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The effect of soil acidity on some growth-related traits of soybean genotypes

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Abstract
Soybean is an important oil seed crop for both human and livestock nutrition. However, Soybean production and productivity are affected by biotic and abiotic stresses. Among those factors, Soil acidity is one of the limiting factors for production of soybean especially, in the study area Pawe, north western Ethiopia. Therefore, this experiment was done to determine the effect of soil acidity on growth- and growth-related traits of soybean genotypes. A pot experiment consisting thirteen soybean genotypes and four improved varieties was done using split plot design with three replications. Limed (pH 5.8) and acidic soil (pH 4.5) considered as main plot factor and varieties as sub plot factor at Pawe Agricultural Research Center lathouse in 2017. Analysis of variance revealed that there were highly significant differences between soil, genotypes and genotypes × soil interaction for, root dry weight, shoot fresh and dry weight plant^{-1}. The extents of soil acidity effects on growth related traits had significantly varies from genotype to genotypes. In general, Soil acidity was reduced root length, nodule dry weight, root fresh and dry weight, shoot dry weight and total dry biomass yield plant^{-1} by 10, 20, 27.9, 25.22, 20.9, and 22.17% respectively. Generally, this experiment was done under pot experiment. Therefore, to verify the findings from a pot, these genotypes better to be tested under a field condition in multiple environment trial at acidic prone areas of Ethiopia.

Keywords: Effect, genotype, soybean, soil acidity

1. Introduction

Soybean (*Glycine max* (L.) Merrill) is one of the most important crops in the world and has higher protein content than any other pulses (Giller and Dashiell, 2007) [5]. The crop extensively produced in temperate, tropical and subtropical regions of the world. According to the USDA, (2017) [22] report, USA, Brazil, Argentina, China and India, are top five world soybean producing countries, which account for 89.53% of world supply.

In Ethiopia, Soybeans is produced on more than 38072.70 ha annually with national average yield of 2.271 tons ha^{-1} (CSA, 2018**)** [3]. The major soybean producing areas are western and south western part of the country such as Benishangul Gumuz, Amhara, parts of Oromia and Gambela region (Sopov, 2015; USDA, 2016**)** [19, 21]. According to the CSA, (2018) [3] report, Amhara, Benishangul Gumuz, and Oromia, are top three soybean producing Regions in Ethiopia, which account for 99.96% of production. The yield gap of soybean production at research and farmers' fields is usually resulted from utilization of improper agricultural inputs, damage by biotic and abiotic stresses, limited availability of seed and limited familiarity with the varieties, limited usage of modern agronomic practices and poor extension services (Atnaf *et al*., 2015) [13].

Soil acidity is one of the edaphic factors affecting adversely the growth and productivity of soybean (Villagarcia *et al*., 2001) [23]. In Ethiopia, soil acidity is a problem that has not been addressed in depth (Dubale, 2001) [17]. The problem is widespread in the western, southern, south western and north western part of the country, where reliable rainfall is available. In the past, soil acidification accounted for more than 40% of the total land, of which, the distribution is stronger in the high potential areas (Mesfin, 2007) [11]. The poor fertility of acid soils is due to a combination of mineral toxicities of aluminum and manganese and deficiencies of phosphorus, calcium, and molybdenum. Al toxicity is the most important limiting factor of growth and productivity of plant in acid soils. It has been estimated that Al^{3+} toxicity represents the greatest constraint on plant productivity in 67% of the world's acidic soil regions (Line *et al.*, 2012).

Zheng (2010) [25] also reported that the major constraint of soybean plant in acid soil is Al toxicity which inhibits the cell division and elongation, shortens root growth and affects absorption of water and nutrient.

So far, the effects of soil acidity on different growth-related traits of soybean is not well determined in Ethiopia. Most of researches was done on soybean by the national and regional research institute focused on optimal growing conditions. Therefore, the present study was conducted to determine the effect of soil acidity on growth- and growth-related traits of soybean genotypes.

2. Materials and Methods

2.1. Experimental Site, Materials, Design and Procedures

The experiment was carried out at Pawe Agricultural Research Center ($11^0$18`49.6``N and $036^0$24`29.1``E) which is found in Benishangul Gumuz Regional State in Metekel Zone. The site receives 1586mm rainfall annually. The mean annual maximum and minimum temperatures are 32.6^0c and 16.5^0c, respectively. Seventeen medium maturing soybean genotypes were used for this study. The 13 soybean promising genotypes were introduced in 2013 from the International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria and four nationally released varieties.

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. The soils collected from the acidic field at depth of 0-30cm were mixed thoroughly to maintain the chemical and physical properties of soil homogeneity. 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.

2.2. Analyses of Soil Physical and Chemical Properties

Soils were collected from acidic fields of Pawe Agricultural Research Center at the depth of 0-30 cm. 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) [1], organic carbon, and organic matter Walkley and Black method (Walkley and Black, 1934) [24] pH 1:2.5 soil to water ratio method (Schofield and Tailor,1951) [18], 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. Soil Physical and chemical properties analysis results were mentioned below on Table 4.

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	texture %	clay (90)	silt (6)	sand (4)	

2.3. Data Collected

The phenological and growth-related parameters data were recorded. At late flowering stage, three plants were taken from each pot and the following traits were measured; plant height (cm), Number of nodules plant^{-1}, number of branches plant^{-1}, root length, root fresh weight plant^{-1} (g), root dry weight plant^{-1} (g), nodule fresh weight, nodule dry weight, total dry biomass yield, root to shoot ratio, shoot fresh weight plant^{-1} (g), and shoot dry weight plant^{-1} (g). Total dry biomass yield, root and shoot dry weight plant^{-1} were determined after oven drying of shoot and root biomass of those uprooted plants at flowering stage at 70^0C for 48 hours and average to number of plants.

2.4. Statistical Analysis

Analyses of variance (ANOVA) on all measured characters were performed by SAS 9.3 software (SAS, 2011). and the variations were quantified using the following model. $Y_{ijk} = \mu + G_i + E_j + (GE)_{ij} + R_k + G_R + e_{ijk}$

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. Crop Phenology

Analysis of variance revealed that there was significant variation among genotypes in day to seedling emergence. However, soil and soil by genotypes interaction were none significant (Table 3). These may be the reason that germination may not require additional nutrients rather than those stored on seeds. This result is comparable with Jan *et al.* (2002) [7] who reported embryo grows at the expense of stored food materials and did not require any external nutrition. Nutrients and food reserves in the cotyledons supply the needs of the young plant during emergence for about 7 to 10 days after emergence (ISUST and USDA, 1985).

Table 2: Mean days to 50% emergence and flowering of soybean genotypes at both limed and acidic soil conditions

Days to 50% emergence			Days to 50% flowering	
Genotypes	Limed	Acidic	Limed	Acidic
Tgx-1989-11F	5.33	5.67	41.67	41.33
Tgx-1989-42F	5	4.33	42.33	42.67
Tgx-1990-107FN	5.33	4.67	39	37.67
Tgx-1989-75F	5	5	43.33	43.33
Gizo*	4	4.33	42.33	43.67
Tgx-1990-87F	5.33	5	43	42.67
Tgx-1990-95F	5	5	42	42
Tgx-1993-4FN	4.33	4.33	37.67	36.67
Wello*	4.33	4.67	43.67	43
Korme*	4.67	5	42.33	42
Tgx-1987-45F	4.67	6.33	42.67	40.67
Tgx-1990-101F	5	5.33	41.33	41.67
Tgx-1990-47F	4.33	4.33	42.67	40.33
Tgx-1990-78F	4.67	5.67	42.33	40.33
Tgx-1991-10F	4.33	5	42.33	42
Tgx-1904-6F	4	4.33	42.33	40.67
Wogayen*	4	4.67	37	36.67
Means	4.67	4.92	41.65	41.02
Range	4.00-5.33	4.33-6.33	37.00-43.67	36.67-43.67

Days to emergence of genotypes were ranged from 4 to 5.33 days at limed soil. Genotypes Wogayen, Tgx-1904-6F and Gizo were emerged early, while genotypes Tgx-1989-11F, Tgx-1990-107FN and Tgx-1990-87F were emerged late. At acidic soil, days to emergence of genotypes were ranged from 4.33 to 6.33 days. Genotypes Tgx-1993-4FN, Tgx-1904-6F, Tgx-1989-42F and Gizo were emerged early, while genotypes Tgx-1987-45F, Tgx-1990-78F and Tgx-1989-11F were emerged late (Table 2).

Analysis of variance showed that days to flowering was varied highly significantly among genotypes and significantly affected by genotype by soil interactions. This result was agreed with the finding of (Ojo *et al*., 2010; Uguru *et al*., 2012; Hanafiah *et al*., 2015; Kuswantoro, 2015; Muchlish and Krisnawati, 2016) [14, 8, 20, 12]. On the other hand, controversial result was obtained by Ojo (2016) [16] and Kuswantoro (2017) [8]. Days to flowering were ranged from 37 to 43.67 days at limed soil. Genotypes Wogayen, Tgx-1993-4FN and Tgx-1990-107FN were flowered early, while genotypes Wello, Tgx-1989-75F and Tgx-1990-87F were flowered late. At acidic soil, days to flowering were ranged from 36.67 to 43.67 days. Genotypes Wogayen, Tgx-1993-4FN and Tgx-1990-107FN were flowered early, while genotypes Gizo, Tgx-1989-42F and Tgx-1989-75F were flowering late (Table 2).

3.2. Growth related parameters

The analysis of variance showed that there were highly significant differences in number of nodules plant^{-1} among genotypes and between soil conditions. Nodules fresh weight and nodules dry weight plant^{-1} were varied highly significantly among the genotypes and significantly between soil conditions (Table 3). But the effect of genotypes by soil interaction was none significantly different on traits number of nodules plant^{-1} and nodules fresh weight plant^{-1}. This result was consistence with the study of (Uguru *et al*., 2012) [20].

Number of nodules plant^{-1} of genotypes was ranged from 181.11 to 435.44 on acidic soil (Table 4). Genotype Tgx-1990-78F, Tgx-1990-87F and Tgx-1989-11F had high number of nodules plant^{-1}, while genotype Tgx-1993-4FN, Wogayen and Tgx-1904-6F had low number of nodules plant^{-1} (Table 4). On limed soil, number of nodules plant^{-1} of genotypes was ranged from 99.11to 283.89. Genotypes Tgx-1990-87F, Tgx-1990-78F and Tgx-1990-47F had high number of nodules, while genotypes Tgx-1993-4FN, Wogayen and Tgx-1990-101F had low number of nodule plant^{-1} (Table 5).

Table 3: Mean squares of some phenology and growth-related parameters of soybean genotypes

Source of variation	Def.	DE	DF	NN	NFW	NDW	RL	RFW	RDW	SFW	SDW	TDBY	RTSR
Block	2	0.79^{ns}	0.64^{ns}	2508.47^{ns}	0.11^{ns}	0.03^{ns}	2.54^{ns}	5.87^{ns}	0.05^{ns}	0.58^{ns}	0.05^{ns}	0.14^{ns}	0.001^{ns}
Soil condition	1	1.66^{ns}	10.04^{ns}	414895.7^{**}	19.5^{*}	2.05^{*}	960.48^{*}	2194.97^{**}	51.51^{**}	1116.7^{**}	142^{**}	421^{**}	0.02^{ns}
Main plot error	2	1.25	0.98	496.09	0.61	0.03	7.95	0.92	0.05	0.66	0.12	0.13	0.001
Genotype	16	1.16^{**}	23.65^{**}	15622.96^{**}	1.76^{**}	0.09^{**}	214.86^{**}	65.64^{**}	1.19^{**}	35.99^{**}	3.64^{**}	5.48^{**}	0.02^{**}
Genotype X Soil	16	0.49^{ns}	1.44^{*}	2254.36^{ns}	0.44^{ns}	0.05^{**}	18.98^{**}	46.85^{**}	1.62^{**}	30.32^{**}	3.11^{**}	7.65^{**}	0.01^{**}
sub plot error	64	0.38	0.75	1583.35	0.29	0.01	1.35	0.79	0.03	1.26	0.07	0.12	0
G.M		4.79	41.33	266.54	4.9	1.26	57.07	28.63	4.92	35.95	10.1	16.3	0.49
CV		12.9	2.1	14.93	11.1	7.75	2.07	3.1	3.19	3.12	2.57	2.13	4
R^2		0.57	0.9	0.88	0.75	87	0.98	0.99	0.98	0.96	0.98	0.99	0.95

Def = degree of freedom, DE = days to 50% emergence, DF = days to 50% flowering, G.M = grand mean, NN = nodule number, NFW = nodule fresh weight, NDW = nodule dry weight, RL = root length, RFW = root fresh weight, RDW = root dry weight, SFW = shoot fresh weight, SDW = shoot dry weight, PH = plant height, NB = number of branch, TDBY = total dry biomass yield, RTSR = root to shoot ratio, ns = none significant, * and ** = significant at 5% and 1% alpha levels of significant respectively

Nodule dry weight plant^{-1} was highly significantly influenced by the interaction of soil and genotypes (Table 3). Nodules dry weight plant^{-1} of genotypes was ranged from 0.89 to 1.47g on acidic soil (Table 4). Genotype Tgx-1990-47F, Tgx-1990-78F and Tgx-1991-10F had high nodules dry weight, while genotype Gizo, Tgx-1904-6F and Tgx-1990-107FN had low nodules dry weight plant^{-1} (Table 4). On limed soil, nodules dry weight of genotypes was ranged from 1.10 to 1.54g. Genotype Tgx-1990-87F, Tgx-1990-95F, TGX-1990-101F and Tgx-1990-47F had high nodules dry weight, while genotypes Tgx-1993-4FN, Gizo and Tgx-1904-6F had low nodules dry weight plant^{-1} (Table 5).

Soil conditions (acid and limed) were significantly different in root length of genotypes, while the effects of genotypes and genotype by soil interaction were highly significant (Table 3). Similar result was reported by Ojo *et al*. (2012) [14] who studied on screening of 49 tropically adapted genotypes of soybean for aluminum stress tolerance in short term hydroponics. Butare *et al*. (2011) [2] also reported highly significant aluminum and genotypes, and significant genotype by aluminum interaction effects on root length of 11 soybean genotypes grown under hydroponic system with two level of Al (20 µM Al and 0 µM Al). The root length of genotypes was ranged from 49.00 cm for genotype Tgx-1990-107FN to 70.00 cm for genotype Tgx-1990-87F on limed soil (Table 5), and from 43.33cm for genotype Tgx-1990-107FN to 61.00 cm for genotype Tgx-1990-87F on acidic soil (Table 4).

Table 4: Mean of growth-related parameters of soybean genotypes at acidic soil condition

S. N	Genotypes	NN	NFW	NDW	RL	RFW	RDW	SFW	SDW	TDBY	RTSR
1	Tgx-1989-11F	387.78	3.93	1.11	52	27.72	4.78	33.89	8.42	14.31	0.57
2	Tgx-1989-42F	337.56	4.7	1.06	50	22.56	4.17	28.33	7.44	12.67	0.56
3	Tgx-1990-107FN	285.44	4.06	1	43.33	18.94	3.17	28.67	8.84	13.01	0.36
4	Tgx-1989-75F	305.89	4.98	1.22	57.33	26.44	4.22	38.17	11.36	16.8	0.37
5	Gizo*	366.67	4.1	0.89	59.33	24.11	3.78	31.83	7.98	12.64	0.47
6	Tgx-1990-87F	408.33	4.94	1.02	61	19.94	4.46	30.39	7.93	13.41	0.56
7	Tgx-1990-95F	342.67	4.66	1.16	51.33	21.11	4.16	34.83	10.18	15.49	0.41
8	Tgx-1993-4FN	181.11	3.44	1.06	45	21.78	3.92	28.61	8.07	13.04	0.49
9	Wello*	331.11	4.5	1.06	59.33	20.44	4.11	30.44	8.27	13.43	0.5
10	Korme*	316.44	4.42	1.2	59.67	31.22	4.7	33.94	9.33	15.23	0.5
11	Tgx-1987-45F	356	4.42	1.07	53.33	26.22	3.98	30.17	8.36	13.4	0.48
12	Tgx-1990-101F	313.33	4.82	1.17	60.67	27.11	4.67	37.78	9.36	15.19	0.5
13	Tgx-1990-47F	370.33	4.89	1.47	50.33	22.39	4.56	31.67	8.53	14.56	0.53
14	Tgx-1990-78F	435.44	5.44	1.33	54.33	29.89	4.83	36.78	10.33	16.5	0.47
15	Tgx-1991-10F	380.56	5.04	1.28	56	26.28	4.14	34.33	9.53	14.96	0.44
16	Tgx-1904-6F	254.33	3.48	0.91	59	25.06	4.29	32.22	8.47	13.67	0.51
17	Wogayen*	242.44	3.97	1.06	46	16.61	3.59	32.89	9.27	13.91	0.39
	Grand means	330.32	4.46	1.12	54	23.99	4.21	32.64	8.92	14.25	0.48

NN= nodule number, NFW= nodule fresh weight, NDW= nodule dry weight, RL= root length, RFW= root fresh weight, RDW= root dry weight, SFW= shoot fresh weight, SDW= shoot dry weight, PH= plant height, NB= number of branch, TDBY= total dry biomass yield, RTSR= root to shoot ratios

Table 5: Mean of growth-related parameters of soybean genotypes at limed soil condition

S. N	Genotypes	NN	NFW	NDW	RL	RFW	RDW	SFW	SDW	TDBY	RTSR
1	Tgx-1989-11F	182.56	5	1.33	57.33	33.72	5.03	39	11.29	17.66	0.45
2	Tgx-1989-42F	202.22	5.44	1.51	53	37.83	6.43	41.44	11.9	19.84	0.54
3	Tgx-1990-107FN	161	5.78	1.34	49	30.39	6.43	39.89	12.58	20.36	0.51
4	Tgx-1989-75F	209.67	5.17	1.46	58	33.94	5.41	48.28	12.33	19.2	0.44
5	Gizo*	192.44	4.83	1.2	61	32.11	5.97	37.33	11.89	19.06	0.5
6	Tgx-1990-87F	283.89	6.61	1.54	70	42.83	8.06	43.44	12.07	21.67	0.67
7	Tgx-1990-95F	231.78	6	1.54	59.33	30.78	4.42	36.28	11.26	17.22	0.39
8	Tgx-1993-4FN	99.11	3.56	1.1	49.67	25.11	4.79	34.28	9.82	15.71	0.49
9	Wello*	186.67	5.5	1.51	64.67	32.33	6.04	39.28	9.09	16.64	0.67
10	Korme*	222.33	4.89	1.38	66.67	32	5.51	35.06	10.04	16.93	0.55
11	Tgx-1987-45F	234.11	5.56	1.37	69.67	39	5.29	43.94	12.62	19.28	0.42
12	Tgx-1990-101F	165.78	5.28	1.54	65	31.83	5.8	39.56	11.6	18.94	0.5
13	Tgx-1990-47F	243.89	5.78	1.53	59	29.22	5.33	37.17	12.42	19.29	0.43
14	Tgx-1990-78F	254.22	5.78	1.5	60	38.22	5.09	37.06	11.67	18.26	0.44
15	Tgx-1991-10F	221.11	5.17	1.32	65	27.39	4.84	36.28	9.78	15.94	0.5
16	Tgx-1904-6F	192	5	1.23	65	38.56	5.06	40.17	10.16	16.44	0.5
17	Wogayen*	164.22	5.33	1.44	50	30.28	6.17	39	11.27	18.88	0.55
	Grand mean	202.76	5.33	1.4	60.14	33.27	5.63	39.26	11.28	18.31	0.5

NN= nodule number, NFW= nodule fresh weight, NDW= nodule dry weight, RL= root length, RFW= root fresh weight, RDW= root dry weight, SFW= shoot fresh weight, SDW= shoot dry weight, PH= plant height, NB= number of branch, TDBY= total dry biomass yield, RTSR= root to shoot ratios

The effect of soil acidity on root length of soybean was varies significantly from genotype to genotype. In this study, the percent of reduction in root length due to soil acidity was ranges from 1.2 to 24 (Table 6). The top four genotypes which had less than 7% of root length reduction was Tgx-1989-75F, Gizo, Tgx-1989-42F and Tgx-1990-101F. The average root length was decreased from 60.14cm on limed soil to 54cm on acidic soil conditions which is 10.21% reduction (Table 7).

There were highly significant variations between soil conditions, among genotypes and genotype by soil interaction effect on root fresh weight plant^{-1}. Root fresh weight plant^{-1} of genotypes was ranged from 25.11g for genotype Tgx-1993-4FN to 42.83g for genotype Tgx-1990-87F on limed soil (Table 5), and from 16.61 for genotype Wogayen to 31.22g for Korme on acidic soil (Table 4). The average root fresh weight was decreased from 33.27g on limed soil to 23.99g on acidic soil conditions which is 27.89% reduction (Table 5 and 4). The effects of soils, genotypes and genotypes by soil interaction on root dry weight plant^{-1} were highly significant (Table 3). This is in line with the results reported by Uguru *et al*., 2012 [20] for the study conducted on 49 soybean genotypes tested on acidic sand culture. Root dry weight plant^{-1} of genotypes was ranged from 4.42g for genotype Tgx-1990-95F to 8.06g for genotype Tgx-1990-87F on limed soil (Table 5) and from 3.17g for genotype Tgx-1990-107FN to 4.78g for genotype Tgx-1989-11F on acidic soil (Table 4).

The effect of soil acidity on soybean root dry weight plant^{-1} was significantly varies from genotype to genotype. In this finding the effects of soil acidity on root dry weights of the genotypes was ranged from 5 to 51% (Table 6). Tgx-1989-11F, Tgx-1990-78F and Tgx-1990-95F were a top three genotypes which had under 7% root dry weight reduction due to soil acidity. Generally, the average root dry weight of soybean was decreased from 5.63 on limed soil to 4.21g on acidic soil condition which is 25.22% reduction (Table 7).

There were highly significant variations among genotypes and between soils conditions in shoot fresh and dry weight, and highly significant genotype by soil interaction effect on shoot fresh and shoot dry weights plant^{-1} (Table 3). This result is consistence with Butare *et al*., 2011 [2]; Fageria *et al*., 2012 [4]; Ojo *et al*., 2012 [14] which showed that shoot dry weight was significantly varied among genotypes, between acidity levels and significantly affected by genotype by acidity interaction. However, none significant genotype by planting medium (limed and un limed) interaction was reported by Hanafiah *et al*. (2015). Shoot fresh weight plant^{-1} of genotypes was ranged from 34.28g for genotype Tgx-1993-4FN to 48.28g for genotype Tgx1989-75F on limed soil (Table 5), and from 28.33 for genotype Tgx-1989-42F to 38.17g for genotype Tgx-1989-75F on acidic soil (Table 4). The average shoot fresh weight plant^{-1} was decreased from 39.26g on limed soil to 32.64g on acidic soil which is 16.86% reduction (Table 7).

Shoot dry weight plant^{-1} of genotypes was ranged from 9.09g for genotype Wello to 12.62g for genotype Tgx-1987-45F on limed soil (Table 5), and from 7.44 for genotype Tgx-1989-42F to 11.36g for genotype Tgx-1989-75F on acidic soil (Table 4). The magnitude of shoot dry weight reduction due to soil acidity was significantly different among the tested soybean genotypes. The percent of reduction on shoot dry weight of soybean genotypes was ranged from 3 to 37% (Table 6). Shoot dry weight reduction was under 11% on genotypes Tgx-1991-10F, Korme, Tgx-1989-75F, Wello and Tgx-1990-95F (Table 6). In general, the average shoot dry weight plant^{-1} was decreased from 11.28g on limed soil to 8.92g on acidic soil which is 20.92% reduction (Table 7).

The analysis of variance revealed that there were highly significant variations of total dry biomass yield plant^{-1} on both soil conditions and genotypes, and the effect of genotype by soil interaction on total dry biomass yield was highly significant. This result is comparable with the results reported by Ojo *et al*. (2012) [14]; Ojo and Ayuba (2016) [15]. Total dry biomass yield plant^{-1} at flowering of genotypes ranged from 15.71g for genotype Tgx-1993-4FN to 21.67g for genotype Tgx-1990-87F on limed soil (Table 5), and from 12.64g for genotype Gizo to 16.8g for genotype Tgx-1989-75F on acidic soil (Table 4). The percent of reduction due to soil acidity on total dry biomass yield of soybean genotypes was ranged from 6.2 to 38% (Table 6). The minimum reduction (≤ 13%) of total dry biomass yield was recorded on genotypes Tgx-1991-10F, Tgx-1990-78F, Korme, Tgx-1990-95F and Tgx-1989-75F (Table 6). The average total dry biomass yield plant^{-1} was decreased from 18.31g on limed soil to 14.25g on acidic soil which is 22.17% reduction (Table 7).

The analysis of variance showed that genotypes were highly significantly different on root to shoot ratio (Table 3). Similar result was reported by Kuswantoro, 2015 [9]; Muchlish and Krisnawati, 2016 [12]. The effects of genotype and genotypes by soil interaction on root to shoot ratio were highly significant (Table 3). Similarly, Butare *et al*. (2011) [2] reported the presence of highly significant effects of aluminum levels, genotypes and genotype by aluminum interaction. The root to shoot dry weight ratio plant^{-1} of genotypes was ranged from 0.39 to 0.67 on limed soil (Table 5), and from 0.36 to 0.57 on acidic soil (Table 4). The average root to shoot dry weight ratio plant^{-1} was decreased by 4% from 0.5 on limed soil to 0.48 on acidic soil conditions (Table 7).

Table 6: mean difference between limed and acidic soil conditions, and percent of reduction due to soil acidity on some growth-related traits of soybean genotypes

Traits		NDW		RL		RDW		SDW		TDBY	
S. No.	Genotypes	Difference	% of reduction	Difference	% of reduction	Difference	% of reduction	Difference	% of reduction	Difference	% of reduction
1	Tgx-1989-11F	0.2	17	5.3	9.3	0.3	5	2.9	25	3.35	19
2	Tgx-1989-42F	0.5	30	3	5.7	2.3	35	4.5	37	7.17	36
3	Tgx-1990-107FN	0.3	25	5.7	12	3.3	51	3.7	30	7.35	36
4	Tgx-1989-75F	0.2	16	0.7	1.2	1.2	22	1	8	2.4	13
5	Gizo*	0.3	26	1.7	2.7	2.2	37	3.9	33	6.42	34
6	Tgx-1990-87F	0.5	34	9	13	3.6	45	4.1	34	8.26	38
7	Tgx-1990-95F	0.4	25	8	14	0.3	6	1.1	10	1.73	10
8	Tgx-1993-4FN	0	4	4.7	9.4	0.9	18	1.8	18	2.67	17
9	Wello*	0.5	30	5.3	8.3	1.9	32	0.8	9	3.21	19
10	Korme*	0.2	13	7	11	0.8	15	0.7	7	1.7	10
11	Tgx-1987-45F	0.3	22	16	24	1.3	25	4.3	34	5.88	31
12	Tgx-1990-101F	0.4	24	4.3	6.7	1.1	19	2.2	19	3.75	20
13	Tgx-1990-47F	0.1	4	8.7	15	0.8	14	3.9	31	4.73	25
14	Tgx-1990-78F	0.2	11	5.7	9.5	0.3	5	1.3	11	1.76	9.6
15	Tgx-1991-10F	0	3	9	14	0.7	14	0.3	3	0.98	6.2
16	Tgx-1904-6F	0.3	26	6	9.2	0.8	15	1.7	17	2.77	17
17	Wogayen*	0.4	26	4	8	2.6	42	2	18	4.97	26

Difference = mean difference (Limed – Acidic), %= percent of reduction due to soil acidity, NDW= nodule dry weight, RL= root length, RFW= root fresh weight, RDW= root dry weight, SDW= shoot dry weight, PH= plant height, and TDBY= total dry biomass yield

Table 7: Range, average mean performance at both soil conditions, mean difference and percent of reduction due to soil acidity on various traits of soybean

Traits	Range		Grand Mean		Difference	% of reduction due to acidity
	limed	acidic	limed	acidic		
NN	99.11-283.89	181.11-435.44	202.76	330.32	-127.56	-62.91
NFW	3.56-6.61	3.44-5.44	5.33	4.46	0.87	16.32
NDW	1.10-1.54	0.89-1.47	1.4	1.12	0.28	20
RL	49.00-70.00	43.33-61.00	60.14	54	6.14	10.21
RFW	25.11-42.83	16.61-31.22	33.27	23.99	9.28	27.89
RDW	4.42-8.06	3.17-4.83	5.63	4.21	1.42	25.22
SFW	34.28-48.28	28.33-38.17	39.26	32.64	6.62	16.86
SDW	9.09-12.62	7.44-11.36	11.28	8.92	2.36	20.93
TDBY	15.71-21.67	12.64-16.80	18.31	14.25	4.06	22.17
RTSR	0.39-0.67	0.36-0.57	0.5	0.48	0.02	4

diff= mean difference (Limed – Acidic), %= percent of reduction due to soil acidity, NN= nodule number, NFW= nodule fresh weight, NDW= nodule dry weight, RL= root length, RFW= root fresh weight, RDW= root dry weight, SFW= shoot fresh weight, SDW= shoot dry weight, PH= plant height, TDBY= total dry biomass yield, and RTSR= root to shoot ratios

4. Conclusion and recommendation

The result revealed that highly significant differences in main plot effect (acidic and limed soils) was found on traits nodule number, root fresh and dry weight, shoot fresh and dry weight, total dry biomass yield plant^{-1} and highly significant on nodule fresh and dry weight, and root length of soybean plants. On the other hand, highly significant genotype and genotype × soil interaction effects were observed on nodule dry weight, root length, root fresh and dry weight, shoot fresh and dry weight, total dry biomass yield plant^{-1}, and root to shoots dry weight ratio.

The extents of soil acidity effects on growth related traits had significantly varies from genotype to genotypes in this study. In average, Soil acidity had reduced root length by 10%, nodule dry weight by 20%, root fresh weight by 27.9%, root dry weight by 25.22%, shoot dry weight 20.9%, and total dry biomass yield 22.17%. Generally, this experiment was done under lathouse condition. Therefore, to verify the findings from the lathouse experiment, these genotypes better to be studied in a field condition under multi environment trial in acid prone areas of Ethiopia

5. References

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