



Rehabilitation of Old and Moribund Cacao Soil Using Organic Amendments in Ibadan and Owena of South West Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All the Authors were involved in the design of the study and the statistical analysis. Author MOO wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To evaluate the effects of organic amendment in the rehabilitation of two moribund cacao plantations at Ibadan (Oyo State) and Owena (Ondo State) using organic materials that included Cocoa Pod Husk (CPH) and Neem Leaf powder (NL).

Study Design: The experiment was laid out in a Randomized Complete Block Design in four replicates with four treatments which were CPH, CPH+NL (90:10), CPH+NL (80:20) and untreated.

Place and Duration of Study: Cocoa plantations at Ibadan and Owena, Nigeria between May, 2014 and Dec 2017.

Methodology: Initial soil sampling was done. Organic materials were applied to eight cacao trees in a ring at the base of trees in treated plots at the beginning of the rains in April/May and August/September. The treatments are: CPH Only @ 0.5 kg/tree, CPH Fortified with Neem Leaf (90:10) @ 0.45 kg + 0.05 kg/tree, respectively, CPH fortified with Neem Leaf (80:20) @ 0.40 kg + 0.10 kg/tree respectively. No application (control treatment).

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Results: Eleven fungi species assigned to seven genera were recovered across the treatments. Organic amendments significantly ($p < 0.05$) increased soil mineralization, microbial populations and pod production. After the second year of applications, CPH had the highest percentage of pod production over the control (64%) in Ibadan, while in Owena, CPH, CPH+NL (80:20) and CPH+NL (90:10) had percentage pod increase of 68, 64 and 63%, respectively, over the control. Organic materials had significant ($p \leq 0.05$) effect in raising the soil pH in the two locations from 6.41 to 6.82 in Owena and from 6.50 to 6.89 in Ibadan, compared to untreated soil.

Conclusion: The use of organic amendments in the rehabilitation of old and moribund cocoa (near death), improved soil nutrients as well as increased pod production and the microbial populations from the two plantations.

Keywords: Cocoa pod husks; neem; fungi; soil nutrient; yield.

1. INTRODUCTION

Cocoa pod husks (CPH) is one of the major wastes being generated annually in cocoa farms in Nigeria with about 800,000 tonnes [1]. On dry basis, about 60% of cocoa pod is made up of husks [2]. Research efforts of turning waste into wealth have led to various attempts of finding diverse uses for CPH. Cocoa pod husks are being used as fertilizer and soil amendment to suppress nematode populations in cocoa soils [3,4]. Currently in part of Africa, several studies carried out revealed that plant derived ash including those of wood and CPH increased NPK, Ca, Mg, soil pH and yield of vegetables, rice, millet, maize and tomato [5,6,7,8,9,10]. Neem products, including leaf, seed kernel, seed powder, seed extracts, oil, saw dust and particularly oil cake, have been reported as effective for the control of several nematode species [11,12,2,10].

Neem constituents, such as nimbin, salanin, thionemone, azadirachtin and various flavonoids, have nematicidal effects; triterpene compounds in neem oil cake inhibit the nitrification process and increase available nitrogen for the same amount of fertilizer.

Soil is a most precious natural resource and contains the most diverse assemblages of living organisms. Indigenous microbial populations in soil are of fundamental importance for ecosystem functioning in both natural and managed agricultural soils [13,14] because of their involvement in such key processes as soil structure formation, organic matter decomposition, nutrient cycling and toxic removal [14]. The community of soil flora and fauna is influenced directly or indirectly by management practices, for example cultivation and application of organic and inorganic fertilizers [15,16]. Soil management to provide ecosystem services

while simultaneously maintaining or enhancing soil quality is a key to sustainably managed agro ecosystems [17]. This research was undertaken to determine the effects of cocoa pod husk and neem leaf on soil fertility and microbial populations.

2. MATERIALS AND METHODS

The experiment was conducted both in Ibadan (Lat 7°10' N, Longitude 3°52' E) and Owena (Lat 7° N, Longitude 5°70' N). Cocoa plantations less than 40 years of age, having more than 825 trees per hectare with yield more than 400 kg per hectare were selected in Ibadan and Owena.

2.1 Collection and Processing of Organic Material

The organic materials: Cocoa pod husk (CPH) and Neem leaf (NL) used for this experiment were collected from fermentary unit of Cocoa Research Institute of Nigeria, Ibadan. Fresh and uninfected cocoa pods were dried and milled to pass through 4 mm sieve before application into the soils in plastic cups. The nutrient content of cocoa pod husk and neem leaf were determined.

2.2 Field Experimentation and Design

The experiment was laid out in a randomized complete block design (RCBD) with four treatments replicated 3 times. Organic materials were applied in a ring at the base of trees in treated plots at the beginning of the rains in April/May and August/September, while trees receiving no application served as control.

The treatments were:

CPH at 0.5 kg/tree.
CPH fortified with Neem Leaf (90:10) at 0.45 kg + 0.05 kg/tree, respectively.

CPH fortified with Neem Leaf (80:20) at 0.40 kg + 0.10 kg/tree, respectively.

No application (Control treatment)

2.3 Microbiological Analysis of Soil

Soil samples were taken from the rhizosphere of moribund (near death) cocoa trees at 0-25 cm deep. The soil sample was collected separately per plot marked for each treatment. Two hundred and fifty gram (250 g) of the soil samples were used for microbiological analysis, while the remaining samples were air dried and sieved for the determination of soil physico-chemical properties, and for assessing the effect of organic amendments on the diversity of soil microbial populations. Microbial isolation and estimation using soil plate method [18] were carried out with rose bengal agar media supplemented with streptomycin sulphate. Media was prepared according to the composition and sterilized in autoclave. Microorganisms were counted using plate and serial dilution methods and the inoculated plates were incubated at 25°C along 5-7 days. The colony forming unit were counted and expressed as CFU g⁻¹ of soil on a moisture free basis after incubation. Fungi were identified according to their macroscopic and microscopic features. Identification at the species level was carried out according to the morphological characters found principally in publications by [19,20]. Pure cultures of fungi were maintained in test tubes slants containing Czapek Dox agar medium [21] and preserved in deep freezer at 20°C.

2.4 Soil Physico-chemical Properties

The pH of the soil samples was taken using an electronic digital pH meter in 1:5 soil water suspension. The moisture content of the soil samples were determined gravimetrically in hot air oven at 105°C for 24hrs and then reweighed. The method [22] was used for Organic carbon determination. Total Nitrogen (N), available phosphorus (P) and exchangeable potassium (K) were determined by Kjeldahl distillation [23], molybdenum blue method [24] and Flame photometer method [23], respectively.

2.5 Application of Organic Material and Nutrient Release Pattern

The organic materials were applied around the base of the trees using plastic cups. The nutrient release pattern was assessed at 2-weeks' interval for the first one month and at one month

interval for another four months to give six sampling / incubation periods. N mineralised was determined by micro-Kjedahl method. P mineralised was extracted from the incubated samples using Bray P1 method. The available P in the filtrate was determined colorimetrically by molybdenum blue method. K mineralised was extracted with 1 N NH₄OAc at pH 7.0. The K in the filtrate was determined by flame photometer. The pH was determined in water (1:2 Soil: water ratio). The extract was shaken and a pH meter with glass electrode used to measure the pH as described by Jackson [25].

2.6 Data Collection

The experiment was monitored for three years. Data were collected on number of pods harvested per tree for two years. Soil was sampled every four months to determine the effect of amendments on microbial populations and soil nutrient mineralization.

2.7 Data Analysis

Data were subjected to Analyses of Variance and means separated using the Duncan Multiple Range Test (DMRT) with SAS-SNK test at 5% level of significance.

3. RESULTS

The initial physical and chemical analysis of soil samples collected from the two locations before the application of treatments showed that the soil texture in the locations were sandy loam which is ideal for cocoa. The soil Nitrogen, P and K were less than the normal value as established.

The result of nutrient composition analysis of both the CPH and NL showed that NL is high in nitrogen than CPH, but with more Ca and K in CPH than in NL (Table 2).

3.1 Isolated Fungi Species from Cocoa rhizosphere

Eleven fungi species assigned to 7 genera were recovered from the two locations. The species recovered were; *Aspergillus niger*, *Aspergillus flavus*, *Rhizopus solonifer*, *Arthrobotrys conoides*, *Trichoderma harzianum*, *Trichoderma viride*, *Paecilomyces lilacinus*, *Verticillium chlamydosporium*, *Penicillium glabrum* and *Penicillium digitatum*. *Penicillium glabrum* was only recovered in Owena soil.

Table 1. The physical and chemical properties of Ibadan and Owena soils prior to the application of CPH and NL

Soil properties	Ibadan (Values)	Owena (Values)
Physical properties		
Sand (%)	66	82
Silt (%)	24	12
Clay (%)	10	6
Textural class	Sandy loam	Sandy loam
Chemical properties		
pH	6.00	5.38
Organic carbon(g kg ⁻¹)	2.20	3.56
Organic matter	0.55	0.61
N (g kg ⁻¹)	0.47	0.60
P (mg kg ⁻¹)	4.11	5.12
Exchangeable bases		
K (cmol (+) kg ⁻¹)	0.22	0.25
Ca (cmol (+) kg ⁻¹)	0.45	0.60
Mg (cmol (+) kg ⁻¹)	1.23	1.28
Na (cmol (+) kg ⁻¹)	0.63	0.76
Mn (cmol (+) kg ⁻¹)	0.06	0.07
Exchangeable acidity (cmol (+) kg⁻¹)		
Al	5.56	5.73
H	3.40	3.73
EC	5.13	5.22
Base Saturation	82%	84%

Table 2. Nutrient composition of Cocoa Pod Husk (CPH) and Neem Leaf (NL) used as organic materials to rehabilitate cocoa soil at Ibadan and Owena, Nigeria

Nutrient contents	CPH	NL
N (g kg-1)	11.2	26.7
Organic carbon (g kg-1)	236.2	120.1
C/N	21.1	4.5
P (g kg-1)	1.4	4.5
K (g kg-1)	38.6	24.0
Ca (g kg-1)	3.1	1.8
Mg (g kg-1)	1.7	2.4
Zn (mg kg-1)	25.0	50.0
Mn (mg kg-1)	34.0	29.0
Fe (mg kg-1)	64.0	69.0
Cu (mg kg-1)	28.0	25.0
B (mg kg-1)	1.8	1.7

3.2 Effect of Organic Amendments on Fungi Population

The application of the organic amendments in the two locations significantly increased the population of fungi above the initial populations compared to the control (Figs. 1, 2 and 3).

3.3 Effects of Organic Amendments on Nutrients Mineralization

The nutrient release pattern of CPH and NL showed that soil N mineralization (0.26 kg⁻¹) was significantly (P≤0.05) reduced in the CPH treatment when compared with the control (0.51 gkg⁻¹) in Ibadan soil. For Owena soil, N mineralization also followed a similar trend with CPH being significantly (P≤0.05) reduced (0.27 gkg⁻¹ and 0.28 gkg⁻¹), respectively, at two months after application. Nitrogen release was significantly (P≤0.05) higher from the eight months after application (MAA) in all the treatments containing CPH when compared to the untreated plots. Also at 16 MAA the N mineralized in the soil treated with CPH and neem-fortified CPH were significantly (P≤0.05) higher than the untreated soil in Ibadan and Owena (Fig. 4). At 16 MAA, the N mineralized in the soil treated with CPH, CPH+NL (80:20), CPH+NL (90:10), were significantly (P≤0.05) higher than those of control soil.

From the result Phosphorus released by CPH+NL (90:10) was significantly higher than all other organic materials at 2 MAA (Fig. 5). Generally, the organic materials released higher

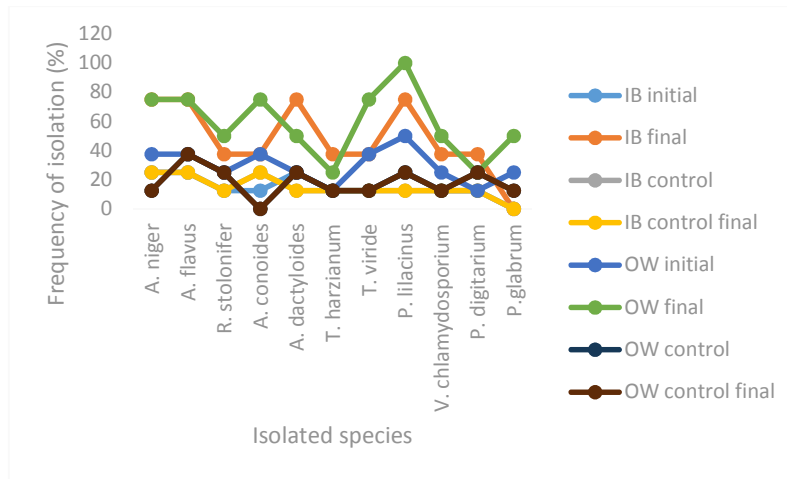


Fig. 1. Effect of CPH on fungi populations from cocoa soil at Ibadan (IB) and Owena (OW), Nigeria

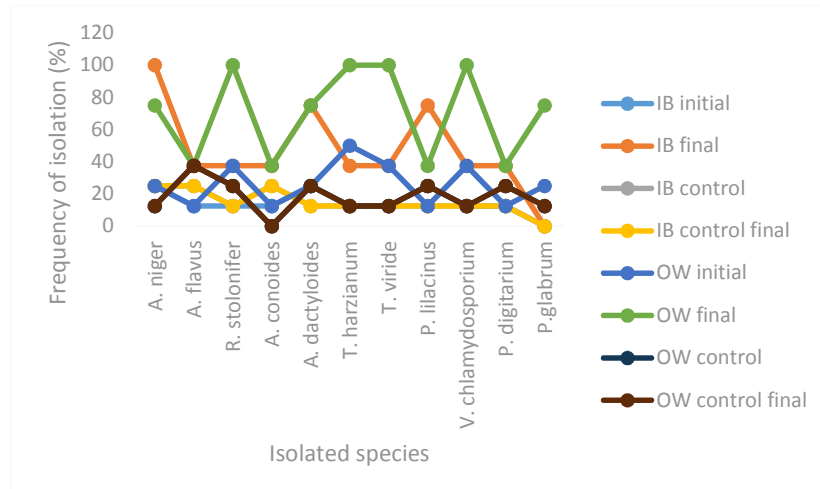


Fig. 2. Effect of CPH + NL (90:10) on fungi populations from cocoa soil at Ibadan (IB) and Owena (OW), Nigeria

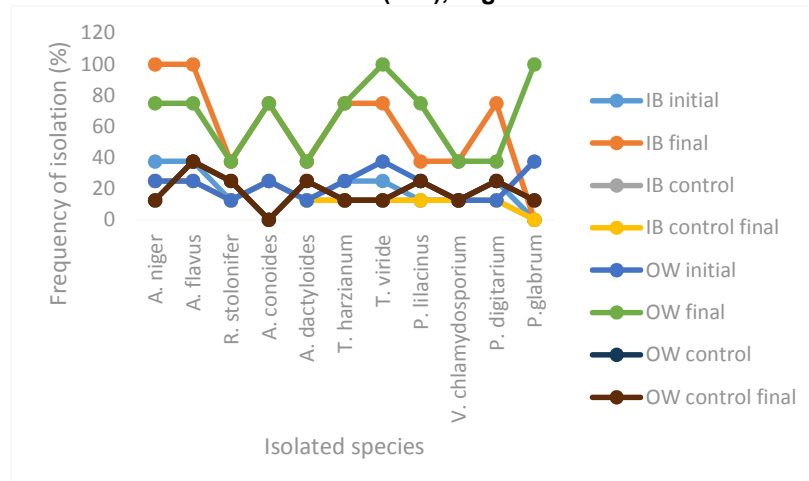


Fig. 3. Effect of CPH + NL (80:20) on fungi populations from cocoa soil at Ibadan (IB) and Owena (OW), Nigeria

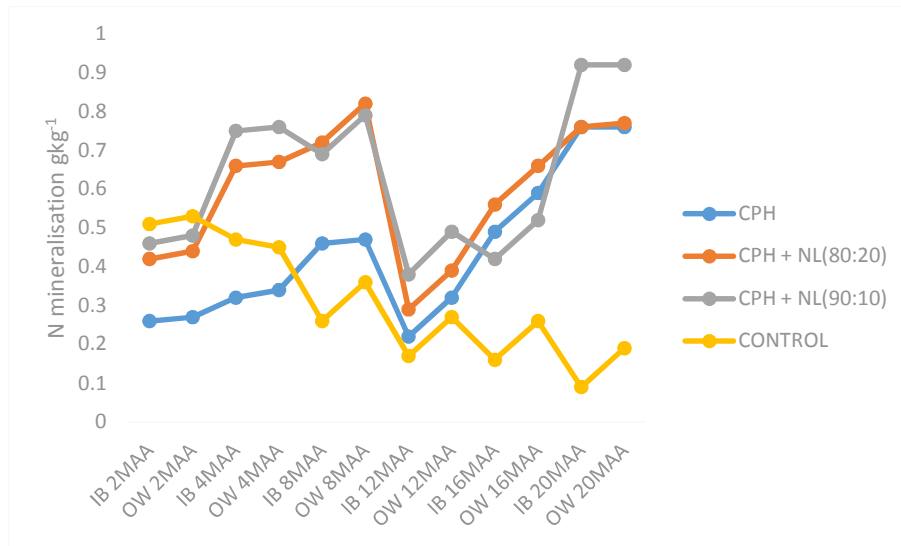


Fig. 4. Effect of organic amendment on Nitrogen mineralisation from two to twenty months after application (MAA) on cocoa soil at Ibadan (IB) and Owena (OW), Nigeria

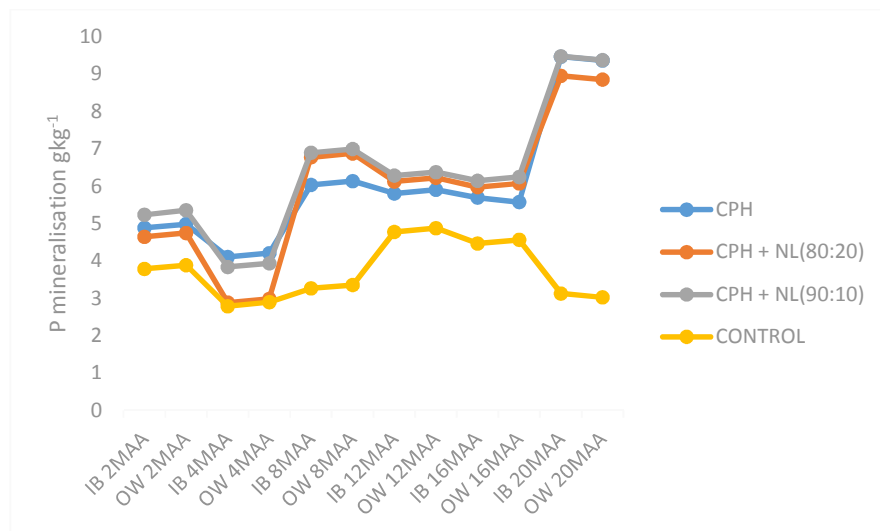


Fig. 5. Effect of organic amendment on Phosphorus mineralisation from two to twenty Months after Application (MAA) on cocoa soil at Ibadan (IB) and Owena (OW), Nigeria

amount of P in comparison to control as from 12 MAA. Neem leaf-fortified CPH gave higher P release as from 12 MAA up till 20 MAA. The P released by CPH (6.38 mg kg⁻¹ soil) and CPH + NL (80:20) (6.39 mg kg⁻¹ soil) at 20 MAA was significantly (P≤0.05) higher than P released by other organic materials (Fig. 5).

Amount of K released from all the organic materials was significantly (P≤0.05) higher in comparison with the control at 2, 8, 16 and 20

MAA from the treated soil of Ibadan. CPH applied alone and neem fortified CPH significantly (P≤0.05) enhanced K release at 2, 4 and 16 MAA (Fig. 6). At 20 MAA, CPH+NL (90:10) significantly released more K than all the other organic material treatments. Soil treated CPH + NL (90:10) significantly (P≤0.05) released K more than CPH + NL (80:20). Amount of P released from all the organic materials were also significantly (P≤0.05) higher when compared to the untreated plot at 2, 8, 16 and 20 MAA from the treated soil of Owena (Fig. 6).

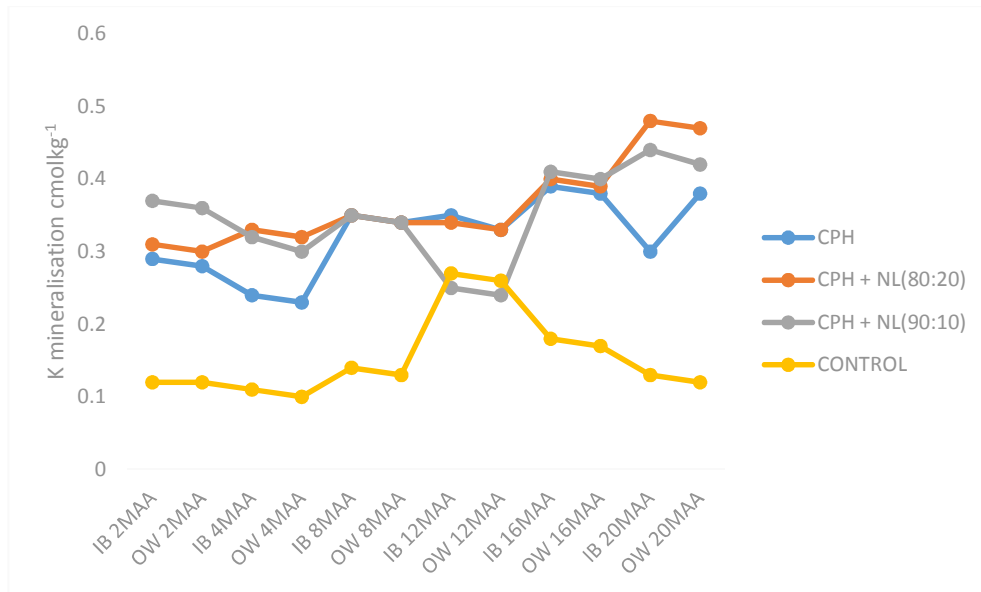


Fig. 6. Effect of organic amendment on Potassium mineralisation from two to twenty Months after Application (MAA) on cocoa soil at Ibadan (IB) and Owena (OW), Nigeria

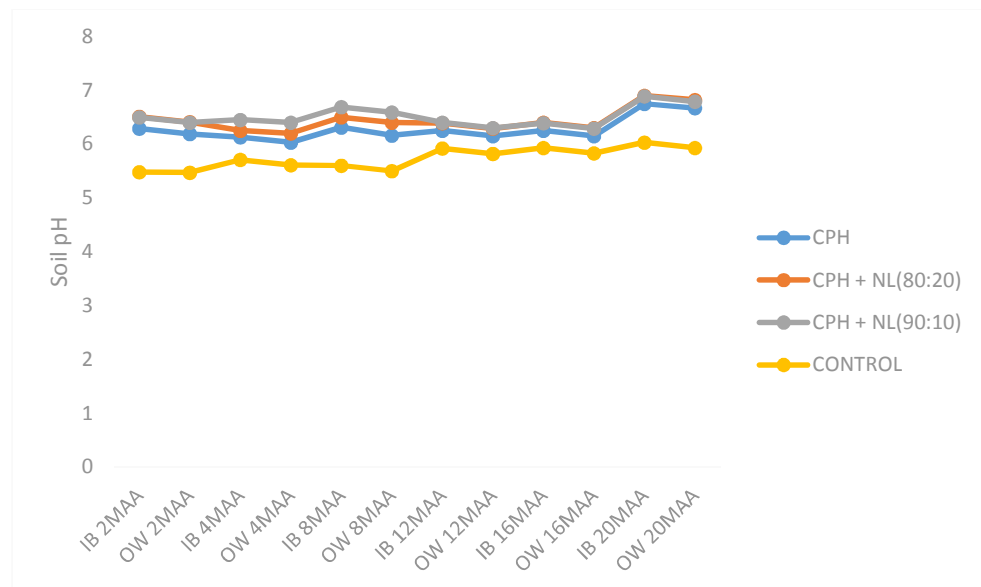


Fig. 7. Effect of organic amendment on soil Ph from two to twenty Months after Application (MAA) on cocoa soil at Ibadan (IB) and Owena (OW), Nigeria

3.4 Effect of Organic Amendment on Soil pH

The application of organic materials significantly ($P \leq 0.05$) raised the pH of the soil to the optimum in the two locations when compared to that of the control (Fig. 7).

3.5 Effects of Organic Amendments on Pod Production

The application of organic material significantly ($P \leq 0.05$) increased the pod production of moribund cocoa in CPH, CPH+NL (80:20), CPH+NL (90:10) from 40, 39 and 39 pods in 2012 to 64, 61, 60 pods, respectively,

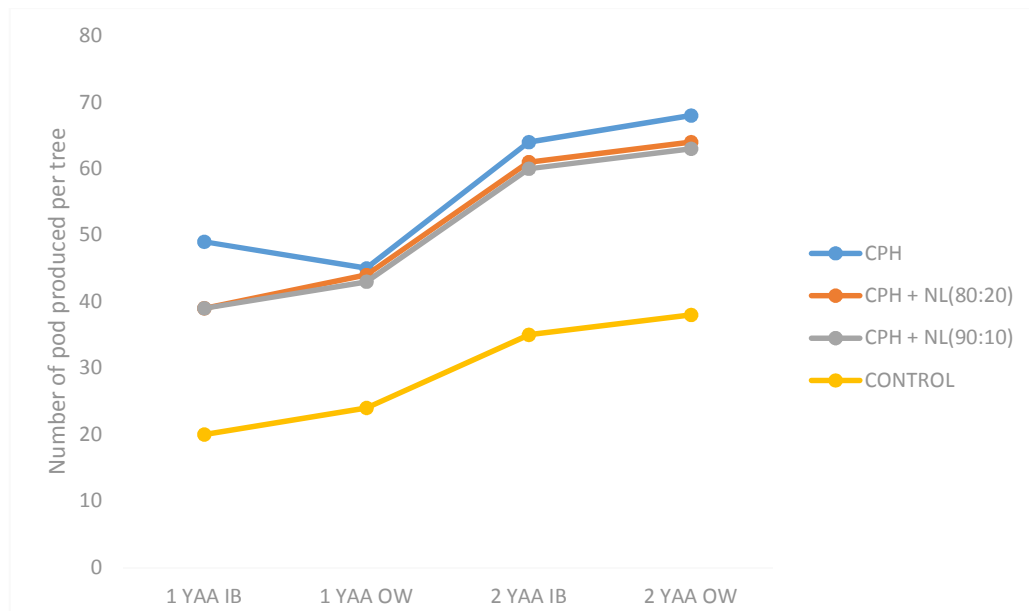


Fig. 8. Effect of organic amendment on yield two Years after Application (YAA) on cocoa soil at Ibadan (IB) and Owena (OW), Nigeria

in 2013 in Ibadan. Pod production from Owena moribund cocoa trees in CPH, CPH+NL (80:20), CPH+NL (90:10), also recorded an increase in number from 47, 43 and 43 in 2012 to 68, 64 and 63 in 2013, respectively, when compared to the untreated plot (Fig. 8).

4. DISCUSSION

The initial results from the study prior to the application of organic amendments showed that the soil from the two locations were ideal for cocoa in terms of the physical properties and textural class, but are deficient in N, P and K. Egbe [26] reported that the standard value of N, P and K requirement ideal for cocoa is N = 0.9 g/kg, P = 10 mg/kg and K = 0.3 cmol/kg. This could be responsible for the low yield (less than 20 pods per tree) as experienced before the application of organic amendments. The CPH and neem leaf nutrient composition analysis showed that neem leaf has more N content than CPH that have more Calcium and Potassium. This result is similar to the reports of Ipinmoroti [27], Adeoye et al. [28] and Oguntuga [29] which showed that neem leaf has more nitrogen content than CPH. The application of organic amendments increased the population of fungi above the initial populations in this experiment. This finding is in line with the works of Main et al. [30], who reported that the application of organic amendment to the soil increased the microbial diversity and numbers. The application of organic

amendment also significantly increased the mineralization of Nitrogen, Phosphorus and Potassium. This result is similar to the findings of Ladd [31], Azam et al. [32] and Smith and Sharply [33] that posited that when low nitrogen crop residues are buried in the soil, nitrogen is immobilized, but high nitrogen containing residues improve N mineralization. Minimum residue N contents of 1.5 to 1.7% (C/N ratios of 25 to 30) have been suggested to supply the need of soil microbes during crop residues decomposition [34]. The results obtained in this study corroborate this trend. The higher nitrogen released in soil treated with CPH as from eight weeks after incubation compared to the control suggests re-mineralization of nitrogen immobilized at the start of incubation which has been retained in organic forms of N biomass and liberated thereafter when decomposition progressed. The reduced Nitrogen mineralization observed in the untreated soil, might be due to immobilization of nitrogen released from soil organic matter. Fortification of CPH with neem is a release precursor for nitrogen. This was similar to the report of Ogunlade et al. [2] when pacesetter grade B organic fertilizer was fortified with neem leaf powder. The beneficial effects of organic incorporation have been generally considered to be due to increase in soil nutrients, improvement in soil physical and chemical properties [35,36,37]. Therefore, the increase in pod production and yield could be attributed to the effects of organic amendment on microbial

populations, soil nutrient replacement and good agricultural practices such as regular weeding and pruning.

5. CONCLUSION

Application of organic amendments to an old and moribund cocoa plantation, not only improves the mineralization of nutrients, but also increases yield and beneficial soil microbial populations.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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