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Profitability of Plantain as Shade Crop to Cocoa under Different Soil Treatments

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ABSTRACT— ***Effects of poultry litter amendment on plant-parasitic nematodes, soil fertility and profitability of plantain as shade crop for cocoa establishment in the field were evaluated. The soil was treated with different levels of cured poultry litter and carbofuran as nematicide. The results of this study demonstrate the highly-damaging nature of plant-parasitic nematodes to plantain production. The percentage of plantain dead roots was positively correlated with P. coffeae, R. similis, H. multicinctus and M. incognita. When percentage root necrosis was regressed against nematode population density at harvest, a positive correlation was observed for P. coffeae ($r = 0.96; P \leq 0.001$), R. similis ($r = 0.91; P \leq 0.001$), H. multicinctus ($r = 0.62; P \leq 0.001$) and M. incognita ($r = 0.36; P = 0.036$). There was a positive relationship between root necrosis percentage and percentage of dead roots. The population densities of both M. incognita ($r = 0.58; P \leq 0.001$) and H. multicinctus ($r = 0.46; P = 0.005$) were positively correlated with percentage gall index, while no relationships were detected between percentage gall index and population densities of P. coffeae and R. similis. The percentage of large lesions was positively correlated with R. similis ($r = 0.65; P \leq 0.001$) and negatively correlated with P. coffeae, though not significant ($r = -0.12; P = 0.51$). In contrast, the percentage of small lesions was positively correlated with P. coffeae ($r = 0.78; P \leq 0.001$) and negatively correlated with R. similis ($r = -0.66; P \leq 0.001$). No relationships were detected between percentage lesions and population densities of M. incognita and H. multicinctus. Addition of poultry litters had a beneficial effect on the chemical properties and organic matter content of the soil, which increased from 2.32 to 2.43%. Vegetative growth and yield of plantain was significantly improved by poultry litter treatments with significant reduction in the number of days from first to second flowering of plantain from 279 to 260 days, respectively. Plantain output from each of the soil treatments was analyzed using Benefit Cost Ratio (BCR) and Net Present Value (NPV). The result of the analysis showed that the BCR values for all the treatments were greater than 1 and the NPVs were positive. However, the highest profit was recorded when the soil is treated with poultry litter at 0.4 ton per hectare. The study therefore recommended that for maximum plantain output as shade crop to cocoa and management of plant-parasitic nematodes, the soil must be treated with poultry litter at 0.4 tonne per hectare.***

Keywords— Cocoa, plantain, soil treatments, profitability, shade crops

1. INTRODUCTION

Cocoa (*Theobroma cacao)* is a perennial tree crop majorly grown in the rain forest belt of Nigeria. The contributions of cocoa to the nation's economic development are vast and in terms of foreign exchange earnings, no single agricultural export commodity has earned more than cocoa [1]. With respect to employment, the cocoa sub-sector still offers quite a sizeable number of people employment, both directly and indirectly [2]. In addition, it is an important source of raw materials, as well as source of revenue to governments of cocoa producing states [3].

However, this important commodity requires shade crop at the seedling stage to effectively protect the seedlings from the scotching of sun. The more frequently employed shade crop for cocoa is plantain. Plantain is one of the most important shade crops and it is among the ten most important food security crops that feed the world [4]. Plantain is the fourth most important food crop in the world after rice, wheat and maize, and is used as food, beverages and cooked foods [5]. This major food staple and cash crop is important in the rural and urban economy, social and cultural life in sub-Saharan Africa [6]. Nigeria is one of the major plantain producing and consuming countries in Africa, and is ranked among the 20 most important plantain producing countries worldwide [7]. It should however be noted that the output of this important shade crop has drastically reduced as a result of diminishing fertility status of soil.

Due to constantly increasing pressure on available land as a result of high population densities, fallow lands have significantly reduced and rarely exceed six years [8]. As a general rule, land fallow that is less than ten years would not recover adequately and the quality of the soil decreases with more exploitation. As a result of diminishing fertility status due to shorter fallow periods, farmers are no longer producing enough foods to feed the ever growing population [9]. Most plantations in Nigeria are very old and there is dearth of forestlands for establishment of new plantation. The soil nutrients in plantations are being mined annually via harvest. [10] showed that a crop of 1000kg dry cocoa beans for instance removed about 20KgN, 4KgP and 10KgK and where the method of harvesting (as in Nigeria) involves the removal of pod husks from the field, the amount of K (potassium) removed is increased more than five folds. [11], in an assessment of soil nutrient status of cocoa plantation across cocoa ecologies of Nigeria, reported that a vital micro-nutrient, specifically phosphorus is grossly inadequate for optimum cocoa yield.

However, balancing the food, fiber and living environment needs of the increasing world population in a limited space and with many biological, technological, ecological and conflicting socio-economic restrictions is no longer a one nation, but a global challenge. Therefore, in order to meet the food and fiber requirements for human beings, many genetic, molecular and traditional technologies are applied to change a plant to fit the soil or change the soil to fit the plant [12]. In the process of selecting the desired traits, over emphasis and/or under emphasis of other traits inevitably occur and often lead to challenges of cross and multi-disciplinary integration and sustainability. Plant-parasitic nematodes, broadly distributed and often interacting with other biotic and abiotic factors, are among the biological restrictions limiting global food and fiber production, to the tune of $100 billion annual crop loss by old and conservatives estimates [13].

Plant-parasitic nematodes are present in all agricultural production soils and climates [14] parasitizing root and/or shoot tissues. Whether plant-parasitic nematodes parasitize their plant hosts as ecto- or migratory or sedentary endo-parasites, they all disrupt water and nutrient uptake [15] due to physical root destruction, which, in turn, create cascading physiological changes in an infected plant [16]. Plant-parasitic nematodes have caused losses in plantain around the world with damage of roots and corm of plantain, rotting of the root system and plant toppling resulting in yield reduction [17, 18]. Regrettably, edible Musa varieties currently grown by many farmers in Nigeria and West Africa are susceptible to nematode diseases [19, 20]. Although the use of clean planting material obtained through corm paring and / or hot water treatment of plantain suckers [21] are attractive management options available to the small-scale farmers in the nursery, there is the need to control the nematodes in established plantations on the field. While chemical control can reduce the impact of nematode infestations [22], effective nematicides are too expensive for resource-poor farmers and often results in a noticeable decrease of many soil biological processes, notably by suppressing predators and parasites of these nematodes [23], contamination of aquifers [24] and negative shifts such as health hazards, environmental pollution and potential atmospheric ozone depletion [25]. However, soils, especially those with a low microbial population, are more vulnerable to reinvasion of pathogens even after fumigation [26]. Nematode populations might become sensitized or resistant to repeated applications of nematicides [27]. With increased social and legislative pressure to restrict the use of Methyl Bromide, an effective soil fumigant used extensively to control a broad spectrum of pests [28] and the recent ban of carbofuran on cocoa and plantain [29, 30], there is the need to evaluate alternative approaches for management of plant-parasitic nematodes for optimal yield.

Organic soil materials that are generally used for increasing agricultural productivity have been shown to have a suppressive effect on plant-parasitic nematodes [31-33]. Poultry is an important segment of agricultural production in Nigeria [34] and the industry generates enormous quantities of wastes in form of manure or litter that require environmentally acceptable means of disposal. Disposal by using it as soil amendments in agricultural land is a desirable option. Litter, if used appropriately, can be substituted for mineral fertilizers [35]. This research was conceived to study the effect of poultry litter soil amendment on plant-parasitic nematodes and profitability of plantain as shade crop during the first four years of cocoa establishment in the field. The hope is that the current level of frustration faced by farmers through poor cocoa seedlings establishment, toppling and reduced yield of plantain caused by plant-parasitic nematodes and declining soil fertility can be ameliorated.

2. MATERIALS AND METHODS

The research works were carried out at the Cocoa Research Institute of Nigeria (CRIN) in Ibadan, Nigeria. Ibadan lies between the latitude 7^0 30’ N and longitude 3^0 54’ E at an altitude of 200 m above sea level. It is located in the tropical rain forest ecosystem with mean solar radiation of 18mj/m^2/day and an annual average rainfall of 2000 mm with a bimodal pattern.

Poultry litter used in the experiment was collected from coops with good farm sanitation and air-dried. Analysis was carried out to determine the macro and micro nutrient content of the poultry litter [36]. Soil samples were analysed for physico-chemical properties and nematodes assay [37, 38].

The field experiment was conducted over four crop cycles on the False horn plantain (*Musa* spp. L., AAB – group cv. Agbagba) as intercrop (and shade crop) planted with cacao (*T. cacao* cv. F3 Amazon) in Zone Six of CRIN research farm. The experiment was set as a randomized complete block design of a 4x3 factorial arrangement with four rates of poultry litter (0, 0.2, 0.3, 0.4t/ha) and three rates of carbofuran (0, 1.25, 2.50kg active ingredient [a.i]/ha). Each treatment had 3 replications. The poultry litter in the relevant treatments were incorporated into the soil by mixing the litter with the soil at planting time and again at 3, 6 and 9 months after planting, while the carbofuran treatments were applied by mixing it with soil at planting and repeated after three months around the plants. There were twelve treatments in all. Soil samples were collected with a soil auger at 15cm depth before and after treatment applications to determine the physico-chemical properties of the soil and assess the nematode populations. The physico-chemical properties of the soil were determined using the various procedures followed for soil analysis outlined by Ryan *et al*. [37].

Healthy sword suckers of plantain of approximately uniform size (50-60cm tall, 30-40cm pseudostem girth) pared to remove lesions was planted at a spacing of 3x3m. The suckers were planted in holes 40cm deep and 30cm wide and firmed up with soil. Cocoa seedlings were planted four weeks later at the same spacing. The unit plot size was 31.5m2 accommodating 8 plant stands, each of the cacao and plantain. Weeding of the entire plots were done at three months intervals, while mulching and watering of cocoa seedlings (during dry season) were done at the first year of establishment. Twenty-four soil samples were taken from each experimental unit with a soil auger at 15cm depth within a 25cm radius from the base of cacao stems. Root samples were taken only from plantain plants at the time of harvesting from an excavation of 20 x 20 x 20cm extending outward from the corm of the plant [39]. Soil and root samples were transported in plastic bags to the laboratory for assessment, extraction, identification and quantification of nematodes [39, 38].

Survival counts of plantain and cocoa were recorded at 6 months after planting (MAP). Aerial growth data measured on each plant included plant height (PH, m), pseudostem circumference of plantain at soil level (PC, cm), stem girth of cacao (SG, cm), number of leaves (NL) of cacao and that of mother plant of plantain at flowering and at harvest of plantain, number of days (DF1) from field planting of plantain to first flowering, number of days (DF2) from first to second flowering, number of suckers (NS), and height of the tallest suckers (HS, m). In addition, leaf area (LA, cm2) of cacao was determined using electronic leaf area metre, while that of plantain was calculated according to Kumar *et al*. [40] by counting the number of leaves (N), measuring the length (L) and breadth (B) of the third leaf from the top and calculating the leaf area as follows: TLA = L x B x 0.80 x N x 0.662. At harvest of plantain, records were taken on the weight of bunches (WB, kg) and rachis (WR, kg), number of hands (NH) and fingers (NF) per bunch.

The yield from each of the treatments was subjected to Benefit Cost Ratio (BCR) analysis as well as Net Present Value (NPV) analysis to determine the level of profitability of the project while the yield parameters such as fingers per bunch, hands per bunch, rachis weight and bunch weight were subjected to significant test to determine whether there are significant relationship between each of the yield parameters and the materials for the soil treatment which are poultry litter and carbofuran.

Benefit Cost Ratio is the ratio of the discounted benefit to the discounted cost.

$$BCR = \sum_{t=1}^{t=N} \frac{B_t}{(1+r)^t} \Big/ \sum_{t=1}^{t=N} \frac{C_t}{(1+r)^t}$$

Where:

B_t = Benefit derived at time t;
C_t = Discounted costs at time t;
t = Period of the project;
r = Prevailing interest rate.

According to Gittinger [41], the decision rule is that for an investment to be economically viable, the ratio must be greater than unity. If the BCR is less than unity, then the project is not profitable. Hence, more cost in being incurred than the benefit and if the BCR is greater than one, the project is profitable. However, the most profitable project is the one with the highest BCR.

Net Present Value (NPV) is the measure of the project worth that is used to find the value of the money invested over a number of years. NPV is discounted benefit less discounted cost, that is,

$$NPV = \sum_{t=1}^{t=N} \frac{B_t}{(1+r)^t} - \sum_{t=1}^{t=N} \frac{C_t}{(1+r)^t}$$

Where 'B_t','t' and 'r' are as previously defined.

If NPV is positive, then the project is profitable and if NPV is negative, the project is not profitable and NPV of zero is the breakeven stage.

Nematode population densities were log10(x + 1) transformed and percentage data were square root transformed prior to analysis [42]. Analyses of variance (ANOVA) were carried out to test for main effects and interactions. Pre-planned comparisons between treatment combinations were tested with linear contrasts. Regression analyses were used to develop linear models relating nematode numbers and rate of poultry litter applications to plantain growth. All analyses were performed using GENSTAT (version 7.1, VSN International Ltd., Lawes Agricultural Trust, Hempstead, UK).

3. RESULTS AND DISCUSSION

The nutrient content (%) of poultry litter (PL) that was used to amend soil was Nitrogen 3.24, Carbon 27.9, Phosphorus 1.86, Potassium 0.05, Calcium 1.40, Magnesium 0.64, Sodium 0.02, Manganese 0.08, Iron 0.10, Copper 0.09 and Zinc 0.04. The addition of poultry litters had a beneficial effect on the chemical properties and organic matter content of the soil, which increased from 2.32 to 2.43% (Table 1). Similarly, N, P, K, Mg, Ca, Na, Mn, Fe, Cu and Zn content increased after the mother plant crop. However, soil physical properties remained unchanged after the mother plant crop.

Days to 50% flowering (DF1) in plantain at the first cycle (mother plant) was 279 days in PL alone or combined with carbofuran at 0.3 and 0.4t/ha amended plots. This was increased to 284 days in both PL alone or combined with carbofuran at 0.2t/ha and carbofuran alone at 2.50kg a.i./ha amended plots. DF1 was greatly increased to 291 days in un-amended and carbofuran at 1.25kg a.i./ha treated plots (Table 2). At the second cycle (ratoon crop), there was a significant reduction in the number of days from first to second flowering (DF2) of plantain in PL amended plots (Table 3). Vegetative growth of plantain was improved by poultry litter in this experiment (Table 2, 3). Height and pseudo-stem girth of plantain at flowering was enhanced by soil amendments. This confirmed the report of Mohanty *et al*. [43] that plant growth enhancing effects of poultry litter leads to an increase in the stem and leaf biomass of plants. Phosphorus uptake is enhanced by the application of poultry manure, and this could be attributed to the greater leaf biomass yield in poultry manure-treated soil [43]. Although there were no significant differences in the number of suckers of plantain at both cycles under poultry litter amended and un-amended plots, there was a significant increase in the height of the tallest sucker at flowering of the mother plant in poultry litter amended plots (Table 2). This resulted in a significant reduction in the number of days from first to second flowering of plantain in poultry litter amended plots (Table 3). This was in agreement with earlier report [44] that growth of vigorous suckers reduces the cycle duration and results in higher yields [45]. Thus a larger sucker at flowering and harvest of the mother plant is desirable because it will guarantee a fast succession of harvests and thus increase the yield on time basis [46].

At harvest of plantain plants, damage to roots was greater under un-amended than amended plots (Table 4). The percentage of dead roots of mother plants was on average significantly lower in poultry litter (PL) alone or combined with carbofuran at 0.4, 0.3, 0.2t/ha amended plots compared to carbofuran at 2.50, 1.25kg a.i./ha, and un-amended plots (20, 21, 29% vs 34, 40, 41%, respectively). Similarly, root necrosis percentage of mother plants was significantly lower in PL alone or combined with carbofuran at 0.4, 0.3, 0.2t/ha amended plots compared to carbofuran at 2.50, 1.25kg a.i./ha and un-amended plots (18, 20, 34% vs 42, 52, 53%, respectively). Fewer galls were observed on the roots of the harvested plantain in all treatments (Table 4). However, there was a significant reduction in the percentage of gall index of the mother plant in the PL-amended plots at 0.3, 0.4t/ha compared to carbofuran-amended and un-amended plots (Table 4). Larger lesions were observed in the corms of plantain at harvest in the un-amended plots compared to the amended plots (Table 4). However, the PL treatments have the higher percentages of small lesions.

Relationships between nematode population densities and vegetative growth of plantain revealed various statistically significant interactions (Table 5). The percentage of dead roots was positively correlated with *P. coffeae*, *R. similis*, *H. multicinctus* and *M. incognita*. When percentage root necrosis was regressed against nematode population density at harvest, a positive correlation was observed for *P. coffeae* ($r = 0.96$; $P \leq 0.001$), *R. similis* ($r = 0.91$; $P \leq 0.001$), *H. multicinctus* ($r = 0.62$; $P \leq 0.001$) and *M. incognita* ($r = 0.36$; $P = 0.036$). There was a positive relationship between root necrosis percentage and percentage of dead roots. The population densities of both *M. incognita* ($r = 0.58$; $P \leq 0.001$) and *H. multicinctus* ($r = 0.46$; $P = 0.005$) were positively correlated with percentage gall index, while no relationships were detected between percentage gall index and population densities of *P. coffeae* and *R. similis*. The percentage of large lesions was positively correlated with *R. similis* ($r = 0.65$; $P \leq 0.001$) and negatively correlated with *P. coffeae*, though not significant ($r = -0.12$; $P = 0.51$). In contrast, the percentage of small lesions was positively correlated with *P. coffeae* ($r = 0.78$; $P \leq 0.001$) and negatively correlated with *R. similis* ($r = -0.66$; $P \leq 0.001$). No relationships were detected between percentage lesions and population densities of *M. incognita* and *H. multicinctus*.

The results of this study demonstrate the highly-damaging nature of plant-parasitic nematodes to plantain production. This is consistent with the earlier report that *Radopholus similis* together with *Pratylenchus coffeae* are amongst the most important biotic constraints of plantain in Nigeria [47, 48, 18], *H. multicinctus* and *P. coffeae* amongst the most important in Ghana [49], *P. goodeyi* and *Meloidogyne* spp. amongst the most important in Rwanda [50] and *R. similis* amongst the most important in lowland Cameroon [51]. Within West Africa the endoparasitic nematode species common to plantain often occur in combination [52-54] as observed in this experiment. Whilst the pest status of *R. similis* and *P. coffeae* on Musa is well established, that of *H. multicinctus* is less established. This study correlated nematode root damage primarily with *R. similis* and *P. coffeae*, but also with *H. multicinctus* even though *H. multicinctus* density was low in all treatments. Evidence is beginning to accumulate implicating *H. multicinctus* as a causal agent of plantain damage [52, 55] but this species has often been considered as coincidental with root damage, as opposed to instrumental [52]. However, *H. multicinctus* is highly prevalent in many West Africa plantain-growing areas and regularly associated with necrotic root systems and toppled plants [55]. It certainly appears to be less pathogenic than either *R. similis* or *P.*

Table 1. Physical and chemical analysis of the experimental soil before the study and after the mother plant crop

S/no	Properties	Pre-plant	Post Harvest		
			Poultry litter amended	Carbofuran amended	Un-amended
1.	Physical properties				
	Sand (%)	79.2	79.2	79.2	79.2
	Silt (%)	13.4	13.4	13.4	13.4
	Clay (%)	7.4	7.4	7.4	7.4 Sandy Loam
	Textural Class	Sandy Loam	Sandy Loam	Sandy Loam	
2.	Chemical properties				
	pH in H_2O 1:1	7.3	7.6	7.2	7.3
	Organic carbon (%)	1.35	1.41	1.37	1.37
	Organic matter (%)	2.32	2.43	2.36	2.36
	Total nitrogen (%)	0.18	0.34	0.20	0.20
	Available phosphorus ($mgkg^{-1}$)	11.82	12.10	11.86	11.86
	Exchangeable potassium ($cmolkg^{-1}$)	0.15	0.18	0.15	0.15
	Exchangeable magnesium ($cmolkg^{-1}$)	0.65	0.70	0.62	0.62
	Exchangeable calcium ($cmolkg^{-1}$)	1.16	1.21	1.19	1.19
	Exchangeable sodium ($cmolkg^{-1}$)	0.06	0.09	0.09	0.09
	Effective cation exchange capacity ($cmolkg^{-1}$)	2.52	2.78	2.65	2.65
	Extractable manganese ($cmolkg^{-1}$)	72.17	73.46	72.57	72.57
	Extractable iron ($cmolkg^{-1}$)	50.25	52.08	50.41	50.41
	Extractable copper ($cmolkg^{-1}$)	6.64	6.75	6.60	6.60
	Extractable zinc ($cmolkg^{-1}$)	13.78	14.28	13.89	13.89

Table 2. Effects of poultry litter and carbofuran soil amendments on the growth of plantain cv. Agbagba (*Musa* spp., AAB-group) during the first cycle.

Treatments	Days to 50% flowering[1]	Plant height at flowering[1] (m)	Plant height of tallest sucker[1] (m)	Pseudo-stem girth[1] (cm)	Number of leaves at flowering[1]	Number of leaves at harvest[1]	Leaf area[1] (cm^2)
PL at 0.4t/ha	278.7c	2.67a	1.67a	64.13a	13.67a	9.67a	121233.1a
PL at 0.4t/ha+C at 2.50kg a.i./ha	278.7c	2.67a	1.63a	64.14a	ns	ns	121232.9a
PL at 0.4t/ha+C at 1.25kg a.i./ha	278.9c	2.69a	1.67a	64.13a	ns	ns	121233.3a
PL at 0.3t/ha	279.3c	2.64a	1.63a	63.17b	13.67a	9.67a	121183.3b
PL at 0.3t/ha+C at 2.50kg a.i./ha	279.3c	2.63a	1.65a	63.15b	ns	ns	121183.5b
PL at 0.3t/ha+C at 1.25kg a.i./ha	279.3c	2.67a	1.65a	63.15b	ns	ns	121183.7b
PL at 0.2t/ha	284.3b	2.51b	1.31b	60.73c	11.00b	7.00b	119101.3c
PL at 0.2t/ha+C at 2.50kg a.i./ha	284.4b	2.50b	1.31b	60.73c	ns	ns	119101.7c
PL at 0.2t/ha+C at 1.25kg a.i./ha	284.3b	2.63a	1.33b	60.69c	ns	ns	119101.5c
C at 2.50kg a.i./ha	284.4b	2.47c	1.17c	51.33d	ns	ns	98122.3d
C at 1.25kg a.i./ha	291.3a	2.27d	1.03d	51.31d	ns	ns	98024.1e
Control (no amendments)	291.4a	2.27d	1.07d	51.31d	10.89b	7.00b	98024.4e

PL = Poultry litter.

C = Carbofuran.

[1]Means followed by the same letter in the same column do not differ significantly according to Fisher's LSD test (5%).

ns = not significant.

Table 3. Effects of poultry litter amendments on growth parameters of plantain cv. Agbagba (*Musa* spp., AAB-group) over two production cycles

Treatments*	Production Cycle	Days to 50% flowering[1]	Plant height at flowering[1] (m)	Pseudo-stem girth[1] (cm)	Number of suckers[1]	Number of leaves at flowering[1]	Number of leaves at harvest[1]	Leaf Area[1] (cm^2)
T1	**1**	**278.7c**	**2.67c**	**64.13b**	**6.56a**	**13.67a**	**9.67a**	**121233.1b**
T1	**2**	**260.1e**	**3.40a**	**68.20a**	**5.30a**	**13.67a**	**8.67a**	**123242.1a**
T4	**1**	**279.3c**	**2.64c**	**63.17b**	**6.56a**	**13.67a**	**9.67a**	**121183.3b**
T4	**2**	**260.3e**	**3.40a**	**67.93a**	**5.30a**	**13.67a**	**8.67a**	**123240.5a**
T7	**1**	**284.3b**	**2.51d**	**60.73c**	**5.20a**	**11.00b**	**7.00b**	**119101.3c**
T7	**2**	**260.4e**	**3.37a**	**67.40a**	**5.20a**	**13.33a**	**8.67a**	**123239.9a**
T12	**1**	**291.7a**	**2.27e**	**51.31d**	**5.22a**	**10.89b**	**7.00b**	**116005.7d**
T12	**2**	**271.8d**	**3.03b**	**61.23c**	**5.30a**	**13.35a**	**8.44a**	**123202.0a**
SE		**3.88**	**0.09**	**1.19**	**1.37**	**1.55**	**1.41**	**802**

*T1: Poultry litter at 0.4t/ha, T4: Poultry litter at 0.3t/ha, T7: Poultry litter at 0.2t/ha, T12: Control with no amendments.

[1]Means followed by the same letter in the same column do not differ significantly according to Fisher’s LSD test (5%).

SE: Standard error of mean.

Table 4. Effects of poultry litter and carbofuran soil amendments on root and corm damage of plantain cv. Agbagba (*Musa* spp., AAB-group) mother plant measured at harvest in nematode-infested soil.

Treatments	Dead[† 1] roots (%)	Root[† 1] necrosis (%)	Gall[† 1] Index (%)	Large[† 1] Lesion (%)	Small[† 1] Lesion (%)
PL[*] at 0.4t/ha	20.33d	18.33e	5.67d	33.67e	66.33a
	20.34d	18.33e	5.33d	33.33e	66.67a
PL at 0.4t/ha + C[#] at 2.50kg a.i./ha	20.33d	18.37e	5.65d	33.67e	66.33a
PL at 0.4t/ha + C at 1.25kg a.i./ha	20.53d	20.43d	7.67c	37.33d	62.67b
PL at 0.3t/ha	20.67d	20.33d	7.53c	37.67d	62.33b
PL at 0.3t/ha + C at 2.50kg a.i./ha	20.65d	20.46d	7.69c	37.67d	62.33b
PL at 0.3t/ha + C at 1.25kg a.i./ha	28.67c	34.33c	10.33b	45.39c	54.61c
PL at 0.2t/ha	29.33c	34.00c	10.67b	45.67c	54.33c
PL at 0.2t/ha + C at 2.50kg a.i./ha	29.31c	33.76c	10.67b	45.33c	54.67c
PL at 0.2t/ha + C at 1.25kg a.i./ha	34.33b	41.67b	10.00b	62.27b	37.73d
C at 2.50kg a.i./ha	40.45a	52.33a	10.33b	64.43a	35.57e
C at 1.25kg a.i./ha	40.65a	52.67a	12.33a	64.43a	35.57e
Control (no amendments)					

[*] Poultry Litter, [#] Carbofuran
[†]Analysis undertaken on square root transformed data, back-converted data shown.
[1]Means followed by the same letter in the same column do not differ significantly according to Fisher's LSD test (5%).

Table 5. Linear correlation matrix (half) of mean values for nematode population densities / 5g fresh root weight, percentage dead roots, gall index, root necrosis, large lesions and small lesions of plantain cv. Agbagba (*Musa* spp., AAB-group).

	Pc	Mi (J2)	Hm	Dead roots (%)	Gall index (%)	Root necrosis (%)	Large lesions (%)	Small lesions (%)
R. similis	**0.96*****	**0.41***	**0.67*****	**0.88*****	**0.25**	**0.91*****	**0.65*****	**-0.66*****
P. coffeae	**-**	**0.46****	**0.72*****	**0.95*****	**0.24**	**0.96*****	**-0.12**	**0.78*****
***M. incognita* (J2)**		**-**	**0.84*****	**0.39***	**0.58*****	**0.36***	**0.15**	**-0.18**
H. multicinctus			**-**	**0.56****	**0.46****	**0.62*****	**0.15**	**-0.17**
Dead roots (%)				**-**	**0.16**	**0.89*****	**0.16**	**-0.22**
Gall index (%)					**-**	**0.21**	**-0.13**	**0.29**
Root necrosis (%)						**-**	**0.28**	**-0.26**
Large lesion (%)							**-**	**-0.99*****

Pc: *Pratylenchus coffeae*; Mi: *Meloidogyne incognita*; Hm: *Helicotylenchus multicinctus*.

*, **, *** : correlation coefficient significant at P ≤ 0.05, 0.01 or 0.001, respectively.

coffeae, but its damaging effect in this study cannot be neglected. Nevertheless, it is difficult to distinguish the effect of individual nematodes among combinations of species, although the use of path analysis has helped identify the pathogenic effect of *H. multicinctus* on East African Highland banana (*Musa* spp., AAA) [56].

Significant differences were recorded in yield parameters of the mother plants of plantain between the treatments (Table 6). The number of fingers and hands per bunch increased significantly in plants grown in PL alone or combined with carbofuran amended plots compared to the unamended plots. However, plants grown in PL alone or combined with carbofuran at 0.4t/ha amended plots had the greatest number of fingers and hands per bunch. The largest bunch weight, rachis weight and total yield per hectares were recorded in plants grown in PL alone or combined with carbofuran at 0.4t/ha amended plots, whereas the smallest bunch weight and lowest yield were observed in Carbofuran at 1.25kg a.i./ha amended and un-amended plots. Carbofuran treatments had no significant effect on rachis weight (Table 6). Comparing the effect of poultry litter amendments on yield parameters in both cycles, there was a general significant decline in the number of fingers and hands per bunch, rachis and bunch weights, and yield per hectare in all treatments of the second cycle compared to the first (Table 7). However, the PL treatments had significant higher bunch weights and yields than the un-amended plots in both cycles.

The result of the analysis of Benefit Cost Ratio (BCR) of the yield of plantain when the soil was subjected to different treatments is shown in Table 8. The result showed that plantain yield had the highest BCR of 2.94 when the soil upon which the crop was planted was treated with poultry litter at 0.4 ton/ha. This was closely followed with the BCR of 2.69 and 2.53 when the soil was treated with poultry litter at 0.3 ton/ha and with poultry litter at 0.3 ton/ha plus carbofuran at 1.25 kg a.i./ha respectively. However, the lowest BCR of 1.59 was recorded when the soil was treated with carbofuran at 1.25 kg/ha. Meanwhile, the BCR of 1.72 was recorded for the control experiment in which case the soil was not given any amendment. Looking at the result, it could be discovered that all the BCR values are greater than one showing that the cost incurred in each of the treatments was lesser than the benefits derived from the investment, hence the investing in all the treatments is economically viable. However, the most profitable treatment is poultry litter at 0.4 ton/ha where the highest BCR of 2.94 was recorded while the least profitable treatment is carbofuran at 1.25kg/ha where the lowest BCR of 1.59 was recorded.

Analysis of Net Present Value (NPV) of the yield of plantain when the soil was subjected to different treatments is shown in Table 9. The result showed that plantain yield had the highest NPV of ₦4,371.80 when the soil was treated with poultry litter at 0.4 ton/ha. This was followed with the soil treated with poultry litter at 0.4 ton/ha plus carbofuran at 1.2kg/ha with the NPV of ₦4,006.40. The soil treated with carbofuran at 1.25kg/ha had the lowest NPV of ₦1,435.90/ha. All the NPV values had positive values showing that the cost incurred in each of the treatments was lesser than the benefits derived from the investment; hence the investment in all the treatments is profitable. However, the most profitable treatment was poultry litter at 0.4 ton/ ha where the highest NPV of ₦4,371.80/ha was recorded. A critical look at the result of the analysis of both the Benefit Cost Ratio and the Net Present Values showed that there is a keen similarity between the two results in that the treatment that is having the highest BCR is also the same treatment that is having the highest NPV. Also, the treatment that is having the lowest BCR is also the treatment that is having the lowest NPV showing the level of accuracy of the result.

Over recent years, plantain yield and plantation longevity in West Africa have been gradually declining [57]. Numerous constraints, including soil fertility depletion, high soil acidity, various pathogens, and lack of suitable planting material are held responsible for this decline and the resultant escalation in the price of plantain regionally [58]. Plant parasitic nematodes are responsible for a significant decrease in yield of plantains [51, 48]. Plantain is a nutrient-demanding crop requiring high soil fertility [59], the observed increase in the growth and yield of plantain in this experiment in poultry litter amended soils compared to both the carbofuran treated and untreated soils may be attributed to, among others, the increase in nutrients supply to the soil, resulting from the addition of organic amendments and reduction in population densities of plant-parasitic nematodes. Many factors could affect the response of nematode communities to nutrient sources. Most importantly, nematode communities were often affected by the nutrient composition, particularly the C:N ratio, of the organic amendments [60]. In general, amending the soil with a low C:N ratio (less than 20:1) substrate resulted in an abundance of enrichment-opportunist antagonistic microbes [61] and rapid mineralization of N in the form of $NH4^+$ or $NO3^-$ for absorption and uptake by plant roots. The poultry litter used in this experiment has a low C:N ratio (9:1) and this resulted in the suppression of nematode population on plantain with yield increase.

Table 6. Effects of poultry litter and carbofuran soil amendments on the yield of plantain cv. Agbagba (*Musa* spp., AAB-group) during the first cycle.

Treatments	Fingers/bunch[1]	Hands/bunch[1]	Rachis weight[1] (kg)	Bunch weight[1] (kg)	Yield[1] (t/ha)
PL at 0.4t/ha	30.33a	7.33a	0.97a	11.86a	15.06a
PL at 0.4t/ha+C at 2.50kg a.i./ha	30.35a	7.34a	ns	11.86a	15.06a
PL at 0.4t/ha+C at 1.25kg a.i./ha	30.32a	7.33a	ns	11.87a	15.07a
PL at 0.3t/ha	30.29a	7.14b	0.93ab	11.28b	14.32b
PL at 0.3t/ha+C at 2.50kg a.i./ha	30.28a	7.13b	ns	11.25b	14.29b
PL at 0.3t/ha+C at 1.25kg a.i./ha	30.31a	7.15b	ns	11.29b	14.34b
PL at 0.2t/ha	25.33b	6.83c	0.90b	8.13c	10.32c
PL at 0.2t/ha+C at 2.50kg a.i./ha	25.37b	6.83c	ns	8.14c	10.34c
PL at 0.2t/ha+C at 1.25kg a.i./ha	25.34b	6.83c	ns	8.18c	10.39c
C at 2.50kg a.i./ha	20.33c	6.57d	ns	6.13d	7.78d
C at 1.25kg a.i./ha	20.33d	6.57d	ns	5.78e	7.34e
Control (no amendments)	20.34d	6.53d	0.81c	5.73e	7.28e

PL = Poultry litter.
C = Carbofuran.
[1]Means followed by the same letter in the same column do not differ significantly according to Fisher's LSD test (5%).
ns = not significant.

Table 7. Effect of poultry litter amendments on yield parameters of plantain cv. Agbagba (*Musa* spp., AAB-group) over two production cycles.

Treatments*	Production cycle[1]	Fingers/ bunch[1]	Hands/ bunch[1]	Rachis weight[1] (kg)	Bunch weight[1] (kg)	Yield[1] (t/ha)
T1	**1**	**30.33a**	**7.33a**	**0.97a**	**11.86a**	**15.06a**
T1	**2**	**23.56c**	**6.77c**	**0.90b**	**10.20c**	**12.95c**
T4	**1**	**30.29a**	**7.14b**	**0.93ab**	**11.28b**	**14.32b**
T4	**2**	**23.56c**	**6.77c**	**0.80c**	**10.12c**	**12.85c**
T7	**1**	**25.33b**	**6.83c**	**0.90b**	**8.13d**	**10.32d**
T7	**2**	**23.33c**	**6.74c**	**0.80c**	**7.11e**	**9.03e**
T12	**1**	**20.34d**	**6.53d**	**0.81c**	**5.73f**	**7.28f**
T12	**2**	**18.44e**	**5.83e**	**0.60d**	**4.96g**	**6.30g**
SE		**1.70**	**0.18**	**0.04**	**0.23**	**0.23**

*T1: Poultry litter at 0.4t/ha, T4: Poultry litter at 0.3t/ha, T7: Poultry litter at 0.2t/ha, T12: Control with no amendments.
[1]Means followed by the same letter in the same column do not differ significantly according to Fisher's LSD test (5%).
SE: Standard error of mean.

Table 8. Benefit Cost analysis of plantain (*Musa* spp., AAB-group) mother plant grown under twelve treatments

Treatments	**Cost (₦) (‘000)**	**Discounted Cost (₦) (‘000)**	**Benefit (₦) (‘000)**	**Discounted Benefit (₦) (‘000)**	**B/C (ratio)**
PL at 0.4t/ha	259.4	225.68	761.91	662.86	2.94
PL at 0.4t/ha+C at 2.50kg a.i./ha	343.4	298.76	761.91	662.86	2.22
PL at 0.4t/ha+C at 1.25kg a.i./ha	301.4	262.22	761.91	662.86	2.53
PL at 0.3t/ha	259.4	225.68	698.41	607.62	2.69
PL at 0.3t/ha+C at 2.50kg a.i./ha	343.4	298.76	698.41	607.62	2.03
PL at 0.3t/ha+C at 1.25kg a.i./ha	301.4	262.22	698.41	607.62	2.32
PL at 0.2t/ha	259.4	225.68	571.43	497.14	2.20
PL at 0.2t/ha+C at 2.50kg a.i./ha	343.4	298.76	571.43	497.14	1.66
PL at 0.2t/ha+C at 1.25kg a.i./ha	301.4	262.22	571.43	497.14	1.90
C at 2.50kg a.i./ha	300.4	261.35	507.94	441.91	1.69
C at 1.25kg a.i./ha	279.4	243.08	444.45	386.67	1.59
Control (no amendments)	258.4	224.81	444.45	386.67	1.72

PL = Poultry litter
C = Carbofuran
†Discount factor used was 0.87.

Table 9. Net Present Value analysis of plantain (*Musa* spp., AAB-group) mother plant grown under twelve treatments

Treatments	Cost (₦) ('000s)	Discounted Cost (₦) ('000)	Benefit (₦) ('000)	Discounted Benefit (₦) ('000)	NPV (₦)
PL at 0.4t/ha	259.4	225.68	761.91	662.86	4371.80
PL at 0.4t/ha+C at 2.50kg a.i./ha	343.4	298.76	761.91	662.86	3641.00
PL at 0.4t/ha+C at 1.25kg a.i./ha	301.4	262.22	761.91	662.86	4006.40
PL at 0.3t/ha	259.4	225.68	698.41	607.62	3819.40
PL at 0.3t/ha+C at 2.50kg a.i./ha	343.4	298.76	698.41	607.62	3088.60
PL at 0.3t/ha+C at 1.25kg a.i./ha	301.4	262.22	698.41	607.62	3454.00
PL at 0.2t/ha	259.4	225.68	571.43	497.14	2714.60
PL at 0.2t/ha+C at 2.50kg a.i./ha	343.4	298.76	571.43	497.14	1983.80
PL at 0.2t/ha+C at 1.25kg a.i./ha	301.4	262.22	571.43	497.14	2349.20
C at 2.50kg a.i./ha	300.4	261.35	507.94	441.91	1805.06
C at 1.25kg a.i./ha	279.4	243.08	444.45	386.67	1435.90
Control (no amendments)	258.4	224.81	444.45	386.67	1618.60

PL = Poultry litter, C = Carbofuran, [†]Discount factor used was 0.87.

4. CONCLUSION

In general, production costs were higher in carbofuran alone or combined with poultry litter treatments while the best benefit to cost ratio was observed in poultry litter alone treatments. Vegetative growth and yield of plantain was improved by poultry litter in this experiment with increased nutrients supply to the soil and reduced population densities of plant-parasitic nematodes. The study, therefore, recommended that for maximum plantain output and management of plant-parasitic nematodes, the soil must be treated with poultry litter at 0.4 tonne per hectare.

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