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Research Paper

Effect of lime application on soil physicochemical characteristics and plant nutrient contents of three soybean cultivars [*Glycine max* (*L.*) Merril] in coastal plain sands of Nigeria

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Soybean [*Glycine max* (*L.*) Merril] is one of the ost important legume crops. Soybeans have become one the strategic commodities after rice and corn. Experiment was carried out in 2012 and 2013 planting seasons to evaluate the influence of lime on the physicochemical properties and nutrient content of vegetative plant parts of three soybean cultivars (*Glycine max (L.*) on acid sands of Calabar, Nigeria. Levels of lime used were 0, 3600 kg ha^{-1} in 2012, 0 and 1600 kg ha^{-1} in 2013 seasons. The result showed that the application of lime significantly ($P<0.05$) influenced in soil chemical composition and the mineral content in plant material of the three soybean cultivars. The particle size distribution showed that the soil was predominantly sandy loam texture. The silt fractions increased down the soil depth such that their values were higher in some cases in the subsoil than the surface soil. The sand content was steady in the soil profile. The N (g/kg), Avail P (mg/kg), exchangeable bases Ca, Mg, K (cmol/kg) had their values higher on the surface soil than the subsoil and these values were influenced by liming. The Al and Fe activities were reduced at high soil pH due to liming, making the exchangeable bases available for plants absorption. The availability of nutrient content in plant material was increased with reduced lime level in the second year. Cultivar differences in their nutrient content in the plant part was significant ($p<0.05$). The cultivar TGM 626, tended to have more nutrient contents in the plant materials than either TGM 630 or TGM 631. These results imply that, for acidic soils liming is the best practice to increase fertilizer use efficiency.

Key words: Calcium carbonate, *Glycine max,* mineral nutrition, soil characterization

INTRODUCTION

Soybean perhaps is one of the oldest crops that originated from China before 1000 BC and has been cultivated in Asia for centuries and has spread to several parts of the world (Kroll, 1997). Soybean is much widely spread as it is found in nearly every country in sub-saharan Africa where Nigeria is the largest producer. Soybean is grown throughout the world with the largest production in the United States, Brazil, China, Mexico, Indonesia and Argentina. The crop is also grown in Philippines, Japan, East India, Hawaii, Australia and some parts of Africa, and came into Nigeria in 1908 (Ezedinma, 1964) through the Portuguese during the slave trade. The International Institute for Tropical Agriculture Ibadan had soybean varieties combining promiscuity, good seed longevity and resistance to bacterial pustule with early maturity (IITA, 1985).

The crop is also used as green manure and cover crop to improve soil fertility. Soybean is mainly cultivated for its seeds which are used domestically and commercially for human food and livestock feeds. Soymilk is processed and sold as beverages in both rural and urban communities. United States is the world's largest producer and exporter of soybean and accounts for over 90% of world's production (IITA, 2015). More than 216 million tons of soybeans were produced worldwide in 2007, of which 1.5 million were in Africa (IITA, 2015). Nigeria currently produces 500,000 metric tonnes of soybean annualy worth N300,000 billion, with most of it produced in Benue State, where it accounts for 45% of the total production in the country (Anga, 2016). The humid tropical environment of south eastern states including Cross River State is the most challenging for soybean production. The soils are characterized by low contents of exchangeable bases, organic carbon, total nitrogen and very coarse textured (Juo, 1981). Tropical soils such as the African savanna are naturally acidic because high levels of rainfall over many years have leached basic ions, resulting in reduced soil fertility (Caires *et al.,* 2008). According to Fageria *et al.* (2011), tropical soils are highly weathered and are dominated by 1:1 clay minerals such as kaolinite and iron oxides (hematite and goethite) and Al (gibbsite), which have a high P adsorption capacity. In these areas, satisfactory cash crop grain yields are dependent on proper liming and soil fertilization (Caires *et al.,* 2001; Alleoni *et al.,* 2009; Souza *et al.,* 2011).

Most African tropical soils are degraded and characterized by low levels of soils nutrients and consequently by a continued decrease of crop yield (Saïdou *et al.,* 2012). In recognition of the remarkable role of soybean in protein and edible oil supply, the crop has a high commercial value and concentration of protein, about 40%, calcium, phosphorus, fiber, and in addition it is cholesterol free (Greenberg and Hartung, 1998). In addition it provides food, cash, animal feed, increased other crop yield and contributes for soil improvement through biological nitrogen fixation (ICRISAT, 2009). Its high demand, has led to the need to increase and expand production to such areas as Calabar in the humid agro-ecological zone of Cross River State, with highly weathered leached acid soils, and poor fertility status. Udo, (1977) reported that soils from Calabar are derived from coastal plain sands dominated by quartz, Fe and Al oxides. The clay mineral is kaolinite. Many factors influence the low productivity which include inherent poor soil fertility of the African soils (Bationo *et al.,* 2006), continuous declining of the soil fertility (Kimani *et al.,* 2004; Okalebo *et al.,* 2006), poor management practices, low agricultural input use, worsened by the predominance of Humic Ultisol soil class with moderate to high acidity (Kanyanjua *et al.,* 2002).

The most common material used for acidity correction is limestone, which effectively increases soil pH, calcium and magnesium content and base saturation reduces the levels of exchangeable aluminum in the soil (Caires *et al.,* 2004). However, the reactions produced by limestone are generally limited to the location at which application/incorporation occurs due to the low mobility of limestone in soil. The results of field studies show that the movement of lime to depth varies according to the timing and rate of liming, the form of lime applied, the soil type, the weather conditions, the addition of acidic fertilizers and the cropping system (Conyers *et al.,* 2003; Caires et al., 2008; Churka Blum *et al*., 2013).

According to Caires *et al.* (2003), liming, whether applied to the surface or incorporated into the soil, provided more intense soil acidity correction in the superficial layer (0 to 0.5 m). On the other hand, a stronger reaction also occurred in the 0.05 to 0.10 m and 0.10 to 0.20 m layers when lime was incorporated into the soil. Caires *et al.* (2005 Ref not available) added that the effects of surface liming on all three acidity-related variables (pH, Al, and basic cations) were significant at depths of 0 to 0.05 m and 0.05 to 0.1 0 m from 1 year onward and at a depth of 0.10 to 0.20 m from 2.5 years onward. As a result, the reactions of lime in the soil are subject to further delays, especially at times relatively close to the time of application (Caires *et al.,* 1998; Fageria and Baligar, 2008).

In a similar study, Ubi and Osodeke, (2009) found that liming with $CaCo_3$ at 50 kg ha^{-1} can reduce activity and solubility of aluminum and iron which can be toxic in all but very low concentration. They also reported that the effect of liming was to reduce the amount of extractable aluminum and iron and when lime is combined with phosphate, the reduction effect of aluminum and iron are enhanced. In this region increasing population with respective increased demand for food and land, causes less availability of land for agriculture. This associated to the previous underlined factors are found as the major reasons for food insecurity and poverty amongst smallholder farmers. To increase soybean and other crop yield is important to identify suitable technologies which include use of high yielding varieties, application of inorganic and organic resources providing therefore nutrients and improve soil physical and chemical properties. Interventions leading to improvement on soil pH to enable crop development and microorganism's activity are critical, since this impairs not only mineralization process but also the uptake of water and nutrients by the plant (IFDC, 2008). Thus, combination of organic resources with small amounts of inorganic resources will give better effects since inorganic sources are readily available and of rapid action. Liming will improve soil pH creating the conditions for microorganism's activity, root development (IFDC, 2008) and N_2 fixation (Lapinskas and Piaulokaitė-Motuzienė, 2006) which in addition will increase nutrient availability and uptake.

There is scarce information regarding effects of organic and inorganic or their combination on soybean N uptake and yields in the study area. It was in consideration of this and the nutritional significance of soybean that this study was undertaken to determine the effect of lime on the soil physical and chemical properties and the nutrient content of three soybean cultivars. Moreover, there is need for additional information about the effect of this approach on soil chemical characteristics, plant mineral nutrition and crop production.

MATERIALS AND METHODS

Experimental site

The experiment was conducted for two growing seasons (2012 and 2013) at Ikot Omin, Calabar, Cross River State, to determine the effect of lime on the physicochemical properties of the soil and nutrient content of the three soybean cultivars. The study area is located between latitude 05°32' and 04°27'N and longitude 07°15' and 09°28'E. The area is of humid tropical climate, characterized by high rainfall with two main seasons, dry and rainy season (Figure 1). The vegetation is tropical rain forest of the humid agro-ecological zone in Nigeria. According to USDA, system of classification (Soil Survey Staff, 2003) Calabar soils is typic paleudult. The soil is acid sands derived from coastal plain sands, consisting sand deposits which lies across Cross River and underlain by massive deposits of limestone, quartz, Fe and Al oxides dominate the soil with kaolinite as clay mineral and the soil texture is sandy loam (Udo, 1977).

Soybean cultivation

Three cultivars of soybeans (TGM 630, TGM 626, and TGM 631) tested were brought from International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria. These varieties had a maturity cycle of 100-120 days with potential grain yield of 4tha^{-1}. Dolomite lime $CaMg(CO_3)_2$ which supplies adequate Ca and Mg; Kamprath, (1970) was obtained from Mfamosing Limestone Quarry, Akamkpa Local Government Area of Cross River State. The limestone has chemical composition of 25.2 Cmol kg Ca, 2.8 Cmol kg Mg and pH of 7.6 as determined in Soil Science Laboratory of University of Calabar, Nigeria.

Experimental design and treatments

Amount of Lime

Lime determination was based on exchangeable Al extracted with neutral unbuffered salt solution for highly weathered soils of low pH like Ultisol (Kamprath, 1970). Page, (1985) recommended the use of 1.5 multiply by the exchangeable Al for maximum yield of most crops and 2 for every Al sensitive crops such as soybean in acid soils. Thus, the simple equation based on the above principle for lime requirement in acid soils was used to determine the lime rate to apply in each year as stated below:

Lime requirement (LR) meg/100g = 2.0 x exchangeable Al meg/100g soil. The values obtained were converted to kg ha^{-1}.

Lime requirement for the experiment

2012	1.8	3600 kg ha^{-1} (1st year)
2013	0.84	1600 kg ha^{-1} (2nd year)

Fertilizer/lime application

Two levels of dolomite lime 0 kg ha^{-1} representing no-lime (control) and 3600 kg ha^{-1}, based on soil test were applied by incorporating into the soil during ploughing and one month before planting in April 2012. In the second year, the calculated lime 1600 kg ha^{-1} was applied before planting in 2013. Based on the soil analysis results of the experimental site before the study, K and P were found to be low. Thus, at the beginning of the first planting, phosphorus and potash fertilizers were applied to all plots at the rate of 122.2 kg P ha^{-1} and 3758 kg K ha^{-1}, respectively.

Soil and plant sampling and analysis

Prior to experiment set up soil samples were collected for initial determination of soil fertility parameters. The soil samples were analyzed for pH, available P, exchangeable cations (Ca, Mg, and K) and exchangeable acidity.Prior to lime application, soil samples were collected with the use of soil galvanized steel auger 4.5 cm in diameter was used for sampling at depths of 0 to 0.15 m and 0.15 to 0.30 m in 2012 season (before liming) and 24 months after the first liming in each plot. The composite soil sample of each depth was air-dried crushed and sieved through a 2 mm sieve and used for physical and chemical analysis. Soil physical and chemical characteristics were determined in Soil Science Laboratory of the University of Calabar, Calabar, Nigeria by using standard analytical methods (Udo *et al.,* 2009) before and after liming. The soil fertility class shown overleaf was used to classify the level of nutrient availability (Table 1). The following is a brief description of the methods used for the analysis. The particle size distribution was determined by the hydrometer methods (Bouyoucos, 1962). The soil pH was determined in 1.2.5

Table 1. Rating of soil fertility classes.

Parameter	Low	Medium	High
Total N, kg^{-1}	<1.5	1.5>2.0	>2.0
Bray 1 P mgkg	<8	8-20	>20
Exchangeable K cmolkg^{-1}	<0.20	0.21-0.40	>0.40
Exchangeable Ca cmolkg^{-1}	<5	5.0-10.0	>10.0
Exchangeable Mg cmolkg^{-1}	<1.5	1.5-3.0	>3.0
Exchangeable Na cmolkg^{-1}	<0.3	0.3-0.7	>0.7
Organic matter gkg^{-1}	<30	20-30	>30

Source: FMA, WR and RD 1989and FMA 8NR (1990).

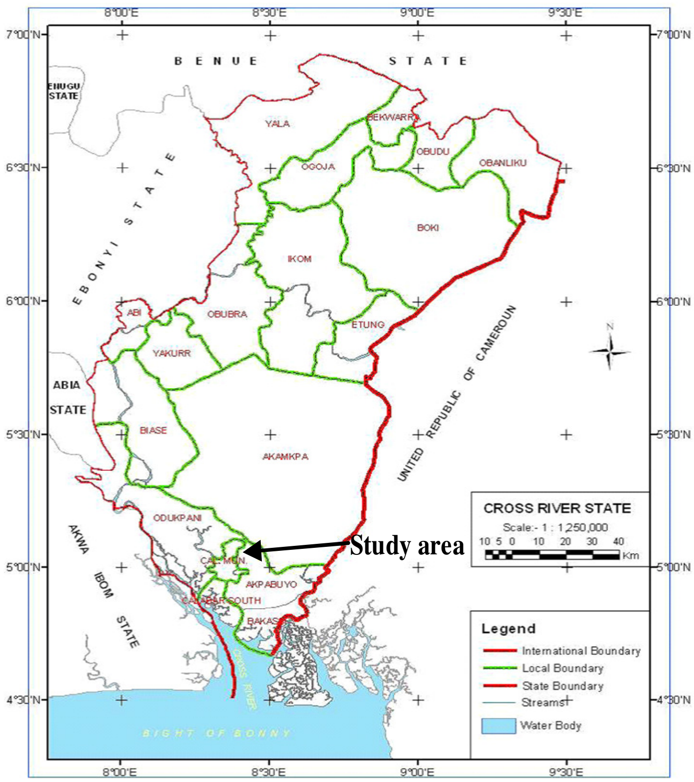

Figure 1. Map of Cross River State showing study area.

soil/water ratio using a glass electrode pH meter (ECE model 3 (Maclean, 1982). Organic matter was determined by the Walkley and Black, (1934) method. Total N was determined by micro-Kjeldahl method (Bremmer, 1965). Phosphorus was extracted by the Bray-1 method (Bray-1P) and determined by the ammonium molybdate blue method (Bray and Kurtz, 1945). Exchangeable bases (Ca, Mg, K and Na) were extracted with IN NH_4OAC pH7 and the amount in the extract measured with Flame Photometry for Na and K while Ca and Mg were determined with Atomic Absorption Spectrophotometer (ASS) method (Sparks, 1996). Exchangeable acidity was extracted with IN KCl (McClean, 1965) while ECEC (Effective Cation Exchange Capacity) was by summation of the exchangeable cations and exchangeable bases. Base saturation was calculated as a sum of the bases (TEB) divided by CEC (Cation Exchange Capacity).

Plant analysis

Nutrient content of vegetative part was determined as follows: percent N was by micro Kjeldahl method, using 0.5 g oven dried ground material (Udo *et al.,* 2009). The nutrient contents determined were N, P, K, Ca and Mg using standard analytical procedure. Two grams of sample was placed on a furnace and ashed at 500°C for

3 h until the ash turned white. After cooling, the samples were transferred to 50 ml volumetric flask washed with 5 ml 0f 30% HCl. The solution was diluted to volume with deionized water and used for individual nutrient determination using an Atomic Adsorption Spectrophotometer for Ca, Mg, and K. Concentrations of all nutrients were expressed on a dry weight basis and the nutrient uptake and accumulation calculated using the respective plant dry weights. The P contents were determined calorimetrically using a spectrophotometer. The procedure involved the use of Vanado-molybdate yellow method (Udo *et al.,* 2009).

Statistical analysis

Data collected were subjected to statistical analyses of variance (ANOVA) using the STATVIEW Software (SAS) version 8. Means were separated using Least Significant Difference (LSD) test at 5% level of probability.

RESULTS

The results of the soil physiochemical of the experimental site before the commencement of the study is presented in (Table 2), in which the texture of the soil was sandy loam (SL). The texture of the surface or top soil was the same with that of the sub-soil, although the clay content was slightly higher in the sub-soil than surface soil. The soil pH decreased slightly down the profile, while soil organic matter, organic carbon, total N decreased significantly down the profile. P increased with increase in profile depth while exchangeable bases of Ca, Mg, K and Na decreased down the profile and their values were moderate to low. Aluminum increased very slightly down the profile while hydrogen slightly decreased. The ECEC and percent base saturation decreased down the profile.

Soil physical and chemical properties

Fertility indices such as texture, cation exchange capacity (CEC), exchangeable bases, percentage base saturation, available phosphorous, organic matter, organic carbon, total exchangeable bases, clay, sand, silt, aluminum and hydrogen were presented in (Tables 2 and 3).

Physical properties

Particle size distribution indicates that the soils were predominantly sandy loam or loamy textures. Clay contents ranged between 140 and 150 g/kg (2012 season) and between 140 and 145 g/kg (2013 season) with means of 145g/kg and 142.5 g/kg with no lime for 2012 and 2013 seasons respectively. Values of clay on the average where lime was applied were between 142-143 g/kg with a mean of 142.5 g/kg (2012 season) and between 140-145 g/kg with a mean of 142.5 g/kg for the 2013 where lime has applied.

The total sand content of the soil where no lime was applied for 2012 and 2013 seasons did not show any difference in their values, even when the soil profile depth was increased from 0-15 cm to 15-30 cm soil depth, their values were the same. The surface horizons had total sand fraction results of 720 g/kg for each of the depths of either 0-15cm or 15-30 cm for the 2012 and 2013 seasons. The sand fraction values (718 kg^{-1}) obtained from the soil surface with lime application at 0-15 cm was the same when the soil depth was increased from 0-15cm to 15-30 cm soil depth in 2012 planting season. Application of lime in 2013 at the rate of 1600 kg ha^{-1} gave an insignificant ($p<0.05$) sand content of the soil (7.8 g/kg) for either 0-15cm or 15-30 cm soil depth. The clay fraction of the soil increased with increase in profile depth ranging from 140 to 150 g/kg with a mean of 145.0 g/kg (2012 season) and ranged between 137 and 135 g/kg with a mean of 136 g/kg (2013 season).

The silt fraction on the whole ranged between 130-136 g/kg with a mean of 133 g/kg with no lime (control) in 2012 season and from 134-136 g/kg with a mean of 135g/kg in 2013 season. Equally silt content with lime ranged from 135-138 g/kg with a mean of 136.5g kg^{-1} (2012 season) and between 135-137g kg^{-1} with a mean of g/kg (2013 seasons). On the whole, the silt content was not influenced by treatment and slight variations in their values were not significant ($p<0.05$). All the soils can be described as heavy textured because of their predominantly clay related textures.

Chemical characteristics

The soil reaction (pH) varied from 3.9 to 4.0 with no lime with a mean of 3.9, indicating that the soils are highly acidic. The values of pH is ranged between 6.0 to 6.6 in lime treated plots season with a mean of 6.3, indicating that lime treated soils were medium acidic to neutral. The organic carbon ranged between 12.6 to 22.2 g/kg with a mean of 17.4 g/kg (2012 season) and between 27.6 to 28.5 g/kg with a mean of 28.3 g/kg (2013 season). Average nitrogen from the unlined plots ranged between 1.2 to 2.1 g/kg in 2012 season with a mean of 1.6 g/kg while values for limed plots ranged between 2.6 to 3.5 g/kg with a mean of 3.1 g/kg in 2013 season. Available P (mg kg^{-1}) ranged between 8.7 to 12.8 with a mean of 10.7 from the unlimed plots, and between 21.6 to 36.8 with a mean of 29.2 for the 2012 and 2013 planting seasons respectively.

The soil exchangeable bases of Ca, Mg, K and Na were higher on the surface soil than on the sub-soil, decreasing down the profile. The Ca from the unlimed plots on the average ranged between 2.2 to 1.4 cmol kg^{-1}

Table 2. Some soil physical and chemical properties of the experimental site area before and after liming.

Parameters	No lime control		2012		No lime		2013	
								After liming
	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15 (cm)	15-30 (cm)	0-15(cm)	15-30 (cm)
pH (H_2O)	4.0	3.9	5.4	6.5	4.0	4.0	6.6	6.8
Org. Carbon(g kg^{-1})	23	14.2	28.7	26.5	21	11	29.5	27.6
Total N g/kg	2.0	1.20	2.8	2.6	2.1	1.03	3.5	2.8
Available P $mgKg^{-1}$	8.7	12.8	24.3	21.6	9.3	9.3	36.8	32.6
Exchangeable cations (cmol-kg^{-1})								
Calcium (Ca)	2.8	1.6	3.6	3.2	1.6	1.2	3.9	3.2
Magnesium (Mg)	0.4	0.3	0.8	0.6	0.4	0.3	0.9	0.7
Potassium (K)	0.03	0.02	0.3	0.2	0.03	0.02	0.4	0.3
Sodium (Na)	0.03	0.02	0.04	0.04	0.03	0.02	0.05	0.04
Aluminum (Al)	5.4	5.7	2.1	1.8	5.40	5.6	1.8	1.4
Hydrogen (H)	3.0	2.8	1.2	0.8	3.0	2.8	1.2	0.7
TEB	3.26	2.0	4.75	4.05	3.25	2.5	6.42	4.14
ECEC	11.66	10.50	7.5	14.2	11.7	10.55	18.6	15.5
%BS	28.0	19.0	38.5	31.7	28.0	29.0	42.1	39.2
Soil particle analysis (g kg^{1})								
Sand	720	720	718	718	720	720	718	718
Clay	140	150	140	140	140	145	143	142
Silt	130	196	135	138	136	134	137	135
Textural class	SL	SL	SL	SL	SL	SL	SL	SL

TEB (Total exchangeable bases), ECEC (Effective cation exchange capacity).

Table 3.Summary of soil physicochemical properties showing magnitude of variability among soil depth (mean of 2012 and 2013 seasons).

	Surface soil	(0-15cm)		Sub-soil	(15-30cm)		Surface soil	(0-15cm)		Sub-soil	(15-30cm)	
	Mean (x)	SD	CV%	Mean (x)	SD	CV%	Mean (x)	SD	CV%	Mean (x)	SD	CV%
	No Lime applied						Lime applied					
pH	40	0.76	14.20	4.00	0.76	14.2	6.0	0.44	16.91	7.01	0.17	
Org. C g/kg	22	5.31	18.12	13	1.88	15.72	29.15	5.21	19.32	28.00	6.79	24.31
Total N g/kg	2.1	0.28	12.14	1.10	0.18	12.76	3.15	0.38	21.89	2.7	0.19	18.92
AV.P mg/kg	9.15	1.5	14.68	11.00	1.75	14.23	33.3	6.25	18.12	29.6	5.16	16.18
Ca cmol/kg	2.2	0.29	13.01	1.40	1.19	13.58	3.75	0.41	22.56	3.2	0.38	21.88
Mg cmol/kg	0.4	0.17	47.56	0.30	0.15	53.56	0.85	0.27	34.18	6.5	0.44	7.04
K cmol/kg	0.03	0.02	33.24	0.35	0.17	48.56	0.35	0.17	48.56	0.25	0.14	52.57
Na cmol/kg	0.03	0.02	33.24	0.020	0.06	12.89	0.45	0.19	52.21	0.04	0.19	52.20
Al cmol/kg	5.40	0.73	14.24	5.65	0.76	15.24	0.04	0.17	89.36	1.6	0.20	49.33
H cmol/kg	3.0	0.07	13.76	2.80	0.32	13.05	1.20	1.12	12.18	0.75	0.26	45.62
TEB cmol/kg	3.26	0.09	15.02	2.50	0.30	12.74	6.38	0.57	17.25	4.14	0.81	33.20
ECEC cmol/kg	11.7	2.1	16.18	10.55	1.73	14.18	18.0	2.78	17.85	15.2	2.62	19.26
%BS	28.0	6.8	21.40	19.00	4.52	24.33	40.5	5.62	21.55	15.1	2.34	18.28
Sand g/kg	720	8.45	12.39	719	8.32	24.28	612.5	7.55	34.63	621	8.72	36.15
Clay g/kg	145	12.18	28.93	145	13.24	26.92	146.0	15.76	39.44	141.0	13.79	35.28
Silt g/kg	130	10.18	26.96	196.0	12.63	33.41	134.5	18.10	43.36	130.0	13.79	35.28

with a mean of 1.8 cmol kg-1 decreasing down the profile depth, values from the limed plots ranged between 3.7 to 3.2 mg kg^{-1} with a mean of 3.5mg kg^{-1}. Mg of the soil ranged between 0.4 to 0.3 cmol kg^{-1} with a mean of 0.4 cmol kg^{-1} for unlimed plots while the limed ranged between 1.3 to 1.7 cmol kg^{-1} with a mean of 1.5 cmol kg^{-1}.

The soil K ranged between 0.02 to 0.03 cmol kg^{-1} with a mean of 0.025 cmol kg^{-1} for both limed and unlimed plots on 2012 season while the values for 2013 season for limed plots ranged between 0.3 to 0.4cmol kg^{-1} with a mean of 0.35cmol kg^{-1}. The K content in 2013 season from the limed plot was higher on the surface soil (0.4cmol kg^{-1}) and decreases down the profile (0.3 cmol kg^{-1}). The values of Na in the soil for the unlimed ranged from 0.02 to 0.03 cmol kg^{-1} with a mean of 0.025 cmol kg^{-1}, while values from limed plots ranged from 0.04 to 0.05 cmol kg^{-1} with a mean of 0.045cmol kg^{-1}. On the average, values obtained from the surface soil were higher than from the sub-soils. The Al and H values followed a similar pattern, higher on the surface soil and decreasing down the profile. The Al and H values obtained from the unlimed plots were higher than that obtained from limed plots, indicating the neutralizing effect of lime on Al and H in acid soils. The total exchangeable bases (TEB) on the average ranged between 2.0 to 3.26 cmol kg^{-1} with a mean of 2.78 $cmol^{-1}$ from plots with no lime and between 5.25 to 5.28 cmol kg^{-1} with a mean of 5.26 cmol kg^{-1} from the plots treated with lime. The total value of TEB, decreased with increase in soil profile and values from the surface soil were significantly ($p<0.05$) higher than values from the sub-soil. The ECEC values from both limed and no lime plots were more than double the critical 4 cmol kg^{-1} recommended for the area. The values of ECEC from plots with no lime from the surface soil were similar to values obtained from the sub-soil. The mean values from plots with no lime ranged between 14.6 to 17.5cmol kg^{-1} with a mean of 15.8 cmol kg^{-1} and their values decreased with soil depth. Percent base saturation (PBS) from the no lime plot did not show any difference between the surface and sub-plot.

Magnitude of nutrients variability with soil depths

In terms of the coefficient of variation (%), soil depth influenced some of the chemical properties examined (Table 3). The variability of soil pH at 15-30 cm where lime was applied was 16.7% higher than other depths. The P content was 12.5% variable and Mg was 65% variable when compared with the other depths. Thus, the organic carbon and Mg were more variable at 15-30 cm than the others while TEB, ECEC and PBS were more variable at 15-30 cm than 0-15 cm soil depth.

% N content

The results of lime application on the N content of three soybean cultivars among two seasons are presented in (Table 4). The highest N content, 41.4 % was obtained from TGM626 where 16000 kg ha^{-1} was applied relative to the control and this value was significantly ($p<0.05$) higher than values of either TGM 630 or TGM 631. There was 37.1% unit increase in N content of the plant when 3600 kg ha^{-1} was applied compared with no lime, and 41.2% unit increase in N content when 1600 kg ha^{-1} was applied in the second growing season. Thus, high lime level of 3600 kg ha^{-1} compared with 1600 kg ha^{-1} tended to reduce N content of the plant in the three cultivars. Variations among the cultivars was glaring in which the highest mean value 35.6% N was obtained from TGM 626 and these values were significantly ($p<0.05$) higher than all other values of either TGM 630 or TGM 631

% P content

The result of the % P content of three soybean cultivars after liming is presented in (Table 5). The highest P content was 6.5% obtained from TGM 626 in 2013 planting season where 1600 kg ha^{-1} was applied compared with no lime. The lowest value 2.0 % P was obtained from TGM 630 where no lime was applied in 2012 planting season. Comparing lime and no lime application, the effect of lime on P content of the three soybean cultivars were 90% unit increase in 2012 and 112.5% unit increase in 2013 for 3600 kg ha^{-1} and 1600 kg ha^{-1} respectively. Cultivar differences were significant ($p<0.05$) in terms of P content of the plant. The cultivar TGM 626 recorded the highest P content 3.5% in 2012 and 4.1% in 2013 and these values were significantly ($p<0.05$) higher than values of either TGM 630 or TGM 631.

% K content

The results of K content of the plant of three soybean cultivars are influenced by lime treatment is presented in (Table 7). The highest value of K (36.5%) was obtained from TGM 626 where 1600 kg ha^{-1} was applied in 2013 planting season while the least 19.3% K occurred in TGM 631, where no lime was applied in 2013. There were 41.7% unit increases in K and 50.5% unit increase in K compared with no lime when 3600 kg ha^{-1} and 1600 $kgha^{-1}$ were applied in 2012 and 2013 seasons respectively. Differences among the cultivars showed that TGM 626 recorded the highest K content of 30.7% in 2013 and 29.8% in 2012 and these values were significantly ($p<0.05$) higher than all other values of either TGM 630 or TGM 631.

Ca content

The application of lime significantly ($p<0.05$) influenced on the Ca content of tested three soybean cultivars, such that the highest value of Ca content 12.5cmol/kg was obtained from TGM 626 where 1600 kg ha^{-1} was applied in 2013 season while the least Ca content 3.1cmol/kg came from TGM 630, where lime was not applied (Table 7). Taking the mean of the three varieties each year, the application of lower rate of 1600 kg ha^{-1} in 2013 season had 13.4% unit increase in Ca content compared with the application of 3600 kg ha^{-1} for 2012 season, indicating that less lime is required to increase the Ca content of soybean. Cultivar differences were glaring, with the three cultivars having their maximum Ca content where 1600$kgha^{-1}$ was applied. On the average values of Ca content recorded by TGM (626 29.8 cmol/kg ha^{-1}) in 2012 season and (30.7 cmol/kg ha^{-1}) in 2013 season were significantly ($p<0.05$) higher than values of Ca obtained from either TGM 630 or TGM 631, for either of the years under similar experimental condition.

Mg content

The results of Mg content of the three soybean cultivars after liming is presented in (Table 8). The highest Mg content 10.3 cmol/kg was obtained from TGM 626 where 1600 kg ha^{-1} was applied compared with no lime (control) while the least 2.2 cmol/kg came from TGM 631 where no lime was applied. Average value of Mg 8.2 cmol/kg obtained from the application of 1600 kg ha^{-1} was significantly ($p<0.05$) higher than the Mg 7.2 cmol/$kgha^{-1}$ obtained from the application of 3600 kg ha^{-1} in 2012. The cultivars varied in their Mg content significantly

Table 4. Effect of lime application on the % N content of the plant of three soybean cultivars (mean of 2012 and 2013 seasons).

	Treatments		
Cultivars	**Lime**	**No Lime**	**Variety mean**
		2012	
TGM 630	31.6	22.7	27.2
TGM 626	39.4	28.6	30.0
TGM 631	28.5	21.4	24.9
Mean	33.17	24.2	-
LSD (0.05)	2.0		
		2013	
TGM 630	33.6	23.8	28.7
TGM 626	41.4	28.8	35.6
TGM 631	30.7	22.1	26.4
Mean	35.2	24.9	-
LSD (0.05)	2.3		

Table 5. Effect of lime application on the P content of the plant of three soybean cultivars (mean of 2012 and 2013 seasons).

	Treatments		
Cultivars	**Lime**	**No Lime**	**Cultivar mean**
		2012	
TGM 630	3.8	2.0	2.9
TGM 626	5.6	2.5	3.5
TGM 631	3.1	2.2	2.6
Mean	4.2	2.2	-
LSD (0.05)	0.5		
		2013	
TGM 630	4.6	2.3	2.3
TGM 626	6.5	2.8	4.1
TGM 631	4.2	2.1	2.1
Mean	5.1	2.4	-
LSD (0.05)	0.8		

Table 6. Effect of lime application of the K content of leaves of three soybean cultivars in 2012 and 2013 planting seasons.

	Treatments		
Cultivars	**Lime**	**No Lime**	**Cultivars mean**
		2012	
TGM 630	31.2	22.1	26.6
TGM 626	35.4	24.2	29.8
TGM 631	30.1	19.3	24.7
Mean	32.2	21.8	-
LSD (0.05)	2.3		
		2013	
TGM 630	32.0	22.2	27.1
TGM 626	36.5	25.0	30.7
TGM 631	31.2	20.1	25.6
Mean	33.2	22.1	-
LSD (0.05)	2.5		

($p<0.05$), with the mean values of TMG 626 (7.3 cmol/kg) in 2012 and (8.1 cmol/kg) in 2013 season showing significant ($p<0.05$) difference from values obtained from either TGM 630 or TGM 631.

Table 7. Effect of lime application of the Ca content of leaves of three soybean cultivars in 2012 and 2013 planting seasons

	Treatments		
Cultivars	**Lime**	**No Lime**	**Cultivar mean**
		2012	
TGM 630	7.2	3.1	5.1
TGM 626	10.9	5.4	8.1
TGM 631	6.5	3.4	3.3
Mean	8.2	3.9	-
LSD (0.05)	2.0		
		2013	
TGM 630	8.3	4.2	6.2
TGM 626	12.5	6.6	9.5
TGM 631	7.2	3.8	5.5
Mean	9.3	4.9	-
LSD (0.05)	2.2		

Table 8.Effect of lime application of the Mg content of leaves of three soybean cultivars during 2012 and 2013 planting seasons.

	Treatments		
Cultivars	**Lime**	**No Lime**	**Cultivar mean**
		2012	
TGM 630	7.0	3.2	5.1
TGM 626	9.2	5.5	7.3
TGM 631	5.5	2.6	4.0
Mean	7.2	3.8	-
LSD (0.05)	2.3		-
		2013	
TGM 630	8.0	3.0	5.5
TGM 626	10.3	5.9	8.1
TGM 631	6.2	2.2	4.2
Mean	8.2	3.7	-
LSD (0.05)	2.5	-	-

DISCUSSION

Soil is an important factor in crop production and its degradation is one of the limiting factors for sustainable agriculture (FAO, 2004). With the ever-growing population, soil fertility management by long fallow periods is practically impossible. The application of mineral fertilizer as sole soil fertility management method under intensive continuous cropping is also no longer feasible due to scarcity, high cost (Akinrinde and Okeleye, 2005) where available and the numerous side effects on the soil. Farmers using mineral fertilizers for years often notice signs of soil exhaustion shown by the sick appearance of plants, leaf discolouration, retarded growth and low yields (Neil and Ray, 1999). Acid soils result from leaching of basic cations (in areas of high rainfall), leaving behind the more resistant Al^{3+}, which predominates. Poor farming practice has more often acidified agricultural soils in developing countries. The particle size description of the soil was mainly dominated by sand followed by clay then silt in all the surface and sub-soil samples studied. This may probably be due to the nature of parent materials associated with the coastal sands, earlier reported (Akimigbo and Asadu, 1983). In some instances, there was clay movement into the sub-soil which suggests the pedogenic processes of agillation common in the inter-tropical soils, (Amalu *et al.,* 2002). The high acidity recorded at the beginning of the study is an indication that the soil was strongly weathered with marked leaching of exchangeable bases due to high rainfall, (Ogunwale and Dixon, 1979). The movement of the limestone when applied on the soil surface is very slow (Churka Blum *et al.,* 2013). The application of lime increased surface and subsoil pH, reduced Al and H activity and increased availability of exchangeable bases (Alley, 1981). The high organic carbon of the surface soil may be due to decomposition of litter and accumulation of organic residue, in which microbial activities encouraged mineralization on the surface soil (Acosta-Martinez *et al.,* 2000). The available P was low at the beginning of the experiment probably due to P-fixation (Lekwa and Whiteside, 1986) prevalent in soils of coastal sands. At low pH, Al and Fe form oxides and hydroxides of Fe and Al as a result of weathering (Agbenin, 2003). The P fixation was more in the surface soil than the subsoil which makes the values of P higher in the subsoil than in the surface soil. The complexion of soluble aluminum by organic matter on the surface soil led to decrease acidity (Hue and Arnien, 1990). This condition promoted the availability of exchangeable bases higher on the surface soil than on the subsoil. In this study, Ca and Mg were the most predominant cations and the application of lime encouraged higher levels on the surface soil than on the subsoil. According to Liebhardt (1981), the application of K to soils directly affects Ca and Mg, as they compete for the same adsorption sites in the soil. Thus, it is probable that greater amounts of K caused the release of Ca and Mg from soil colloids and possibly the leaching of these nutrients to deeper layers.

The K value in the soil was low even after lime treatment but was above the critical level of 0.02cmol/kg recommended for this area (Juo, 1981). Soils of sand stone parent materials are generally low in K, (Juo, 1981). Liming of the soil brought about neutralization of soil pH, decreased exchangeable Al and subsequent replacement of Al with exchangeable bases, (Igbokwe *et al.,* 1982). Micronutrients are influenced strongly by pH, and decreases in pH are accompanied by a greater availability of these nutrients (Fageria et al., 2011).

The application of lime into the soil resulted in the increased mineral content of the plant in the three soybean cultivars, such that the values of each of the elements Ca, Mg, K, Na and P were higher in plots with lime than plots with no lime.

This implies that Al and Fe activities at higher pH levels were reduced due to lime application and provided a conducive environment for nutrients availability for absorption by plants, making them available in good measure in the plant parts. The nature of the fibrous rooting system of the TGM 626 cultivar might have placed it on advantage over other cultivars in absorbing more nutrients from soil solution resulting to higher nutrients in the plant materials of this cultivar, (Alley, 1981).

All over the world, poor growth of soybean in acid soils has been attributed to a number of factors that include: low pH, high level of Al, Mn, and H, low levels of Ca, Mg, P, K, micronutrients like B, Zn etc. (Fageria, 1994) The sedimentary soils of South-Western Nigeria was highly acidic (pH 4.7) with medium organic carbon (10.9 g kg^{-1}), low available P (2.91mg kg^{-1}), high total N (9.47 g kg^{-1}) and adequate K (0.48 $cmolkg^{-1}$) (Adeoye and Agboola, 1985).

Conclusion

The results of this study clearly demonstrated the influence of liming on the availability of plant nutrients and the attendant effect on soil nutrient status and nutrient availability in the plant. This study has confirmed the need to lime strongly acid soils in order to neutralize Al and Fe toxicity. Soil liming improved plant growth and promoted environmental factors for N-fixation. The cultivar TGM 626 tended to respond more to treatment than others and should be used by farmers for better economic returns in soybean production in acid soils.

Authors' declaration

We declare that this study is an original research by our research team and we agree to publish it in the journal.

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