]
GLP 2	1.057[def]	0.243[ab]	2.77a-e	1.647[b-e]	0.447[abc]
Dame	0.82[efg]	-0.137b	2.00[b-e]	1.230[d-g]	0.170[d]
Iboda	0.58[fg]	0.183[ab]	1.67[cde]	0.933[efg]	0.487[a]
Awash Melka	0.560[g]	-0.030[ab]	0.84[e]	0.703[g]	0.293[bcd]
Goberasha	0.557[g]	0.1830[ab]	1.23[de]	0.81[fg]	0.473[ab]
Awash -1	0.520[g]	0.070[ab]	4.24[a]	1.517[c-f]	0.550[a]
Mean	**1.165**	**0.085**	**2.53**	**1.673**	**0.366**
Level significant	**	**NS**	*	*	**
LSD	**0.47**	**0.3819**	**2.0184**	**0.7656**	**0.1911**
CV	**24.51**	**26.9**	**47.88**	**27.44**	**31.29**

Where, TI=tolerance index, SI= Susceptibility index, CV= coefficient of variation, LSD= list significant different, Note: Means with the same letters are statistically not significant ($p>0.05$) different from each other

Recommendation and Conclusion

Overall, the current study revealed that the availability of varietal difference among common bean varieties under both amended and unamended acid soil conditions. The highest grain yield recorded (1.043 t/ha) from the control treatment is by far below the national average (1.59 t/ha), but under lime and phosphorus treated plots higher than (1.989 t/ha) the national average, which shows that the variety was responded to lime and phosphorus than tolerant to acid soil. Increasing yield and pod number in lime and phosphorus treated plot, were found in some common bean varieties. Variety of SER 119 was the tolerant variety based on the ASAI (acid soil adaptability index) for yield based on combined analysis tolerant index and showed high yields under control soil condition at Jimma. These two characters cannot be enough to use as the criteria of common bean tolerance in low pH or acid soil toxicity. Tolerance criteria may be laid on root parameter i.e. root length, number of lateral roots, and root dry weight, because of the use of root parameter as a criterion in common bean tolerance in low pH or acid soil toxicity should be studied further to ensure the increasing root elongation, number of lateral roots and nutrients uptake to support its tolerance. So the root data should be considered during data collection for the future.

In this study, common bean varieties showed inconsistent performance in terms of grain yield across location under both amended regimes, even if the same varieties at the same location showed inconsistent performance over the year, which indicated the presence of weather climatic, environmental and amendment influence on the performance of the variety, except SER 119 variety which showed similar performance across locations and years under recommended lime and phosphorus treated plots only. Generally, until tolerant variety is selected for resource poor farmers, SER 119 variety is selected for those farmers who have the capacity to apply lime with phosphorus based on the yield performance at both locations and also this variety is included in the future work of further selection trials.

References

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.

Delhaize E, Gruber D and Ryan R. 2007. The roles of organic anion permeases in aluminium resistance and mineral nutrition. Febs Letters, 581: 2255-2262.

Ethiosis. 2014. Soil fertility mapping and fertilizer blending. Agricultural Transformation Agency (ATA) Report, Ethiopia soil information system (Ethiosis).Ministry of Agriculture, Addis Ababa.

Fageria K and C Baligar. 2008. Ameliorating soil acidity of tropical Oxisols by liming forsustainable crop production. Advances in agronomy, 99: 345-399.

Foy D, Shalunova P and Lee H. 1993. Acid soil tolerance of soybean (Glycine max L.Merr.) germplasm from the USSR. Journal of plant nutrition, 16:1593-1617.

Hirpa L, Niguse D, Setegn G, Geremew B and Firew M. 2013. Response to soil acidity of common bean genotypes (Phaseolus vulgaris L.) under field conditions at Nedjo, western Ethiopia. Science, Technology and Arts Research Journal, 2: 03-15.

Kochian V, Hoekenga A and Pineros A. 2004. How do crop plants tolerate acid soils? Mechanisms of aluminum tolerance and phosphorous efficiency. Annu. Rev. Plant Biol., 55:459-493.

Liang C, Pinero's A, Tian J, Yao Z, Sun L, Liu J, Shaff J, Coluccio A, Kochian V and Liao H. 2013. Low pH, aluminum, and phosphorus coordinately regulate malate exudation through GmALMT1 to improve soybean adaptation to acid soils. Plant Physiology, 161:1347-1361.

Mesfin A. 2007. Nature and management of acid soils in Ethiopia. Addis Ababa, Ethiopia. 99p.

Rao M. 2001. Role of physiology in improving crop adaptation to a biotic stresses in the tropics: The case of common bean and tropical forages. Hand book of plant and crop physiology, pp.583-613.

SAS (Statistical Analysis System) soft ware. 2012. Version9.3, SAS institute, Cary, NC, USA

Shahid Q, Saleem F, Khan Z and Anjum A. 2009. Performance of soybean (Glycine max L.) under different phosphorus levels and inoculation. Pakistan Journal of Agricultural Sciences, 46: 237 - 241.

Uguru I, Oyiga C and Jandong A. 2012. Responses of some soybean genotypes to different soil pH regimes in two planting seasons. The African Journal of Plant Science and Biotechnology, 6: 26-37.

Von Uexkull R and Mutert E. 1995. Global Scienrt, d15(lev)rom41(g)6(enn)7(t)-Tc[an)-4(d)-5( )MCcotechnomc i