Effects of Selected Leguminous Crops on the Physical and Chemical Characteristics of Ultisols in Port-Harcourt, Nigeria

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Abstract

The use of leguminous plants are considered a good management practice in any agricultural production system because it can increase cropping system sustainability by reducing soil erosion and ameliorating soil physical, chemical and biological conditions as well as nutrients are made available to the crops. A potted experiment was carried out in a screen house situated in the Rivers State University Teaching and Research Farm to examine the effects of three leguminous crops viz; brown beans (Phaseolus vulgaris), groundnuts (Arachis hypogaea L.) and velvet beans (Mucuna pruriens) on the physical and chemical properties of the soil. Three (3) seeds of each legume was planted in a pot containing ten (10kg) of top soil and replicated thrice. Soil samples were collected from experimental pots before planting and after harvest giving a total of 24 samples which were analyzed for selected physical and chemical properties using standard methods of analysis. The study showed that the three leguminous crops used improved the fertility status of the soil. However, the soils treated with groundnuts appeared to have shown more effects on the soil properties. There was no significant difference in the values for potassium (K) among the treatments. There was an increase in the nitrogen level of soil among the treatment which indicates nitrogen fixation. Ultisols treated with groundnuts showed more positive effects on the chemical properties of the soil after harvest, hence it's recommended for farmers to intercrop with groundnuts.

Key Words: *Fertility Status, Leguminous Crops, Ultisols*

INTRODUCTION

Soil fertility declination has been a major challenge as long as agriculture has increased and developed in tropics. Legumes are plants which belong to the family *Fabaceae* or *Leguminosae*. Fruits or seeds of these plants are called pulses and are used as food. (FAO 2016)**.** The *Leguminosae* family comprises 800 genera and 20,000 species and is the third largest family of flowering plants. Some legumes are seen as weeds of cereal crops and others are major grain crops; the grain crops species are known as grain legumes, or pulses. Stagnari *et al* (2017). They further opined that there are many important benefits of legumes to mankind, which include contributing to climate change mitigation, which has been rarely addressed. Legumes can reduce the emission of greenhouse gases (GHG) such as carbon dioxide (CO_2) and nitrous oxide (N_2O compared with agricultural systems that are depended on mineral (N) fertilization, leguminous plants play important role in the sequestration of carbon in soils and lower the overall fossil energy inputs in the system. The leguminous plant residues which have high nitrogen encourage the growth of microorganisms by supplying readily available nitrogen and hence accelerate the decomposition and soil nutrition Kumar et al (2010). Legume plants and seeds tissues a considerably high in protein content and this is doubtlessly connected with a legume's ability to supply its nitrogen requirement with the assistance of the rhizobia residing in their root. In the tropics researchers have demonstrated that legumes have the potential to sustain soil fertility in smallholder farming system (Mapfumo *et al* 2001).

In some African countries, researches are ongoing to determine the current and potential role of legumes as a direct method of solving the soil fertility problems in smallholder farming systems (Mugendi *et al* 2011) and improving crop yield, although most of the research works are focused on the use of groundnuts as a source of nitrogen. Grain legumes, such as groundnuts, can enhance soil nitrogen (N) through symbiotic biological nitrogen fixation (BNF) and an important source of N fertility, as well as a significant part of human nutrition and food security. Since legumes obtain N from soil N stocks as well as BNF, legume residues are key to capturing potential N benefits for soils, which may contribute to increased yields and food production (Witcombe and Tiemann 2022. Nitrogen fixing organisms in the soil are seen as good tools in management practices in any agricultural production system since it can increase cropping system sustainability and recent studies have shown that the biological nitrogen fixation process is the most efficient way to supply the large amount of nitrogen needed by legumes to produce high yielding crops with a high protein content (Berntsen *at al,* 2006).

A good management practice in an agricultural production process should increase cropping system sustainability by reducing soil erosion and ameliorating soil physical, chemical and biological conditions which leguminous crops can enhance. In highly weathered soils like Utisols, the use of synthetic fertilizers have not been sustainable due to its induced soil acidity, nutrient imbalance and physical degradation leading to increased soil erosion coupled with unavailability and /or expensive nature of synthetic fertilizer to the resource-poor farmers. The leguminous crops available in this region are yet to be fully exploited as to know their viability in terms of enhancing the soil physical and chemical properties. Therefore, this research is focused on investigating the effect of some leguminous crops on the physical and chemical characteristics of the Ultisols of Port Harcourt, River State.

MATERIALS AND METHODS

Study Area

The experiment was carried out at in a screen house located in the Rivers State University Teaching and Research Farm Port Harcourt which lies between latitude 4° 48 14.1" and longitude E6°58 34.8", with an elevation of 8 km above sea level. This is also located within the humid rainforest region of the southern Nigeria with mean annual rainfall that ranged between 2,000mm - 3,000mm per annum. The average annual temperature ranges between 23° c and 29°c (Ikati and Peter 2019).

Soil Sample Collection for Pot Experiment

Soil samples (topsoil, 0-20cm) were collected from the orange orchard section of the Research Farm, weighed 10kg into plastic pots and labeled accordingly. All the pots were transferred to the screen house. Soil samples were collected from the pots to determine physical and chemical properties of the soil before planting.

Source of Planting Materials

Planting seeds of groundnuts (*Arachis hypogaea L.*) and brown beans (*Phaseolus vulgaris*) were sourced locally by purchasing from the market. Velvet beans (*Mucuna pruriens*) was picked from the bush since it's not actually grown for food here but grows as wide plants.

FIELD LAYOUT / OPERATIONS

Three (3) seeds of each of the treatment crops were sown in the pot and each treatment replicated thrice. Watering was done three (3) days after planting and subsequently every other day in all the pots. The treatments were laid out in a completely randomized design (CRD) that was repeated 3times as follows groundnut (G),velvet beans (M), brown beans (B) and the control (c) had no plant on it for comparison.

Soil Sample Collection after Harvest

Soil samples were collected from experimental pots using cylindrical cores (5cm L and 5cm D), for core samples and hand-trowel for collection of other samples and the replicated three(3) times, bagged, labeled and sent to the Soil Science Laboratory for physical and chemical analysis. This was done 30 days after harvest.

Laboratory Analysis

Soil pH was determined in water and in salt (KCL) using pH meter by dipping the glass electrode of pH meter into soil/water and soil/salt suspension, as modified by Mclean (1982).The particle size distributions of the soils were determined by the Hydrometer method (Gee and Or, 2002). Exchangeable bases (Ca, Mg, K and Na) were extracted with 1 N ammonium acetate (NH_40Ac). Exchangeable calcium and magnesium were determined by ethylene diamine-tetra acetic acid (EDTA) titration method while exchangeable potassium and sodium were estimated by flame photometry (Jackson, 1962). Soil organic carbon (SOC) was determined by Walkley and Black digestion method (Olsen and Sommers, 1982). Total nitrogen was estimated by micro-Kjeldahl digestion method (Bremner and Mulvaney, 1982) while available phosphorus was determined by Bray 1 Method (Olsen and Sommers, 1982). Bulk Density was determined using core method as described by Jabro *et al* 2020 Total Porosity (P) was calculated using the formula P(%) = (1- bulk density÷ particle density) x100. As described by Ruwell, 1994

Statistical Analysis

The data generated from the experiment were subjected to analysis of variance (ANOVA) using Turkey type pair-wise comparison test and treatment means were separated using LSD at 5% level of probability.

RESULTS

Effects of Leguminous crops on Soils Physical Properties

The results of the physical properties for soil of the study area were as shown in Table 1. It indicates their textural classification as loamy sand. Distribution of sand fraction ranged from 80.96 % in the experimental pot containing groundnuts to 81.60 % at the control. Silt ranged from 5.73% at the treated pots to 6.40% at the control and clay ranged from 12.0 % at the control to 13.0% at the treated plot. Bulk Density (g/cm^{-3}) ranged from 1.45 at the groundnut treatment pot to 1.63 at the control. Result shows that bulk density significantly decreased with the treatments plots. Total porosity of the soil increased significantly with treatment but had the highest at the brown beans treatment pot and ranged from 0.33 at the control to 0.45 at groundnut treated plot, indicating that there's a significant difference between the treatments and the Control.

Tab 1: Physical Properties of the Soils

Treatment	Sand (%)	Silt (%)	Clay (%)	Bulk Density (g/cm)	Porosity (%)
Control	81.60a	6.40a	12.00a	1.63a	0.33b
Brown Beans	81.26 a	5.73a	13.00a	1.49b	0.41a
Groundnut	80.93 a	5.73a	13.33a	1.45b	0.45 a
Velvet Beans	81.27 a	5.73a	13.00a	1.47b	0.44 a

Means followed by the same letters in the same column are not significantly different from one another at ($p<0.05$) of probability.

Effect of Leguminous crops on Soil Chemical Properties

The results of the effect of the leguminous crops on the chemical properties of the soils were as shown in Table 2. The pH of the soil ranged from 4.03 at the pot treated with velvet beans to 5.9 at the control pot. Organic carbon (%) in the soil ranged from 1.09 at the control to 1.33 at the pot treated with groundnut, soil organic matter (%) ranged 1.88 at the control to 2.29 at the plot treated with groundnut. Total nitrogen (%) ranged from 0.03 at the control pot to 0.09 at the groundnut treated pot. These treatments showed significant differences ($p< 0.05$) between the groundnuts treated pot and the control pot. Available phosphorus (mg/kg) ranged from 19.3 at the control to 21.1 at the plots treated with groundnuts and mucuna. Sodium (Na) (mg/kg**)** ranged from 0.35 at the control to 0.39 at the soils treated with velvet beans and groundnuts. There was a significant increase in the level of Na among the treatments when compared with the control soil. Calcium (Ca) (mg/kg) ranged 0.005 at the plots treated with velvet beans to 0.0011 at the soil treated with Groundnuts. Results showed a significant increase in the level of Ca at the groundnuts pot. Magnesium (Mg) (mg/kg) ranged from 0.001 at the control to 0.005 at the groundnuts treated soils. Potassium (K) (mg/kg) ranged from 0.10 at the control to 0.12 at the mucuna treated plot. There was no significant difference ($p< 0.05$) in the levels of K among the treatments.

Table 2 Chemical Properties of the Soil of the study Area

Treatment	pH	OC (%)	OM (%)	Total N (%)	AV.P (mg/kg)	Na (Cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	K (cmol/kg)
Control	5.9a	1.09b	1.88b	0.03b	19.3 b	0.35b	0.009ab	0.001b	0.10 a
Brown Beans	5.63a	1.22ab	2.11ab	0.05ab	19.9ab	0.38 a	0.009ab	0.004 a	0.11 a
Groundnut	5.0b	1.33 a	2.29a	0.09a	21.1a	0.39a	0.0011a	0.005 a	0.09 a
Mucuna	4.03b	1.26ab	2.18ab	0.05ab	21.1a	0.39a	0.005b	0.002b	0.12 a

Means that do not share same letter in the same column are significantly different at ($p<0.05$).

DISCUSSION

There was no significant difference in the particle size distribution. This agrees with the findings of Obianefo *et al* (2017), that the soil of Port Harcourt is loamy sand in texture. The leguminous crops reduced bulk density significantly and increased porosity of soil at ($p<0.05$) when compared with the control. This conforms to a review by Yuvaraj *et al* 2020 which indicated that leguminous crops have the ability to enhance physical properties of soil by being a soil conditioner. According to them, leguminous crops have the ability to manufacture large biomass which gives rise to substrata for soil organic activities and organic matter. Furthermore, legumes result in higher infiltration of water due to direct impact of crop residue in soil formation and aggregation. Though the groundnut pot had the least value for bulk density and the highest for porosity, this may be due to the presence of rhizobium and increase in nitrogen fixation which will enhance soil aeration and root length effect of groundnuts (Gabasawa et al., 2014; Awodun 2007). Leguminous crops lowered the pH of soils but were significantly low at the mucuna plot. This conforms with the study of (Kawu 2020) where he incorporated leguminous crops into the soil, among which velvet beans plant residue is a part, pH decreased in soil which he attributed to the decomposition of biomass of crop residues which released organic acids which might cause the pH depression in the soils. (Gabasawa and Yusuf 2012;Gabasawa *et al*.,;2016, 2018) and, more recently, Yuvaraj et al 2020 also opined that nodulated legumes acquire their N from the atmospheric N_2 instead of absorbing from soil as nitrate and that the resultant effect is that the pH of soil will be lowered. There was generally a significant increase in the level of the chemical parameters when compared with the control which conforms with the findings of (Gabasawa *et al*.2012, 2016). Stagnari *et al* 2017; Gabasawa (2011, 2021) mentioned that grain legumes have an influence on rhizosphere properties in terms of N supply, soil organic carbon and P handiness and that the enormity of the effect differs across legume species, soil properties and climatic conditions. This might be the reason why the groundnut plot had the highest value for the soil chemical properties. According to Tang (1998) the amounts of H+ produced per kg biomass may slightly increase K level in the soil. Legume crops have high potential for conservation agriculture especially the groundnut, being functional either as growing crop or as crop residue.

CONCLUSION

It was revealed through this study that the three leguminous crops impacted on, especially, the nitrogen fertility status of the Port Harcourt Ultisols. More specifically, however, the groundnut-treated soils prove to have more positive effects on the after-harvest chemical properties of the soil when compared to the before pre-planting fertility status of the same soil. Resource-constrained farmers can, therefore, be advised to be incorporating these leguminous crops, especially groundnuts, into their cropping systems when such N-fertilizer demanding crops as cereals were to be cultivated on their most usually N-deficient soils.

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