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The Effect of Organic Soil Amendments on Root-Knot Nematodes, Soil Nutrients and Growth of Carrot

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Abstract: A study was conducted on a Haplic Acrisol at the Technology Village of the University of Cape Coast, Ghana to assess the impact of ground neem (*Azadirachta indica* A. Juss) leaves-poultry manure on root-knot nematodes, soil nutrients and yield characteristics of carrot (Daucus *carota* L.). Each neem level (10, 30 and 50 g) was thoroughly mixed with 5 g of poultry manure per kg of soil in a plastic pot and seeds of carrots were sown. Carrots were harvested at three months old. The neem leaves at 10 and 30 g plus the poultry manure significantly reduced root-knots on the carrot roots. The higher dose of 50 g neem leaves plus the poultry manure totally prevented the formation of root knots on the carrot roots. The nutrient status of the soil and in the carrot plant significantly increased relative to the amendment level. The yield characteristics of carrot also significantly increased in relation to the amendment level. The improvement of the nutrient status of the soil and the control of nematodes by the amendments might have led to the improvement of the yield characteristics of the carrot. Combined neem leaves and poultry manure may be used in place of synthetic nematicides and fertilizers to control nematodes and improve soil nutrient levels.

Key words: *Azadirachta indica* A. Juss, *Daucus carota* L., poultry manure, root-knot nematode, soil amendment, soil nutrients

INTRODUCTION

The use of inorganic chemicals in agriculture is becoming environmentally unfriendly to mankind. These chemicals especially the pesticides are dangerous to human health (IIRR, 1992). High dosages of fertilizers and liberal use of synthetic pesticides can pollute water, air and soil. Pests can develop resistance to pesticides and previously unimportant pests can emerge. Though inorganic chemicals are known to be hazardous to the environment, they have brought positive gains in agriculture (Sultan *et al*., 1995). Man is therefore faced with the critical dilemma of consistently obtaining high crop yields without polluting soil, air and water and without depleting soil fertility.

One of the alternatives to the use of chemical pesticides in controlling pests and improve the soil's fertility is the use of organic materials. Using organic materials as an alternative can provide a sustainable and environmentally acceptable soil management, often at little or no direct cost to the farmer and so it has many advantages, especially for the resource poor farmer in developing countries who cannot afford costly imported chemical pesticides. Several studies have been carried out on the use of organic materials in soil management practices, however, the products of neem (*Azadirachta indica* A. Juss) have proven to better control soil pests, especially soil parasitic nematodes and also provide soil nutrients (Akhtar, 1999; Chakrabarti, 2000). Poultry manure, which is common in most localities, has been also found to reduce soil parasitic nematodes and to increase soil nutrients (Babatola and Oyedunmade, 1992; McSorley and Frederick, 1999).

Carrot (*Daucus carota* L.) is the most sensitive crop to root-knot nematodes and yield reduction of 45% in commercial fields has been recorded in the United States (Widmer *et al*., 2001). Other yields losses on this crop as a result of nematodes are also known (Schiliro *et al*., 1995). Inorganic pesticides have proved effective in the control of these nematodes on carrots, however, the associated problems attached to the use of these chemicals calls for an alternative, that is, the use of soil amendments which will not only control nematodes but also add nutrients to the soil to enhance the yield of carrot.

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The objective of this study therefore was to evaluate the impact of neem leaves and poultry manure as a soil amendment on root-knot nematodes (*Meloidogyne* sp.), soil fertility and growth of carrot

MATERIALS AND METHODS

The experiment was conducted at the Technology Village of the University of Cape Coast, Ghana (5.07°N, 1.14°W). The soil of the site belongs to the Benya Series, classified as a Haplic Acrisol (FAO/UNESCO, 1988) with a soil pH of 5.12. A composite top-soil (0-15 cm) was collected around sweet pepper plants infested with root-knot nematodes (*Meloidogyne* sp.). The collected soil was used for treatment preparation the following day at a mean moisture content of 5.40%.

Neem leaves were harvested around the experimental site, air-dried for one week and ground to pass through 2 mm sieve. The poultry manure was collected from the University of Cape Coast Research Farm, air dried for three weeks and also passed through a 2 mm sieve. The total N, P and K (Table 1) of the neem leaves and poultry manure were determined as described below under nutrients analyses.

The soil, neem leaves and poultry manure were thoroughly mixed in the combinations shown in Table 2. Treatments were placed in plastic buckets, with a carrying capacity of 7 kg of soil and replicated three times. The treatments were placed under partial shade, that is, on the veranda of the laboratory at the Technology village of the University of Cape Coast. The Completely Randomized Design (CRD) was used.

The carrot was sown on the 22nd of April 2003, two weeks after incubation of treatments. Thinning to 15 plants per pot was done one and half weeks after germination.

The carrots were harvested three months after sowing. The carrot roots were carefully scooped out of the soil to avoid destruction of the rootlets. The soil attached to the roots was gently washed off to expose the root-knots. The number of root-knots per plant was counted and the root-knot Index was calculated following the method of Taylor and Sasser (1978).

The roots (rootlets and the outer skin of the carrot root were scraped off) and leaves of the carrot were oven dried at 40°C for 5 days, ground and the total nitrogen, phosphorus and potassium determined. The total nitrogen, ammonium-N, nitrate-N, total phosphorus, total potassium, available phosphorus and the exchangeable potassium of soil of the treatments were also determined.

Standard laboratory methods were used for the determination of total N and P (Anderson and Ingram, 1989), total K (IITA, 1985), ammonium-N and nitrate-N (Rowel, 1994). Available P and exchangeable K were determined by the method described by IITA (1985). The ash content of the carrot samples was determined by the method described by Stewart *et al.* (1974).

Table 1: Total N, P and K composition of neem leaves and poultry manure

Material	N	P	K	Moisture content (%)
	mg kg^{-1}			
Poultry manure	35512	12932	9543	16.77
Neem leaves	25006	1435	11921	14.05

Table 2: Treatments

Treatments (per kg soil)
No amendment (Control)
5 g PM
10 g NL
10 g NL + 5 g PM
30 g NL + 5 g PM
50 g NL + 5 g PM

PM = Poultry Manure, NL = Neem Leaves

The data were subjected to analysis of variance (ANOVA) and the Duncan's Multiple Range Test for the separation of means using the MSTAT-C statistical software (Freed, 1992). The line of best fit in Microsoft Spread Sheet and Minitab version 11.21 were employed to find the relationships (R^2) between the soil nutrient content and that in the carrot.

RESULTS

Soil amendments and root-knot index: The root-knot index of carrot decreased as the quantity of neem leaves increased in the amendments (Table 3). The soil amended with 10 g NL kg^{-1} soil gave the highest root-knot index of 4.50 followed by the unamended soil with an index of 4.30, the difference between the two treatments, however, was not significant. The lowest root-knot of zero was recorded by the 50 g NL + 5 g PM kg^{-1} soil. The sole poultry manure treatment had an index count of 2.30, which was significantly lower than the index count of the unamended soil, 10 g NL kg^{-1} soil and 10 g NL + 5 g PM kg^{-1} soil.

Nutrient concentration of the soil at harvest of carrot: The nutrient levels of the amended soil were significantly higher than the unamended soil (Table 4). With the exception of the total and available phosphorus and the NH^{+}_{4}-N, concentration of nutrients in the treatments has a proportional reflection of the amount of neem leaves and poultry manure in the amendment. Among the amendments no significant differences were recorded for the total phosphorus concentration among the 50 g NL + 5 g PM kg^{-1} soil, 30 g NL + 5 g PM kg^{-1} soil and the solely 5 g PM kg^{-1} soil treatments; the 10 g NL kg^{-1} soil recorded significantly the lowest concentration for the nutrient. The 10 g NL kg^{-1} soil also registered the lowest concentration of available phosphorus. No systematic significant differences in NH^{+}_{4}-N concentration were recorded among the 50 g NL + 5 g PM kg^{-1} soil, 30 g NL + 5 g PM kg^{-1} soil and the 10 g NL kg^{-1} soil, these treatments had, however, significantly higher NH^{+}_{4}-N concentration than the 10 g NL + 5 g PM kg^{-1} soil and the sole 5 g PM kg^{-1} soil.

Nutrient content of carrot at harvest: The total N, P, K and the ash contents in both the carrot leaves and roots increased with the increasing rates of the neem leaves in the amendment (Table 5). The differences in the nutrient levels in both the carrot leaves and roots were significant among the treatments. There was a general strong positive and linear relationship ($p \leq 0.05$) between the nutrient concentration in the soil and the content in the carrot. Figure 1-3 show this relationship-the nutrient content in the carrot leaves/roots (y-axis) increased relative to the increasing nutrient concentration in the soil (x-axis).

Table 3: Neem leaves and poultry manure soil amendment on root-knot index of carrot

Treatments	Root-knot index
No amendment (Control)	4.30a
5 g PM kg^{-1} soil	2.30c
10 g NL kg^{-1} soil	4.50a
10 g NL + 5 g PM kg^{-1} soil	3.10b
30 g NL + 5 g PM kg^{-1} soil	1.50d
50 g NL + 5 g PM kg^{-1} soil	0.00e
LSD	0.73

Means with same letter (s) are not significantly different ($p \leq 0.05$). NL = Neem Leaves, PM = Poultry Manure

Yield characteristics of carrot: The mean root weight/shoot weight per plant varied among soil treatments (Table 6). The amended soil treatments had significantly heavier mean root weight/shoot weight per plant than the unamended soil. Higher levels of amendment gave corresponding higher mean root weight/shoot weight per plant. The mean root length per plant for the amended soil treatments was significantly longer than the unamended soil. The mean root circumference per plant grown on the amended soil was also significantly larger than those grown on the unamended soil. Higher levels of amendments resulted in longer root length and larger root circumference of the carrot.

Table 4: Nutrient contents of unamended and amended soil at harvest of carrot

Treatments	Total N	Total K	Total P	NH^{+}_{4}N	NO^{-}_{3}-N	Available P	Exch. K ($cmol_c$ kg soil)
	mg kg^{-1} soil						
No amendment (Control)	543e	673e	335d	2.70d	12.00f	12.00f	0.14e
5 g PM kg^{-1} soil	785d	720d	635ab	6.40bc	13.50e	28.90d	0.16d
10 g NL kg^{-1} soil	825d	750cd	447c	7.15ab	17.00d	15.30e	0.18c
10 g NL + 5 g PM kg^{-1} soil	843c	793c	544b	6.15c	23.50c	42.50c	0.20b
30 g NL + 5 g PM kg^{-1} soil	1092b	844b	631ab	7.80a	45.00b	44.10b	0.21b
50 g NL + 5 g PM kg^{-1} soil	1366a	938a	6670a	7.65a	61.12a	59.60a	0.31a
LSD	40.52	44.78	88.77	0.82	1.35	0.96	0.02

Means within columns with the same letter (s) are not significantly different ($p \leq 0.05$). NL = Neem Leaves, PM = Poultry Manure

Table 5: Nutrients and Ash contents in carrot leaves and roots at harvest

	Carrot leaves				Carrot roots			
	N	K	P	Ash	N	K	P	Ash
Treatments	mg kg^{-1}				mg kg^{-1}			
No amendment (Control)	15150f	11521f	1906f	120771f	4423f	7150e	1476e	41543f
5 g PM kg^{-1} soil	16630e	11780e	3194bc	122861e	4874e	7144e	2624b	44031e
10 g NL kg^{-1} soil	18340d	13043d	2415e	137722d	5685d	7420d	2155d	49602d
10 g NL + 5 g PM kg^{-1} soil	21010c	13780c	2714d	145692c	7311c	8461c	2431c	51492c
30 g NL + 5 g PM kg^{-1} soil	27024b	15861b	3336b	170640b	9234b	9441b	2691b	59772b
50 g NL + 5 g PM kg^{-1} soil	29211a	16831a	4020a	174557a	9823a	10120a	2884a	63900a
LSD	232.90	75.12	201.20	49.22	40.10	37.03	76.87	122.30

Means within columns with the same letter (s) are not significantly different ($p \leq 0.05$). NL = Neem Leaves. PM = Poultry Manure

Table 6: Soil amendment with Neem Leaves (NL) and Poultry Manure (PM) on yield characteristics of carrot

Treatments	Mean root length/plant (cm)	Mean circumference of root/plant (cm)	Mean fresh root weight/plant (g)	Mean fresh shoot weight/plant (g)
No amendment (Control)	7.48f	6.60e	8.90e	4.00f
5 g PM kg^{-1} soil	9.20d	9.00d	22.80d	6.05e
10 g NL kg^{-1} soil	8.96e	9.80cd	28.70c	9.90d
10 g NL + 5 g PM kg^{-1} soil	9.88c	10.15bc	29.80c	11.30c
30 g NL + 5 g PM kg^{-1} soil	10.10b	10.80ab	32.50b	13.30b
50 g NL + 5 g PM kg^{-1} soil	10.94a	11.25a	34.20a	15.20a
LSD	0.17	0.88	1.11	0.29

Means within columns with the same letter (s) are not significantly different ($p \leq 0.05$)

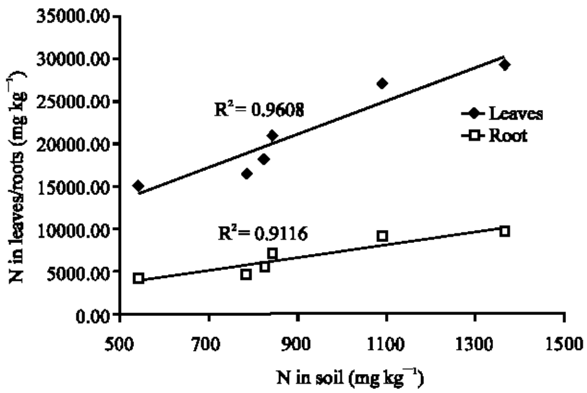

Fig. 1: Relationship between N in soil and N in carrot leaves and roots

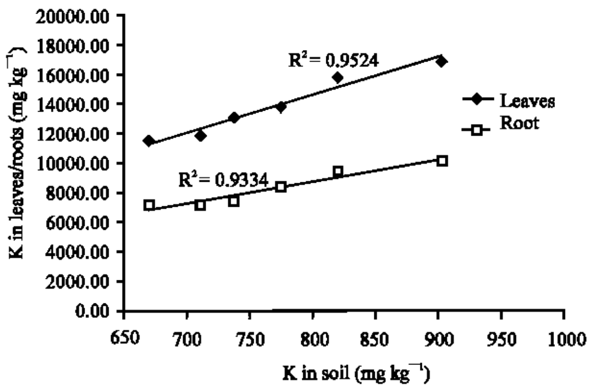

Fig. 2: Relationship between K in soil and K in carrot leaves and roots

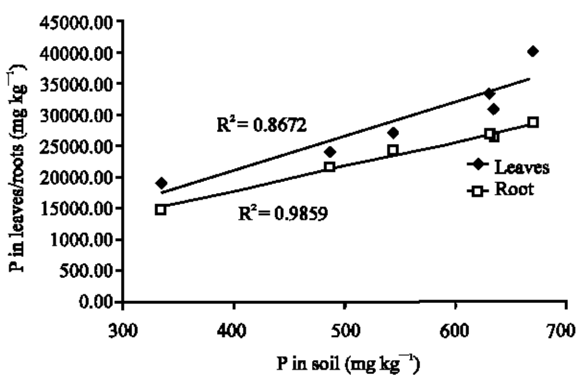

Fig. 3: Relationship between P in soil and P in carrot leaves and roots

DISCUSSION

Root-knot nematodes in carrot were controlled through soil treatment with neem leaves and poultry manure (Table 3). The degree of control was relative to the amount of neem leaves added in the soil amendment. Soil treatment with 50 g neem leaves + 5 g poultry manure/kg soil was the most effective and drastic in the control of the root-knot nematodes. In a similar study Reddy *et al.* (1993) effectively used solely 50 g neem leaves/kg soil to control root-knot nematodes on papaya. Neem products in previous studies were noted for their effectiveness in controlling nematodes on other crops (Deka and Rahman, 1998). The nematicidal action of neem has been assigned to its active ingredient, azadirachtin (Neem Foundation, 1997).

The present study has also revealed the suppressive effect of the poultry manure on parasitic carrot nematodes at 5 g poultry manure/kg soil. The effectiveness of poultry manure in controlling parasitic nematodes in other crops has also been reported (Riegel *et al.*, 1996). The control ability of organic amendments including the poultry manure in the suppression of nematodes has been assigned to chemical by-products from the decomposing materials in the soil, which are toxic to the nematodes (Dunn, 1994).

The 10 g neem leaves/kg soil was not significantly different from the control treatment in controlling the nematodes. The addition of the poultry manure to the 10 g neem leaves/kg soil made it more effective in suppressing root-knot nematodes. The addition of the poultry manure in the amendment might have enhanced the nematicidal effect of the neem leaves.

The neem leaves and the poultry manure are not only pesticidal but also good soil nutrient provider. The incorporation of the neem leaves and poultry manure brought significant increases in the levels of nutrients of the amended soil (Table 4). Increases in soil fertility status have been recorded with the use of neem leaves and other plant material as soil conditioners in Burkina Faso with the neem leaves giving better results (Tilander and Bonzi, 1997). Indian farmers have used the neem leaves over the years to enrich the soil (Neem Foundation, 1997).

Poultry manure when used as soil amendment has had positive influence on soil fertility (Abdel Magid *et al.*, 1995; Larney and Janzen, 1996).

The combination of neem leaves and the poultry manure as soil amendment would, however, be more beneficial than separate additions to the soil, as each has different nutrient content (Table 1). The poultry manure had higher phosphorus content than the neem leaves and therefore had significant positive impact on the total and available phosphorus on the amended soil (Table 4). Soil treatment of 10 g neem leaves + 5 g poultry manure/kg recorded significantly higher total and available phosphorus concentration than the sole 10 g neem leaves/kg.

The peak of nitrogen mineralization in soil occurs between the 2nd and the 6th week of soil organic amendment (Thonnissen *et al*., 2000). The NH^+_4-N, which is a prerequisite for the formation of nitrate in nitrogen mineralization, had concentration levels among most of the treated soil which were statistically the same and this may be due to the low levels of production of the nutrient at the time of analysis. Aside the total and available phosphorus and the NH^+_4-N, the amount of neem leaves and poultry manure in the amendment had proportional effect on the concentration of the nutrients in the treatments. The quantity of organic material used for soil amendment has also been found to impact a proportional rise in the nutrient levels of the soil (Wong *et al*., 1999).

The nutrient levels in the treatments had a corresponding linear effect on the nutrient content in both the carrot leaves and roots (Fig. 1-3). The concentrations of nutrients in soil have been found to have a positive linear impact on the nutrient contents in plants (Manson *et al*., 2002). The accumulation of the nutrients was higher in the leaves than in the roots. Most nutrients are found in high quantities in the leaves than in the other parts of the plant (Harrison *et al*., 2000).

Soil amendments with organic materials increase the level of nutrients in soils and correspondingly also increase the level of the nutrients in the plants growing on them (Singh and Bhati, 2003). Nitrogen, phosphorus and potassium contents in the leaves and roots of carrot in the current study all increased relatively with the increasing levels of neem leaves and their combination with the poultry manure in the soil amended. The general nutrient levels of the carrot plant improved with the soil amendments.

All the yield characteristics of the carrot improved relatively with the rising levels of the amendments and these tended to follow the patterns of the nutrient level changes in the soil treatments and in the carrot plant. The control of nematode with the soil amendments indicated by the root-knot index, might have also played a role in the improvement of the yield characteristics. The application of neem products and other organic matter has been found to improve the status of soil nutrients, control soil parasitic nematodes and thereby improving yield of crops (Deka and Rahman, 1998). Such characters of organic matter have also been portrayed in the present study with the improvement of soil fertility, yield of carrot and the control of carrot root-knot nematodes.

The study has shown that neem leaves and poultry manure could be used in place of synthetic pesticides and fertilizers to improve the fertility status of the soil and the growth and yield of carrots.

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