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Nematode Management

Impact of Organic Amendments on *Meloidogyne* spp. and Yield Improvement of Soybean

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Abstract. Field experiments to investigate the impact of organic amendments on *Meloidogyne* spp**.** and yield improvement of soybean was carried out in 2009 and repeated in 2010 to confirm observed data. Composts prepared from fresh leaves of *Chromolaena odorata, Tithonia diversifolia* and *Carica papaya* stacked with manure from either poultry or cattle sources were applied at the rate of 6 tha^{-1}. Each time, the experiment was laid out in a Randomized Complete Block Design with six replications. Treatments included six composts while untreated plots served as the control. A root-knot nematode-susceptible soybean variety, TGx 1019-2EN was used for the trial. One-week-old soybean seedlings were thinned to one plant per stand and inoculated with 5,000 eggs of *Meloidogyne* spp. seven days after emergence to augment the population in the soil. Data on growth parameters were collected bi-weekly while those on population of *Meloidogyne* spp. were recorded 60 days after inoculation. Matured pods were harvested, threshed, winnowed and weighed. Data were analyzed for variance and means separated. Results showed that composted manure of both poultry and cattle origins significantly (P = 0.05) reduced the root-knot nematode populations by 94.9%. This nematode control strategy resulted in attendant soybean yield increase by up to 60%. Increased biological activities led to increase in grain yield across all treated plots compared with the control. This result provides an impetus for development of environmental-friendly measures for the management of root-knot nematode problem mitigating large scale soybean production towards ensuring sustainable improvements in grain yield production.
Keywords: Compost, grain yield, nematode management, organic manure, root-knot nematodes

INTRODUCTION

Tropical soils comprise of several micro and macro-organisms such as bacteria, fungi, nematodes, mites, earthworms, millipedes and centipedes living and interacting among themselves and with their environment (ecosystems). While some are beneficial to crop and crop ecology, the pathogenic ones constitute nuisance to plant growth and development either through direct injuries or direct infection of host plants. Plant-parasitic nematodes are economically-important agricultural pests owing to the damage and damage potentials they pose on major susceptible crops wherever such crops are cultivated. They are enormous and capable of causing losses of up to 100 % in the yield of crops (Oyediran, 1992); a loss level which no country in the world can afford.

Soybean, (*Glycine max.* (L.) Merril) is the most important grain legume in terms of total production, consumption, and international trade. It is an oilseed, which provides a cheap, and balanced diet (Ogundipe *et al.*, 1989) with proximate analysis of 40 % protein, 32 % carbohydrate, 20 % edible oil, 5 % minerals and 3 % fibre (Singh, 1987). United States of America (USA) is the worlds leading producer of soybean accounting for 49 % of the world's output of 34 %; Asia produced 14 % while Africa produced less than one percent of the world's output. The world average yield in 2000 was 2,210 Kg per hectare, ranging from about 3,520 Kg per hectare in Western Europe to 2,650 Kg per hectare in the USA and 990 kg per hectare in Africa (FAO, 2009).

Meloidogyne incognita (root-knot nematode) was documented as a major constraint to large scale soybean production. (Atungwu *et al*., 2012). Their infestation often results into economic and socio-economic problems arising from low protein intake, insufficiency in food supply, increase in cost of living as well as cost of production. Nematodes cause direct impairment of physiological functions making nematode-infected plants show distinctive symptoms, such as retarded growth and poor inter-node development due to poor nutrient uptake, wilting as a result of poor water uptake, hyperplasia and hypertrophy of cells leading to galling, poor yield and consequent crop loss (Atungwu *et al*., 2012)

The search for suitable and sustainable control method for organisms like plant-parasitic nematodes led to discovery of nematicides. Though, significant increases in crop yield have been recorded with the use of these nematicides, the withdrawal of many nematicides from the market due to environmental concerns and constraints of use such as the high cost (about US $ 500 per hectare per year) have drawn attention to the development of alternative methods, which besides being environmentally-friendly would also be within the purchase capacity of resource-poor farmers worldwide (Gowen, 2000). For instance, traditional nematicides such as fumigant 1, 3-dichloropropene, the carbamates, aldicarb and oxamyl, and the organophosphate (fenamiphos) when applied correctly, will increase crop yield if initial nematode population densities exceeds damage thresholds (Whitehead, 1998). However, there is no long-term suppression of nematode population densities with their use (Starr, 2001).

The recent gradual shift from "conventional" to "organic" agriculture and quests for ecologically-friendly procedures for managing problems of nematode pests mitigating against production of soybean quantitatively and qualitatively, that would also be within the reach of resource-poor farmers led to the discovery of potencies of some organic materials administered as amendments in recent times. Organic materials such as composted manure of animal and green manure of plant origin have been used since the advent of agriculture to improve soil fertility, soil biological and physical properties, and recycle nutrients for expected increase in crop yield (Rodriguez-Kabana *et al*., 1987).

Though sometimes filthy, bulky and slow in the rate and time of nutrient release, constituents of organic materials according to Riegel and Noe, (2000) have been found to enhance microbial activities through the development of nematode antagonists (Riegel *et al*, 1996; Atungwu *et al*., 2012) and the production of nematicidal substances thus leading to a significant increase in crop yield.

Use of organic materials as amendment offers solution to the environmental problems associated with the use of toxic chemicals including nematicides, and there are many organic materials which have been found to compare favourably with synthetic nematicides in terms of crop yield, environmental friendliness, compatibility with other cultural practices and their nematicidal properties.

More research grounds need to be covered in the area of combining these cheap and readily-available materials into a single form called "composts". The need to further prepare and test the efficacies of different sources of composts on nematode reproduction and survival as well as their impacts on grain yield in a nematode-infested soil informed this study.

MATERIALS AND METHOD

Locations of the experiment

The experiment comprised two field trials, the first was located at the experimental plots of the Organic Agriculture Project in Tertiary Institutions in Nigeria (OAPTIN) at the Federal University of Agriculture, Abeokuta, Ogun State and the second at the Olusegun Obasanjo Centre for Organic Agricultural Research and Development (OOCORD), Ibadan. The study spanned 4th June to December 2009 and was repeated in 2010.

Soil sampling

Soil sampling was carried out with a soil auger at 15cm depth. Twelve core samples were taken per plot, bulked and made to form six composite samples as representative samples. The samples sealed and labelled in polythene bags were transported to FUNAAB's Central Laboratory for routine and chemical analysis while initial population of root-knot nematodes was analyzed at Crop Protection laboratory in the same University.

Compost preparation

Six composts of different origin were prepared using fresh leaves of *Chromolaena odorata, Tithonia diversifolia* and *Carica papaya* stacked with poultry and cattle manure in ratio 3:1 for a period of six months. The various composts were: *C. odorata* + poultry manure (A1), *T. diversifolia* + poultry manure (B1), C. *papaya* + poultry manure (C1), *C. odorata* + cattle dung (A2), *T. diversifolia* + cattle dung (B2), and *C. papaya* + cattle dung (C2). The composts were turned regularly within the holding units with a garden fork in order to ensure even distribution of substrates and heat generated during decomposition. This was followed by curing by air-drying for seventy-two (72) hours.

Compost application, layout of experiment and inoculation of seedling

Each compost was applied at the rate of 6 t/ha. The experiment was laid out in a Randomized Complete Block Design with six replicates. The treatment included the six composts while no compost added. Soybean variety, TGx 1019-2EN, susceptible to *Meloidogyne incognita* was planted and thinned to one plant per stand. Seven days after emergence, stands were inoculated with 5,000 eggs of *Meloidogyne incognita* earlier maintained on a pure culture of *Celosia argentea* and extracted through Hussey and Baker (1975) sodium hypochlorite method. This was considered necessary as a way of augmenting the inherent soil populations to 5000±5 eggs per plant.

Estimation of Nematode population

Final population of *Meloidogyne incognita* was estimated from sample of 250 g soil, which was extracted through the Whitehead and Hemmings (1965) tray method 60 days after inoculation.

Data collection

Data were collected on stem girth, number of leaves and branches bi-weekly while pod numbers, seed weight per hectare, root parameters as well as the final population of root-knot nematodes were taken at harvest. All statistical analyses were carried out using the Statistical System Analysis (SAS) guide (SAS, 2000).

RESULTS

Combined analysis of location effect showed that there were no significant differences in leaf number of plant, stem girth (cm) and branch number in the two locations. However, assessment of the results by location revealed that in Ibadan, all the amended plots showed a significantly ($P<0.05$) higher leaf number than the control while the treatment Cattle manure + *Tithonia diversifolia* gave a significantly higher number of leaves than all other untreated plots served as the control with treatments including the control (Table 1).

Fresh root weight (g) and root length (cm) varied significantly in Ibadan. There was a significant difference ($p<0.05$) in fresh root weights (g) of crops in Abeokuta and Ibadan (Table 2). All the amendments stimulated higher root growth when compared with the control. Root-shoot ratio at the two locations was higher across all the amendment treatments than the unamended control. (Table 2).

In table 3, effect of treatment was significant $P<0.05$ on root-knot nematodes population density. This also corresponded with the higher root-knot nematode population obtained from the control plots than the amended plots.

Percentage increase in pods on amended plots obtained from the two locations compared with the unamended control plots showed that poultry manure + *Carica papaya*, Cattle manure + *Thitonia diversifolia* and cattle manure + *Carica papaya* gave pods that were more than 50% higher than what was obtained from unamended control plots in Ibadan (Table 4).

Increase in percentage pod number of amended plots over the control also varied in all treated plots in Abeokuta but, Poultry manure + *C. odorata*, Poultry manure + *Carica papaya* and cattle manure + *C. papaya* gave a higher percentage pod number than other amended plots. Grain yields were also higher on all the amended plots in Ibadan than the control but not in the first experiment in 2009.

Table 1. Mean leaf number, stem girth and branch number per plant of soybean inoculated with *Meloidogyne incognita* in compost-amended plots weeks after inoculation (WAI).

	ABEOKUTA			IBADAN		
COMPOSTS	No. of Leaves	Stem girth (cm)	No of Branches	No. of Leaves	Stem girth (cm)	No. of Branches
Poultry manure + *Chromolaena odorata*	23b	2.93a	6a	48a	2.80a	9a
Poultry manure + *Tithonia diversifolia*	30ab	2.13c	7a	37a	2.13abc	7ab
Poultry manure + *Carica papaya*	37ab	2.83ab	6a	55a	2.23abc	7ab
Cattle manure + *Chromlaena odorata*	37ab	2.63abc	9a	39a	1.80bc	10a
Cattle manure+ *Thitonia diversifolia*	44a	2.48abc	9a	45a	1.80bc	9a
Cattle manure+ *Carica papaya*	32ab	2.40abc	8a	35a	1.67c	8ab
No Compost (Control)	36ab	2.83ab	7a	28a	1.93ab	8ab

Means with same letters within column are not significantly different from one another at 5% probability

Table 2. Mean fresh root weight (gm), shoot weight (gm) and root length (cm) of inoculated soybean plants amended with different compost

	ABEOKUTA				IBADAN			
TREATMENT	**Fresh Root (R)**	**Fresh Shoot (S)**	**Ratio (R: S)**	**Root length** (cm)	**Fresh Root (R)**	**Fresh Shoot (S)**	**Ratio (R: S)**	**Root length** (cm)
Poultry manure + *Chromolaena odorata*	9.15a	88.37a	1:9	29.83ab	10.30a	129.25a	1:11	36.00ab
Poultry manure + *Tithonia diversifolia*	7.73a	77.92a	1:10	35.50a	7.73a	86.77a	1:11	27.00c
Poultry manure + *Carica papaya*	10.68a	93.23a	1:9	35.17a	8.73a	117.17a	1:13	38.00a
Cattle manure + *Chromolaena odorata*	11.70a	111.97a	1:10	33.17ab	7.97a	111.47ab	1:13	33.00ab
Cattle manure+ *Tithonia diversifolia*	9.63a	96.32a	1:10	28.50ab	10.50a	115.07a	1:11	38.67a
Cattle manure+ *Carica papaya*	8.73a	70.03a	1:8	32.67ab	11.43a	123.00a	1:11	31.67ab
No Compost (Control)	10.83a	89.87a	1:7	29.00 ab	10.10a	54.43b	1:5	34.67ab

Means with same letters within column are not significantly different from one another at 5% probability.

Table 3. Mean *Meloidogyne incognita* contained in 250g soil of inoculated soybean fields amended with different compost types 60 days after inoculation and its reproduction factor.

	Meloidogyne incognita population	
TREATMENT	ABEOKUTA	IBADAN
Poultry manure **+ *Chromolaena odorata***	2c	7abc
Poultry manure **+ *Tithonia diversifolia***	5b	9abc
Poultry manure **+ *Carica papaya***	8ab	11ab
Cattle manure **+ *Chromolaena odorata***	7abc	11ab
Cattle manure **+ *Tithonia diversifolia***	7abc	11ab
Cattle manure + ***Carica papaya***	4b	11ab
No Compost (Control)	12a	27a

Table 4. Percentage (%) increase in pod number and grain yield (g) of inoculated soybean plants amended with different compost

	ABEOKUTA		IBADAN	
TREATMENT	**Pod Number/** ha	**Grain Weight** tons / ha	**Pod Number/** ha	**Grain Weight** tons / ha
Poultry manure + *Chromolaena odorata*	37	11	10	24
Poultry manure + *Tithonia diversifolia*	7	3	19	26
Poultry manure + *Carica papaya*	24	3	51	17
Cattle manure + *Chromolaena odorata*	4	3	43	15
Cattle manure+ *Tithonia diversifolia*	5	3	63	9
Cattle manure+ *Carica papaya*	31	13	54	19
Control	0	0	0	0

DISCUSSION

Soybean growth response observed in this study was in line with the report of Atungwu and Kehinde (2008) where organic-based fertilizer reduced nematode populations and gave a significant increase, which was comparable to that of Furadan, a synthetic nematicide, in growth and yield of soybean. Higher grain yields obtained on all amended plots in Ibadan compared with the control in 2010 is suspected to be as a result of increased vegetative growth in plants at the expense of pod formation in Abekuta compared with plants in Ibadan.

Increase in the yield of soybean grown on organic-amended soils have been attributed to the roles of organic substances as: plant-parasitic nematode suppressant (Akhtar and Mahmood 1996), provider of suitable environment for crop root growth, a good source of nematostatic and nematotoxic substances like ammonia (Rodriguez-Kabana *et al*., 1996) and booster of nematophagus organisms such as some fungi species (e.g Arbuscular micorrhizal fungi).

Results obtained from this present work showed that carefully-composted manures applied on nematode-infested soybean fields reduced the population of root-knot nematodes by 94.9%, affirming the report by Atungwu and Lawal (2008) while testing the efficacy of organic-based fertilizer in the management of *M. incognita* in soybean. In addition to enhancement of microbial population and interaction, previous experiments have proven that organic amendments are substances whose regulated and timely application can reduce population densities of plant-parasitic nematodes in infested crop fields and also improve crop yields (Atungwu and Lawal, 2009; Orisajo *et al.*, 2006).

Efficient recycling and amendment of agricultural soils with organic substances that could otherwise be regarded as “wastes” through proper composting as demonstrated by this study has proven to be promising and vital to improving the antagonistic status of soils to the root-knot nematode in South-Western Nigeria. Therefore, collection of organic materials with proven nematostatic or nematicidal properties and the combination of these substances in composted form would not only improve soybean growth (Atungwu *et al*., 2009), but would also lead to significant increase in yield of the crop.

This study has demonstrated that amending soils with compost would likely provide fertile and healthy soils which can suitably ensure better crop yield, wholesome enough to meet the nutritional and dietary needs of the ever-increasing human and livestock populations quantitatively and qualitatively.

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