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Influence of lime and gypsum application on soil properties and yield of cassava (*Manihot esculenta Crantz.*) in a degraded Ultisol in Agbani, Enugu Southeastern Nigeria

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ABSTRACT

The experiment was carried out to examine the influence of lime and gypsum on soil physicochemical properties in a degraded Typic paleusult during 2013 and 2014 rainy season in Agbani, Enugu Southeastern Nigeria (6°29′N and 7°54′E). A Randomized Complete Block Design (RCBD) using lime and gypsum as treatments at the rate of 5000 kg ha^{-1} lime, 2500 kg ha^{-1} gypsum, 5000 kg ha^{-1} lime + 2500 kg ha^{-1} gypsum and a control without lime and gypsum treatments, replicated five (5) times using cassava (TMS 0304) as test crop was used for the experiment. Soil pH in plots amended with 5000 kg ha^{-1} lime (5.7 and 5.4) increased relative to the control by between 16 and 17% for both planting seasons. Soils amended with 2500 kg ha^{-1} of gypsum had lower pH relative to plots amended with 5000 kg ha^{-1} lime. However, Soil application of a combination of 5000 kg ha^{-1} of lime and 2500 kg ha^{-1} of gypsum increased soil pH by 19–20% when compared to the control for both seasons. Soil application of a combination of 5000 kg ha^{-1} of lime and 2500 kg ha^{-1} of gypsum increased soil exchangeable Ca^{2+} by 57% when compared to the control for both seasons. Soil percent base saturation was significantly improved from 72.8% to 93.0% relative to control when 5000 kg ha^{-1} lime + 2500 kg ha^{-1} gypsum was applied to the soil. Results showed that at 90 DAP in both seasons, soil dry bulk density in plots amended with 5000 kg ha^{-1} lime (1.58 and 1.62 Mg m^{-3}) decreased relative to the control by between 5 and 7% for both planting seasons. Soil application of a combination of 5000 kg ha^{-1} of lime and 2500 kg ha^{-1} of gypsum reduced soil dry bulk density by about 17% when compared to the control for both seasons. The highest soil total porosity (46.4%) was found in plots with a combination of lime and gypsum at 5000 kg ha^{-1} and 2500 kg ha^{-1} respectively. The result also showed that soil water transmissivity improved from about 31.85 cm^3 h^{-1} in the control plots to 37.60 cm^3 h^{-1} in plots treated with 2500 kg ha^{-1} gypsum and up to 35.7 cm^3 h^{-1} in treated with 5000 kg ha^{-1} lime then to 41.40 cm^3 h^{-1} in plots treated with 5000 kg ha^{-1} lime + 2500 kg ha^{-1} gypsum. At 90 DAP the highest mean plant height of cassava (86–92 cm) was found in plots treated with 5000 kg ha^{-1} lime + 2500 kg ha^{-1} gypsum. This was followed by plots treated 2500 Kg ha $^{-1}$ gypsum (59–62 cm) and those treated with 5000 kg ha^{-1} lime (61–66 cm) whereas the untreated (control plots) had a plant height of 61–64 cm. Plots treated with 5000 kg ha^{-1} lime + 2500 kg ha^{-1} gypsum had the highest mean fresh tuber yield of 9.5 Mg ha^{-1}. This was followed by plots treated with 2500 kg ha^{-1} gypsum which gave a mean fresh tuber yield of 7.2 Mg ha^{-1}, plots treated with 5000 kg ha^{-1} lime followed with 6.8 Mg ha^{-1} while the lowest tuber yield was found in untreated plots which had 6.1 Mg ha^{-1}. The significant treatment differences on soil physical and chemical properties of the study soil due to effect of the treatments could be attributed to the ability of Ca^{2+} applied via lime and gypsum 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.

1. 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

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tropics. Hahn et al. (1987) postulated that cassava was rapidly adopted by farmers and integrated into the traditional farming and food systems of Africa because of its adaptability to traditional farming and food system, relative ease of cultivation and processing, year round availability and insurance against crop failure, low input requirement and relative high yield of food energy (calories) per calories of labour input. 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 and Howeler, 1978). Cassava can grow in all types of soil but best grown in a well drained sandy loam soil of average fertility. 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 Ultisols are characterized by low fertility and high acidity which may be caused by over exploitation, erosion or leaching. Farmers in attempt to overcome this challenge adopted the strategy of chemical fertilizer application. Approach of farmers toward chemical fertilizer usage has posed a big threat to soil physical quality status. 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. In many highly weathered soils, subsoil penetration by roots and water transmissivity are severely limited by chemical and physical barriers such as Al toxicity, hardpans and dense textural B horizons (Sumner et al., 1990). Previous work has demonstrated the efficiency of surface applied gypsum and lime in ameliorating such chemical and physical barriers after sufficient time has elapsed to allow the gypsum to leach into the subsoil. These improvements in soil physical condition appear to be due to both a root effect and a direct effect of the gypsum on flocculation and aggregation (Sumner et al., 1990; Harrison et al., 1992). Mora et al. (2002) studied the effects of amending an acid Andisol with lime and gypsum on some soil properties pH, aluminum (Al) saturation, the plant-availability of sulfur (S) and phosphorus (P), and the growth, botanical, and chemical composition of a ryegrass/white clover pasture in a field trial. They found that combined amendment of limestone, dolomite and gypsum raised soil pH slightly, decreased Al saturation from 20 to less than 1% and increased the concentration of plant available P, S, calcium (Ca), magnesium (Mg), and potassium (K) in the soil.

With these effects, 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 on the other hand has been introduced in the advanced countries as a necessary tool for soil amendment and fertilizer for over 200 years. 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. It also provides high level of exchangeable divalent cations which tend to coagulate the soil colloids especially for soils of temperate areas (Ngwu, 2006). Moreover, Gypsum provides calcium which is needed to flocculate clay in acid and alkaline soils (Sheinberg et al., 1989; Sumner et al., 1986). Soil flocculation is needed to enhance favourable soil structure for root growth, air and water movement. Water infiltration and hydraulic conductivity of soils are improved by Gypsum application (Sheinberg et al., 1989). It aids in protection against excess water runoff and erosion. Peanut (*Arachis hypogaea* L.) was grown in a highly weathered Typic Paleudult soil amended with lime ($CaCO_3$), gypsum ($CaSO_4$), or varying ratios of each (Syed-Omar et al., 1990). The soils used in this experiment were leached with water after amendment, and the addition of Ca as either gypsum or lime resulted in significant decreases in soil Al. The effects of the addition of lime or gypsum may have been due to a reduction in soil Al and/or an increase in soil pH, rather than an increase in soil Ca (Brauer et al., 2002). Understanding whether the benefits of soil lime and/or gypsum application on the growth crops in degraded Ultisols are due to effects on soil pH, Ca or improvements in soil physical quality is of more of concern today than in the past.

Large deposits of gypsiferous shales are found in parts of Nigeria. Gypsum resources have not been studied extensively with the aim of using them in Nigeria's agriculture, for instance for the fertilization of groundnuts, or to supplement fertilizers with the much needed sulphur nutrient component, or for remediation of alkaline saline soils and amelioration of physically degraded soils (Anikwe, 2011).

Since Agbani soils are degraded Ultisols characterized by low productivity and high acidity, it was deemed necessary to introduce lime and gypsum as an ameliorant 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 some soil physiochemical properties and yield of cassava in a degraded ultisol in Enugu Area, southeastern Nigeria.

2. Materials and methods

2.1. 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°29′N and Longitude 7°54′E with estimated annual rainfall of about 1700–2060 mm. The soil is of shale parent material classified as Typic Paleustult and has a sandy loam texture (Anikwe et al., 2007).

2.2. Field method

The site was slashed and cleared with cutlass and traditional hoe. The total land area of 21 × 21 m (441 m^2) divided into 20 experimental units of 4 × 3 m (12 m^2) with 1 m alley was marked out carefully using randomized complete block design (RCBD) with 4 treatments. Cassava was manually planted using stem cuttings of about 25–30 cm long at 1 × 1m plant spacing. The stem cuttings contained at least three internodes and were planted at angle of 45°. Three weeding regimes 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 (Agricultural lime (Calcium carbonate with 37% calcium) bought from Enugu State Agricultural Development Project and ground gypsum [Ca (19%), Mg (1.30%), S (15.3%), P (30.0 Cmol/kg)) collected from Nigeria Cement Company Nkalagu, were basally applied and worked in with spade prior to planting using, 5000 kg ha^{-1} lime, 2500 kg ha^{-1} gypsum, 5000 kg ha^{-1} lime + 2500 kg ha^{-1} gypsum and control replicated 5 times.

2.3. 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