MANAGEMENT OF *Meloidogyne incognita*on HOT PEPPER (*Capsicum frutescens* L.) WITH PLANT EXTRACTS AND NEEM SEED CAKE

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Abstract
Root-knot nematodes (Meloidogyne spp) are serious pests of vegetable crops pepper inclusive. Ecofriendly management options including botanicals appear to be viable alternative to chemical nematicides. This research evaluated the effects of some plant extracts and organic amendment on the pathogenicity of Meloidogyne incognita on hot pepper CV. EFIA in the Screenhouse. Pepper seedlings were inoculated with 5,000 larvae of M. incognita and plants treated with different concentrations of the extracts. The treatments were: 5% and 10% w/v of neem leaf; mango leaf, pawpaw leaf extracts, 2 and 4 t/ha neem seed cake, nematode free plants (with no plant extracts (control I) and nematode inoculated plants with no plant extracts (control II). The experiment was laid out in a completely randomized design with ten treatments replicated four times. Results obtained showed that all the botanicals significantly ($P<0.05$) inhibited root galling, and other nematode damage indices. Also, plant extracts and soil amendment with neem cake significantly ($p<0.05$) enhanced growth and yield of pepper compared with the control. Soil amendment with 4 t/ha of neem cake was the best among the treatments in nematode control and yield enhancement and could be used for managing M. incognita infected pepper plants.
***Keyword**: Pepper, Root-knot disease, Biopesticide, Capsicum spp.*

Introduction

Pepper (*Capsicum* spp) is a popular spice crop and highly valued for its pungency which is due to the presence of capsaicinoids, alkaloid compounds (C_8H_{22} NO_3) that are common with the genus *Capsicum* (Bosland and Votava, 2000). Apart from its pungent flavor nutritionally it is rich in vitamins A, C, B_{12}, phosphorus, potassium and calcium, in pharmaceutical industries it is a component of antioxidants and anticancer products. In food and cosmetics, the red pigment of the ripe fruits is a natural coloring agent. The world's production of pepper (hot and sweet) as at 2010 stood at 26,537 million tones with China being the lead producer (27% of the world's production). In Africa, Algeria is leading followed by Tunisia.

The production of pepper in sub-Saharan Africa is highly constrained by biotic and abiotic factors. Root-knot nematodes are important pest of vegetable crops including pepper in Nigeria (Coyne et al., 2018; Udo et al., 2023). The predation of pepper plants by nematodes accounts for monumental yield losses that sometimes remain hidden to farmers. In some severe cases, total crop failure may occur. Common symptoms of infection include root galling, leaf chlorosis, stunted growth, wilting, reduction in number of fruits and total fruit yield. Galling of roots affects nutrient and water absorption and further translocation to the shoot system. The control of this recalcitrant pest with chemical nematicides is the most effective method but environmental and human health concerns are very serious drawbacks. The use of ecofriendly alternative methods such as nematicides of natural origin have been highly advocated by researchers (ChitWood,2002; Archana and Prasad,2004). Active biological compounds in plants have been found to impair nematodes activities in cultivated

crops (Udo et al., 2013; El-Ansary et al., 2025) and enhance crop growth and yield. Neem products, plant leaf extracts and plant seed cakes have been reported to suppress nematode population and enhance yield in many crops (Olabayi and Adewuyi,2016; El-Ansary et al.,2025). The efficacy of botanicals in nematode control depends on the plant material, its concentration, environmental factors, nematode species, etc.(ChitWood,2002) and calls for location specific evaluation. Thus, this research was conducted with the aim of assessing the efficacy of locally sourced plant materials in suppressing the activity of an indigenous root-knot nematode *(Meloidogyne incognita*) infecting a commercial variety of hot pepper in Calabar.

Materials and Methods

The experiment was carried out in a sun-lit screen house of Botanic Garden, University of Calabar (Lat $5^0$00' – $5^0$40'N, long $8^0$04' – $8^0$62 E) from February to June 2025. Seeds of hot pepper (*Capsicum frutescens L.*) cv. EFIA were purchased from a East-West seed vendor. The leaves of pawpaw (*Carica papaya*), mango (*Magnifera indica*) and Neem *(Azadirachta indica*) were sourced from the Botanic Garden University of Calabar. Neem seed cake was obtained from Institute of Agricultural Research, Samaru, Zaria, Kaduna state, Nigeria. Indigenous population of M. incognita maintained on Indian Spinach (*Basella alba*) was multiplied on stem cuttings of water leaf plants (*Talinum fructicosum)* grown on heat-sterilized soil in a screenhouse. Heavily galled roots of water leaf plants were uprooted, washed with water and cut into 1 -2 cm pieces for nematode larvae extraction following the method of Hussey and Barker (1973). The second stage infective larvae obtained after blending the roots with an electric blender and sieving were counted under a stereomicroscope, an average of 5 counts gave 5000 larvae per 30 mLs of slurry. The pepper seeds were planted in a heat- sterilized soil admixture of topsoil, poultry manure and river sand, respectively by volume. The plant leaf extracts were prepared by collecting fresh leaves of the respective plants and washing thoroughly in tap water. They were shed- dried for 6hrs. Each leaf was pounded into a paste with mortar and pestle. Each pounded leaf was weighed into two portions, namely, 200 g and 400 g and soaked in 4 liters of tap water for 24hrs (Udo et al., 2020). The extract was obtained by filtering with a double fold muslin cloth and the filtrates were kept in a refrigerator at 4°C until needed. Surface soil 0-15 cm was collected from a fallow land from Crop Science Research Farm University of Calabar. The soil was sterilized in a half metal drum by manually heating with firewood to a temperature of 100°C and maintained for 30 mins. Thirty plastic pots of diameter 19.4cm, depth 24 cm and 8 liters capacity perforated at the bottom were filled each with 7 kg of the heat- sterilized soil. The pots were randomly arranged on the screen house benches at inter-row and intra-row spacing of 60 cm and 30 cm, respectively. The experiment had 10 treatments which included: 5 and 10 % w/v (neem leaf extract), 5 and 10 % w/v (mango leaf extract), 5 and 10 % w/v (paw-paw leaf extract), 2 and 4 t/ha (need seed cake), inoculated untreated plant (control I) and uninoculated untreated plants (Control II). The 10 treatments were replicated 3 times and arranged in a completely randomized design (CRD). For the neem seed cake treatment, 7 and 14 g of the cake was weighed into each plastic pots equivalent to 2 and 4 t/ha, respectively 2 weeks prior to transplanting of pepper seedlings. Four-week-old pepper seedlings were transplanted to each pot and 30 mL of nematode inoculum added to the planting hole. Uninoculated plants served as the control. Also at transplanting, 150 mL of each plant leaf extract was added to the planting hole and another 150 mL was applied 2-weeks after transplanting (Udo et al., 2013). Plants were watered with 500 mL of tap water on alternate days. They were grown to fruiting stage and at harvest data were collected on number of galls per plant, gall index (0-5 scale), number of nematodes per plant, nematodes density in soil, plant height (cm), fresh and dry root weight (g) per plant, dry shoot weight (g), number of

fruits and total fresh fruit weight (g) per plant. Data was subjected to analysis of variance using GenStat software, 8th Edition and means compared with Duncan's new multiple range test at 5% probability level.

Results and Discussion

The results of the effects of aqueous plant extracts and neem seed cake on nematode damage indices on pepper infected with *M. incognita* are presented in Table 1. Application of plant extracts and soil amendment with neem seed cake significantly ($P<0.05$) inhibited root galling, gall index (GT), nematode population in the plants and soil relative to inoculated plants without plant extract application. Among the inoculated plants, these plants without soil amendment with neem cake on plant extracts application significantly had the highest number of galls, nematodes population in the root and soil while those planted in soil amended with 4t/ha neem seed cake significantly had the least number of galls and nematode population in plants and soil. In most cases, soil amendment with neem cake, neem leaf extracts, pawpaw and mango leaf extracts at 10% w/v modified the resistant status of the pepper cultivar from highly susceptible to moderately resistant. This indicates that the plant extracts possessed nematicidal properties that could have impeded nematode activities at pre-penetration and penetration stages.

Table 1: Effect of plant extracts and nematode damage indices of hot pepper (*Capsicum frutuscense*) infected with *M. incognita*

Treatment	Number of galls/plant	Gall index	No. of nematodes/plant	No. nematodes in 7kg of soil
N_1(5%)-T_1	36.00c	3.67a-d	14,833.00d	436.70c
N_2(10%)-T_2	22.33ef	3.00de	8,133.00g	195.00f
P_1(5%)-T_3	55.00b	4.00ab	17,67200c	610.00b
P_2(10%)-T_4	31.00cd	3.34b-e	9,720.00f	246.70e
M_1(5%)-T_5	61.00b	4.00ab	18,768.00b	653.30b
M_2(10%)-T_6	39.00c	4.00ab	1.0717.00e	338.30d
NC_1(2t/ha)-T_7	25.00de	3.00c-e	6440.00h	85.70g
NC_2(4t/ha)-T_8	14.33f	2.67e	4,413.00i	29.3h
Inoc. Control-T_9(I.C)	99.00a	4.34a	2,5170.00a	1026.70a
Uninoc. Control –T_{10} (U.C)	0.00g	0.00f	0j	0.0h

Means with same letters within a column are not significantly different according to Duncan's new multiple range test at 5% probability level. (GI:0 = Immune, 1 = highly resistant, 2 = resistant, 3= moderately resistant, 4 = susceptible, 5 = highly susceptible)

Neem products have been implicated as good candidates for the control of plant parasitic nematodes in several studies (Etim et al., 2024; Olabiyi and Adewuyi, 2016). They contain nematicidal compounds such as *azaclirachtin*, *cuercetin*, *limonoides*, *nimbidin*, *nimbidic* acid, etc (Chitwood, 2002). It is possible that some of these compounds could have been released during decomposition of the neem seed cake or directly as neem leaf extracts. The other plant leaf extracts also showed some nematicidal potentials as galling and nematode reproduction was significantly impeded. Archana and Prasad (2004) concluded that botanicals contain bioactive compounds that are capable of immobilizing, repelling or even killing nematodes, with some inhibiting egg hatch. It is likely the plant extracts used in this study could have contained some secondary metabolites that could have contained some secondary metabolites that could have deterred the second stage juveniles from penetrating

the roots or causing death. Recently, EL-Ansary et al. (2025) concluded that *Jatropha curcus*, *Nigellasativa* and *Simumandisa Chinensis* seed cakes contain bioactive compound that reduced M. incognita population and root galling in pepper.

The results of the effects of plant extracts and neem seed cake on growth attributes and root fresh/dry matter at harvest of hot pepper infected with *M. incognita* are shown in Table 2. Soil amendment with neem seed cake and plant leaf extracts significantly ($P<0.05$), increased plant height and number of branches pepper seedlings compared with unamended inoculated plants (Control). Among the nematode inoculated plants pepper plants grown in soil amended with 4t/ha neem seed cake were significantly taller than plants in other treatments. There was no significant ($P>0.05$) difference in height between plant grown in soil amended with 2t/ha neem seed cake and those of the uninoculated control. Pepper plants inoculated with M. incognita with no plant extracts or neem seed cake amendment significantly had higher fresh and dry root weights than the other treatments. It was followed by uninoculated control plants and those amended with 4t/ha neem seed cake.

Table 2: Effects of plant extracts and neem cake on plant height (cm), number branches, fresh and dry root weights (g)/plant at harvest of hot pepper infected with *M. incognita*

Treatment	Plant height (cm)	No. branches/plant	Fresh root weight (g)/plant	Dry root weight (g)/ plant
N_1(5%)-T_1	52.33d	5.33bc	23.45ef	6.25d
N_2(10%)-T_2	56.00c	6.33ab	20.38g	5.20e
P_1(5%)-T_3	45.00f	5.33bc	24.72cd	6.22d
P_2(10%)-T_4	49.00e	6.00b	22.26f	5.36e
M_1(5%)-T_5	45.00f	4.67c	23.19ef	6.18d
M_2(10%)-T_6	50.33de	6.33ab	20.82g	5.54e
NC_1(2t/ha)-T_7	60.00b	6.33ab	23.87de	6.47cd
NC_2(4t/ha)-T_8	66.33a	7.33a	25.78c	6.93bc
Inoc. Control-T_9(I.C)	40.00g	3.33d	33.61a	9.30a
Uninoc. Control –T_{10} (U.C)	62.33b	6.33ab	27.57b	7.21b

Means with same letters within a column are not significantly different according to Duncan's new multiple range test at 5% probability level; $T_1 = N_1$ is neem leaf extract at 5% w/v; $T_2 = N_2$ is neem leaf extract at 10% w/v; $T_3 = P_1$ is pawpaw leaf extract at 5% w/v; $T_4 = P_2$ is pawpaw leaf extract at 10% w/v; $T_5 = M_1$ is mango leaf extract at 5% w/v; $T_6 = M_2$ is mango leaf extract at 10% w/v; $T_7 = NC_1$ is neem cake at 2t/ha; $T_8 = NC_2$ is neem cake at 4t/ha; T_9 = Inoc. Control (In. C) (T_9); T_{10} = Uninoc. Control (Un.C) (T_{10})

Heavier roots of plants inoculated with M. incognita without botanical treatment could be attributed to the heavy gallings induced by the nematode species. This observation agrees with previous workers (Udo et al., 2023). Enhancement in growth attributes due to plant leaf extracts and neem seed cake amendment could be partially explained by the reduction in root galling by the nematode's species. Galled roots are metabolically inactive and malfunctioned. Nutrients and water absorption/translocation are impaired which account for poor growth (Etim et al., 2024, Udo et al., 2022). Soil treated with botanicals produced plants with few galls and perhaps prompting a more efficient root system.

The results of the effects of plant leaf extracts and neem seed cake on the dry shoot weight/plant, yield attributes and fresh fruit yield of pepper infected with *M. incognita* are presented in Table 3.Accumulation of dry matter in the shoot of pepper plants was significantly ($P<0.05$) enhanced in plant leaf extracts and neem seed cake amended soil

relative to unamended – inoculated plants. Soil amended with 4t/ha neem seed cake significantly ($P<0.05$) enhanced by plant leaf extracts and neem seed cake amendment compared with unamended inoculated plants. Plants grown in soil amended with 4t/ha neem seed cake significantly had the highest number of fruits followed by those amended with 2t/ha neem seed cake and unioculated control. The effects of treatments on total fresh yield followed the trend of number of fruits/plant. Each plant leaf extracts at 10%w/v significantly increased fresh fruit yield compound with 5%w/v concentration. Soil amendment of 4t/ha neem seed cake significantly had plants with the highest fresh fruit yield followed by uninoculated plants and those amended with 2t/ha neem seed cake. The treatments had no consistent effect on the mean weight of fruit. As earlier argued, enhancement in shoot dry matter accumulation, number of fruits set, and fresh fruit yield could be attributed to relatively few galls observed in the roots of plants grown in soils treated with botanicals. With an efficient root system, photosynthesis and the production of assimilates could have definitely been changed in such plants and consequently accounted for higher yields. Soil amended with neem cake at 4t/ha suppressed nematode population and enhanced fruit yield the most relative to other treatments. This could be attributed in part to the release of nutrients to the soil during its decomposition. Chemical analysis of the neem seed cake used this study by earlier authors (Etim et al., 2024) indicated a narrow C:N of 13.88. This implies quick mineralization and a good soil amendment agent for nematode control (Chitwood, 2002). A similar result was reported recently in pepper with the use of some plant seed cakes by El-Ansary et al. (2025).

Table 3: Effects of plant extracts and neem cake on dry shoot weights (g)/plant, number of fruits/plant, total fresh fruit weight(g)/plant and mean weight of fruit(g) of hot pepper infected with *M. incognita*

Treatment	Dry shoot weight (g)/plant	No. fruits/plant	Total fresh fruit weight (g)/plant	Mean weight (g) of fruit
N_1(5%)-T_1	12.79d	14.67ef	73.01g	4.98c
N_2(10%)-T_2	14.54c	17.00c	95.14d	5.61a
P_1(5%)-T_3	11.19e	13.67fg	70.74g	5.18bc
P_2(10%)-T_4	12.87d	16.33cd	83.09e	5.09c
M_1(5%)-T_5	10.40f	12.67g	62.58h	4.95c
M_2(10%)-T_6	12.24d	15.33de	77.67f	5.07c
NC_1(2t/ha)-T_7	16.33b	21.00b	113.95c	5.43ab
NC_2(4t/ha)-T_8	17.70a	24.00a	124.3a	5.18bc
Inoc. Control-T_9(I.C)	10.52f	10.67h	53.19i	4.99c
Uninoc. Control –T_{10} (U.C)	16.77b	21.67b	118.73b	5.48ab

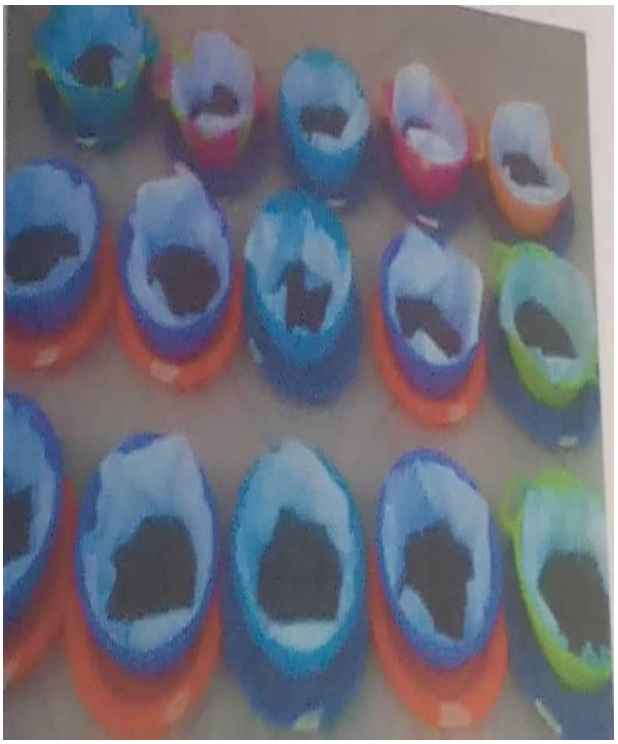
Means with same letters within a column are not significantly different according to Duncan's new multiple range test at 5% probability level




Oven dried roots and shoots

Oven

Oven dried roots and shoots in A4 envelope



Conclusion and Recommendations

A pot trial evaluating the potential of different plant leaf extracts and neem seed cake as soil amendment in the management of *M. incognita*, infecting hot pepper CV. EFIA indicates that all the botanicals were nematicidal. Nematode damage indices were significantly reduced while the growth and fruit yield of pepper were enhanced. Among the botanicals, soil amendment with 4t/ha neem seed cake was the best and could be incorporated into integrated root-knot disease management in pepper.

El-Ansary et al. (2025) concluded that some plant seed cakes contained bioactive compounds capable of inhibiting and killing root-knot nematodes infesting pepper. They concluded that the amendment of soil with is of *Jatropha curcus, Nigella sativa* and *Simmondesia chinensis* seed cakes reduced nematode population, number of galls and enhanced growth of pepper.

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