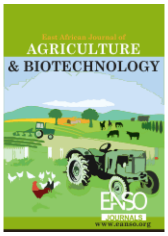

East African Journal of Agriculture and Biotechnology
eajab.eanso.org
Volume 5, Issue 1, 2022
p-ISSN: 2707-4293 | e-ISSN: 2707-4307
Title DOI: https://doi.org/10.37284/2707-4307

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Effects of Liming on Acid Soil to Improve Growth and Yield in Soybean (Glycine max L. Merill)

William Saygbah Kollie[12*], *& Prof. Ernest Semu, PhD*[2]

[1] Martyrs University, P. O. Box 5498, Kampala, Uganda
[2] Sokoine University of Agriculture, P. O. Box 3015, Morogoro, Tanzania
* Author for Correspondence ORCID ID: https://orcid.org/0000-0002-3119-1669; Email: kolliewilliam@gmail.com

Article DOI: https://doi.org/10.37284/eajab.5.1.1006

Date Published:

13 December 2022

Keywords:

Soil Acidity,

Soil pH,

Legumes,

Soybean Yield and

Yield Components,

ABSTRACT

Soil acidity limits crop productivity and affects food security, household income as well as the environment. Given the consequences of soil acidity, appropriate measures such as sustainable use of agricultural lime could be an option to enhance the productive capacity of acid soils. The study was conducted to assess the growth, yield, and yield components of soybean response to liming in acid soil. The experiment was laid out in a split-plot with four replications at the Crop Museum, Sokoine University of Agriculture, Morogoro, Tanzania. Three soybean varieties (*Bossier*, *Laela*, and *Uyole soya*-1) were used as the main plot, and four levels of lime (L0:0, L1:1560; L2:936, and L3:624 kg/ha) were used in the subplot. The analysis of variance revealed that the variety Uyole soya-1 had the highest average number of filled pods per plant, number of pods per plant, number of seeds per pod, and 100 seed weight. The variety *Laela* had the highest grain yield (kg/ha) of all the varieties used in the study. The results also showed that the application of 1560 kg/ha of lime in acid soil raised the soil pH from 5.0 to 6.5 thus having a significant influence on growth, yield and yield components.

APA CITATION

Kollie, W. S., & Semu, E. (2022). Effects of Liming on Acid Soil to Improve Growth and Yield in Soybean (Glycine max L. Merill). *East African Journal of Agriculture and Biotechnology*, *5*(1), 244-252. https://doi.org/10.37284/eajab.5.1.1006

CHICAGO CITATION

Kollie, William Saygbah and Ernest Semu. 2022. "Effects of Liming on Acid Soil to Improve Growth and Yield in Soybean (Glycine max L. Merill)". *East African Journal of Agriculture and Biotechnology* 5 (1), 244-252. https://doi.org/10.37284/eajab.5.1.1006

Article DOI: https://doi.org/10.37284/eajab.5.1.1006

HARVARD CITATION

Kollie, W. S., & Semu, E. (2022) “Effects of Liming on Acid Soil to Improve Growth and Yield in Soybean (Glycine max L. Merill)”, *East African Journal of Agriculture and Biotechnology*, 5(1), pp. 244-252. doi: 10.37284/eajab.5.1.1006.

IEEE CITATION

W. S. Kollie, & E. Semu, “Effects of Liming on Acid Soil to Improve Growth and Yield in Soybean (Glycine max L. Merill)”, *EAJAB*, vol. 5, no. 1, pp. 244-252, Dec. 2022.

MLA CITATION

Kollie, William Saygbah & Ernest Semu. “Effects of Liming on Acid Soil to Improve Growth and Yield in Soybean (Glycine max L. Merill)”. *East African Journal of Agriculture and Biotechnology*, Vol. 5, no. 1, Dec. 2022, pp. 244-252, doi:10.37284/eajab.5.1.1006.

INTRODUCTION

Globally, soil fertility is one of the most critical aspects of crop production. The low soil fertility status of many soils coupled with the non-use of mineral fertilizers by smallholder farmers contribute to the low yields of most annual crops in Sub-Saharan Africa (Sikka *et al.*, 2012). Mineral fertilizers are very expensive and their use is almost negligible in many developing countries. Strongly acidic soils (pH < 4 and 5.0) have low levels of phosphorous, calcium, and molybdenum, along with aluminium and manganese toxicity which affects plant growth, yield, and yield components (Fageria *et al.,* 2013). Application of lime ($CaCO_3$) to acid soil neutralizes the toxicity effects of H^+, Al^{3+}, and Mn^{2+} supplies Ca^{2+} and unlocks other available plant nutrients such as phosphorous, potassium, Boron, and molybdenum which are essential to soybean growth (Athanase *et al*., 2013). About 30% of the world’s total land area consists of acid soils and as much as 50% of the world’s potentially arable lands are acidic (Fageria and Moreira, 2011).

Acid soils cover more of the soils of Sub-Saharan Africa (SSA) and the productive capacity of these soils are low and has contributed to a rapid decline due to their poor fertility, Aluminium toxicity and fragile structure (Aviles *et al.,* 2020). These soils are believed to be old and highly weathered hence exposed to continuous rainfall influenced by leaching. Sustainable increases in productivity on these soils can only be achieved by a gradual transformation of traditional farming systems through the development and acceptance of new farming technologies that will consider socioeconomic and agroecological diversity (Fageria and Nascente, 2014). It is well documented that as soil pH declines, so does the supply of several essential plant nutrients, including calcium, magnesium, and phosphorus; this decline occurs alongside an undesirable increase in aluminium to levels toxic to plants (Miller, 2016). It is also true that many small-scale farmers in Morogoro, Tanzania depend on such soils for their social and economic livelihoods. By improving the soil pH, soybean can improve soil fertility and enhance plant nutrient availability, thus making it possible for resource-limited farmers to save on the cost of purchasing mineral fertilizers.

MATERIALS AND METHODS

Experimental Site

The study was conducted at the Crop Museum, Sokoine University of Agriculture (SUA) Farm Morogoro, and Tanzania. The study area is located between latitude 6˚05’ and longitude 37˚39’ East at an elevation of 568 m above sea level. The field site is located at the foot slopes of Uluguru Mountain in Morogoro Municipal, Tanzania. The rainfall distribution is bimodal with the first season (short rain) lasting from November to January while the second season (long rain) lasting from February to May. The annual rainfall ranges between 800 to 950 mm. The soils are sandy, clay and loam with pH ranging between 5.0 – 5.2. The physiographic feature of the area is an undulating convex land and the slope is about 4% (Kisetu *et al.*, 2013).

 |

Article DOI: https://doi.org/10.37284/eajab.5.1.1006

Table 1: Physical and chemical soil properties at the experimental site

Soil characteristics		Unit	Value	Remarks
Physical characteristics	Sand	%	67	
	Silt	%	06	
	Clay	%	14	Sandy Clay Loam*
	Bulk Density	g/cm^3	1.04	High**
Chemical properties	Soil pH		5.0	Acidic*
	Cation exchange capacity	cmol/kg soil	8.70	Low*
	Organic carbon	%	0.44	Very low*
	Calcium	cmol/kg soil	2.24	Low*
	Magnesium	cmol/kg soil	0.54	Low*
	Total Nitrogen	%	0.06	Very low*
	Phosphorus	Ppm	6.44	Low*
	Sodium	cmol/kg soil	0.13	Low*
	Aluminium	meq/kg soil	4.54	High**
Micronutrients	Zinc	Ppm	2.1	Low*
	Iron	Ppm	96.78	High*
	Manganese	Ppm	40.62	Very high**

*Rating: *Landon (1991); **Lindsay and Norvell (1978)*

Experimental Design

Three soybean varieties (Bossier, Laela and Uyole soya-1) used in the experiment were obtained from Uyole Agricultural Research Institute in Tanzania. Lime (CaCO3) was purchased from an agricultural inputs supplier in Morogoro, Tanzania.
The experiment was laid out in a split-plot - randomized complete block design (RCBD) with four replications. The soybean varieties (Uyole soya-1, Bossier and Laela) were applied as the main plot and lime rates to change the soil pH to 5.5, 6.0 and 6.5 as the subplot. The crop was spaced at 0.5 x 0.2 m for inter-row and intra-row, respectively. The subplot size was 2 x 2 m while the main plot size was 9.5 x 2 m; between subplots was 0.5 m and spacing between main plots and replications was 1 m resulting in 2 m^2. Each plot had four rows with 10 plants per row. The length of the field was 32.5 m, and the width was 13 m. The effective area used for the experiment was 422.5 m^2.

Soil Analysis

Soil samples were collected at a depth of 0-30 cm as recommended by Pleysier (1995) for the physiochemical analyses according to Landon (1991). Soil Bulk Density was determined by the core method as described by Lal and Shukla (2004). Soil pH was determined electrometrically in 1:2.5 soil-water suspensions as described by Mclean (1982). Total nitrogen was determined by the micro-Kjedahl digestion method as described by Bremmer and Mulvaney (1982). Soil available phosphorus was determined based on the Mehlich 3 extraction procedure (Mehlich, 1984). Exchangeable potassium was determined by the use of the ammonium acetate method (McLean and Watson, 1985). The CEC of the soil was determined by a compulsive exchange procedure (Gillman and Sumpter, 1986). Exchangeable aluminium was determined by the KCl method as described by Hiradate *et al.* (1998). Exchangeable calcium was determined by the buffer method as described by Adams and Evans (1962). Zinc was determined by the zincon method as described by Miller (1979). Exchangeable sodium was determined based on the method described by Blakemore *et al.* (1987). Iron, Magnesium and Manganese were determined by the EDTA method as described by Schnug *et al.* (1996).

Data Collection

Crop Growth and Development

Growth characteristics began nine (9) days after emergence (VE) and continued to seventy-nine (79) days at full maturity (R_8), according to Pedersen (2015). Plant height (cm) was recorded as described

Article DOI: https://doi.org/10.37284/eajab.5.1.1006

by Welles and Norman (1991). The leaf area index (L.A.I) was calculated as described by Hunt (1978).

$$LAI = \frac{LAm^2}{GAm^2}$$

Where LA = leaf area and GA = ground area

The harvested plants were oven dried at 70^0C for 48 hours and the dried weights were recorded using (Doran 7000, Doran Inc.) an electronic weighing balance.

Yield and Yield Components

Average pods weight/plant, number of pods/plants, the average number of seeds/pods, number of filled pods/plant, seed weight (g) and average grain yield in (kg/ha) were recorded as described by Chettri (2003).

Number of Pods per Plant

At harvest maturity (R8), 10 soybean plants were harvested by uprooting from the middle row of each replicated plot and pods were counted. The average number of pods was as follows:

$$Pods\ per\ plant = \frac{Total\ number\ of\ pods\ from\ 10\ plants}{Number\ Number\ of\ plants}$$

Average Number of Filled Pods per Plant

Ten soybean plants were harvested from each plot and the number of filled pods was counted. Hence, the average number of filled pods per plant was calculated as follows:

$$Filled\ pods\ per\ plant = \frac{Total\ number\ of\ filled\ pods\ from\ 10\ plants}{Number\ of\ plants}$$

Average Number of Seeds per Pod

Ten pods from ten plants were randomly selected and the number of seeds was counted. The average number of seeds per plant was calculated as follows:

$$Average\ seeds\ per\ pod = \frac{Total\ number\ of\ seeds\ from\ all\ 10\ plants}{Number\ of\ pods}$$

Seed Weight (g)

A hundred seeds were randomly picked from ten plants harvested from each plot and weighed. Seed weight was thereafter calculated as follows:

$$\frac{Weight\ of\ 100\ seeds\ (g)}{100}$$

Average yield (kg/ha)

Yield in kg/ha was calculated by multiplying the average number of filled pods/plant, the average number of seeds/pod and the weight of 100 seeds (g) harvested from the central rows of 1.0 m 2 to get yield per plant (g). The yield per plant (g) was then converted to kg/ha by multiplying the yield per plant by 10 000 m^2 and dividing the sum by 1000 kg. This resulted in a yield (kg/ha).

Data Analysis

All data collected were subjected to analysis of variance (ANOVA) using GENSTAT 15th edition and declared significant at $P < 0.05$ using the statistical model as described by Gomez and Gomez (1984). The mean separation test was done using Duncan's Multiple Range Test and conclusions were made at $P \leq 0.05$ level of significance.

RESULTS AND DISCUSSIONS

Soil Physiochemical Characteristics

Soil analyses in the current study revealed that the soil textural class was classified as sandy clay loam (Ryan *et al.*, 1999) with a bulk density of 1.04g/cm^3 and a soil pH of 5.0. The soil pH was considered strongly acidic according to a rating by Landon (1991) thus resulting in the application of lime (CaCO3). Salvagiotti *et al*. (2008) reported that soybean thrives in the pH range of 6.0 to 6.8.

The cation exchange capacity (CEC) in the current study was low (8.70 cmol/kg soil) according to the rating by Landon (1991). The total organic carbon was also low (0.44 %) according to a rating by Landon (1991). The low organic matter in the study area could be attributed to continuous cultivation, non-return of crop residues, and non-use/limited applications of soil amendments like farmyard manures. Total nitrogen was very low (< 0.06) according to a rating by Landon (1991). Effects of low soil N retards plant growth and reduce crop yield. The soil in the study showed low (6.44 ppm) availability of phosphorus according to a rating by Landon (1991). Soil analysis based on classification by Landon (1991) rated calcium low (2.24 cmol/kg soil), magnesium low (0.54 cmol/kg soil) and potassium low (0.27 cmol/kg soil).

Iron (96.78 ppm) and manganese (40.62 ppm) contents in the study were high according to the rating by Lindsay and Norvell (1978), while

Article DOI: https://doi.org/10.37284/eajab.5.1.1006

available zinc (2.1 ppm) was low (Landon, 1991). However, the application of lime to acid soil supplies Ca^{2+} and neutralizes the toxicity effects of H^{+}, Al^{3+} and Mn^{2+} and make nutrients readily available for plant root uptake. Ibrahim *et al.* (2011) reported that limed acid soils increased plant nutrient output, ameliorated acidic soil conditions, and improved plant growth, yield and yield components.

Aluminium in the current study was high (55.4 meq/kg soil) according to a rating by Landon (1991). A high level of Al occurs in soil when the pH values are equal to or less than 5.4. An excessive amount of Al inhibits plant root development and limits crop growth. Limed acid soils neutralized Al effects and reduced its concentration resulting in a soil environment favourable for plant growth. Kisinyo *et al.* (2012) reported that liming acid soils lead to a considerable increase in the pH with a decrease in exchangeable acidity and displacement of H^{+} and Al^{3+} ions from the soil adsorption sites by Ca^{2+} ions contained in the lime. The results also showed that the soil pH in the study changed over time, thus having significant effects on crop growth yield and yield components. Similarly, Andric *et al.* (2012) reported an increase in soybean yield by 44% in acid soil as a result of lime application.

Soybean Growth Responses as Influenced by Liming

Plant height was significantly influenced (P = 0.001) by lime application. Uyole soya-1 was observed to be the tallest (47.90 cm) and showed improved early growth, followed by Laela (43.13 cm) and Bossier (41.28 cm). The results are similar to those of Alemayehu and Tamado (2021), that reported a significant effect (P = 0.001) on plant height by the main effect of lime application. Lime application had a significant effect (P = 0.001) on the leaf area index. The highest amount of lime (1 560 kg/ha) gave the highest (5.5) LAI, followed by 936 kg/ha lime (3.4) and 624 kg/ha lime (1.9). Similarly, Ibrahim (2018) recorded significant liming effects P≤ 0.001) on LAI among soybean genotypes cultivated in acid soil over those with applied ash.

Table 2: Amount of lime applied to raise the soil pH (from 5.0-6.5)

S/No	Amount of lime applied (kg/ha)	pH value acquired
1	0	5.0
2	624	5.5
3	936	6.0
4	1 560	6.5

The pH 5.0 was used as the control in the experiment since it was the initial pH of the soil prior to liming.

Plant dried weight were significantly higher (P = 0.001) at pH 6.5, 6.0 and 5.5 but was lowest at pH 5.0. Application of 1 560 kg/ha lime had the highest (876 kg/ha) biological yield in the study, followed by 936 kg/ha lime (815.1 kg/ha) and 624 kg/ha lime (703.0 kg/ha) while 0 kg/ha of lime gave the lowest (499.9 kg/ha) biological yield in all the varieties (*Table 3*). The results are similar to those of Rukia *et al.* (2020) who reported significant effects (P = 0.001) on plant dry weight in tropical soybean varieties.

Table 3: Effects of soybean varieties and soil pH on plant height (cm), LAI and plant dry weight

Treatment		Plant Height (cm)	LAI	Plant dry weight (kg/ha)
Soybean varieties Factor (a)	Bossier	41.28a*	2.9a	686.3a
	Laela	43.13a	2.9a	755.4a
	Uyole soya-1	47.90b	2.9a	729.2a
	Grand mean	44.1	2.9	723.6
	CV a (%)	3.10	23.0	15.2
	P value	0.001	0.70	0.21
Lime (kg ha) Factor (b)	0 (pH 5.0)	37.04a	0.8a	499.9a
	624 (pH 5.5	41.84b	1.9b	703.0b

Article DOI: https://doi.org/10.37284/eajab.5.1.1006

Treatment		Plant Height (cm)	LAI	Plant dry weight (kg/ha)
	936 (pH 6.0)	47.25c	3.4c	815.1bc
	1 560 (pH 6.5)	50.28c	5.5d	876.6c
	Grand mean	44.1	2.9	723.6
	CV b (%)	3.7	5.8	7.0
	P value	0.001	0.001	0.001

**Means in the same column followed by the same letter do not differ significantly using the Duncan Multiple Range Test at P≤ 0.05.*

Effects of Lime Application on Soybean Yield Components

The study showed significant effects (P = 0.001) on an average number of pods per plant among soybean varieties. The highest (52.07) average number of pods per plant was observed in Uyole soya1 followed by Bossier (51.92) and Laela (42.97). The results are in agreement with those of Bekere *et al.* (2013) who reported significant effects (P = 0.001) on legumes' yield and yield attributes have grown in limed acid soil. A significant effect (P = 0.001) was also observed for treatment application on average pod number per plant. The highest (59.86) pod number per plant was observed from the highest amount of applied lime (1 560 kg/ha) followed by 936 kg/ha lime (50.86) and 624 kg/ha lime (49.63) while 0 kg/ha lime had the lowest (35.61) average pod number per plant.

Table 4: Effects of liming on soybean yield components

Treatments		Average number of pods	Average number of filled pods
Soybean varieties factor (a)	Bossier	51.92b*	50.26a
	Laela	42.97a	41.19a
	Uyole Soya-1	52.97b	51.99b
	Grand Mean	49	47.8
	CV a (%)	14.4	16
	P (value)	0.001	0.001
Lime (kg/ha)	0(pH 5.0)	35.6a	34.51a
	624 (pH 5.5)	49.63b	48.79b
	936 (pH 6.0)	50.86b	49.31b
	1560 (pH 6.5)	59.86c	58.63c
	Grand mean	49	47.8
	CV b (%)	7.88	15.2
	P (value)	0.001	0.001

**Means in the same column followed by the same letter do not differ significantly using Duncan Multiple Range Test at P≤ 0.05.*

The average number of filled pods had significant effects (P = 0.001) among soybean varieties. Uyole soya -1 gave the highest (51.99) number of filled pods per plant, followed by Bossier (50.26) and Laela (41.19). A significant effect (P = 0.001) was also observed on filled pods when different levels of lime were applied. More filled pods were observed under limed soil as opposed to non–limed plots. The study revealed that the applied lime raised the pH to levels (5.4, 6.3 and 6.6) at which soybean thrived. Plants that received 1 560 kg/ha lime produced the highest (58.61) average number of filled pods per plant, followed by 936 kg/ha (49.31) and 624 kg/ha (48.79). The results are in agreement with those of Bekere *et al.* (2013) who reported significant effects (P = 0.001) on pod formation in soybean when lime was applied. It was also observed that 0 kg/ha gave the lowest (34.51) average number of filled pods per plant.

Article DOI: https://doi.org/10.37284/eajab.5.1.1006

Effects of Lime Application on Soybean Yield

A significant effect (*P* = 0.001) was observed on the average number of seeds per pod among soybean genotypes. The results are in agreement with those reported by Bekere and Hailemariam (2012). Their findings showed that average seeds per pod recorded from soils treated with lime were significantly (*P* = 0.001) influenced. Their findings concluded that liming acid soil neutralized its toxicity effects, raised the pH, and made nutrients readily available needed by soybean to enhance growth and development. Significant effects (*P* = 0.005) were also observed among soybean varieties on 100 seed weight (g/100 seed). The results are in conformity with those of Chalk *et al.* (2010) who reported significantly higher seed weight on legumes treated with lime. Application of 1 560, 936 and 624 kg/ha of lime showed significant effects (*P* = 0.04) on crop yield performance, such as seed weight, compared to plots with no applied lime. Application of 1560 kg/ha yielded the other lime levels applied. This is because lime makes the soil environment suitable for leguminous plants and their associated microorganisms as well as increases the concentration of essential plant nutrients by raising the pH and precipitating exchangeable Al^{3+} (Kisinyo *et al.*, 2012).

Table 5: Effects of lime on soybean yield

Treatment		Average number of seeds/pod	100 seed weight (g)	Grain yield (kg)
Soybean varieties factor (a)	Bossier	22.19b	17.03a	2143ab
	Laela	14.40a	18.27b	2302b
	Uyole soya-1	21.55b	17.96ab	1990a
	Grand mean	19.38	17.75	2145
	CV a (%)	32.6	7.71	14.8
	P value	0.001	0.05	0.05
Lime (kg/ha) factor b	0 (pH 5.5)	19.65a	16.94a	1224a
	624 (pH 5.5)	18.86a	17.33a	1808b
	936 (pH 6.0)	19.26	18.19b	2477c
	1560 (pH 6.5)	19.72a	18.54b	3071d
	Grand mean	19.38	17.75	2145
	CV b (%)	14.9	81	7.2
	P value	0.99	0.04	0.001

**Means in the same column followed by the same letter do not differ significantly using Duncan Multiple Range Test at P≤ 0.05.*

CONCLUSION

The findings in the study suggest a great potential for soybeans production in acid soil when lime is applied. The study showed that lime application tends to influence soybean growth, yield, and yield components. It was also observed that plots treated with different lime levels (1 560, 936 and 624 kg/ha) produced higher grain yield than plots treated with no lime. The initial soil pH (5.0) at the experimental site was also observed to have changed over time when different levels of lime were applied, thus implying a better soil environment for plant growth. Moreover, it was revealed that Uyole soya-1 had the highest average number of filled pods per plant, the average number of pods per plant, the average number of seeds per pod and 100 seed weight (g). Laela was observed to have had the highest grain yield of all the varieties used in the study. It is therefore concluded that lime application of 1560 kg/ha significantly increased the soil pH and subsequently influenced crop growth yield component with Laela being the most lime-efficient variety recording the highest grain yield compared to other varieties in the study.

ACKNOWLEDGEMENT

The study was sponsored by the International Institute for Tropical Agriculture (IITA) and supervised by Professor Ernest Semu and Professor

Article DOI: https://doi.org/10.37284/eajab.5.1.1006

Cornel Rweyemamu, Sokoine University of Agriculture (SUA), Morogoro, Tanzania.

REFERENCES

Adams, F., and C.E. Evans. (1962). A rapid method for measuring the lime requirement of Red-Yellow Podzolic soils. *Protection Soil Society of America*: pp. 255-357.

Alemayehu Dabesa, Tamado Tana, "Response of Soybean (Glycine max L. (Merrill)) to Bradyrhizobium Inoculation, Lime, and Phosphorus Applications at Bako, Western Ethiopia", International Journal of Agronomy, vol. 2021, Article ID 6686957, 12 pages, 2021. https://doi.org/10.1155/2021/6686957

Andric, L., Rastija, M., Teklic, T. and Kovacevic, V. (2012). Response of maize and soybeans to liming. *Turkish Journal of Agriculture and Forestry*, (36): pp.415 - 420.

Athanase, N., Vicky, R., Jayne, M. N., &Sylvestre, H. (2013). Soil acidification and lime quality, sources of soil acidity, its effects on plant nutrients, efficiency of lime and liming requirements. Agricultural Advances, 2(9): pp. 259-269.

Aviles D, Berglund K, Wesström K, Joel A. (2020) . Effect of liming products on soil detachment. Acta Agr Scand B - Soil Plant Science. 70:48–55.

Bekere, W. and Hailemariam, A. (2012). Influences of inoculation methods and phosphorus levels on nitrogen fixation attributes and yield of soybean (Glycine max L. Merril) At Haru, Western Ethiopia. American Journal of Plant Nutrition and Fertilizer Technology 2: 45 – 55.

Bekere, W., Kebede T. and Dawud J. (2013). Growth and Nodulation Response of Soybean (*Glycine max L. Merrill*) to Lime, *Bradyrhizobium japonicum* and Nitrogen Fertilizer in Acid Soil at Melko, South Western Ethiopia. *International Journal of Soil Science* 8(1): 25 – 31.

Blakemore, L. C., Searle, P. L. and Daly, B. K. (1987). Methods for Chemical Analysis of Soils. Report No. 80. Soil Bureau Scientific, New Zealand. 103pp.

Bremner, J. M. and Mulvaney C. S. (1982). Methods of Determining Total Nitrogen (Edited by Page A. L.), Methods of Soil Analysis, 624pp.

Chalk, P.M., Alves, B. J. R., Boddey, R. M. and Urquiaga, S. (2010). Integrated effects of abiotic stresses on inoculants performance, legume growth and symbiotic dependence estimated by 15 N dilutions. Plant Soil 328: pp. 1 – 16.

Chettri, S. S. (2003). Study of variation for yield and yield contributing characters in soybean. Soybean Science 23: 6 – 9.

Fageria, N. K., Nascente, A. S. (2014). Management of soil acidity of South American soils for sustainable crop production. *Journal of Advance Agronomy*. 128: pp. 221–275

Fageria, N. K., & Moreira, A. (2011). Advances in Agronomy. In Donald, L. (Edited). The Role of Mineral Nutrition on Root Growth of Crop Plants (1st edition., pp. 251-331). Academic press.

Fageria, N. K., Moreira, A., Castro, C., Moraes, M.F. (2013). Optimal acidity indices for soybean production in Brazilian oxisols. *Community of Soil Science and Plant Analysis*. 44(20): pp. 2941–2951.

Gillman, G. P. and Sumpter, E. A. (1986). Modification to the compulsive exchange method for measuring exchange characteristics of soils. Australian Journal of Soil Research 24: 61 – 66.

Gomez, A. K., Gomez, A. A. (1984). Statistical Procedure for Agricultural Research. John Wiley and Sons, Inc., London. 1984;680.

Hiradate, S., Taniguchi, S. and Sakurai, K. (1998). Aluminium speciation in aluminiumsilica solutions and potassium chloride extracts of acidic soils. Soil Science Society of America Journal 62: 630 – 636.

Hunt, R. (1978). Plant Growth Analysis. Edward Arnold, Olondon, UK. 38pp.

Ibrahim, I. (2018). Evaluation of liming, inoculation and phosphorus fertilizer on yield components and yield of soybean (glycine max (l.) Merrill in the guinea savannah of Ghana. P 87.

Ibrahim, A. K., Usman, A., Abubakar, B., and Aminu, U. H. (2011). Extractable micro nutrients status in relation to other soil properties in Billiri Local Government Area. Journal of Soil Science and Environment Management 3 (10): pp. 282 – 285.

Kisetu, E., and Teveli, C. N. M. (2013). Response of green gram (Vignaradiata L.) to an

 |

Article DOI: https://doi.org/10.37284/eajab.5.1.1006

application of Minjingu Mazao fertilizer grown on Olasiti soils from Minjingu Manyara, Tanzania. Pakistan Journal of Biological Science 16: 1601 – 1604.

Kisinyo, P. O., Gudu, S. O., Othieno, C. O., Okalebo, J. R., Opala, P. A., Maghanga, J. K., Agalo, J. J., Ng'etich, W. K., Kisinyo, J. A., Osiyo, R. J., Nekesa, A. O., Makatiani, E. T., Odee, D. W. and Ogola, B. O. (2012). Effects of lime, phosphorus and rhizobia on Sesbaniasesban performance in a Western Kenyan acid soil. *African Journal of Agricultural Research* 7(18): pp. 2800 – 2809.

Lal, R. and Shukla, M. K. (2004). Principles of Soil Physics. The Ohio State University Columbus, Ohio, USA. 324pp.

Landon, J. R. (1991). Booker Tropical Soil Manual. A Handbook of Soil Survey and Agriculture Land Evaluation in Tropical and Subtropical. Longman Publishers, London. 474pp.

Lindsay, W. L. and Norvell, W. A. (1978). Development of a DTPA soil test for zinc, iron manganese and copper. Soil Science Society of America Journal 42: Pp.421 – 428.

McLean, E. O. (1982). Soil pH and lime requirement. In: Methods of Soil Analysis, Chemical and Microbiological Properties. (Edited by. Page, A. L.), Madison, Wisconsin. pp. 199 – 224.

McLean, E. O. and Watson, M. E. (1985). Soil Measurements of plant available potassium. In: Potassium in Agriculture. (Edited by Munson, R.D.), ASA, CSSA, and SSSA, Madison. pp. 277 – 308.

Mehlich, A. (1984). Mehlich 3 soil test extractant: A modification of Mehlich 2 extractant. Communications. Soil Science and Plant Analysis 15: 1409 - 141 6.

Miller, D. G. (1979). Colorimetric determination of zinc with zincon and cyclohexanone. Journal of Water Pollution Control Federation 51: 2402.

Miller, Jarrod (2016). Soil pH Affects Nutrient Availability. Available at: https://www.researchgate.net/publication/305775103.

Pedersen, P. (2015). Soybean growth and development. Iowa State University. Available at: [htt://extension.agron.iastate.edu/soybean/production growthstages.htm].

Pleysier, J. L. (1995). Soil Sampling and Sample Preparation. Training Program, Research. Guide No. 2. International Institute of Tropical Agriculture, Ibadan, Nigeria. 27pp.

Rukia Bakari, Nancy Mungai, Moses Thuita & Cargele Masso (2020) Impact of soil acidity and liming on soybean (Glycinemax) nodulation and nitrogen fixation in Kenyan soils, Acta Agriculturae Scandinavica, Section B — Soil & Plant Science, 70:8, 667-678, DOI: 10.1080/09064710.2020.1833976

Ryan, J., Garabet, A., Rashid, A. and El-Gharous, M. (1999). Assessment of soil and plant analysis laboratories in the West Asia – North Africa region. Communication in Soil Science and Plant Analysis 30: Pp. 885 – 894.

Salvagiotti, F., Cassman, K. G., Specht, J. E., Walters, D. T., Weiss, A. and Doberman, A. (2008). Nitrogen uptake, fixation, and response to fertilizer N in soybeans: A review. Field Crops Research 108: 1 – 13.

Schnug, E., Fleckstein, J. and Hankelaus, S. (1996). The ubiquitous extractant for micronutrients in soil. Communications in Soil Science and Plant Analysis 27: 1721 – 1730.

Sikka, R., Singh, D., DeolJS., (2012). Productivity and nutrient uptake by soybean as influenced by intergrated nutrient and some other agronomic management practices. Legume Resource Management. 36(6): pp. 545–551

Welles, J. M. and Norman, J. M. (1991). Instrument for indirect measurement of canopy architecture Agronomy Journal 83: 818 – 825.

 |