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Effect of mycorrhizae on soil physical, chemical properties and nutrient uptake of rubber (*Hevea brasiliensis*) Saplings

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Abstract

Field trials were conducted during the cropping season at Rubber Research Institute of Nigeria, Iyanomo to determine the effect of different soil amendments on the soil physical and chemical properties and on the growth of rubber (*Hevea brasiliensis*) saplings. The experiment was conducted in 3 x 4 factorial randomized complete block design (RCBD). The field was partitioned into plots each measuring 1 m x 1 m with 1 m between plots giving rise to a total of 36 plots under a spacing of 30 cm x 30 cm. The treatments included four strains of Mycorrhizae (M_0, M_1, M_2 and M_3 with M_0 as control) Mycorrhizae was applied at 5000kg ha-^{1} each along with NPK 15:15:15 at 112 kg ha^{-1} and poultry manure at 6000 kg ha^{-1} altogether having 12 treatments. Plant data were collected at monthly intervals for seven months. Soil samples were collected before and after the application of treatments from 0-15 cm depth. The result showed general improvements in the soil physical and chemical properties of organic matter, nitrogen, pH, calcium, Avail phosphorus, ECEC and base saturation. The treatments of *Glomus clarius* + NPK 15:15:15 was found better over other treatments with higher growth response of rubber saplings on height and girth during second, third, fourth and seventh months respectively.
Also, the nitrogen, available P and calcium uptake of rubber saplings were higher and of a better performance. Farmers need to be made aware of the use of Mycorrhizae and poultry manure as good soil treatments in raising rubber saplings in the nursery

Keywords: Mycorrhizae, Nutrient uptake, Rubber Saplings, Iyanomo and Manure

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1.0 Introduction

Rubber (*Hevea brasiliensis* Muell. Arg.) belongs to the family of latex producing plants referred to as Euphorbiaceae. It could be propagated directly by seed or by budded stumps. Rubber was brought to African Countries including Nigeria in early 1960 (Oyenuga, 1967). One of the most important bases for increased rubber production lies in the development and effective distribution of rubber planting materials that are high yielding, disease and wind tolerant, early maturing and high field survival rate. The fertility management of rubber at the young stage is critical to the productivity of rubber at maturity. This can be achieved only through proper soil fertility management in the nursery where saplings are produced. Lack of soil fertility is a common problem in the tropics especially the soils of the rubber belt of Nigeria with few exceptions has ‘sub-optimal nutrient status. They are well known for their low available phosphorus (Uzu et al., 1985) and the nitrogen content is also low as a result of low organic matter content. The available potassium content is invariably low except in some soils in the north of Calabar (Onuwaje and Uzu, 1980), hence, there is a need for soil fertility improvement using fertilizers. Fertilizers, if used properly, can enhance the productivity of rubber and their over-use can have a deleterious effect on plant quality also the negative consequences of the application of inorganic fertilizers have been shown in many studies (Assawalam and Ugwa, 1993). Ayoola and Adeniyan (2006) reported that the use of inorganic fertilizers has not been helpful under intensive agriculture because it is often associated with reduced yield as a result of nutrient imbalance, leaching and pollution of groundwater. Since in Nigeria, most of the rubber growing soils are predominantly sandy to sandy loam textured in the surface area they are, therefore, susceptible to nutrient losses. This necessitates the need for an alternative source of nutrients that is readily available, relatively cheap and environmentally friendly. Arbuscular mycorrhizae (AM) colonizes in the roots of more than 80 per cent of higher plants due to their ubiquity and symbiotic capacity to colonize roots of plants (Morera-Souze *et al.*, 2003). Arbuscular mycorrhizae are significantly associated in nutrient uptake especially phosphorus in most agricultural soils and native plants (Haridas, 1981). Poultry manure is a waste from the poultry industry and is known that animal manures have been used effectively as organic manures for centuries. Poultry manure has long been recognized as perhaps the most desirable of natural organic manures because of its high nitrogen content. In addition, this manure supplies other essential plants nutrients too. This study aims to evaluate the effectiveness of mycorrhizae and poultry manure in increasing the production of improved varieties of *Hevea* saplings. The study aimed in determining the effect of mycorrhizae, NPK fertilizer and poultry manure on soil chemical properties and incidentally on the growth of rubber seedlings.

2.0 Materials and Methods

The field experiment was carried out in 2015 during the early cropping season at the experimental site of the Soil and Plant Nutrition Division of the Rubber Research Institute of Nigeria, main station Iyanomo, Benin City, Edo State. The study area occupies a land area of 2070 hectares about 29 kilometres away from Benin City, Edo State, Southern Nigeria. The main access road is through Obaretin Village situated at 19 km to Benin- Sapele highway. The Area is located within the coordinates of 5º34'E and 5º38'E Longitudes, 6º08'N and 6º11'N Latitudes. The area lies within the humid rainforest agro-ecological zone. Mean annual rainfall is above 2000 mm, distributed in a bimodal pattern with peaks in July and September. The soils of this rain forest belt are mainly leached Ultisols with pH ranging between 4.0 and 5.5. The soil has been described as acid sand derived from unconsolidated grits and sandstones containing clay peds of varying proportions. The soils were deep, red, porous, non-mottled and non-concretionary with texture ranging from loamy sand at the surface to sandy clay in the sub-surface. The detailed characteristics and classification of the soils in this area have been reported (Orimoloye, 2011; Orimoloye and Akinbola, 2013).

The treatments included four strains of mycorrhizae (M0, M1, M2 and M3), NPK 15:15:15 and poultry manure. Each treatment was applied at the rate of 500 g, 11.2 g and 600 g/ plot each. The treatments combinations is made of 12 treatments which are as follows: M_1F_0–*Glomus mosseae,* M_2F_0–*Glomus clarius,* M_3F_0–*Glomus deserticola,* M_0F_1– Chemical fertilizer 15:15:15 (NPK), M_0F_2– poultry manure, M_1F_1–*Glomus mosseae*+ NPK 15:15:15, M_2F_1–*Glomus clarius*+ NPK 15:15:15,M_3F_1–*Glomus deserticola* + NPK 15: 15:15, M_1F_2–*Glomus mosseae* + poultry manure, M_2F_2–*Glomus clarius*+ poultry manure, M_3F_2–*Glomus deserticola* + poultry manure and M_0F_0 which was the absolute control. Plant observation on growth characters *viz*., height, girth, leaf area and a number of leaves were collected at monthly intervals for seven months. Soil samples were collected before and after application of treatments from 0-15cm depth and were subjected to laboratory analysis (physical and chemical. All data sets generated were subjected to analysis of variance (ANOVA) using Genstat (2008) statistical package. The significant means were separated with LSD and using Duncan Multiple Range Test (DMRT) at a 5.0 per cent level of probability

particle size analysis

Particle size analysis was determined by hydrometer method of (IITA, 1979)

Soil pH

Soil pH was determined at 1:2, Soil to water ratio using glass electrode digital pH meter.

Available phosphorous

Available phosphorous was extracted using Bray-1 solution, (IITA, 1979) and the phosphate in the extract was assayed calorimetrically by the molybdenum blue colour method as described by (IITA, 1979).

Organic carbon

Organic carbon was determined by chromic acid wet oxidation procedure as described by (USDA, SCS, 1982).

Organic matter

Organic matter was determined by calculation using this formula % organic carbon x 1.728.

Exchangeable basses

The bases were extracted using a 1N neutral ammonium acetate solution. The calcium and magnesium content of the solution was determined volumetrically by the EDTA titration procedure (Houba *et al*, 1988). The level of calcium, potassium and sodium were determined by flame photometry. Magnesium content was obtained difference.

Total nitrogen

The total nitrogen of the soil and plant were determined by the Micro-kjeldal procedure as described by (IITA, 1979).

Exchangeable acidity

Exchangeable acidity was determined by the KCL and titration method of (Houba *et al*, 1988).

3.0 Results and Discussion

The physical and chemical characteristics of the soil before the application of treatments is shown in Table 1. The soil was sandy in texture with a base saturation of 80.6%. The soil texture of the study area was sandy. The soils were also characterized by low pH, low ECEC as observed by Juo, (1981), and Kang and Juo, (1986). The sandy surface soils with clayey subsoil typically characteristic of the study area are described as desirable for rubber growth under high rainfall conditions by Asawalam and Ugwa (1993). The sandy nature may be due to excessive rainfall experienced in the region and the influence of the parent material. This explains why the soil has low nitrogen which may be as a result of excess leaching and low organic matter content of the soil before treatments. Exchangeable bases in the soil were also very low with calcium having the highest value of 1.23 cmol kg^{-1} in the pre cropping, which is less than 2.5 cmol kg^{-1} being the critical levels for fertile soils (Obigbesan and Akinrunde, 2000). Other cations such as potassium (K) had values of 0.90 cmol kg^{-1} and magnesium (Mg) with values of 0.97 cmol kg^{-1} in the experiment was also low. They fell between the critical levels are 0.16 - 2.5 cmol kg^{-1} for K and 0.20 - 0.40 cmol kg^{-1} for Mg (Adeoye and Agboola, 1985). The percentage base saturation was a little bit high since the basic cations were low which is as a result of high precipitation leading to the leaching condition of the area. The available P was slightly higher as 3.26 mg kg^{-1}in pre cropping which was also below the critical levels of 10-16 mg kg^{-1} as reported by Adeoye and Agboola (1985). All these values are indicative of the low fertility status of the study area. However, the acidic nature of the soil may be attributed to high rainfall experienced in the region which in turn makes the soil fragile and susceptible to erosion and leaching.

Table1. Pre cropping soil physical properties

Parameters	**Values** 2015
Sand (g kg^{-1})	936.59
Silt (g kg^{-1})	12.80
Clay (g kg^{-1})	50.61
Textural class	Sandy
pH	4.80
Organic carbon (g kg^{-1})	1.78
Total N (g kg^{-1})	0.23
Available P (mg kg^{-1})	5.65
Exchangeable acidity (cmol kg^{-1})	0.82
Available K (c mol kg^{-1})	0.90
Exchangeable Na (c mol kg^{-1})	0.30
Exchangeable Ca (c mol kg^{-1})	1.23
Exchangeable Mg (c mol kg^{-1})	0.97
ECEC (c mol kg^{-1})	47.7
Base Saturation (%)	80.57

Effect of soil chemical properties under rubber saplings

The effect of soil chemical properties are presented in Table 2. There was a significant difference ($P<0.05$) among all treatments on pH, Magnesium, Exchangeable Acidity, Available Phosphorus. *Glomus clarius* + NPK 15:15:15 (M_2F_1) showed a higher value of 5.10 in pH when compared to the other treatments including control. The control (M_0F_0) showed a higher value of 4.12 and 6.98 g kg^{-1} in organic carbon and organic matter when compared to other treatments. while *Glomus mosseae* + poultry manure (M_1F_2), *Glomus clarius* (M_2F_0), *Glomus deserticola*+ NPK 15:15:15 (M_3F_1) and *Glomus clarius*+ poultry manure (M_2F_2) showed a higher value of 36.40 mg kg^{-1}, 0.80 cmol kg^{-1}, 8.00 cmol kg $^{-1}$and 0.50 cmol kg^{-1} in the available P, K, Ca and exchangeable acidity than the other treatments including a control.

Table 2. Effect of treatments on soil chemical properties

TREATNT	Ph	Org C	Org M g/kg	N	Ava P mg/kg	K	Mg	Ca cmol/kg	Na	EA	ECEC	%BS
M0F0	4.4	3.8	6.5	0.22	2.0	0.22	0.30	5.00	0.65	0.17	5.75	98.6
M1F0	4.1	3.8	6.6	0.21	1.7	0.79	0.80	7.00	0.65	0.28	8.82	96.8
M2F0	4.5	3.9	6.8	0.22	1.3	0.80	1.70	7.00	0.62	0.24	9.07	97.4
M3F0	4.9	3.9	6.8	0.22	1.3	0.24	0.60	2.00	0.44	0.16	2.94	94.6
M0F1	4.5	3.6	6.3	0.21	1.8	0.79	4.70	3.00	0.65	0.12	9.36	98.7
M0F2	4.2	3.9	6.7	0.22	1.3	0.25	0.50	7.00	0.51	0.28	8.04	96.5
M1F1	4.5	3.9	6.7	0.22	1.3	0.23	0.80	2.52	0.65	0.16	8.64	98.2
M2F1	5.1	3.9	6.7	0.22	1.3	0.24	0.10	3.00	0.52	0.24	4.12	94.2
M3F1	4.9	3.9	6.7	0.22	2.1	0.21	0.13	8.00	0.40	0.12	8,88	98.6
M1F2	4.4	4.0	6.8	0.22	3.6	0.23	0.30	1.00	0.44	0.17	2.09	94.3
M2F2	4.4	3.9	6.8	0.22	1.8	0.79	0.40	7.00	0.65	0.50	8.34	97.6
M3F2	4.3	3.9	6.7	0.22	3.5	0.21	0.80	2.00	0.65	0.27	3.50	97.7
LSD (P-0.05)	0.6	Ns	ns	Ns	0.5	Ns	0.08	Ns	Ns	0.31	Ns	Ns

ns= not significant , M_0F_0-control, M_1- *Glomusmosseae*, M_2-*Glomus clarius*, M_3 –*Glomusdeserticola*, F_1–NPK 15:15:15, F_2 – poultry manure, M_1F_1 – *Glomusmosseae*+NPK 15:15:15, M_2F_1 – *Glomusclarius*+NPK 15:`15:15, M_3F_1 – *Glomusdeserticola*+NPK 15:15:15, M_1F_2–*Glomusmosseae*+poultry manure, M_2F_2 – *Glomusclarius*+poultry manure, M_3F_2- *Glomusdeserticola*+poultry manure

Effect of treatments on uptake of nutrients

In Table 3, there was a significant difference among the various treatments concerning Nitrogen, Available P, and Calcium. *Glomus mosseae* and poultry manure (M1F2) had a higher Nitrogen uptake (0.17kg ha^{-1}), available P, uptake value of 2.69 kg ha^{-1} and significantly differed from the other treatments. The *Hevea* saplings grown on the soil treated with NPK 15:15:15 – M1F1 recorded the highest Potassium (0.44 kg ha^{-1}) show no significant difference ($P>0.05$) and calcium uptake with values of 2.72 kg ha^{-1} with *Glomus* *deserticola* and NPK 15:15:15 (M3F1) respectively and significantly differed from the other treatment for Calcium, while *Hevea* saplings grown on soils treated with NPK 15:15:15 (M0F1) is significantly higher in Magnesium uptake 1.85 kg ha^{-1} than the other treatment including control. The nutrient uptakes by Hevea brasiliensis saplings, in all the treatments were significant in the studies. This may be attributed to the nutrient uptake ability of the rubber sapling and soil nutrient interaction. There was generally a relationship between some of the major elements. The supply of one can increase, decrease or maintain their percentage of dry matter in the leaf (Remison 1997). The effects are described as an antagonist when the nutrient of an element is reduced by the application of another element and synergetic when application increased the leaf content of an element. This treatment tends to influence plant nutrient uptake and content. Also, the Nitrogen, available P and calcium uptake of rubber sapling were higher in the studies. Potassium and Magnesium show no significant difference in studies respectively.

Table 3. Effect of treatment on nutrient uptake by rubber saplings

Treatment	N	P	K (kg ha^{-1})	Ca	Mg
M0F0	0.11(4)	0.91(3)	0.11	2.09(3)	0.14
M1F0	0.06(7)	0.46(9)	0.20	1.93(4)	0.22
M2F0	0.07(6)	0.41(10)	0.43	1.66(5)	0.52
M3F0	0.14(2)	0.79(4)	0.16	0.96(9)	0.38
M0F1	0.08(5)	0.69(6)	0.44	1.33(7)	1.85
M0F2	0.08(5)	0.46(9)	0.08	0.19(12)	0.17
M1F1	0.07(6)	0.36(11)	0.06	2.11(2)	0.21
M2F1	0.12(3)	0.67(7)	0.12	1.52(6)	0.05
M3F1	0.08(5)	0.77(5)	0.07	2.72(1)	0.05
M1F2	0.17(1)	2.69(1)	0.18	0,77(11)	0.23
M2F2	0.06(7)	0.52(8)	0.18	0.97(8)	0.11
M3F2	0.06(7)	1.35(2)	0.08	0.78(10)	0.31
LSD (0.05)	**0.06**	**0.43**	**Ns**	**1.42**	**Ns**

ns= not significant , M_0F_0-control, M_1- *Glomusmosseae*, M_2-*Glomus clarius*, M_3–*Glomusdeserticola*, F_1–NPK 15:15:15, F_2 – poultry manure, M_1F_1 – *Glomusmosseae*+NPK 15:15:15, M_2F_1 – *Glomusclarius*+NPK 15:`15:15, M_3F_1 – *Glomusdeserticola*+NPK 15:15:15, M_1F_2–*Glomusmosseae*+poultry manure, M_2F_2 – *Glomusclarius*+poultry manure, M_3F_2- *Glomusdeserticola*+poultry manure

4.0 Conclusion

There was a general increase in the physical and chemical properties of the soil through the addition of the different soil amendments (organic manures and inorganic fertilizers). The result also showed that height, girth, leaf area and the number of leaves increased significantly in the saplings with various treatments. The use of organic materials showed better improvement of the plant height and girth than the leaf area and number of leaves when compared to other treatments.

The use of the treatments also increased the nutrient uptake of rubber saplings in the studies. Only Potassium (K) and Magnesium (Mg) did not have significant effects since Nigerian soils vary in their characteristics concerning pH, organic matter, availability of plant nutrients, and erosion related problems. It was also observed that Mycorrhizae and poultry manure performed very well when compared to NPK. Farmers need to be made aware of the use of Mycorrhizae and poultry manure as good soil treatments in raising rubber saplings in the nursery.

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