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INFLUENCE OF LIME AND GYPSUM APPLICATION ON SOIL PROPERTIES AND TUBER INITIATION OF CASSAVA(*Manihot esculenta* Crantz.) IN A DEGRADED ULTISOLS IN AGBANI, ENUGU SOUTHEASTERN NIGERIA

EZE, J.C., ANIKWE, M.A.N and IBUDIALO, A.N

Department of Agronomy Ecological Management Enugu State University of Science and Technology, Enugu State Nigeria

Corresponding Author: +2348066431475 E-mail address: cjezee@yahoo.com

ABSTRACT

The experiment was carried out to examine the influence of Lime and Gypsum on soil physicochemical properties in a degraded ultisol during 2013 and 2014 Rainy season in Agbani, Enugu Southeastern Nigeria (6^0 29'N and 7^0 54'E). A Randomized Complete Block Design (RCBD) using Lime and Gypsum as treatments at the rate of Lime 5000 kgha^{-1}, Gypsum 2500 kgha^{-1}, Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1} and Control, replicated five (5) times using cassava (TMS 0304) as test crop that was adopted. At 90 DAP in each of the season, the results showed a significant treatment difference in pH when treated with Lime 5000 kgha^{-1} (7.6), Gypsum 2500 kgha^{-1} (7.5), Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1} (7.5) and Control 6.7. Post soil Ca^{2+} content of the soil was highly influenced by Lime 5000 kgha^{-1} (4.7 cmol/kg), Gypsum 2500 kgha^{-1} (3.6 cmol/kg), Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1} (5.2 cmol/kg) and Control (2.4 cmol/kg). Available P was also significantly influenced by Lime 5000 kgha^{-1} (13.9 cmol/kg), but Gypsum 2500 kgha^{-1} and Control had no influence on the available P (7.6 cmol/kg) whereas Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1} reduced it to 5.7 cmol/kg. Base saturation was significantly increased by Lime 5000 kgha^{-1} to 75.3 %, Gypsum 2500 kgha^{-1} to 91.6 %, Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1} to 93.0 % and Control to 72.8 %). The results indicated a significant treatment effect on Bulk density. It was reduced by Lime 5000 kgha^{-1} to 1.60 gcm^{-3}, Gypsum 2500 kgha^{-1} to 1.52gcm^{-3}, Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1} to 1.44 gcm^{-3} while Control stagnated it to 1.68 gcm^{-3}. Similarly total porosity was influenced by Lime 5000 kgha^{-1} (39.7 %), Gypsum 2500 kgha^{-1} (42.9 %), Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1} (45.90 %) and Control (36.8 %) while saturated hydraulic conductivity (35.7 cm/hr, 37.6 cm/hr, 41.4 cm/hr and 31.9 cm^3/hr) was also significantly influenced by Lime 5000 kgha^{-1}, Gypsum 2500 kgha^{-1}, Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1} and Control respectively. At 90 DAP in each of the seasons, there were significant treatment influences on cassava tuber initiation which resulted to mean tuber yield of 2.6 kg by Lime 5000 kgha^{-1}, 3.9 kg by Gypsum 2500 kgha^{-1}, 6.2 kg by Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1} and 2.1 kg by Control. However this significant treatment influence found at 5 % level of probability can be attributed to the influence of the treatments on the physical properties of the soil which increased the soil and vegetative functionality of the study site.

Key words: lime, Gypsum, soil properties, tuber initiation, degraded ultisols

INTRODUCTION

Cassava *(Manihot spp.*) belongs to the family of Euphorbiaceae and from the genus of *Manihot*. Cassava is an important root crop popularly grown in sub-Sahara Africa more especially in the Humid tropics. It is believed to have originated from Brazil and was first introduced into Central Africa during the last part of the 16th century (Anikwe, *et al.*, 2005). It requires a good amount of rainfall and humid climate with a temperature range of 25 ^{0}C to 29 ^{0}C. It has feeder roots that grow vertically into the soil to a depth of 1m, thus the reason for its ability to tolerate drought and low soil fertility (Cock, *et al.,* 1978). Cassava can grow in all types of soil but best grown in a well drained sandy loam soil of average fertility. It is propagated by stem cuttings of about 25 cm to 30 cm long with at least 3 to 4 nodes. There is every need to adopt the most suitable cultural practices and method that will boost the yield of cassava. Even though cassava is said to have the ability to yield under low soil fertility, the relative yield is higher under high soil fertility. Hence the need to improve our degraded ultisols for better yield.

Degraded ultisol is an ultisols characterized by low fertility and high acidity which may be caused by over exploitation, erosion or leaching. According to Anikwe, 2006 less attention has been given to the soil physical status without considering the fact that both the chemical and biological functions of the soil with reference to crop production are controlled by the physical status of the soil. Poor soil structure and acidity are attributes of long term effect of continuous application of chemical fertilizer. With this effect it is pertinent to study the possible influence of lime and Gypsum on the physicochemical properties of the degraded ultisols.

Lime is basically calcium or magnesium oxide, carbonates and hydroxides. There are about four types of lime; quicklime (CaO), slake lime ($Ca(OH)_2$), limestone ($CaCO_3$) and dolomite. Lime is applied in the soil to neutralize soil acidity caused by Al^{3+} and H^+ ions, supply Ca or Mg as nutrient for plant growth and improve the physical conditions of the soil by providing high level of exchangeable divalent cations which tend to coagulate the soil colloids especially for soils of temperate areas (Ngwu, 2006).

Gypsum ($CaSO_4$) has been used as reliable fertilizer to supplement sulfur (S) requirement of the soil. It is a cheap means to remedy soils suffering from S deficiency. Moreover, Gypsum provides calcium which is needed to flocculate clay in acid and alkaline soils (Sheinberg *et al.*, 1989; Summer, 1993; Summer *et al.,* 1992). Also water infiltration and hydraulic conductivity of the soils are improved by Gypsum (Shainberg *et al.,* 1989).

Since Agbani soils are degraded ultisols characterized by high acidity, it was deemed necessary to introduce lime and Gypsum as ameliorating agent and fertilizer in order to reclaim and improve the fertility and productivity of the soil.

The general objective of this research work is to examine the influence of lime and Gypsum on soil physiochemical properties in a degraded ultisols.

The specific objectives are:

1. To examine the influence of lime and Gypsum on soil physical and chemical properties.
2. To examine the influence of lime and Gypsum on tuber initiation of cassava in Agbani area, Enugu Southeastern Nigeria.

MATERIALS AND METHODS

Soil Characterization

The research was carried out at Research Farm of Faculty of Agriculture and Natural Resources Management Enugu State University of Science and Technology, Agbani during 2013 and 2014 farming season. The farm is located in Latitude 6^0 29'N and Longitude 7^0 54'E with estimated annual rainfall of about 1700 mm – 2060 mm. The soil is of shale parent material classified as Typic Paleustult and has a sandy loam texture (Anikwe *et al.*, 1999).

Field Method

The site was slashed and cleared with cutlass and traditional hoe. The total land area of 21m × 21 m (441m^2) divided into 20 experimental units of 4 m × 3 m (12 m^2) with 1m alley was marked out carefully using randomized complete block design (RCBD) with 4 treatments Cassava was manually planted using stem cuttings of about 25 cm – 30 cm long at 1m × 1m plant spacing. The stem cuttings contained at least three internodes and were planted at angle of 45^0. Three weeding regime were employed to reduce weed competition in each of the season. These were manually done using small hoe at 30, 60 and 90 DAP. The treatments were basally applied and worked in with spade prior to planting using, Lime 5000 $kgha^{-1}$, Gypsum 2500 $kgha^{-1}$, lime 5000 + Gypsum 2500 $kgha^{-1}$ and Control replicated 5 times.

Determination of Soil and Plant parameters:

Soil samples (collected from 4 points in each plot at 90 DAP was analysed in the laboratory for total nitrogen (N), available phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sodium (Na), pH, SOC, and Cation Exchange Capacity (CEC). Total N was determined by the macro Kjeldahl method (Bremner, 1982). Available P was determined using Bray II method as outlined in Olsen (1982). SOC was analysed by the Walkley/Black procedure (Nelson and Summers, 1982). Soil pH in KCl was measured by the glass electrode pH meter (McLean, 1982). The exchangeable cations and CEC were determined by the method described by Thomas (1982). Particle size distribution was determined by hydrometer method (Gee and Orr, 2002). Dry bulk density was determined by the core method (Grossman and Reinsch, 2002).

Meter rule was used to measure plant height from the base level to the tip of the last formed leaf. Five plants were selected at random in each plot and measured, which was averaged to give plant height per plant. In determining the number of leaves, five plants were also randomly selected from each plot. These numbers of the leaves were averaged to determine number of leaves per plant. Five plants per plots were as well harvested to get the fresh tuber weight at 90 DAP, the fresh tubers were weighed in a scale and the average taken to give the tuber weight per plant. Also, the leaf area index was determined at 30, 60 and 90 DAP according to the method of Watson (1958).

Data Analysis

The data collected from the experiments were analyzed using Analysis of Variance (ANOVA) for Randomized Complete Block Design using Fisher's least significant different at P = 0.05 according to the procedures outlined by Steel and Torrie (1980) and detection between treatment means as described by (Obi, 2002).

RESULTS

Soil Chemical Properties of the Study Sites

Soil pH: The results presented in table 1 show that the soil pH was unaffected in all the untreated plots (6.8 and 6.5) at 90 DAP whereas, plots treated with lime 5000 $kgha^{-1}$ had a pH rise to 7.7 and 7.4 both season. Plots treated with Gypsum 2500 $kgha^{-1}$ had pH rise to 7.5 and 7.4 while the plots treated with lime 5000 + Gypsum 2500 $kgha^{-1}$ had pH rise to 7.4 and 7.5 in both seasons.

Calcium: Results of this soil analysis as shown in the table 1 below however show that exchangeable Ca^{2+} of the soil was highly influenced by lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$ with an increment from 2.20 cmol/kg to 5.2 cmol/kg. Lime 5000 $kgha^{-1}$ also proved to be a good source of Ca^{2+} to the soil by increasing the Ca^{2+} content to 4.7 cmol/kg. Gypsum 2500 $kgha^{-1}$ as well shows a significant increment of Ca^{2+} to 3.9 cmol/kg whereas the untreated plots had 2.20 cmol/kgs. These results indicate that lime and Gypsum are good sources of exchangeable Ca^{2+} in the soil according to (Ngwu, 2006). The Lime and Gypsum significantly affected the amount of Ca^{2+} in the soil since both supply Ca^{2+} to the soil. Highest amount of Ca^{2+} was seen in plots treated with lime 5000 + Gypsum 2500 $kgha^{-1}$ since the treatment contains double source of Ca^{2+}.

Available Phosphorus: Results of the experiment as shown in table 1 indicate that soil application of lime 5000 $kgha^{-1}$ had a high significant effect on the availability of soil P by increasing the available P from 7.5 cmol/kg and 7.9 cmol/kg in the respective season to 13.9 cmol/kg. Whereas application of Gypsum 2500$kgha^{-1}$ stagnated the available P indicating that Gypsum has no effect on improving soil available P. Furthermore, application of lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$ was negative. It reduced available P to 5.7 cmol/kg showing that Gypsum is not a remedy to unavailability of P. Untreated plots showed no change in available P showing that available P was in a steady state in the soil during the research.

Base saturation: The results of this research as shown in table 1 indicate that lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$ had the best significant influence on the base saturation of the soil by increasing the base saturation from 72.8 % to 93.0 %. Gypsum 2500 $kgha^{-1}$ on the other hand also significantly increased the base saturation of the soil to 91.6 % whereas lime 5000 $kgha^{-1}$ had the least significant increment to 75.3 %. Base saturation in untreated plots remained 72.8 %.

Soil Physical Properties of the Study Sites

Bulk density: According to the results of this experiment as shown in table 2, the bulk density of the study area before treatment application was 1.68 g/cm^2. It was found out 90 DAP in both season, that the application of lime 5000 $kgha^{-1}$, Gypsum 2500 $kgha^{-1}$ and lime 5000 + Gypsum 2500 $kgha^{-1}$ significantly changed the bulk density to 1.60g/cm^2, 1.52g/cm^2 and 1.44g/cm^2 respectively while in untreated plots slightly increased to 1.68g/cm^2. It can be deduced from these results that the bulk density of soil is generally reduced by application of lime and Gypsum.

Total porosity: The result of the experiment (table 2) show that the total porosity of the plots treated with lime 5000 $kgha^{-1}$ was increased from 36.98 % to 40.38 % indicating that lime ($CaCO_3$) flocculates soil particles and creates more pore spaces within the soil layer. Plots treated with Gypsum 2500 $kgha^{-1}$ indicated a slight increase in total porosity from 36.98% to 38.49%. Plots treated with lime 5000 + Gypsum 2500 $kgha^{-1}$ show a rise in porosity from 36.98 % to 46.4 % and untreated plots indicated no rise in total porosity. There were significant treatment applications.

Saturated Hydraulic conductivity: Saturated hydraulic conductivity of the study area in table 2 indicated a diverse change 90 days after treatments application. The result show that the soil was able to conduct more water after the treatments resulting to increase from 31.85 kcm^3hr^{-1} to 37.60 kcm^3hr^{-1} when treated with Gypsum 2500 $kgha^{-1}$ and 35.7 kcm^3hr^{-1} when treated with lime 5000 $kgha^{-1}$ and 41.40 kcm^3hr^{-1} when treated with lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$and remained the same in untreated plots.

Influence of Lime and Gypsum on Plant Height at 30, 60 and 90 DAP.

Results of the study in table 3 show that the treatment application did not significantly affect plant height of cassava at 30 DAP in the first season but significantly influenced the plant height in the second season. The highest mean plant height at 30 DAP was found in plots treated with lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$ which had 14.15 cm. This was followed by untreated plots with 10.9 cm, plot treated with Gypsum 2500 $kgha^{-1}$ had a plant height of 10.5 cm. Finally plots treated with lime 5000 $kgha^{-1}$ had 9.3 cm. At 60 DAP the highest mean plant height was found in plots treated with lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$ which had 57.0 cm, followed by plots treated with Gypsum 2500 $kgha^{-1}$which had plant height of 32.4 cm, then untreated plots with 31.1 cm.and finally plots treated with lime 5000 $kgha^{-1}$ had 30.0 cm. At 90 DAP the highest mean plant height was found in plots treated with lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$ which had 89.7 cm, followed by plots treated with lime 5000 $kgha^{-1}$ with 64.0 cm. Untreated plots followed with plant height of 62.8 cm. Finally plots treated with Gypsum 2500 $kgha^{-1}$ which had 60.9.

Influence of Lime and Gypsum on Number of Leaves at 30, 60 and 90 DAP.

Results of the study in table 4 show that the treatment application did not significantly affect number of leaves of cassava at 30 DAP in the first season but had a significant effect in the second season. The highest mean number of leaves at 30 DAP was found in plots treated with lime 5000 + Gypsum 2500 $kgha^{-1}$ which had 23.1. This was followed by untreated plots with 16.3, plot treated with Gypsum 3000 $kgha^{-1}$ which had 17.0, and finally plots treated with lime 5000 $kgha^{-1}$ which had 14.4. At 60 DAP the highest mean number of leaves was found in plots treated with lime 5000 + Gypsum 2500 $kgha^{-1}$ which had 56.9, followed by plots treated with Gypsum 2500 $kgha^{-1}$ with 43.1, then plots treated with lime 5000 $kgha^{-1}$ had 37.6 and finally untreated plot followed with 42.7. However at 90 DAP the highest mean number of leaves was found in plots treated with lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$ which had 81.2, followed by plots treated with Gypsum 2500 $kgha^{-1}$ had 67.9, untreated plots followed with 58.9 and finally followed by plots treated with lime 5000 $kgha^{-1}$ which had 52.3.

Influence of Lime and Gypsum on Leaf Area Index (LAI) of Cassava at 30, 60 and 90 DAP.

Below is table 5 showing the influence of lime and Gypsum on leaf area index (LAI) at 30, 60 and 90 DAP. The results however show that the treatment application had a significant effect on the LAI. At 30 DAP, plots treated with lime 5000 + Gypsum 2500 $kgha^{-1}$ gave the highest LAI 46.25. This was followed by plots treated with Gypsum 2500 $kgha^{-1}$ which had 29.55, plot treated with lime 5000 $kgha^{-1}$ which had 16.35 followed and finally untreated plots with 14.00. At 60 DAP the highest mean LAI was found in plots treated with lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$ which had 263.40, followed by plots treated with Gypsum 2500 $kgha^{-1}$ which had 142.45, then plots treated with lime 5000 $kgha^{-1}$ which had 115.20 and finally untreated plots which had 102.05. However at 90 DAP the highest mean LAI was found in plots treated with lime 5000 + Gypsum 2500 $kgha^{-1}$ which had 413.00, followed by plots treated with Gypsum 2500 $kgha^{-1}$ which had 346.55, plots treated with lime 5000 $kgha^{-1}$ followed with 256.80 and finally untreated plots which had 208.30.

Influence of Lime and Gypsum on Tuber Initiation (kg) of Cassava at 90 DAP.

The results of the influence of lime and Gypsum on cassava tuber initiation in 2013 and 2014 seasons are shown in Table 6 below. These results show that plots treated with lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$ had the highest mean tuber initiation of 6.2 kg. This was followed by plots treated with Gypsum 2500 $kgha^{-1}$ which gave 3.9 kg, plots treated with lime 5000 $kgha^{-1}$ followed with 2.6 kg while the lowest tuber initiation was found in untreated plots which had 2.1 kg.

Relationship between Tuber Initiation of Cassava and Soil Physiochemical Properties as Influenced by Lime and Gypsum Application.

The results presented in table 12 show that Cassava tuber initiation negatively correlated with bulk density (-0.9657) and positively correlated with total porosity (0.9659), hydraulic conductivity (0.9817) and gravimetric analysis (0.9388). This result indicates that bulk density inversely relates with tuber initiation meaning that as bulk density decrease, tuber yield increases. Total porosity, hydraulic conductivity and gravimetric analysis relates directly with tuber initiation of cassava, indicating that as they increase progressively tuber initiation increases as well. Soil pH slightly related with tuber initiation though with a thin relationship indicating that effect of pH on tuber initiation is minimal. CEC (0.4277), K^+ (0.1843), Mg^{2+} (0.1117) and available P (0.1103) were all unrelated to tuber initiation of cassava. This may be because, soil physical quality is an aspect of soil quality parameter that dictates the availability, distribution and uptake of nutrients in the soil. According to Anikwe (2006), who stated that decline in soil physical quality has serious consequences for the chemical and biological conditions of our soils, which inversely manifests on the growth and yield of crops.

DISCUSSION

The respective increase in pH of the study site in both seasons may be because lime and Gypsum increase soil pH. According to Ngwu, (2006), Lime or Gypsum is applied to the soils to neutralize soil acidity caused by Al^{3+} and H^+. According to the pioneering work of Summer (1970) and Reeve and Summer (1972) who first demonstrated the feasibility of using Gypsum to penetrate to the subsoil, lime has proved to correct acidity in surfaces of soils but the fact is that it has been found unsuitable for correcting subsoil acidity because lime does not move readily down the profile. This however shows that the significant treatment effect may be because, lime and Gypsum have acid neutralizing potential. The pH of soils treated with Lime 5000 $kgha^{-1}$ significantly increased because lime has the potential of short term surface amelioration of soil acidity. The most effective amelioration of surface soil layers are achieved by broadcast application of lime followed by mechanical blending. Intimate blending of lime with soil to the desired depth of amelioration is the ideal but in certain situations such as pastures, it is impossible and it was found that earthworms enhances the amelioration of sub-surface acid soil through the transportation and subsequent burial of surface applied lime resulting to increase in pH as high as one unit up to depths of 0.15 m (Baker *et al.,* 1995., Chan, 2003). More so, the pH of soils treated with Gypsum 2500 $kgha^{-1}$ increased inferiorly to that of lime because amelioration of subsoil acidity is achieved either by application of Gypsum (Sumner and Carter, 1988; Farina *et al.,* 2000) or mechanical lime incorporation to depth (Farina *et al.,* 2000) which implies that Gypsum is mostly required for amelioration of sub-soil acidity.

The higher percent base saturation in treated soils was as a result of increased release of Na, K, Ca and Mg by decomposing lime and Gypsum. Higher percent base saturation in the treated soils relative to untreated soils imply that the treated soils have more exchangeable cations which is a positive productivity indicator (Woomer *et al.,* 2011). In a similar manner, Bulk density of the soil was highly influenced by the treatments because according to Shainberg *et al.* (1994) Gypsum can break up compacted soils and decrease penetrometer resistance. Bulk density is inversely related to total porosity and hydraulic conductivity which implies that a reduction in bulk density causes an increase in the total porosity and hydraulic conductivity of the soil. These were visualized in the results got from this research. Calcium is known to flocculate soil particles and therefore, creates more pore spaces in the soil. According to Lal *et al.,* (2014), if all soil separates or primary particles are aggregated into secondary particles, the porosity is much greater than when not aggregated. Also, satisfactory correlations were obtained and the conclusion was drawn that porosity and other physical properties are significantly influenced by liming (Classens *et al.,* 2000). Aggregates are clusters of soil particles; their spacing influences water infiltration whereas calcium binds soil particles into aggregates to help with water infiltration (Walworth, 2006). Also by improving soil composition, Gypsum helps prevent soil particulate dispersion, decreases surface crust formation, aids in seedling emergence, increases water infiltration, and decreases the loss of soil and nutrients due to surface runoff and erosion (Chen and Dick, 2011). Gypsum improve water infiltration rates (Wildman *et al.*,1988), improve hydraulic conductivity of the soil, better water storage in the soil all lead to deeper rooting and better water use efficiency (Shainberg *et al.*, 1989).

At 30 DAP no significant treatment difference was found on plant height and number of leaves, even though the pH of the soil before the treatment application is optimum (6.65) for the growth of cassava. The non-significant treatment difference may probably be because the calcium content of the soil is already optimum (2.20 cmol/kg) before the treatment application, which means that it is not necessary for further addition of Ca. According to Meredith (1965) for most crops, response to Ca fertilizer is expected when exchangeable Ca is less than 0. 2 - 0.8 cmol/kg whereas at 60 and 90 DAP the treatment application became significantly effective. However this may be because the treatment application was able to improve the physical condition of the soil at this point. Gypsum provides calcium which is needed to flocculate clay in acid and alkaline soils (Sheinberg *et al.,* 1989; Summer, 1993; Summer *et al.*, 1992). Soil flocculation is needed to enhance favourable soil structure for root growth, air and water movement. Also, application of lime to acid soils decreases the solubility of Al and Mn and possibly increases the availability of P and by liming the soil, soil P can be available to plants (Ngwu, 2006). Lime puts soils in desirable pH range allowing the plant nutrient to be readily available for plant use. It also reduces the toxic-

Table 1: Effect of lime and Gypsum application on selected soil chemical properties at 90 DAP

Treatments	pH(H_20)		Ca^{2+}(Cmol/Kg)		Av. P (Cmol/Kg)		Base Sat.(%)	
	2013	2014	2013	2014	2013	2014	2013	2014
Lime 0 + Gypsum 0kgha^{-1}	6.8	6.5	2.2	2.6	7.5	7.9	71.3	74.2
Lime 5000kgha^{-1}	7.7	7.4	4.6	4.8	13.5	14.2	74.7	75.8
Gypsum 2500kgha^{-1}	7.5	7.4	3.8	4.0	7.5	7.7	90.0	93.2
Lime 5000+Gypsum 2500kgha^{-1}	7.4	7.5	5.0	5.4	5.6	5.8	91.3	94.7
P=0.05	0.7	0.5	1.4	1.1	1.8	2.1	1.9	2.3

Table 2: Effect of lime and Gypsum application on selected soil physical properties at 90 DAP

Treatments	Bulk Density (gcm^{-2})		Total Porosity (%)		K Sat. (Cm/hr)	
	2013	2014	2013	2014	2013	2014
Control	1.67	1.68	37.0	36.6	30.3	33.4
Lime 5000 kgha^{-1}	1.58	1.62	40.4	38.9	35.3	36.1
Gypsum 2500 kgha^{-1}	1.53	1.50	42.3	43.4	36.8	38.4
Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1}	1.42	1.45	46.4	45.3	40.8	42.0
P=0.05	0.04	0.02	3.4	3.1	2.2	2.6

ity of Al, Mn, Fe, improves soil structure and controls infiltration (Ngwu, 2006).

Similarly no significant treatment difference was found at 30 DAP while, at 60 and 90 DAP the treatments significantly affected number of cassava leaves. This may be because the treatment has actually reacted with the soils and was able to moderate the physical condition of the soil which favours the growth of cassava. Gypsum provides calcium which is needed to flocculate clay in acid and alkaline soils (Sheinberg *et al.,* 1989; Summer, 1993; Summer *et al.*, 1992). Soil flocculation is needed to enhance favourable soil structure for root growth, air and water movement. Also application of lime to acid soils decreases the solubility of Al and Mn and possibly increases the availability of P and by liming the soil, soil P can be available to plants (Ngwu, 2006). Lime puts soils in desirable pH range allowing the plant nutrient to be readily available for plant use. It also reduces the toxicity of Al, Mn, Fe, improves soil structure and controls in-

Table 3: Influence of Lime and Gypsum on Plant Height (cm) at 30, 60 and 90 DAP.

	Days After Planting					
	30		60		90	
Treatments	2013	2014	2013	2014	2013	2014
Control	9.8	12.0	10.9	30.2	64.0	62.8
Lime 5000 kgha^{-1}	8.2	10.4	9.3	29.7	66.0	64.0
Gypsum 2500kgha^{-1}	9.1	11.8	10.5	31.7	62.4	60.9
Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1}	12.5	15.8	14.2	50.0	92.6	89.7
F-LSD$_{(005)}$	NS	1.2	2.1	2.6	3.1	3.8

Table 4: Influence of Lime And Gypsum on Number of Leaves at 30, 60 and 90 DAP.

	Days After Planting					
	30		60		90	
Treatments	2013	2014	2013	2014	2013	2014
Control	16.4	16.2	40.2	45.2	56.2	58.9
Lime 5000 kgha^{-1}	14.0	14.8	35.2	40.0	48.2	52.3
Gypsum 2500kgha^{-1}	16.0	18.0	40.4	45.8	74.0	67.9
Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1}	22.2	24.0	53.4	60.4	76.0	86.4
F-LSD$_{(005)}$	NS	1.9	3.2	3.1	2.7	2.8

Table 5: Influence of Lime and Gypsum on Leaf Area Index (LAI) of Cassava at 30, 60 and 90 DAP.

	Days After Planting					
	30		60		90	
Treatments	2013	2014	2013	2014	2013	2014
Control	11.4	16.6	94.1	110.0	102.1	250.2
Lime 5000 kgha^{-1}	14.5	18.2	110.2	120.2	115.2	282.4
Gypsum 2500kgha^{-1}	28.5	30.6	139.1	145.8	142.5	348.2
Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1}	44.5	48.0	246.8	280.0	263.4	416.0
F-LSD$_{(005)}$	3.2	2.4	18.7	16.2	33.9	32.2

Table 6: Influence of Lime and Gypsum on Tuber Initiation (kg) of Cassava at 90 DAP.

	90 DAP	
Treatments	**2013**	**2014**
Control	**2.0**	**2.2**
Lime 5000 kgha^{-1}	**2.3**	**2.8**
Gypsum 2500kgha^{-1}	**3.4**	**4.4**
Lime 5000 kgha^{-1} + Gypsum 2500 kgha^{-1}	**4.4**	**8.0**
F-LSD$_{(005)}$	**0.2**	**0.1**

Table 7: Relationship between Tuber Initiation of Cassava and Soil Physiochemical Properties as Influenced by Lime and Gypsum Application

Soil property	r	r^2
Sand	-0.5478*	0.3001
Silt	-0.1843	0.0340
Clay	-	-
Bulk Density	-0.9657***	0.9326
Total Porosity	0.9659***	0.9330
Ksat	0.9817***	0.9637
Gravimetric Analysis	0.9388***	0.8813
$pH_{(H2O)}$	0.5294*	0.2803
Ca^{2+}	0.7342**	0.5390
K^+	0.1843	0.0340
Mg^{2+}	0.1117	0.8940
Na^+	-0.6663*	0.0124
CEC	0.4277	0.1829
Base saturation	0.9455***	0.8940
Available P	0.1103	0.0122
Organic carbon	0.8360**	0.6989

P = 0.05

* means differences statistically significant.

filtration (Ngwu, 2006).

Lime puts soils in desirable pH range allowing the plant nutrient to be readily available for plant use. It also reduces the toxicity of Al, Mn, Fe, improves soil structure and controls infiltration (Ngwu, 2006).

In the other hand, tuber initiation however was significantly influenced in both seasons. The significant treatment effect found can be attributed to the ability of Ca to flocculate soil particles thereby creating an enabling soil physical condition for better nutrient uptake, proper infiltration and aeration and increased P availability. As the bulk density of the soil was reduced by the treatments it is obvious that there will be a significant effect on the growth parameters of the crop because bulk density can be used to determine if soil layer is too compact to allow root penetration, adequate aeration and infiltration (Anikwe, 2006). Also Anikwe (2006) and Arshad *et al.* (1996) indicated that for loamy sands, ideal bulk density for plant growth is <1.60. It can be deduced that soil treatment with lime 5000 + Gypsum 2500 $kgha^{-1}$ gave the best result needed for the optimum growth of cassava. Moreover bulk density has a chain effect on the soil physical properties. It relates inversely to total porosity, infiltration rate, aeration, permeability and nutrient distribution in the soil.

CONCLUSION

The biophysical results of this research showed that soil application of lime and Gypsum had a significant increase on the growth characteristics of cassava (*Manihot esculenta* Crantz.) in the study area. The significant treatment effect found could be attributed to the ability of Ca^{2+} to flocculate soil particles thereby creating an enabling soil physical condition for better nutrient uptake, proper infiltration and aeration, increased P availability and optimum pH for proper growth of cassava. Gypsum provides calcium which is needed to flocculate soil particles in acid and alkaline soils (Sheinberg *et al.*, 1989; Summer, 1993; Summer *et al.*, 1992). Soil flocculation is needed to enhance favourable soil structure for root growth, air and water movement. Also application of lime to acid soils decreases the solubility of Al and Mn and possibly increases the availability of P and by liming the soil, soil P can be available to plants (Ngwu, 2006). Lime puts soils in desirable pH range allowing the plant nutrient to be readily available for plant use. It also reduces the toxicity of Al, Mn, Fe, improves soil structure and controls infiltration (Ngwu, 2006). It is therefore concluded that Ca^{2+} primarily from lime and Gypsum acted as a catalyst for improved soil and vegetative functionality.

RECOMMENDATIONS

From the results of this research, the following recommendations are being proposed: (i) Application of lime and Gypsum in the study area for increase in soil and vegetative functionality as a result of their positive influence on soil physical health and pH. (ii) Addition of supplemental available P when treated with Lime 5000 $kgha^{-1}$ + Gypsum 2500 $kgha^{-1}$. (iii) Since this work was done for part of cassava growth period, future work should therefore be done to the harvest stage to enable the determination of the influence of the factors investigated in this study on yield of cassava. (iv) This type of research should be carried out in the different ecological zones and soil types in the country so as to also, determine the influence of lime and Gypsum on soil properties, growth and yield of cassava.

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