International Invention of Scientific Journal

Available Online at http://www.iisj.in

- eISSN: 2457-0958

Volume 05 | Issue 04 | April, 2021 |

The effect of soil acidity on yield and yield related traits of soybean genotypes

Corresponding Authors: Molla Malede[1], Berhanu Abate[2], Mulugeta Atinaf[3]

[1]Soybean variety improvement, Pawe agricultural center EIAR, Pawe, Ethiopia

[2]Hawassa University Plant and horticultural science, Hawassa, Ethiopia

[3]Rice variety improvement, Fogera agricultural center EIAR, Fogera, Ethiopia

Article Received 25-02-2020, Accepted 05-04-2021 , Published 10-04-2021

ABSTRACT

Soybean production and productivity are affected by biotic and abiotic stresses. Among those factors, Soil acidity is one of the limiting factors for the production of soybean in northwestern Ethiopia. Therefore, this experiment was conducted to determine the effects of soil acidity on, soybean yield, to investigate genotype responses to limed and acidic soil, and identify high-yielder soybean genotypes at acidic soil conditions. A pot experiment consisting of thirteen soybean genotypes and four improved varieties was done using a split-plot design with three replications. Limed (pH 5.8) and acidic soil (pH 4.5) considered as the main plot factor and genotype as subplot factor. Analysis of variance confirmed that there were highly significant differences between soil, among genotypes and genotypes × soil interaction for the number of pods plant^{-1}, grain yield plant^{-1}, and harvest index. The extent of soil acidity effects on yield-related traits had significantly varied from genotype to genotypes. Generally, Soil acidity was reduced grain yield, pod numbers, pod dry weight, seed numbers, hundred seed weight, biomass yield plant-1, and harvest index of soybean by 45.9, 39.2, 43.1, 44.6, 5.3 33.3, and 17.4% respectively. Genotypes Tgx-1990-87F, Tgx-1989-42F, Tgx-1990-101F, and Tgx-1987-45F had high grain yield plant-1 at both soil conditions with minimum yield reduction as compared as to the average percent of yield reduction due to soil acidity. Therefore, better to test these genotypes under acidic field conditions in Ethiopia to verify the findings from a pot experiment.

Keywords: Genotype, Percent of Reduction, Soil Acidity effects, Soybean, Yield

1. INTRODUCTION

Soybean (Glycine max (L.) Merrill) is one of the most necessary crops within the world and has higher protein content than the other pulses (Giller and Dashiell, 2007). In Ethiopia, Soybeans is produced on more than 64,720.12 ha annually with national average yield of 23.1 tons ha^{-1} (CSA, 2019**)**. The significant soybean delivering zones are North Western and South Western parts of the country; Amhara, Benishangul Gumuz, and some parts of Oromia region which account 99.6% of production. There is a yield gap at farmers' field as compared with the research. These resulted from utilization of improper agricultural inputs, biotic and abiotic stresses, limited availability of seed (limited seed company engagement in this crop) and poor extension services (Atnaf *et al*., 2015).

Soil acidity is one of the edaphic factors affecting adversely the growth and productivity of soybean (Villagarcia *et al*., 2001). Acid soils limit crop production on 30-40% of the world's cultivable land and up to seventy percent of the world's probably cultivable land (Haug, 1983). Soybean development in acidic soil is limited by low pH (< 5.5), low cation exchange capacity (CEC), and poor microorganism activity (Utama, 2008). The poor fertility of acid soils is because of a mixture of mineral toxicities of aluminum and manganese and deficiencies of phosphorus, calcium, and molybdenum. Major constraint of soybean in acid soil is Al toxicity which inhibits the cell division and elongation, shortens root growth and affects absorption of water and nutrient (Zheng, 2010). Optimizing the development and productivity of soybean in acid soils can be performed through soil amendment with lime for optimal plant growth, or using soybean varieties adaptive to low soil pH. Soil amending though liming is less practical; required large quantities of lime, locally unavailability and frequent application (The *et al.*, 2006; Ezeh *et al*., 2007), slow mobility and the difficulties of mechanical incorporation into the sub soil with traditional farm equipment for small scale farmers (Wang *et al.*, 2006). Therefore, provision of soybean varieties adaptable to acid soil sounds more; because the availability of these variety is cost effective and applicable for long years. So far in Ethiopia, information on variety response to soil acidity and soil acidity effects on soybean is lacking. Most of the released soybean varieties were tested primarily for optimal growing conditions. So, the objective of this study was to determine the effect of soil acidity on yield and related traits, to investigate genotype responses to limed and acidic soil conditions and identify high yielder genotypes at acidic soil condition.

2. MATERIALS AND METHODS

2.1. Description of the study area

The experiment was carried out at Pawe Agricultural Research Center (11018`49.6``N and 036024`29.1``E) which is found in Benishangul Gumuz Regional State in Metekel Zone. It is located about 570 km away from Addis Ababa, the capital city of Ethiopia. The altitude of the site is between 1120 m.a.s.l. The soil type of the site is well-drained clay soil with a pH value of 4.3 -5.5. The site receives 1586mm rainfall annually. The mean annual maximum and minimum temperatures are 32.60c and 16.50c, respectively.

2.2. Experimental materials

Seventeen medium maturing soybean genotypes were used for this study. The 13 soybean promising genotypes were introduced in 2013from the International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria. These materials were selected on soybean national trails due to their outstanding yield performance. And four nationally released varieties. These materials were selected because they are recently released and high yielder than the rest of medium maturing varieties.

2.3. Analyses of Soil Physical and Chemical Properties

The soil physical and chemical properties were analyzed at Pawe Agricultural Research Center Soil Analysis Laboratory, Pawe and Horti-coop Soil and Water Analysis Laboratory, Debere Zeit.Soil physical and chemical properties were analyzed: soil texture hydrometric method (Bouyoucos, 1951), organic carbon, and organic matter Walkley and Black method (Walkley and Black, 1934), pH 1:2.5 soil to water ratio method (Schofield and Tailor,1951), Exchangeable acidity and Exchangeable Al^{3+}(1N KCl Extraction method), Cation exchange capacity (CEC) ammonium acetate method, total Nitrogen (TN) ES ISO 11261:2015 (Kjeldahl Method), electric conductivity (EC) ES ISO 11265: 2014 (1:5), availability of soil Calcium (Ca), Potassium (K), Magnesium (Mg), Phosphors (P), Sulfur (S), Silicon (Si), Molybdenum (Mo), Boron (B), Copper

(Cu), Iron (Fe), Manganese (Mn) and Zinc (Zn) by Mehlich-3 methods.

2.4. Experimental design and procedures

The study was a two-factor pot experiment which had soil factor with two levels (acid and limed soils) and 17 genotypes. The design was split plot, the soil factors assigned on main plot and the genotypes were laid on subplot with three replications in lathe house of Pawe Agricultural Research Center. In this experiment, plastic pots with 28cm in diameter and the capacity of 10 kg soil were used. Planting was done seven days after applying 72.92g quick lime (Calcium oxide) per pot. At planting, 0.62g Di-ammonium phosphate (DAP) fertilizer was applied per pot. Six seeds with uniform size were planted at a depth of 5cm in each pot and thinned to three at trifoliate leaf. The water run out through perforated bottom of the pots was used again to minimize loss of nutrients through leaching.

2.5. Data collected

Phenological traits: Days to 50% flowering: Number of days to flowering was counted from date of planting to date when plants in each pot started flowering, while days to 95% maturity was calculated from date of planting to the date of physiological maturity.

Yield and yield contributing traits: Number of pods plant^{-1} was calculated from all pods harvested at physiological maturity from each pot and averaged to the number of plants, whereas number of seeds pod^{-1} was determined as seeds harvested from each pot at physiological maturity were counted and averaged to the number of pods harvested from each pot. 100 seed weight (g) was measured using 100 seeds counted indiscriminately from the harvested seeds of each pot and grain yield plant^{-1} (g) was determined by weighting seeds harvested from each pot and averaged to the number of plants.

2.6. Statistical analysis

Analyses of variance (ANOVA) on all measured characters were performed by SAS 9.3 software and the variations were quantified using the following model.

$$Y_{ijk} = \mu + G_i + E_j + (GE)_{ij} + R_k + G_R + e_{ijk} [1]$$

Where μ= grand mean, G_i=effect of genotype i, E_j= effect of environment (soil) j, $(GE)_{ij}$= effect of genotype and soil interaction, R_k= effect of replication k; G_R= error a, and e_{ijk}= error term

3. RESULTS AND DISCUSSIONS

3.1. Effect of liming on soil chemical properties

Laboratory analysis (Table 1) revealed that liming changed soil pH from 4.5 to 5.8, available P from 6.05 to 6.38, exchangeable acidity from 1.285 to 0.161, exchangeable Al3+ from 1.04 to 0.08, exchangeable cations (K+ 84.54 to 88.23, Mg2+ 634.1 to 647.6 and Ca2+ 1823.45 to 2683.35). The content of available micronutrients was also changed such as Zn from 0.42 to 0.62, Fe 50.26 to 46.5, S 22.37 to 23.6, Mo 0.28 to 0.3, B 0.05 to 0.08, and Mn 84.1 to 54.46. These results were comparable with the results of Buni (2014) who reported that lime application significantly increased available phosphorus, soil pH, and reduced exchangeable acidity, available Fe, Mn, and Zn. Yaregal Damite (2018) also reported the presence of significant increment in available P, K+, Ca2+, pH, B, S, and Mg2+ and decreased exchangeable acidity, electric conductivity, Fe, and Mn in response to the lime application on acidic soil.

Table 1: Physical and chemical properties of soil before planting and after limed

S. No.	Parameters and unit	Acidic	Decision	Limed	Decision
1	pH	4.5	V. Strong acid	5.8	M. acidic
2	Ex. Acidity (mg/100gsoil)	1.285	-	0.161	-
3	OM %	1.978	Low	2.126	low
4	OC %	1.147	Low	1.233	low
5	Ava. P(ppm)	6.05	Low	6.38	low
6	N (%)	0.1	Low	0.1	low
7	K^{+}(ppm)	84.54	low	88.23	low
8	Ca^{2+}(ppm)	1823.45	moderate	2683.35	high
9	Mg^{2+}(ppm)	634.11	high	647.6	high
10	S(ppm)	22.37	moderate	23.6	moderate
11	Fe(ppm)	50.26	low	46.5	low
12	Al^{3+}(mg/100gsoil)	1.044	-	0.08	-
13	Mn(ppm)	84.06	high	54.46	high
14	Zn(ppm)	0.42	low	0.62	low
15	B(ppm)	0.05	low	0.08	low
16	Cu(ppm)	4.36	moderate	4.35	moderate
17	Mo(ppm)	0.28	moderate	0.3	moderate
18	CEC (mg/100gsoil)	25.29	moderate	25.2	moderate
19	EC (ms/cm)	0.03	low	0.08	low
20	Soil texture (%)	Clay (90%)	Silt (6%)	Sand (4%)	

Where, OM= organic matter, OC= organic carbon, V. very, M. = moderate and Ex. = exchangeable

3.4. Yield and yield components of soybean genotypes

Soil conditions had a significant effect on days to maturity (Table 2). The genotype, genotype by soil interaction also had highly significant effects on this trait. At limed soil, had an average day to maturity of 98 days as compared to 95 days for acidic condition. The analysis of variance results (Table 3) confirmed that the number of pods plant^{-1} was highly significantly affected by genotypes x soil interaction effects. This indicated that the presence of genetic variability in a number of pods plant^{-1} among the tested 17 genotypes for soil acidity response. Similar results were reported by Ojo et al., 2010; Kuswantoro, 2015 and Kuswantoro, 2017. However, Fageria *et al*. (2012) reported no significant genotype by soil acidity interaction effects on the number of pods plant^{-1}.

The mean number of pods plant^{-1} under both limed and acidic soil conditions is presented in (Table 2). The effect of soil acidity on the numbers of pods had highly significant and the percent of reduction ranged from 27.11 to 53.56%. Relative minimum pod reduction due to soil acidity was observed on Tgx-1990-95F, Tgx-1987-45F, Wogayen, Tgx-1993-4FN, and Korme (Table 3). The lowest number of pods was found on Wogayen and Korme at both soil conditions Even if a low percentage of the reduction in this trait was recorded. Comparatively, the highest performance in numbers of pods at acidic soil and relative higher performance at limed soil was found on Tgx-19934FN, Tgx-199078F, Tgx-1987-45F, and Tgx-1990-95F. Overall genotype, the average number of pods plant^{-1} reduced due to soil acidity was 39.2 percent. In the previous study, 20 percent on common bean (Hirpa Legesse *et al*., 2013), 42.2 (Uguru *et al*., 2012), 9.5 (Adie and Krisnawati, 2016) percent of pod reduction due to soil acidity were reported on soybean genotypes.

A highly significant genotypic, soil and genotypes by soil interaction variation in pods dry weight plant^{-1} was observed in this study (Table 2). The percent of pods dry weight reduction due to soil acidity had ranged from 35.2 to 56.4 percent (Table 3). The top nine soybean genotypes which had low pod dry weight reduction due to soil acidity in comparison with the overall genotype mean were Tgx-1987-45F, Wogayen, Tgx-1989-42F, Tgx-1990-47F, Tgx-1990-87F, Tgx-1993-4FN, Tgx-1990-95F, Tgx-1990-101F, and Gizo.

Among those, genotype Tgx-1990-87F had the highest pod dry weight at both limed and acidic condition, Tgx-1990-101F ranked 3rd at limed and 2nd at acidic, and Tgx-1989-42F ranked 2nd at acidic and 5th at limed soil condition with a relatively low percentage of reduction in pod dry weight 37, 40, 35.74% respectively. On the other hand, Gizo and Wogayen had low pod dry weight reduction due to acidity but low in pod dry weight production in both soil conditions. In general, Pod dry weight plant^{-1} was declined by 43.1 percent due to soil acidity in this experiment. In the previous study, 60.4 percent of pod weight reduction due to soil acidity was reported on soybean (Uguru *et al.*, 2012).

Table 2: Mean squares of yield and yield component of 17 soybean genotypes

Source of Variation	DF	DM	PPP	PW	NSPP	SPPd	HSW	BY	GY	HI
Block	2	1.07^{ns}	0.85 ^{ns}	0.10 ^{ns}	12.64 ^{ns}	0.01 ^{ns}	1.65 ^{ns}	0.90 ^{ns}	0.006 ^{ns}	0.0002 ^{ns}
Soil condition	1	165.69*	1902.36**	228.75**	9589.42**	0.90 ^{ns}	7.31 ^{ns}	258.25**	104.04**	0.167**
Main plot Error	2	5.36	0.75	0.01	27.38	0.13	1.48	0.58	0.006	3.50E-05
Genotype	16	175.73**	73.98**	6.71**	170.96**	0.11 ^{ns}	12.15**	5.38**	2.12**	0.0086**
Genotype*soil	16	6.58**	11.20**	0.90**	35.24 ^{ns}	0.06 ^{ns}	1.22 ^{ns}	1.40**	0.39**	0.0054**
Sub plot Error	64	2.31	0.45	0.06	24.63	0.06	0.93	0.34	0.02	0.001
Mean		96.67	17.73	5.45	33.84	1.91	9.72	7.96	3.39	0.42
CV		1.60	3.77	4.3	14.69	12.9	9.92	7.33	4.1	6.21
R^2		0.95	0.99	0.99	0.89	0.5	0.79	94	0.99	0.90

DF= degree of freedom, DM=days to 95% maturity, PPP= numbers of pods per plant, PW= pods dry weight plant^{-1}, NSPP = numbers of seeds plant^{-1}, SPPd= numbers of seeds pod^{-1}, HSW= 100 seeds weight, BY = above ground biomass yield plant^{-1}, HI= harvest index and GY= grain yield plant^{-1}, ns**,** ***** and ****** = non-significant, significant at 5% and 1% alpha levels of significant, respectively.

The number of seeds plant^{-1} was varied highly significantly between soil conditions and at the genotypic levels (Table 2). The number of seeds plant-1 was ranged from 28.89 to 56.56 on limed soil, and from 15.33 to 29.78 on acidic soil (Table 4). Genotype Tgx-1904-6F, Tgx-1990-101F, and Tgx-1989-42F on limed soil, Tgx-1990-101F, Tgx-1987-45F, Tgx-1990-95F, Tgx-1990-87F and Tgx-1989-42F on acidic soil produced the highest number of seeds plant^{-1}, while Korme Wogayen and Gizo on limed soil, Korme, Tgx-1990-107FN and Wello on acidic soil gave lowest grain yield plant^{-1}. The effects of soil acidity on the numbers of seeds were great as compared to other yield-related traits in this experiment. The extent of seed reduction ranges from 34.4 to 55.4 percent depending upon the genotypic response to soil acidity. On average, the number of seeds plant^{-1} was reduced by 44.56 percent due to soil acidity (Table 4).

Hundred seed weight was highly significantly different only among genotypes (Table 2). This result is in line with the finding reported by Ojo et al., 2010 and Kuswantoro, 2015. Hundred seeds weight was ranged from 7.17g to 12.67g on limed soil, and from 7g to 12g on acidic soil

(Table 4). Genotype Tgx-1990-107FN, Tgx-1990-78F, Tgx-1990-87F, and Tgx-1989-11F on limed soil, Tgx-1990-78F, Tgx-1990-87F and Tgx-1990-107FN on acidic soil had the highest hundred seed weight. Due to soil acidity, on average hundred seeds weight was decreased 5.3%. On the other hand, 3.8 to 14.2 percent of increment in 100 seeds weight was obtained on genotypes Tgx-1990-101F, Tgx-1904-6F, Tgx-1990-101F Tgx-1990-47F, and Korme. These may be happed during partitioning the huge amounts of photo and nutrient assimilate to low numbers of seed plant^{-1}. Previously, similar results were reported in common beans (Hirpa Legesse *et al*., 2013).

The analysis of variance (Table 2) showed that genotypes, soil condition, and genotypes × soil interaction had a highly significant effect on grain yield plant^{-1}. The same result was reported in grain yield plant^{-1} (Fageria *et al*., 2012; Kuswantoro, 2015; Muchlish and Krisnawati, 2016). Grain yields were decreased by soil acid conditions much more in some cultivars as compared to other (Table 5). The percent of yield reduction due to soil acidity conditions varies from a low as 32.15 in Wogayen to as high as 58.73% in Gizo. Wogayen, Tgx-1990-47F, Tgx-1987-45F, Tgx-1989-42F, Tgx-1990-101F, Tgx-1989-11F, Tgx-1993-4FN, Tgx-1990-87F, Tgx-1990-95F, and Tgx-1991-10F had yield declines due to soil acidity of 32-44.5 percent, while Tgx-1989-75F, Tgx-1990-78F, Tgx-1990-107FN, Wello, and Gizo had 51.5-58.7 percent average grain yield reductions. Overall genotype average grain yield reduced due to soil acidity was 45.91%. In the past study, Abruna *et al*. (1976) reported 53.63% of yield reduction on Hardee soybean variety at average soil pH of 5.5 and 4.55 at four locations on rainfed and irrigation conditions. Similarly, Board and Caldwell (1991) 25 percent, Hirpa Legesse*et al*. (2013) 25.7% of yield reduction was reported on soybean and common bean respectively. Grain yield was higher in limed soil versus acidic soil in all genotypes in this study. Genotype Tgx-1990-78F, Tgx-1990-87F, and Tgx-1990-101F on limed soil, Tgx-1990-87F and Tgx-1989-42F on acidic soil produced the highest grain yield plant^{-1}, while Korme and Wogayen on limed soil, Wello, and Korme on acidic soil gave the lowest grain yield plant^{-1} (Table5).

The effects of genotypes, soils, and genotypes × soil interaction was highly significant on above-ground biomass yield plant^{-1} and harvest index. Biomass yield was ranged from 7.28g to 11.67g at limed soil, and from 4.83 to 8.78g at acidic soil (Table 5). At limed soil, the top five best performance genotypes in terms of biomass yield were Tgx-1990-87F, Tgx-1990-78F, Tgx-1989-75F, Tgx-1990-101F, and Tgx-1990-107FN, whereas Tgx-1990-87F, Tgx-1987-45F, Tgx-1990-95F, Tgx-1990-101F, and Wogayen were performed best at acidic condition. In this study, the percentage of reduction in biomass yield due to soil acidity was varied significantly from genotype to genotype in ranges of 22.1 to 46.5 percent. Relatively minimum percent of reduction was recorded on Wogayen, Tgx-1990-87F, Tgx-1987-45F, and Gizo. However, Wogayen and Gizo had low biomass yield at both soil conditions as compare to those genotypes. The average biomass yield plant^{-1} was declined by 33.3% due to soil acidity.

The harvest index of genotypes was ranged from 36 to 52% at limed soil, and 26 to 44% at acidic soil conditions. Harvest index was decreased due to soil acidity in most genotypes ranging from 8.9 to 44.2% (Table 5). Exceptionally, the harvest index was increased due to soil acidity on genotypes Korme and Tgx-1989-11F by 5.4 and 7.2% respectively. Basically, the grain and biomass yield of these genotypes were relatively low as compared to the rest of the genotypes at acidic soil conditions. Similar results were reported on some common bean genotypes (Hirpa Legesse *et al*., 2013). Harvest index percent of reduction due to soil acidity was low in genotypes Tgx-1990-101F, Tgx-1991-10F, Tgx-1904-6F, Tgx-1990-47F, and Tgx-1989-75F. In this study, the average percentage of reduction due to soil acidity on the harvest index was 17.39%. In common beans, 3% of the reduction in harvest index was reported (Hirpa Legesse *et al*., 2013).

Table 3: mean, mean difference and percent of reduction due to soil acidity on days to 95% maturity, number of pods $plant^{-1}$ and pod dry weight $plant^{-1}$ of soybean genotypes

Traits	Days to 95% maturity				Number of pods $plant^{-1}$				Pod dry weight $plant^{-1}$			
Genotype	Limed	Acidic	Difference	% of reduction	Limed	Acidic	Difference	% of reduction	Limed	Acidic	Difference	% of reduction
Tgx-1989-11F	104	96.67	7.33	7.05	19.67	12.33	7.34	37.32	7.33	3.89	3.44	46.93
Tgx-1989-42F	104	100.67	3.33	3.20	25.33	15.33	10	39.48	7.61	4.89	2.72	35.74
Tgx-1990-107FN	87.67	85	2.67	3.05	18.67	8.67	10	53.56	7.89	3.44	4.45	56.40
Tgx-1989-75F	104	101	3	2.88	25	13	12	48.00	7.94	4	3.94	49.62
Gizo*	99.33	97.67	1.66	1.67	16.33	10.33	6	36.74	4.44	2.61	1.83	41.22
Tgx-1990-87F	100.67	100.33	0.34	0.34	26.43	17	9.43	35.68	8.83	5.56	3.27	37.03
Tgx-1990-95F	96.33	95	1.33	1.38	22.87	16.67	6.2	27.11	7.44	4.56	2.88	38.71
Tgx-1993-4FN	100.33	92.67	7.66	7.63	25	17.67	7.33	29.32	7.06	4.44	2.62	37.11
Wello*	98.67	96	2.67	2.71	19.33	10.67	8.66	44.80	5.44	2.5	2.94	54.04
Korme*	95	93	2	2.11	13.33	9.33	4	30.01	4.61	2.56	2.05	44.47
Tgx-1987-45F	102	99.67	2.33	2.28	23	16.67	6.33	27.52	7.33	4.75	2.58	35.20
Tgx-1990-101F	94.33	93.67	0.66	0.70	28	16.67	11.33	40.46	8.06	4.83	3.23	40.07
Tgx-1990-47F	96.33	95.67	0.66	0.69	23	13.33	9.67	42.04	6.11	3.89	2.22	36.33
Tgx-1990-78F	101.33	100	1.33	1.31	23.33	12	11.33	48.56	8.56	4.28	4.28	50.00
Tgx-1991-10F	102.33	98.67	3.66	3.58	24.87	15	9.87	39.69	7.56	4.22	3.34	44.18
Tgx-1904-6F	95.33	94	1.33	1.40	26.67	13.33	13.34	50.02	6.5	3.28	3.22	49.54
Wogayen*	83.33	82	1.33	1.60	14	10	4	28.57	5.33	3.44	1.89	35.46
Mean	97.94	95.39	2.55	2.60	22.05	13.41	8.64	39.18	6.94	3.95	2.99	43.08
Range	83.33-104	82.00-101.00			13.33-28.00	8.67-17.67			4.44-8.83	2.50-5.56		

Table 4: Mean, mean difference and percent of reduction due to soil acidity on Number of seeds plant^{-1} and pods^{-1}, and 100 seed weight of soybean genotypes

Traits	Number of seeds plant^{-1}				Number of seeds pods $^{-1}$				100 seed weight			
Genotype	Limed	Acidic	Difference	% of reduction	Limed	Acidic	Difference	% of reduction	Limed	Acidic	Difference	% of reduction
Tgx-1989-11F	39.44	22.22	17.22	43.66	2.01	1.8	0.21	10.45	12	9.67	2.33	19.42
Tgx-1989-42F	48.11	28.44	19.67	40.89	1.9	1.84	0.06	3.16	10.33	10.33	0	0.00
Tgx-1990-107FN	40.89	18.22	22.67	55.44	2.18	2.1	0.08	3.67	12.67	11.33	1.34	10.58
Tgx-1989-75F	45.33	23.56	21.77	48.03	1.81	1.81	0	0.00	10.17	9	1.17	11.50
Gizo*	34	20.44	13.56	39.88	2.08	1.98	0.1	4.81	8.17	7	1.17	14.32
Tgx-1990-87F	44.56	28.56	16	35.91	1.69	1.68	0.01	0.59	12	11.5	0.5	4.17
Tgx-1990-95F	46.78	29.56	17.22	36.81	2.04	1.77	0.27	13.24	10.33	8.83	1.5	14.52
Tgx-1993-4FN	42.67	28	14.67	34.38	1.71	1.58	0.13	7.60	10.67	9.5	1.17	10.97
Wello*	41.56	19.67	21.89	52.67	2.15	1.84	0.31	14.42	8.23	7.67	0.56	6.80
Korme*	33.67	15.33	18.34	54.47	2.52	1.64	0.88	34.92	8.67	9	-0.33	-3.81
Tgx-1987-45F	45.56	29.56	16	35.12	1.98	1.78	0.2	10.10	9.83	9.17	0.66	6.71
Tgx-1990-101F	52.44	29.78	22.66	43.21	1.87	1.79	0.08	4.28	8.83	9.63	-0.8	-9.06
Tgx-1990-47F	47.33	25.22	22.11	46.71	2.05	1.89	0.16	7.80	8.17	9.33	-1.16	-14.20
Tgx-1990-78F	44.33	20.56	23.77	53.62	1.9	1.71	0.19	10.00	12.33	12	0.33	2.68
Tgx-1991-10F	48	26.89	21.11	43.98	1.93	1.79	0.14	7.25	9.83	9	0.83	8.44
Tgx-1904-6F	56.56	25.56	31	54.81	2.12	1.92	0.2	9.43	7.17	7.67	-0.5	-6.97
Wogayen*	28.89	18.89	10	34.61	2.07	1.89	0.18	8.70	10.33	10	0.33	3.19
Mean	43.54	24.14	19.4	44.56	2	1.81	0.19	9.5	9.98	9.45	0.53	5.31
Range	28.89-56.56	15.33-29.78			1.69-2.52	1.58-2.10			7.17-12.67	7.00-12.00		

Table 5: Mean on both soil condition, mean difference and percent of reduction due to soil acidity on grain, biomass yield and harvest index of soybean genotypes

Traits	Grain yield plant^{-1}				Biomass yield plant^{-1}				Harvest index			
Genotype	Limed	Acidic	Difference	% of reduction	Limed	Acidic	Difference	% of reduction	Limed	Acidic	Difference	% of reduction
Tgx-1989-11F	4.06	2.39	1.67	41.13	9.56	5.94	3.62	37.87	0.41	0.44	-0.03	-7.32
Tgx-1989-42F	5	3.06	1.94	38.80	9.89	7.11	2.78	28.11	0.5	0.43	0.07	14.00
Tgx-1990-107FN	5	2.11	2.89	57.80	10.28	5.5	4.78	46.50	0.49	0.38	0.11	22.45
Tgx-1989-75F	4.72	2.28	2.44	51.69	10.78	6.06	4.72	43.78	0.44	0.38	0.06	13.64
Gizo*	3.78	1.56	2.22	58.73	7.28	5.44	1.84	25.27	0.52	0.29	0.23	44.23
Tgx-1990-87F	5.56	3.17	2.39	42.99	11.67	8.78	2.89	24.76	0.48	0.36	0.12	25.00
Tgx-1990-95F	4.83	2.72	2.11	43.69	9.67	7.11	2.56	26.47	0.5	0.38	0.12	24.00
Tgx-1993-4FN	4.56	2.61	1.95	42.76	8.78	6.33	2.45	27.90	0.52	0.42	0.1	19.23
Wello*	3.61	1.5	2.11	58.45	8.94	5.94	3	33.56	0.41	0.26	0.15	36.59
Korme*	3.01	1.61	1.4	46.51	7.61	4.83	2.78	36.53	0.37	0.39	-0.02	-5.41
Tgx-1987-45F	4.72	2.89	1.83	38.77	9.67	7.25	2.42	25.03	0.49	0.4	0.09	18.37
Tgx-1990-101F	4.78	2.89	1.89	39.54	10.72	7	3.72	34.70	0.45	0.41	0.04	8.89
Tgx-1990-47F	3.83	2.39	1.44	37.60	8.67	6.33	2.34	26.99	0.44	0.38	0.06	13.64
Tgx-1990-78F	5.61	2.56	3.05	54.37	11.14	6.33	4.81	43.18	0.49	0.4	0.09	18.37
Tgx-1991-10F	4.61	2.56	2.05	44.47	10.03	6.25	3.78	37.69	0.47	0.41	0.06	12.77
Tgx-1904-6F	4.06	2.11	1.95	48.03	9.17	5.39	3.78	41.22	0.44	0.38	0.06	13.64
Wogayen*	3.11	2.11	1	32.15	8.56	6.67	1.89	22.08	0.36	0.31	0.05	13.89
Mean	4.4	2.38	2.02	45.91	9.55	6.37	3.18	33.30	0.46	0.38	0.08	17.39
Range	3.01-5.61	1.50-3.17			7.28-11.67	4.83-8.78			0.36-0.52	0.26-0.44		

4. SUMMARY AND CONCLUSIONS

Soil acidity is one of the constraints of soybean production worldwide. In Ethiopia, the area of acid-affected soil covers about 40% of total land which extends widely in western, southern, southwestern, and northwestern parts of the country. The present study was conducted to determine the effect of soil acidity on yield and related traits, to investigate genotypes response to limed and acidic soil conditions, and to identify high yielder genotypes at acidic soil conditions. In this study, thirteen soybean promising genotypes and four improved varieties were evaluated using a split-plot design with three replications under limed and acidic soil in lathouse at Pawe Agricultural Research Center in 2017.

Analysis of variance revealed highly significant differences in main plot effect (acidic and limed soils), genotypes effect, and genotypes × soil interaction effects for numbers of pods, pods dry weight, biomass yield, grain yield, and harvest index. The extent of soil acidity effects on yield and yield-related traits had significantly different from genotype to genotypes.

Soil acidity was significantly reduced grain yield, number of pods, pod dry weight, number of seeds, hundred seed weight, biomass yield plant^{-1}, and harvest index by 45.9, 39.2, 43.1, 44.6, 5.3 33.3, and 17.4% respectively. Generally, Genotypes Tgx-1990-87F, Tgx-1989-42F, Tgx-1990-101F, and Tgx-1987-45F had high grain yield at both soil conditions with minimum yield reduction as compared as to the average percent of yield reduction. Therefore, better to test these genotypes under acidic field conditions in Ethiopia to verify the findings from a pot experiment.

5. References

1. Giller KE and Dashiell KE. Glycine max (L.) Merrill. In: van der Vossen, H.A.M. and Mkamilo, G. S. (Eds.) Plant Resources of tropical Africa 14. Vegetable oils. PROTA Foundation, Wageningen. Netherlands/Backhuys Publishers, Leiden, Netherlands/CTA, Wageningen, Netherlands,78 – 74, 2007.

2. Central Statistical Agency (CSA), “Agricultural sample survey report on area and production of major crops (private peasant holdings, meher season) Vol.1, statistical bulletin 589, Addis Ababa, Ethiopia, 2019.
3. Mulugeta Atnaf, Kassahun Tesfaye, Kifle Dagne. The Importance of Legumes in the Ethiopian Farming System and Overall Economy: An Overview. American Journal of Experimental Agriculture; vol. 7, no.6, pp. 347-358, 2015.

4. Villagarcia M, Carter TE Jr, Rufty TW, Niewoehner AS, Jennette MW, Arellano C et al. Genotypic rankings for aluminum tolerance of soybean roots grown in hydroponics and sand culture. Crop Science,vol.41, no.5, pp. 1499 – 1507, 2001.

5. **A.** Haug. Molecular aspects of aluminum toxicity. CRC Crit. Rev. Plant. Sci., vol. 1:345-373, 1983.

6. Utama MZH, Physiological aluminum tolerance mechanism in leguminous soil covers species against nitrate, ammonium and nitrite metabolism. Bulletin Agronomy, vol. 36, pp. 175-179, 2008.

7. Zheng SJ. Crop production on acidic soils: overcoming aluminum toxicity andphosphorus deficiency. Annual Botany, vol. 106, pp. 183-184, 2010.

8. C. The, H. Calba, C. Zonkeng, E. Ngonkeu, V. Adetimirin, H. Mafouasson, S. Meka, and W. Horst, Responses of maize grain yield to changes in acid soil characteristics

after soil amendments. Plant and Soil, vol. 284, pp. 45-57, 2006.

9. KN. Ezeh, AM. Omogoye, EA. Akinrinde, Aluminum influence on performance of some cowpea varieties on a Nigerian Alfisol. World J. Agric. Science, vol. 3, pp. 517-522, 2007.

10.J.P. Wang, H. Raman, G.P. Zhang, N. Mendham, and M.X. Zhou, Aluminum tolerance in barley (*Hordeum vulgare L.*): Physiological mechanisms, genetics and screening methods. Journal of Zhejiang University Science, vol. 7, pp. 769-787, 2006.

11. GH. Bouyoucos, Reclamation of the hydrometer for making mechanical analysis of soil. Agronomy journal, vol. 43, pp. 434-438, 1951.

12. A. Walkley, IA. Black, An examination of the degtjareff method for determination of soil organic matter and a proposal modification of the chromic acid titration method. Soil science, vol. 37, PP. 29-38, 1934.

13. R. K. Schofield, AW. Tailor, The measurement of soil pH. Soil science society of America proclamation, vol. 19, pp. 165-167,1955.

14. A. Buni, The Effect of Liming on Acidic Soils for Improving Soil Properties and Yield of Haricot Bean. Journal of Environmental and Analytical Toxicology, vol. 4, no. 248, 2014.

15. Yaregal Damtie, Evaluation of improved maize varieties (zea mays l.) to soil acidity tolerance in Assossa, Ethiopia. MSc. thesis, Haromaya University, Ethiopia.32p, 2018.

16. Ojo GOS., Bello LL, Adeyemo MO. Genotypic variation for acid stress tolerance in soybean in the humid rain forest acid soil of south Eastern Nigeria. Journal of Applied Bioscience, vol. 36, pp. 2360-2366, 2010.

17. H. Kuswantoro, Increasing Grain Size Improves Grain Yield of Acid Adaptive Soybean Lines in Optimal Soil Condition. Journal of Plant Sciences, vol. 10, no.3, pp. 79-89, 2015.

18. H. Kuswantoro, Genetic variability and heritability of acid adaptive soybean promising lines. Biodiversitas vol. 18, pp. 378-382, 2017.

19. N. K. Fageria,V.C. Baligar, L.C. Melo, and J. P. DE Oliveira, Differential Soil Acidity Tolerance of Dry Bean Genotypes. Communications in Soil Science and Plant Analysis, vol. 43, pp. 1523–1531, 2012.

20. Hirpa Legesse, Nigussie Dechassa, Setegn Gebeyehu, Geremew Bultosaand Firew Mekbib, Response to Soil Acidity of Common Bean Genotypes (Phaseolus vulgaris L.) Under Field Conditions at Nedjo, Western Ethiopia. Sci. Technol. Arts Res. J., vol. 2, no. 3,pp. 03-15, 2013.

21. MI. Uguru, BC. Oyiga, EA. Jandong, Responses of some soybean genotypes to different soil pH regimes in two planting seasons. The African J. Plant Science Biotechnology; vol 6, pp. 26-37, 2012.

22.M. Muchlish, Adie, KW. Ayda, Identification of soybean genotypes adaptive and productive to acid soil agro-ecosystem. Biodiversity, vol.17, no. 2,pp. 565-570, 2016.

23.F. Abruna, J. Rodriguez, JB. Feliciano, S. Silva, and JV. Chandler, Crop Response to Soil Acidity Factors in Ultisols and Oxisols in Puerto Rico-Soybeans," Journalof Agriculture of

University of Puerto Rico, Rio Piedras, P.R., 1976.
24.JE. Board,and A. G. Caldwell, Response of determinate soybean cultivars to low pH soils. LSU Agricultural Experiment Station Reports. 349, 1991.
http://digitalcommons.lsu.edu/agexp/349