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Effect of Plant Manure Sources on Root-Knot Nematode Infection and Yield of Bambara Groundnut (*Vigna Subterranean* L.) Verdcourt) in the Derived Savannah

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Abstract
A field experiment laid out in a randomized complete block design with three replications was carried out at the Research and Teaching Farm, Federal College of Agriculture, Ishiagu, Nigeria in 2016 cropping season to determine the response of bambara groundnut [*Vigna subterranean* (L.) Verdcourt] to root-knot nematode (*Meloidogyne* spp.) infections under different soil amendments. The treatments comprised eight (8) soil amendments viz:no manure control, rice-husk dust (10 Mt ha^{-1}), dried neem leaves (10 Mt ha^{-1}), dried *gmelina* leaves (10 Mt ha^{-1}), rice-husk dust +dried neem leaves (5 Mt ha^{-1}) each, rice-husk dust +dried *gmelina* leaves (5 Mt ha^{-1}) each, dried neem leaves + dried *gmelina* leaves (5 Mt ha^{-1}) each, rice-husk dust + dried neem leaves + dried *gmelina* leaves (3.33 Mt ha^{-1}) each. Soil amendments significantly affected number of pods/plant, pod weight/plant and fresh pod yield/ha as well as number of galled roots and gall index, with the control plot exhibiting the highest number of galled roots and gall index (GI). Dried neem leaves (10 Mt ha^{-1}) had the least number of galled roots and GI, which invariably gave the highest fresh pod yield (38.0 Mt ha^{-1}) relative to the other treatments due to its high nematicidal characteristics that impeded the severity of the nematodes in the soil.
Keywords: Gall-index, growth, *Meloidogyne* spp., soil-amendment, yield.

1. Introduction

Bambara groundnut (*Vigna subterranean* L. Verdc.), which is one of the most important food crops after cowpea (*Vigna unguiculata*) and groundnut (*Arachis hypogea*) (Oparaeke and Bunmi, 2006) is widely cultivated by farmers in the West and Central Africa countries for its fodder, grains and ability to maintain the fertility of the soil through atmospheric nitrogen fixation. According to Yao Djè Beket, Bonny, Irié and Zoro, (2005) and Bamshaiye, Adegbola and Bamishaiye, (2011) the crop has the ability to adapt to various marginal agro-climatic conditions in Sub-Sahara Africa, hence, Burkina Faso closely followed by Northern Cameroon and Nigeria are highest producers of the crop in Africa (FAO, 2013).
The seeds of bambara groundnut are highly nutritious containing about 65% carbohydrates and 18% proteins (Yao Dje *et al.,* 2005). The fodders of the crop according to Brink, Ramolemana and Sibuga, (2006) is a veritable source of animal feed while the leaves can

also be used for medicinal purposes in the form of anti-vomiting therapy when chewed raw Sobda, Wassouo and Koubala, (2013). The seeds of the crop are included in the diet menu of people living in Sub-Sahara Africa as a good source of dietary protein (Sobda *et al.,* 2013). Furthermore, as a legume crop, bambara groundnut has the ability to fix nitrogen into the soil, thus contributing immensely to soil fertility improvement (Mkandawire, 2007; Oyiga and Uguru, 2011).
One of the major constraints to bambara groundnut production is low fodder and low grain yield associated with not only genetic factor but also the presence of nematodes in cultivated areas (Sitaramaiah and Singh, 1978; Onwubiko, Odum, Utazi and Poly-Mbah, (2011). Furthermore, Abubakar, Adamu and Manga, (2004) stated that soil amendments have been effective in the control of root diseases in plants. Contrary to other legumes, particularly cowpea (*Vigna unguiculata*), bambara groundnut is known to have less insect pests attack, however, the crop is highly susceptible to root-knot nematode infestation. Hence, the deployment of good management strategies to control the pest is a critical criterion to increased yield. Therefore, the objectives of the trial were to assess the effect of different plant organic manure sources to vegetative growth and grain yield of bambara groundnut as well as its effect on root-knot nematode infestation on the crop.

2. Materials and Methods

The rain-fed field experiment was conducted in 2016 at the Research and Training Farm, Federal College of Agriculture (FCA) Ishiagu, Ebonyi State, which lies at latitude 05º 56´N and longitude 07º 41´ at an altitude of 150 m above sea level in the derived savannah zone of southeastern Nigeria (Meteorological Unit, FCA, Ishiagu). The main annual rainfall of the area is 1350 mm, which begins in April and ends in October with an average temperature of 29 °C.
Before planting, a composite soil sample was collected from representative field locations with the aid of a soil augar to a depth of 0-30 cm. The soil samples were bulked together, air-dried, sieved and a sub-sample collected for physico-chemical analysis in a soil science laboratory. The physical characteristics of the experimental soil was determined by the Hydrometer method as described by Bouyoucos (1962). The soil pH (1:2.50; Soil:Water ratio) was measured with the aid of an electronic glass electrode pH meter, Jenway model 3510 (Jackson, 1973) while soil organic carbon (OC) was estimated using wet oxidation method through chromic acid digestion as outlined by Walkley and Black (1934). The total soil nitrogen (TN) content in percentage was determined by the semi-micro kjedahl digestion method using sulphuric acid and copper sulphate with sodium sulphate catalyst mixture as outlined by Bremner (1996). Available soil phosphorus (Av. P) was determined by the molybdenum blue colorimetry method (Olsen and Sommers, 1982) while the soil exchangeable potassium (K) was extracted using ammonium acetate extraction method whereby the extracts of K were read on flame photometer using FP 8800 model, with acetylene of propane burner. The physico-chemical properties of the experimental plots showed that texturally, the soil was sandy loam with pH value of 4.9, while the organic carbon (2.40 %) and total nitrogen were low (0.07 %). Also, low levels of available phosphorus (8.92 mg kg^{-1}) and exchangeable potassium (0.18 cmol kg^{-1}) were recorded.

The experimental site was cleared and marked. The experimental plots measured 2 x 2 m ($4m^{-2}$) with 1 m and 0.5 m gap between the blocks and within the plots, respectively. The treatment materials consisted of fresh leaves of *gmelina* (*Gmelina arborea) and* neem

(*Azadirachta indica*), and rice (*Oryza sativa*) husk dust. The g*melina* and neem leaves were obtained from the mother trees of the plant located within the premises of the Federal College of Agriculture, Ishiagu, Ebonyi State. The rice husk dust was obtained from a rice mill near the college. The collected fresh leaves were properly chopped, weighed, applied to the various plots as specified and a garden fork used to incorporate them into the soil. The plant materials were allowed to decompose for two weeks before planting the bambara groundnut.

The experiment was laid out in a randomized complete block design (RCBD) with three replications and eight (8) treatments applications. The treatments were as follows: No manure application (Control), Rice husk dust (RHD) at 10 Mt ha^{-1}, Dried Neem leaves (DNL) at 10 Mt ha^{-1}, Dried *Gmelina* leaves (DGL) at 10 Mt ha^{-1}, Rice husk dust (RHD) + Dried Neem leaves (DNL) at 5 Mt ha^{-1} each, Rice husk dust (RHD) + Dried *Gmelina* leaves (DGL) at 5 Mt ha^{-1} each, Dried Neem leaves (DNL) + Dried *Gmelina* leaves (DGL) at 5 Mt ha^{-1} each, Rice husk dust (RHD) + Dried Neem leaves (DNL) + Dried *Gmelina* leaves (DGL) at 3.33 Mt ha^{-1} each.

The Bambara groundnut seeds sourced from the National seeds unit, Umudike were sown two seeds per hole at the planting space of 50 cm by 40 cm inter- and intra-row spacing, which gave a plant population of 50,000 plants/ha. The farm was weeded manually with hand (hoe) at 4 weeks after planting (WAP). Growth data were collected on plant height at 2, 4, 6 and 8 WAP while number of galled roots/plant, number of galls per root (gall index), number of fresh pods/plant, fresh pod weight/plant and fresh pod yield (Mt ha^{-1}) were obtained at harvest. At harvest, root samples were washed and thoroughly examined for the presence of galls. Number of galls per plant, were counted. Gall index (GI) was determined on the scale shown in Table 1 according to Taylor and Sasser (1978) as modified by Ogwulumba and Okonta (2015).

Table 1: Nematode gall index scale/rating

Scale/rating	Number of galls	Infection level
0	No gall	No infection
1	1 – 10	Mild
2	11 -20	Moderate
3	21-30	Moderately high
4	31-40	High
5	41-50	Very high
6	>51	Very very high

Source: Gall index was scaled according to Taylor and Sasser (1978) as modified by Ogwulumba and Okonta (2015).

Harvesting was done manually by digging out the pods from the ground after which the soil around the pods was removed completely by washing. The fresh pods from the plots were weighted on a scale and the values used to determine the fresh pod yield per hectare.

Data collected were subjected to analysis of variance (ANOVA) according to the procedure for randomized complete block design (RCBD) using Genstat Discovery Edition 3. Significant treatment means were separated using Fisher's Least Significant Difference (F-LSD) at 5% level of probability according to the pattern outlined by Obi (2002).

3. Results

In contrast to plant height at 4 weeks after planting (WAP), (Table 2), plant materials had no significant (P>0.05) effect on plant height of bambara groundnut at all the sampled ages. The application of rice husk dust at 10 Mt ha^{-1} closely followed by the combined application of rice husk dust (5 Mt ha^{-1}) and dried *gmelina* leaves (5 Mt ha^{-1}) induced greater plant height relative to the other single or combined plant manure sources. The plant materials used as soil amendment significantly (P<0.05) affected number of pods plant^{-1} and fresh pod weight plant^{-1} and fresh pod yield (Mt ha^{-1}) (Table 3). The application of Dried Neem leaves at 10 Mt ha^{-1} closely followed by RHD (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 Mt ha^{-1}) gave the highest number of pods plant^{-1}, fresh pod weight plant^{-1} and fresh pod yield (Mt ha^{-1}) compared with the other treatments.

Table 2: Effect of plant organic manure sources on plant height (cm) of bambara groundnut at different ages

Treatments	2	4	6	8
	Weeks after planting			
No plant manure (0 Mt ha^{-1})	19.73	23.1	35.17	38.09
Rice husk dust [RHD] (10 Mt ha^{-1})	19.8	30.1	36.5	38.4
Dried Neem leaves (10 Mt ha^{-1})	18.4	23.2	30.6	35
Dried *Gmelina* leaves	19.2	27.3	34.7	37.3
RHD (5 Mt ha^{-1}) + Dried Neem leaves (5 Mt ha^{-1})	19	25.7	34.4	36.3
RHD (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 t/ha)	18	28.12	29.5	33.9
Dried Neem leaves (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 Mt ha^{-1})	18.6	25	33.6	36.3
RHD (3.3 Mt ha^{-1}) + Dried Neem leaves (3.3 Mt ha^{-1}) + Dried *Gmelina* leaves (3.3 Mt ha^{-1})	18.5	24.2	25.3	32.7
$F\text{-}LSD_{(0.05)}$	ns	3.302	ns	ns

ns = not significant

Plant manure sources significantly (P<0.05) influenced number of galled roots plant^{-1} and gall index at harvest (Table 4). It was observed that plants in the control plot (no plant manure) had the highest galled root concentration and the corresponding gall index (5.5). The sole application of dried neem leaves at 10 t ha^{-1} gave the lowest nematode gall concentration and gall index followed by the combined application of dried neem leaves (5 Mt ha^{-1}) and dried *Gmelina* leaves (5 Mt ha^{-1}).

The mean sequence of number of galled roots plant and gall index from the different plant manure sources was in the order: Dried Neem leaves (10 Mt ha^{-1}) <Dried Neem leaves (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 Mt ha^{-1})< RHD (3.3 Mt ha^{-1}) + Dried Neem leaves (3.3 Mt ha^{-1}) + Dried *Gmelina* leaves (3.3 Mt ha^{-1})< RHD (5 Mt ha^{-1}) + Dried Neem leaves (5 Mt ha^{-1})< Dried *Gmelina* leaves< Rice husk dust [RHD] (10 Mt ha^{-1})< No plant manure (0 Mt ha^{-1}) and : Dried Neem leaves (10 Mt ha^{-1}) <Dried Neem leaves (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 Mt ha^{-1})< RHD (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 Mt ha^{-1})< Dried *Gmelina* leaves< RHD (5 Mt ha^{-1}) + Dried Neem leaves (5 Mt ha^{-1})< RHD (3.3 Mt ha^{-1}) + Dried Neem leaves (3.3 Mt ha^{-1}) + Dried *Gmelina* leaves (3.3 Mt ha^{-1})< Rice husk dust [RHD] (10 t/ha)< No plant manure (0 Mt ha^{-1}), respectively.

Table 3: Effect of different plant manure sources on fresh pod yield and yield components of Bambara groundnut

Treatments	No. of pods/ plant	Fresh pod weight /plant (kg)	Fresh pod yield (Mt ha^{-1})
No plant manure (0 Mt ha^{-1})	141	0.47	7.80
Rice husk dust [RHD] (10 Mt ha^{-1})	323	1.07	17.8
Dried Neem leaves (10 Mt ha^{-1})	690	2.28	38.0
Dried *Gmelina* leaves	337	1.12	18.7
RHD (5 Mt ha^{-1}) + Dried Neem leaves (5 Mt ha^{-1})	402	0.85	14.2
RHD (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 t/ha)	529	1.75	29.2
Dried Neem leaves (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 Mt ha^{-1})	423	1.40	23.3
RHD (3.3 Mt ha^{-1}) + Dried Neem leaves (3.3 Mt ha^{-1}) + Dried *Gmelina* leaves (3.3 Mt ha^{-1})	392	1.30	21.7
F-LSD$_{(0.05)}$	204	0.432	8.87

Table 4: Effect of different plant manure sources on number of galled roots and gall index of bambara groundnut at harvest

No plant manure application	No. galled roots	Gall index
No plant manure (0 Mt ha^{-1})	32	5.5
Rice husk dust [RHD] (10 Mt ha^{-1})	19	2.9
Dried neem leaves (10 Mt ha^{-1})	5	0.7
Dried *Gmelina* leaves	16	2.2
RHD (5 Mt ha^{-1}) + Dried neem leaves (5 Mt ha^{-1})	14	2.4
RHD (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 Mt ha^{-1})	16	2.0
Dried neem leaves (5 Mt ha^{-1}) + Dried *Gmelina* leaves (5 Mt ha^{-1})	10	1.7
RHD (3.3 Mt ha^{-1}) + Dried neem leaves (3.3 Mt ha^{-1}) + Dried *Gmelina* leaves (3.3 Mt ha^{-1})	12	2.4
F-LSD$_{(0.05)}$	2.27	1.44

4. Discussion

Based on results of this study, the application of plant organic manure had no significant effect on plant height of bambara groundnut except at 4 WAP, which was at contrast with its effect on fresh nut yield and yield components of the crop. The obtained result could be attributed to the varying weather conditions as well as the time the plant organic manure applied initiated its treatment suppressive effects on the nematode population in the soil, which was recorded to be highest under no manure application and lowest when dried neem leaves at 10 Mt ha^{-1} were applied to the soil. The findings were in agreement with Goli (1995) in his works on nematode infestation on bambara groundnut in Zimbabwe, Ogwulumba and Aja (2012) on tumeric (*Curcuma longa*) and Ononuju, Ikwunagu, Okoracha and Okorie (2014) in their studies on the effect of organic wastes on root-knot nematodes of okra (*Abelmoschus esculenta*) in Nigeria in which they submitted that plant height of the crops were not significantly affected by nematode infestation.

Furthermore, our findings showed that there was a general reduction in *Meloidogyne* species infestation on Bambara groundnut upon application of the various plant organic manures. The amount and concentration of the galls on roots showed the severity and susceptibility level of our test crop. This was evident in general reduction of gall concentration on roots when compared with the control. The application of sole neem at 10 Mt ha^{-1} have proven to be more effective since the plot on which it was applied had the least number of galled roots and subsequently gall index. This could be due to inactivation of larvae and reduction in juveniles' penetration into the plant roots as reported by Bhattacharya and Goswami (1988) in their studies on the effect of *Meloidogyne* species on tomato (*Lycopersicum esculentum*). Also, it may be due to reduction of larvae hatching and increased resistance developed by the plant, which deterred invasions by the nematodes as demonstrated by Sitaramaiah and Singh (1978) in their works on the response of *Meloidogyne javanica* to organic amendments as well as Ogwulumba and Okonta (2015) in their studies on response of *Meloidogyne incognita* infestation to the application of *Jathropha curcas* leaf powder in soybean (*Glycine max*) production in which they reported reduction in number of galled roots due to the positive effects of soil amendments.

The observed increase in the number of pods and weight pods of Bambara groundnut in plots treated with neem dried leaves at 10 Mt ha^{-1} could be attributed to plants growing under pest free environment provided by the application of neem leaves. The neem plant organic manure increased the plants' resistance against the fecundity and virulence of the nematodes. The findings were in consonance with previous studies by Dafour, Strandberg and Strandberg, (2013) on allelopathic plants in which they reported that organic matter is the basis of sustainable nematode control and the maintenance of a healthy soil food.

5. Conclusion

The study showed that the application of plant manure such as neem leaf was able to suppress the root knot nematode (*Meloidogyne species*) infection on bambara groundnut, which invariably increased the yield. The application of sole neem dried leaves has proven to be more effective, cheap and sustainable due to high nematicidal properties which helped in suppressing the root knot nematode (*Meloidogyne species*) in the soil there by increasing the yield of the crop.

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