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# Effects of Bambara Groundnut (*Voandzecia Subtonanea*) (L) Verda) Biomass on Soil Physical and Chemical Properties in the Southern Guinea Savanna Zone of Nigeria.

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***Abstract-*** **This study was conducted at the University of Agriculture Makurdi Research Farm in the sub-humid Southern Guinea Savanna Zone of Nigeria, during the 2010 and 2011 cropping seasons to determine the effects of Bambara groundnuts (*Voandzecia Subtonanea) (L)* Verde biomass on soil physical and chemical properties. Five treatments (comprising 0, 5, 10, 15 and 20 t ha$^{-1}$ of bambara groundnut biomass) were laid in a Randomized Complete Block Design (RCBD) and replicated three times. The biomass was incorporated as green manure after 120 days of planting bambara groundnut on the same piece of land. A composite soil sample was taken at planting while samples were taken on treatment basis at 30, 60 and 90 days after treatment application. The samples were analyzed at the NICANSOL laboratory following standard procedures. The results obtained showed that incorporation of bambara groundnut biomass had no significant effects on the particle size distribution of the soil. The green manure produced significant effects on the soil pH, O.M., available P, CEC and the exchangeable K, Mg, Ca and Na both in 2010 and 2011 cropping seasons. Twenty (20) t ha$^{-1}$ bambara groundnuts biomass produced the best residual soil physical and chemical properties both in both seasons. Whereas at 60 and 80 DAP, 15 t ha$^{-1}$ bambaranuts biomass led to the best effect on soil chemical and physical properties. Therefore 15-20 t ha$^{-1}$ incorporation of bambara groundnut biomass is recommended for use in soil fertility maintenance in the study area.**

***Index Terms*— Bambara groundnuts, Biomass, Green manure, Southern Guinea Savanna, Soil Properties.**

## I. INTRODUCTION

Tropical soils are fragile, heavily leached with low natural fertility (Ojeniyi, 2002; 2010). The soils, most especially of the savanna belt suffer deficiencies in Organic Matter (O.M), Cation exchange capacity (CEC), Nitrogen (N), Phosphorus (P) and they are shallow in depth, with high acidity (Sanginga *et al*., 2001; Ojeniyi, 2002). According to Lekwa and Latheside (1996), about 63% of the agricultural soils in Nigeria are low in productivity and over 90% of them are Alfisols and Ultisols which have low organic matter (O.M.), and are sandy with Ca, Mg and K being leached from the surface horizons. Under these conditions continuous and intensive cultivation without adequate measures to replenish soil nutrients, soil fertility and crop yields would deteriorate rapidly (Bala *et al*., 2003).

Chemical fertilization was used to boost crop production in the last 50 years (Ojeniyi, 2002), yet it has been established that chemical fertilizers have failed to make the necessary impact in tropical agriculture, particularly in Nigeria (Ojeniyi, 1995), because of imbalanced nutrient supply, resultant soil acidity with repetitive usage, loses through volatilization, erosion and leaching as well as scarcity, high cost and inadequate distribution mechanism to the rural farmers who are the target beneficiaries (Ojeniyi, 2010).

Consequently, the soil requires alternative management mechanism in order to improve their quality and productivity. The traditional system of maintaining soil fertility through bush follow had been rendered obsolete due to increased population and the resultant shortage of land and decrease in fallow periods (FAO, 1989; Ojeniyi, 2010). The use of organic manure sources such as animal wastes, sewage sludge, human and industrial wastes are limited by inadequate availability, low quality, transportation, handling problems and heavy metal poisoning (Ojeniyi, 2010). Therefore, green manuring is a probable alternative.

Green manure is a plant material or green herb in its vegetative stage that is incorporated into the soil and allowed to decompose to supply nutrients to a standing or subsequent crop. Green manures are important sources of natural fertility, especially nitrogen (Adetunji, 2005). There are three main important sources of green manure, which include legumes, perennial legumes and non-grow legumes (Adetunji, 2005). Their main value lies in their ability to building up soil organic matter and nitrogen, so that adequate nitrogen can be made available to future crops. The cultivation of leguminous crops in rotation with other crops offers a potential for meeting soil fertility requirements at a minimum cost to farmers (Giller and Wilson, 1991). After harvest of legume crops, their residues can be incorporated as green manure (Ojeniyi, 2002). In areas where rain fed is adequate, grain legume crops needed to be grown as short term crops occupying the land for only part of the rainy season, before the main crop. Soils can be enriched in nitrogen and organic matter by turning the biomass of these crops into the soil. The incorporation and subsequent decomposition of their biomass would provide organic matter and other plant nutrients in the soil especially nitrogen phosphorus and potassium. These nutrients will improve the physical quality and the chemical properties of the soil. This study was carried out to determine the effect of bambara groundnuts biomass used as green manure, on soil physical and chemical properties in the study area.

## II. Materials and Methods

Field experiments were conducted at the University of Agriculture Makurdi Teaching and Research Farm, in the sub-humid Southern Guinea Savanna Zone of Nigeria (Lat. $7^0$ 41'N and Long. $8^0$ 31'E) during the 2010 and 2011 cropping seasons (April to October). The average annual rainfall is 1250 mm while the temperature is about $28^0$ C and it is on an elevation of 97 m above sea level. The soil of the experimental site is an Inceptisol. The site was cleared manually with hoe and cutlass in March and ridging was done in April. Seeds of an early maturing variety of bambara groundnuts were planted on ridges at an inter-row spacing of 75 cm and intra-row distances of 40 cm. The seed rate was one seed per hole, giving a population density of 36,000 plants per hectare. Weeding was done at 4 and 8 weeks after planting. The crops were harvested at full maturity, 13 weeks after planting.

After the harvest of the bambara groundnuts, the same site was cleared for the second stage of the experiment. The experiment consisted of five treatment plots measuring 5 m x 5 m each, with inter-block alley of 1 m and intra-block distance of 0.5 m, replicated three times and laid in Randomized Complete Block Design (RCBD). The total experimental area measured 0.459 ha$^{-1}$ equivalent to (27 m x 17 m) 459m$^2$. Bambara groundnuts biomass was applied to the plots as follows: 0, 5, 10, 15 and 20 t ha$^{-1}$ respectively. Maize (*Zea mays*) was used as test crop and was planted two weeks after the incorporation of the bambara groundnut biomass.

Soil auger was used to take composite surface soil samples (0-20 cm) before planting and after harvest of bambara groundnuts and before maize was planted. After the test crop was planted soil samples were taken at 30 and 60 days after incorporation and after harvest of the test crop. This was done to monitor the soil chemical changes resulting from biomass decomposition and nutrient release into the soil. The soil samples were air dried, sieved using 2.0 mm mesh and analyzed at the NICANSOL laboratory for pH, PSD, total N, 0.M., O.C, available P and the exchangeable basis following standard procedures.

The pH was determined in water (1:1) and in 0.01M Kcl solution (IITA, 1979). The particle size distribution of the soil was determined by the hydrometer method, (Bouyoucous, 1951). The chromic acid titration method was used to determine the 0.C. and O.M (Black, 1965). Total N in the soil was determined by the regular Macro-kjeldahl method (Black, 1965). The amount of exchangeable cations held by a unit soil mass was determined using $NH_4^+$DAC (at pH 7.0) displacement method. The exchangeable K, Ca, Mg and Na were determined using the EDTA titration method (Black, 1965) whereas; the available P was determined by Bray-1 method. Flame photometer was used to determined K and Ca while AAS was used to determine Mg and Na.

## III. Results and Discussion

The results of the analysis of the soil before planting bambara groundnuts in 2010 and 2011 cropping seasons are presented in table 1. The results showed that the soil was sandy with high percentage of sand and with little silt and clay. The chemical composition showed that the soil was poor in natural fertility. The pH, the N content of the soil as well as available P, CEC, and the exchangeable bases (K, Mg, Ca and Na respectively) were low.

Table 2 presents the results of the analysis of the soil after harvest of bambara groundnuts in 2010 and 2011 cropping seasons. The results indicated that there was no effect of the treatments on the soil textural class. The nutrient composition of the soil showed that there was an improvement in total N, CEC, Mg, K, Ca and Na.

Table 3 presents the results of soil analysis taken 30 days after incorporation of the biomass for the two seasons. The results showed that in both cropping seasons, bambara groundnuts biomass incorporation had no effect on the soil textural class even though the proportion of sand and clay seemed to increase in 2011. The chemical composition showed higher pH in the treated plots than the control in both seasons. The incorporation of the biomass increased the organic matter (O.M) content of the soil at 30 DAP. All the treated plots had significantly higher O.M content than the control. Similarly, application of 15 t ha$^{-1}$ of the biomass produced the highest value of N (0.26%) in 2010 while 20 t ha$^{-1}$ produced the highest value of N (0.33%) in 2011. The P content of the soil, the CEC and the exchangeable bases were significantly higher than the control, after 30 days of incorporation in both seasons.

The results of the analyses of the soil samples taken at 60 days after incorporation are presented in table 4. It showed that the physical structure of the soil was improved. In 2010 cropping season, the sand fraction was reduced in plots treated with 15 and 20 t ha$^{-1}$ bambaranuts biomass, while the silt increased, but there was no effect on the clay fraction. In 2011 season, the sand fraction was reduced in all the treatments except for the control; there was an increase in the silt and clay contents of the soils compared with the control. There was marginal increase in the pH of the soil in 2010 cropping season, however in 2011 season, 15 and 20 t ha$^{-1}$ produced higher pH than the control. Meanwhile the 2011 pH values were generally lower than 2010. The O.M content in all the

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treatments in 2010 and 2011 seasons were significantly higher when compared with the control. The N-content of the soil in the treated plots was higher than in the control plots. The 2011 values of the soil N were much higher than the 2010 values. Fifteen (15) t ha$^{-1}$ bambaranuts biomass produced the highest values of N in 2010 and 2011 seasons. The available P was higher in the treated plots at 60 days after planting the test crop in both seasons. In 2010 season, 15 t ha$^{-1}$ biomass produced the highest P values, whereas in 2011, 20 t ha$^{-1}$ produced the highest value of P. All the treated plots produced increased CEC than the control at 60 days after planting in 2010. In 2011, the CEC values were higher in the treated plots than the control. Ten (10) t ha-1 produced the highest value of CEC in 2011 season. The exchangeable K produced at 60 DAP was slightly higher in the treated plots than the control, in both seasons. The treated plots produced higher Mg, Ca and Na than the control.

The results of the soil analyses after harvest of test crop (table 5) showed that the residual soil properties were better than the pre-cropping soil properties. The soil parameters measured including pH, O.M, N, P, CEC and the exchangeable bases were all appreciated after harvest of the test crop plots treated with 15 t ha$^{-1}$ bambaranuts biomass produced the best results.

The results of the soil analyses before the treatment application confirmed the poor inherent fertility of the soil of the study area which agrees with the earlier findings of Agboola (1972), Duncan, (1974) and Agboola, (1975) who in their separate studies found that tropical soils are deficient in nutrients thus requiring amendments for proper crop growth. The N, K, Mg, Ca and Na were generally below the critical range considered favourable for normal plant growth. The results on the effect of bambara groundnut biomass on soil pH agrees with that of Opara-Nadi *et al*., (1987), who reported that application of organic manures tends to increase soil pH. Similarly, Chadhoker (1992), pointed out that regular application of green manure from legumes improved both the physical and chemical conditions of the soil as well as provision of plant nutrients. Read *et al.*, (1985) stated that leguminous organic manures that decompose rapidly could make nitrogen more readily available to associate crops in alley than those that have slow or low rate of decomposition. The high CEC obtained from this study can be attributed to the buffering capacity of the soil which was provided by the high O.M. of the added manures (Lal and Kang, 1982; Opara-Nadi *et al.*, 1987).

Furthermore, the results obtained indicated higher N content especially at 60 DAP when compared with the control. According to Wilson *et al.*,(1986), 50% of the added legumes N may be released within the first nine weeks of incorporation, depending on the initial N content of the soil, the C/N of the legume material and the prevailing environmental conditions especially temperature and rainfall. Chadhocker (1982) observed that green manures provided the soil with higher N, P, Mg, Na and CEC than the control.

## IV. Conclusion

Bambara groundnuts biomass had significant effects on soil chemical properties. After harvest of test crop, the biomass produced better residual soil properties than the control and it is therefore recommended that 15-20 t ha$^{-1}$ of the biomass can be incorporated into the soil for soil fertility maintenance and sustainable maize production.

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TABLE I. OIL PROPERTIES BEFORE CROPPING BAMBARA GROUNDNUTS.

| | **2010** | **2011** |
|---|---|---|
| Sand (%) | 82.56 | 80.25 |
| Silt (%) | 6.72 | 6.0 |
| Clay (%) | 10.72 | 13.57 |
| pH ($H_20$) | 6.42 | 6.35 |
| pH (Kcl) | 5.01 | 5.12 |
| O.C (%) | 0.96 | 0.98 |
| O.M (%) | 1.66 | 1.69 |
| N (%) | 0.048 | 0.042 |
| P (Mg, $Kg^{-1}$) | 4.05 | 4.45 |
| CEC(CMol $kg^{-1}$) | 1.72 | 1.92 |
| K (CMol $kg^{-1}$) | 0.36 | 0.42 |
| Mg (CMol. $Kg^{-1}$) | 1.12 | 1.22 |
| Ca (CMol $Kg^{-1}$) | 0.70 | 0.80 |
| Na (CMol $Kg^{-1}$) | 0.80 | 0.83 |

TABLE II. PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL AFTER HARVEST OF BAMBARA GROUNDNUTS.

| | **2010** | **2011** |
|---|---|---|
| Sand (%) | 80.48 | 78.48 |
| Silt (%) | 8.96 | 9.0 |
| Clay (%) | 10.56 | 12.52 |
| pH ($H_20$) | 6.24 | 6.38 |
| pH (Kcl) | 5.55 | 5.65 |
| O.C (%) | 1.73 | 1.79 |
| O.M (%) | 2.99 | 3.56 |
| N (%) | 0.028 | 0.042 |
| P (Mg, $Kg^{-1}$) | 3.75 | 3.83 |
| CEC(CMol $kg^{-1}$) | 2.01 | 2.15 |
| K (CMol $kg^{-1}$) | 0.50 | 0.58 |
| Mg (Mol. $Kg^{-1}$) | 1.20 | 1.33 |
| Ca (Mol $Kg^{-1}$) | 0.75 | 0.87 |
| Na (Mol $Kg^{-1}$) | 0.85 | 0.88 |

TABLE III. PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL AS AFFECTED BY BAMBARA GROUNDNUT BIOMASS AT 30 DAYS AFTER INCORPORATION.

| **Soil properties** | **2010** | | | | | **2011** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bambara groudnuts biomass | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | 20 t ha$^{-1}$ |
| Sand (%) | 92.48 | 90.48 | 88.45 | 86.48 | 88.48 | 90.24 | 78.24 | 78.24 | 76.24 | 78.24 |
| Silt (%) | 4.0 | 2.0 | 4.0 | 6.0 | 4.0 | 4.0 | 16.0 | 16.0 | 18.0 | 16.0 |
| Clay (%) | 7.52 | 7.52 | 7.52 | 7.52 | 7.52 | 5.76 | 5.76 | 5.76 | 5.76 | 5.76 |
| pH ($H_20$) | 5.80 | 6.43 | 6.54 | 6.68 | 6.79 | 5.28 | 6.75 | 6.99 | 6.95 | 6.90 |
| pH (Kcl) | 5.20 | 5.23 | 5.39 | 5.27 | 5.29 | 5.01 | 5.31 | 5.43 | 5.42 | 5.49 |
| O.C (%) | 2.05 | 2.18 | 2.52 | 3.04 | 2.56 | 1.56 | 3.0 | 6.14 | 4.32 | 4.15 |
| O.M (%) | 1.12 | 1.26 | 1.46 | 1.76 | 1.88 | 1.09 | 1.74 | 3.55 | 2.50 | 2.82 |
| N (%) | 0.014 | 0.028 | 0.14 | 0.26 | 0.042 | 0.034 | 0.136 | 0.198 | 2.244 | 0.328 |
| P (Mg, Kg$^{-1}$) | 3.75 | 5.25 | 5.25 | 6.85 | 6.15 | 3.46 | 5.75 | 6.79 | 5.96 | 6.25 |
| CEC(CMolkg$^{-1}$) | 1.35 | 5.80 | 10.86 | 11.80 | 10.20 | 1.44 | 5.04 | 11.52 | 10.96 | 10.36 |
| K (CMol kg$^{-1}$) | 2.10 | 2.30 | 2.20 | 2.45 | 2.35 | 1.99 | 2.53 | 2.57 | 2.33 | 2.24 |
| Mg (CMol.Kg$^{-1}$) | 0.62 | 1.23 | 2.81 | 3.80 | 3.65 | 0.65 | 1.33 | 1.43 | 1.44 | 1.72 |
| Ca (CMol Kg $^{-1}$) | 3.20 | 5.80 | 4.60 | 4.40 | 5.40 | 3.85 | 6.88 | 6.90 | 6.78 | 6.78 |
| Na (CMol Kg$^{-1}$) | 1.30 | 1.40 | 1.45 | 1.60 | 1.60 | 1.70 | 1.81 | 1.87 | 1.79 | 1.91 |

TABLE IV. PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL AS AFFECTED BY BAMBARA GROUNDNUT BIOMASS AT 60 DAYS AFTER INCORPORATION.

| | **2010** | | | | | **2011** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Soil properties** | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | 20 t $ha^{-1}$ |
| Sand (%) | 92.48 | 92.48 | 92.48 | 88.48 | 88.48 | 90.48 | 81.68 | 78.96 | 77.68 | 73.68 |
| Silt (%) | 0.00 | 0.00 | 0.00 | 4.0 | 8.0 | 2.32 | 14.56 | 13.28 | 12.56 | 20.56 |
| Clay (%) | 7.52 | 7.52 | 7.52 | 7.52 | 7.52 | 6.22 | 3.76 | 7.76 | 7.76 | 5.76 |
| pH ($H_20$) | 6.04 | 6.13 | 6.15 | 6.20 | 6.19 | 6.04 | 6.06 | 6.06 | 6.22 | 6.33 |
| pH (Kcl) | 5.08 | 5.23 | 5.23 | 5.42 | 5.40 | 5.23 | 5.36 | 5.57 | 5.23 | 5.43 |
| O.C (%) | 1.08 | 1.08 | 1.18 | 1.28 | 1.78 | 1.10 | 1.10 | 1.42 | 1.90 | 3.07 |
| O.M (%) | 2.07 | 1.87 | 2.04 | 2.21 | 3.08 | 1.90 | 1.90 | 3.58 | 3.29 | 3.46 |
| N (%) | 0.042 | 0.056 | 0.84 | 0.098 | 0.090 | 0.044 | 0.112 | 0.18 | 0.122 | 0.27 |
| P (Mg, $Kg^{-1}$) | 4.35 | 4.45 | 4.65 | 7.35 | 1.25 | 4.54 | 4.59 | 6.67 | 6.98 | 7.04 |
| CEC(CMol$kg^{-1}$) | 2.0 | 2.10 | 2.60 | 2.80 | 3.10 | 1.84 | 3.12 | 3.44 | 3.80 | 4.64 |
| K (CMol $kg^{-1}$) | 1.40 | 1.41 | 1.40 | 1.50 | 2.20 | 2.12 | 2.88 | 3.91 | 2.91 | 3.90 |
| Mg (CMol.$Kg^{-1}$) | 1.68 | 1.75 | 1.89 | 1.92 | 1.77 | 1.69 | 1.75 | 1.83 | 1.77 | 1.82 |
| Ca (CMol $Kg^{-1}$) | 3.80 | 5.90 | 5.20 | 8.90 | 8.30 | 5.52 | 3.59 | 5.91 | 5.84 | 5.94 |
| Na (CMol $Kg^{-1}$) | 1.10 | 1.10 | 1.80 | 1.51 | 1.50 | 1.12 | 1.49 | 1.46 | 1.52 | 1.48 |

TABLE V. PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL AFTER HARVEST OF MAIZE IN PLOTS TREATED WITH BAMBARA GROUNDNUTS BIOMASS.

| **Soil properties** | **2010** | | | | | **2011** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bambaranuts biomass | 0 | 5 | 10 | 15 | 20 | 0 | 5 | 10 | 15 | 20 t $ha^{-1}$ |
| Sand (%) | 90.48 | 88.48 | 88.48 | 88.88 | 88.48 | 82.96 | 80.96 | 78.96 | 79.68 | 74.24 |
| Silt (%) | 2.0 | 4.0 | 4.0 | 4.0 | 4.0 | 11.28 | 13.28 | 11.28 | 12.56 | 22.0 |
| Clay (%) | 7.52 | 7.52 | 7.52 | 7.52 | 7.52 | 5.76 | 5.76 | 3.76 | 7.76 | 3.76 |
| pH ($H_20$) | 5.80 | 6.08 | 6.13 | 6.15 | 6.20 | 5.12 | 6.21 | 6.26 | 6.31 | 6.25 |
| pH (Kcl) | 5.01 | 5.01 | 5.23 | 5.15 | 5.47 | 5.98 | 5.06 | 5.0 | 5.16 | 5.07 |
| O.C (%) | 0.78 | 0.82 | 0.80 | 1.18 | 1.19 | 1.10 | 1.13 | 1.34 | 1.20 | 1.24 |
| O.M (%) | 1.36 | 1.35 | 1.42 | 2.04 | 2.56 | 1.90 | 2.08 | 2.14 | 2.04 | 2.32 |
| N (%) | 0.014 | 0.056 | 0.070 | 0.084 | 0.084 | 0.016 | 0.126 | 0.126 | 0.154 | 0.126 |
| P (Mg, $Kg^{-1}$) | 4.05 | 4.05 | 7.05 | 6.50 | 10.75 | 4.08 | 8.15 | 8.29 | 8.19 | 8.14 |
| CEC($CMolkg^{-1}$) | 1.80 | 1.60 | 1.44 | 3.44 | 2.80 | 3.44 | 3.76 | 5.20 | 4.16 | 4.24 |
| K (CMol $kg^{-1}$) | 1.50 | 1.80 | 2.40 | 2.50 | 2.0 | 2.27 | 2.59 | 2.59 | 3.16 | 2.48 |
| Mg ($CMol.Kg^{-1}$) | 0.62 | 0.85 | 1.20 | 1.62 | 1.60 | 1.49 | 1.52 | 1.84 | 1.95 | 1.96 |
| Ca (CMol $Kg^{-1}$) | 2.49 | 2.70 | 3.90 | 6.60 | 3.10 | 2.49 | 2.95 | 3.15 | 2.85 | 3.98 |
| Na (CMol $Kg^{-1}$) | 1.30 | 1.30 | 1.50 | 1.60 | 1.80 | 1.32 | 1.58 | 1.72 | 1.68 | 1.68 |