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Effects of Mycorrhizal Inoculant and Organic Mulches on Nematode Damage to Cooking Banana

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Abstract

An experiment was conducted at the Teaching and Research Farm of the Federal University of Technology, Akure, Nigeria to investigate the ability of mycorrhizal fungi, oil palm bunch refuse and sawdust mulches to modulate banana growth and nematode infection. Twenty four suckers of cooking banana cultivar 'Fougamo' used for the experiment were collected within the Federal University of Technology, Akure campus. Vegetative growth parameters were measured at termination of experiment while root and rhizome damage was assessed. The mycorrhizal inoculants and the two organic mulches enhanced aerial and subterranean growth. Sawdust mulch increased area of youngest leaf opened by 215%, mycorrhizal fungi by 234% and oilpalm bunch refuse much by 267% respectively. Feeding habit of the three plant parasitic nematode species recovered from the cultivar: *Pratylenchus* coffeae, *Radopholus similis* and *Helicotylenchus multicinctus* was influenced by the type of organic input. Mycorrhizal inoculants supported more vigorous plants and prevented root invasion by *P. coffeae* and *R. similis*. Its use may be a promising alternative to the more bulky organic material or an important aspect in developing an integrated management package.

Keywords: Organic mulch, mycorrhizal fungi, banana, plant growth, root health, plant parasitic nematodes

1. Introduction

Banana and plantain, often commonly grouped as "bananas" are botanical relatives belonging to the genus *Musa* and family *Musaceae* (Simmond and Shepherd, 1955). While banana consists of the dessert banana and the cooking bananas, which are starchier than the dessert bananas and are eaten cooked or processed; plantain is starchy with firmer pulps and may not be eaten raw.

In Nigeria, plantain is an important group of bananas produced on a small scale field production or in backyard gardens (Swennen and Vuylskeke, 1988). In the 1980s when plantain production was threatened by the black Sigatoka leaf disease, the cooking banana Fougamou was introduced. Although this could not replace plantain in demand because of the culinary and cultural significance of plantain in Nigeria, it was widely adopted and put to some other uses. However, the production of banana is adversely affected by several abiotic and biotic constraints (Fongeyn, 1976, Wilson, 1983) including declining soil fertility and plant parasitic nematodes. Similarly, a number of plant parasitic nematodes have been identified on East African Highland cooking bananas. Among these are the *Radopholus similis* (Cobb) Thorne, *Helicotylenchus multinctus* (Cobb) Golden, and *Meloidogyne* spp (Bridge, 1988; Sikora *et al.,* 1989; Speijer *et al.,* 1999). In West Africa, species of nematodes associated with plantain and banana includes *Radopholus similis, Pratylenchus* spp. and *Helicotylenchus multicintus*.

The severity of crop losses due to nematodes varies according to agronomic practices (Speijer *et al*., 1999), nematode density and related damage, nematode species profile and pathogenicity of the individual species (Pinochet, 1979; Sarah *et al*., 1993). In South Eastern Nigeria, plant parasitic nematodes reduced plantain production by an average of 50% (Olaniyi, 2011) and greatly reduced longevity of the plantation (Coyne *et al.,* 2005). Hence suitable practices which reduce the losses to pathogens and additionally address the soil fertility depletion problem are required (Coyne *et al.,* 2005).

Poor soil fertility aggravates nematode damage (Sikora *et al.*, 1989; Speijer *et al.,* 1999) but organic mulch provides supplementary nutrients and mitigates the impact of plant parasitic nematodes on plantain and banana (Obiefuna, 1991; Speijer *et al.,* 1999). The use of synthetic nematicides to control *Musa* nematodes can be effective (Gowen and Quénéhervé, 1990) but is expensive for resource – poor farmers and the chemicals are

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often unavailable in rural areas in Africa. Therefore, the use of organic and environmentally safe options in the control of plant parasitic nematodes has a lot of benefits to resource-poor farmers.

Mycorrhizal fungi are obligate symbionts of plants that biotrophically colonize the root cortex and develop an extrametrical mycelium which helps the plant acquire water and mineral nutrients from the soil. It also may protect plants against soil-borne plant pathogens including nematodes. Many mycorrhizal associations are reported to have a suppressive effect over sedentary endoparasitic nematodes. In some crops this effect is significant enough to consider mycorrihizal infection as a more or less effective means of biological control (Pinochet *et al.,* 1996).

Therefore, this study was carried out to assess the level of protection against plant parasitic nematodes conferred on banana roots and rhizome by mycorrihizal fungi in comparison with sawdust and oil palm bunch refuse mulches.

2. Materials and Method

2.1 Experimental Site and Field Lay-Out

The experiment was carried out at the Crop Section of the Teaching and Research farm of the Federal University of Technology, Akure, Ondo State, Nigeria. Akure lies in tropical rainforest belt, between latitude 5°N and longitude 15°E with an average annual rainfall of about 1613mm per annum and annual mean temperature of about 27°C.

There were three blocks with 24 plants per block and six plants per plot arranged in a Randomized Complete Block Design (RCBD). Each plot represented a treatment and the blocks the replicates. Hence there were four plots representing the four treatments assigned. There were a total of 72 plants in all spaced within the plots at 2m within rows and 3m between rows. Distance between blocks was 3m. The whole experimental field was also lined with boarder plants at the four sides of the field.

2.2 Planting, Soil Sampling and Treatment Application

Planting materials were suckers of cooking banana, cultivar Fougamou collected within the Federal University of Technology, Akure campus. Before planting, the suckers were all cleaned by paring. Paring is the removal of adhering soil and outer layer of the rhizome to expose surface infection and removing such tissues before planting. The length of each sucker was reduced to approximately 30cm and then planted. Planting was done on 18^{th} Oct, 2006.

At planting, twelve (12) composite soil samples were collected from planting holes at 0-10cm depth. These were then bulked and then divided into two halves. One half of the sample was used to determine pre-plant plant parasitic nematode population densities while the second half was used for soil chemical analysis. The soil chemical analysis involved the determination of nitrogen, available phosphorus, potassium, calcium, magnesium, organic matter and organic Carbon contents as well the hydrogen ion concentration (pH). The mulch materials used for treatment application were also analyzed for Nitrogen, phosphorus and potassium contents.

Two weeks after planting treatments were randomly assigned to plots per block as plants mulched with oil palm bunch refuse, sawdust or inoculated with mycorrhizal fungi using spore inoculants in sterile soil carrier, which packaged as organic fertilizer by the Ondo State Poverty Alleviation Authority, Oda road in Akure, Nigeria. The mycorrhizal inoculant was said to contain *Glomus* species but this was not ascertained. The oil palm bunch refuse was obtained at the oil processing unit of the Federal College of Agriculture, Akure while fresh sawdust was obtained from a saw-mill along Owo express way in Akure. The materials were applied at the rate of 3.25kg for oil palm bunch refuse, 1.25kg for sawdust and 0.4kg for mycorrhizal inoculants for the experiment. The plants were irrigated regularly as the need arose.

2.3 Data Collection and Analysis

At 16 weeks after planting (DAP), plants were carefully uprooted and plant growth parameters assessed. Parameters considered included height of the plant from the soil level to point of intersection of the youngest leaves, girth of pseudostem at soil level, number of green and dead leaves, area of youngest leaf opened and leaf emission (i.e. the presence of the unfurled 'cigar' leaf). Additionally, shoot, rhizome and root fresh weights were taken, numbers of root at point of detachment from the rhizome were counted and average root length and diameter calculated. Root and rhizome health were assessed according to Speijer and De Waele (1997) while nematode species densities were estimated after their extraction from roots and rhizosphere, and expressed as number per 100g of fresh root weight and 1 litre of soil.

Nematode counts were log(x+1) transformed before subjecting to statistical analysis (Gomez & Gomez, 1984). Data on root and rhizome damage (expressed in percentages) were arcsine transformed before statistically analyzed. The general linear model (GLM) procedure in statistical package for social science (SPSS) was used for the analysis of variance.

3. Results

3.1 Nutrient Content of The Organic Mulch Materials, Pre-Plant Soil Nutrient and Plant Parasitic Nematode Status

The chemical status of the soil at planting and the chemical content of the organic mulch materials used is given on table 1.

Table 1. Nutrient status of experimental field soil at planting and of mulch materials

ne = not estimated

	pH	%N	P(ppm)	K(cmol/kg)	OM (%)	OC (%)	Ca	Mg
Mean value before planting	5.6	0.21	1.25	0.13	8.30	4.72	3.63	1.33
Oil palm bunch refuse	ne	1.06	4.80	2.40	ne	ne	ne	ne
Sawdust	ne	0.28	0.40	1.38	ne	ne	ne	ne

Three nematode species, *Helicotylenchus multicinctus, Pratylenchus coffeae* and *Radopholus similis* were recovered from pre-plant soil samples (Table 2).

Table 2. Pre-plant densities of plant parasitic nematode species in field soil

Nematode species	Density/1 litre soil
Helicotylenchus multicinctus	379
Pratylenchus coffeae	354
Radopholus similis	13

3.2 Effects of Treatments on Aerial Growth Parameters of Cooking Banana cvr. Fougamou

At termination of the experiment 16 weeks after planting (DAP), mycorrhizal fungi inoculated plants supported statistically taller plants compared with other treatments, i.e. oil palm bunch refuse and sawdust mulches, as well as the control (Table 3). Compared with the control, mychorrhizal fungal inoculant and the two organic mulch materials supported plants with thicker pseudostems, more green leaves and leaves with wider area. Although oilpalm bunch refuse gave highest value for pseudostem thickness (girth) and number of green leaves, the values were not statistically different from the sawdust mulch and mychorrhizal fungal inoculant. Mycorrhizal inoculants gave the overall best growth advantage considering all growth parameters assessed (Table 3).

Table 3. Effect of organic input on growth of cooking banana cultivar Fougamou 16 weeks after planting (WAP)

GTH = Circumference of the Pseudostem at soil level; PHT = Plant height; GLV = number of green leaves, DLV = number of dead leaves; AYL = area of youngest leaf opened; LE = leaf emission

Treatment	Vegetative growth parameters					
	PHT(cm)	GTH (cm)	GLV	DLV	AYL (cm^2)	LE
Oil Palm Bunch refuse	23.8b	10.1a	7.7a	1.1a	463.9a	0.3a
Mycorrhiza inoculant	27.4a	9.3a	6.5a	1.3a	406.8a	0.1a
Sawdust	25.1b	9.1a	7.4a	0.9a	374.4a	0.1a
Control	19.3b	6.2b	4.3b	0.7a	173.9b	0a

3.3 Effects of Organic Inputs on Subterranean Growth of Cooking Banana cvr. Fougamou

At termination of experiment 16 weeks after planting (WAP), plants that received organic input had more roots than the control (Table 4). The trend is the same for total root length, root diameter and root fresh weight. Plants in all the treatments had significantly more root bases than the control plants (Table 4).

Table 4. Effect of organic mulches and mychorrizal fungi on the subterranean growth of the cooking banana cultivar Fougamou 16 weeks after planting

TOR = total number of roots detached from the rhizome; RLT = mean root length of roots; RDM = mean root diameter; FWT = root fresh weight; RBS = number of root bases on the rhizome

Treatment	TOR	RLT (cm)	RDM (cm)	FWT (gm)	RBS
Control	7.5b	49.0b	2.3b	42.5b	20b
Sawdust	16.8a	164.3a	4.9a	118.3a	62a
Mycorrhizal fungi	10.7a	118.7a	3.6a	103.3a	45a
Oilpalm bunch refuse	14.5a	134.2a	4.3a	115.0a	44a

3.4 Effects of Organic Mulch and Mycorrhizal Inoculant on Nematode Densities, Root and Rhizome Damage

There was no significant difference in the incidence of rhizome lesions and root necrosis among the treatments including the control (data not shown).

Only *P. coffeae* was observed in the roots of both the control plants and those mulched with oilpalm bunch refuse while *H. multicinctus* was recovered from both sawdust mulch-treated and mycorrhizal fungi-inoculated plants. *Radopholus similis* was additionally recovered from the roots of sawdust mulched plants (Table 5). The three species were recovered from the rhizophere of mycorrhizal fungi inoculated and sawdust mulched plants (Table 5).

Table 5. Effect of mychorrhizal fungi and organic mulches on the densities of plant parasitic nematodes recovered from roots and rhizosphere of cooking banana cultivar Fougamou 16 weeks after planting.

Treatment	Plant parasitic nematode species (densities/100g root)		
	Helicotylenchus multicinctus	***Radopholus similis***	***Pratylenchus coffeae***
Control	0	0	500
Sawdust mulch	400	100	0
Mycorrhizal fungi	350	0	0
Oilpalm bunch refuse mulch	0	0	250
	Plant parasitic nematode species (densities/1 Litre soil)		
Treatment	***Helicotylenchus multicinctus***	***Radopholus similis***	***Pratylenchus coffeae***
Control	0	0	0
Sawdust mulch	350	400	500
Mycorrhizal fungi	450	500	600
Oilpalm bunch refuse mulch	300	0	333

4. Discussion

Oil palm bunch refuse mulch, sawdust mulch and mycorrhizal fungi supported taller plants with thicker pseudostem and larger leaves, hence, they enhanced the vigour of the banana plants, cultivar Fougamou. In accord, Rotimi *et al.* (2004a) and Salau *et al.* (1992) reported enhanced plantain growth in South Eastern Nigeria when organic mulch materials were applied. In the current study, mycorrhizal treatment outperformed the organic mulches in supporting tallest plants which were more uniform in height even though the treatments were statistically similar. This revealed that primarily the type of organic input used dictates the effect on plant growth in line with the report of Olaniyi (2008). Mycorrhizal fungi may be a better organic input than the bulkier organic mulch and its usefulness relative to bunch yield needs to be established. The beneficial effect of mycorrhiza on plant growth has been attributed to improved uptake of nutrients, especially phosphorus (Smith & Reed, 1997). This is supported by the greatly reduced amount of phosphorus in mycorrhizal fungi inoculated soil in this study, implying that phosphorus might have been made available for more ready uptake by the plant.

Mulched plants and those treated with mycorrhizal fungi had longer, thicker, heavier and healthier roots than the control. Hence organic inputs had positive impact on subterranean growth of the plant and may result in better anchorage and mineral extraction and transportation, which may translate into better yield of superior quality.

In all, three migratory endoparasitic nematode species: *Pratylenchus coffeae*, *Radopholus similis* and *Helicotylenchus multicinctus,* which were also present in the field before establishment of the experiment, were recovered from the soil and plant roots of banana cultivar Fougamou in this study. From Speijer *et al.*'s (2001) report, *H. multicinctus* though predominant on plantain in Nigeria was not strongly associated with damage to plantain; whereas *P. coffeae*, followed closely by *R. similis* were most damaging. It is good to note however, that densities encountered in the present study were quite low and it is understandable, being a short term trial and planting materials were pared (i.e. cleaned by removing adhering soil and peeling off the outer layer of the rhizome). It also takes time for nematode densities to build up to alarming levels (Rotimi *et al*., 2004 a & b), especially when clean planting materials were planted initially.

Only *H. multicintus* was recovered from the roots of plants that received the mycorrhizal inoculant suggesting that the symbiotic association of the fungus within the plant root must have prevented invasion by the more damaging migratory species; *P. coffeae* and *R. similis*. Rotimi *et al.* (2005) demonstrated that feeding habit of plant parasitic nematodes on plantain is influenced by cultivar type. The foregoing study has shown that feeding habit of plant parasitic nematodes on banana cultivar Fougamou is influenced by the organic inputs and bio-association. The lesion nematode (*Pratylenchus coffeae*) and the burrowing nematode (*Radopholus similis*), which are migratory endoparasites preferentially fed ectoparasitically in banana roots in the presence of invading mycorrhizal fungi, whose mycelia might have colonized the roots.

Since mycorrhizal fungi restrained the two species of plant parasitic nematode established by Speijer *et* al. (2001) as the most serious on plantain in Nigeria namely *Pratylenchus coffeae* and *Radopholus similis,* to ectoparasitic feeding on the cooking banana cultivar Fougamou, it may be a good control material for plant parasitic nematodes and should be tested with other banana and plantain cultivars. In this study, only *P. coffeae* was recovered from the root of control plants implying that it prevented the invasion of the other two species since they were recovered from pre-plant soil samples. It is likely that when an environment which suppresses *P. coffeae* is created as with the sawdust mulch and mycorrhizal fungi, other species may become secondarily important. Similarly, Rotimi and Speijer (2004) had earlier observed that when a key nematode species is suppressed by synthetic nematicide, an otherwise unimportant species may surge to be of primary significance. This further underscores the difficulty in the control of plant parasitic nematodes due to concomitant parasitism.

The overall growth advantage and protection against plant parasitic nematodes obtained with the mychorrhizal fungi inoculation is commendable but whether this would equally translate to yield advantage needs to be verified through further experimentations. Mycorrhizal fungi inoculum could be developed, produced and packaged as organic plant protectant. However, efficacy needs to be confirmed through further experimentation till yield stage, in order to establish the level of protection mycorrhizal fungi would confer on banana root and rhizome, and the extent of yield advantage possible.

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