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STRATEGICALLY MANAGEMENT OF ROOT-KNOT NEMATODE *MELOIDOGYNE SPP.* USING BOTANICALS

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ABSTRACT

In the past few decades in India, control of plant-parasitic nematode (PPN) species arises as a major challenge. There is a lack of synchronized information. In this regard, this review paper has focused on the study of strategies enforced in the control of PPN. Among various PPN, *Meloidogyne* species has been proven as one of the most damaging species therefore it is selected as the center point. The utilization of inorganic chemicals to control the Phyto parasitic nematode devise several environmental concerns. Thus, this review focuses on providing eco-friendly approaches that focus on the functional management of these species. This review paper will assist the coworkers by giving gross information about the management of the *Meloidogyne* species.

Keywords: Plant-parasitic nematode (PPN), Root-Knot Nematode *Meloidogyne* species

INTRODUCTION:

Perceiving the damage, the optimum goal of a nematologist is to eradicate the attack of Phyto parasitic nematode *Meloidogyne* species. To meet the continuously increasing demand for the sustainable agriculture several authors have contributed their observation in form of their research findings. This review will emphasize on the exploration of methods for management of the nematodes using various botanicals. The eminent depletion in the *Meloidogyne incognita* (Kofoid & White) population was

observed by integrating the chopped shoots of the latex bearing of *Ficus elastic* Roxb **[1]**. After this study oil cakes of mustard, castor, sesame, and linseed used for the Management of the species and the oil cakes of mustard and linseed offer better results **[2]**. Deduction in the infection was observed up to 29.9% in cowpea and 23.3% in green gram by using the corbofuran **[3]**. The effect of *punica granatum* L. *Thymus vulgarais* L. and *Artemisia absinthium* L. to manage the *M. incognita* were studied and observation indicated that all tested extracts caused 100% mortality **[4]**. At the same time, Prosopis was also reported to be nematicidal property against the root-knot nematode **[5]**. The Phyto paratoxic consequences of neem as nematicide was observed in many studies. Akhtar and Mahmood **[6]** treated the chili seedlings with decomposed and un-decomposed oilcakes, neem, and castor leaves. They found oil cakes and neem leaves were more effective as compared to leaves of castor against root-knot diseases caused by *M. incognita*. Oka *et al.* **[7]** observed the nematicidal activity of extracts and powder of *Inula viscose* L. and found *M. javanica* was most sensitive to the leaf powder. Nematicidal property of eight plant species against *M. incognita*, were reported by Prasad *et al.* **[8]** and found the reduction of galls formation and maximum mortality in *Calotropis procera* (Aiton). Calotropis showed maximum nematicidal activity *M. incognita* **[9]**. The efficacy of bio-control agent *Verticillium chlamydosporium* Goddard, neem cake, carbofuran and marigold against *M. incognita* were assessed in tomato plants, individually and in combination. Maximum parasitisation of *V. chlamydosporium* was also seen at the time of integration of carbofuran **[10]**. The effect of fruit of *Anethum graveolens* L., flower buds of *Syzygium aromaticum* L., rhizome of *Cnidium officinale* (L.), rhizome of *Coptis chinensis* Franch, the root bark of *Paeonia suffructicosa* and stem bark of *phellodendron amurense* Rupr and *Cinnamomum cassia* (L.) on *M. incognita* were noticed. Efficiency against *M. incognita* was highest for root bark of *P. suffructicosa* followed by stem bark of *C. cassia* **[11]**. The impact of aqueous based extract obtained from leaves of *Crotalaria virgulata* Klotzsch for its effects on second-stage juveniles of *M. incognita* was also recorded **[12]**. The effect of Phyto-chemicals extracted from *Lantana camara* were also done. Camaric acid, Lantanillic acid and Oleanolic acid showed 98%, 95% and 70% mortality respectively for *M. incognita* **[13]**. In tomato crops, the effect of neem-cake and carbofuran

individually and in combination were observed. The highest inhibition in root-knot larvae penetration was experienced in neem-cake extract with carbofuran **[14]**. Anitha and Rajendran **[15]** assessed the effectiveness of *Pseudomonas fluorescens* (Trevisan) neem cake and carbofuran either singly, or in combinations as soil application before sowing in the nursery for management of *M. graminicola* and observed all three treatments caused a significant reduction in *M. graminicola* population. Garlic bulbs and neem leaf caused the maximum inhibition of egg hatching and were lethal to larvae **[16]**. Adegbite **[17]** explores the neem, Siam weed, lemongrass and castor bean for their nematicidal properties. Neem and Siam weed were found responsible for 100% larval mortality. These were also accountable for inhibiting egg hatching process with 100% success rate whereas castor bean and lemon grass showed 62% & 75% respectively. The nematicidal activity of carvacrol, thymol, linalool, terpineol and menthone against *M. incognita* were noticed hatching was completely inhibited at low concentrations of carvacrol, thymol and linalool **[18]**. Similarly, Meyer *et al.* **[19]** noted the effect of *Plantago lanceolata* L. and *P. rugelii* Decne to control *M. incognita* population were found to be toxic to eggs and J2. The toxicity of *Ocimum sanctum* Linn. was assessed by investigating the effect of *Azadirachta indica* A.Juss., *Carica papaya* L. *O. sanctum*, *Ricinus communis* L. and *Tagetes patula* L. in controlling the hatch of eggs of the *M. incognita* **[20]**. The nematicidal activity from 27 different samples against *M. incognita* by preparing the methanol or hexane extracts were screened out. *Dinbera retroflexa* (Vahl) (leaves), *Cucumis melo* L. var. agrestis (fruits), *Acacia nilotica* (L.) (pods), *Eucalyptus microtheca* F. Muell. (leaves), and *Chenopodium album* L. (leaves) extracts showed extremely high promising rates of mortality *i.e.,* 95–99%. The mortality rate elevated with increasing exposure time for most of the extracts **[21]**. Turmeric caused the integrated nematode control strategies of root-knot nematodes (RKNs) **[22]**. The effect of *Cymbopogon flexuosus* (Nees ex Steud.) and *Calendula officinalis* L. were observed by Tiyagi *et al.* **[23]** to manage root-knot nematode and found *C. flexuosus* caused maximum mortality. The essential oils of *Origanum vulgare* L. *Origanum Dictamnus* L. *Mentha. Pulegium* L. and *Melisaa officinalis* L. revealed potential activity against *M. incognita* while studying the effect of eight essential oils as well as 13 single terpenes for their nematode population

reduction feature against *M. incognita* **[24]**. The control of *M. incognita* on chickpea by *Melia azedarach* L. was also noticed **[25]**. The bark extract of different plant species viz., *A. indica, A. nilotica, Emblica officinalis* Gaertn. *Eucalyptus citriodora* Hook. *Mangifera indica* L. and *Terminalia arjuna* (Roxb.) against the *M. incognita* were assessed. *A. indica* was proved to be the 100 percent check in egg hatching while conducting an experiment **[26]**. Phosphonothioate revealed the maximum reduction of *M. graminicola* population in the field experiment for the strategic management of *M. graminicola* **[27]**. The nematicidal activities of methanol extracts from ten plant species were also assesed. The result showed that *Nepeta cataria* L. was most effective against *M. incognita* **[28]**. Leaf powder of *Myrtus communis* L. extracts with ethanol and methanol exhibited the upmost nematicidal activity among all extracts tested **[29]**. Eugenol and methyl eugenol exhibited stronger nematicidal activity from the 37 constituents of the essential oil which are extracted from *Agastache rugosa* (Fisch) flowering aerial parts against the *M. incognita* **[30]**. The combination effect of marigold leaves along with different concentrations of antagonist fungus (*Paecilomyces lilacinus*) (Thom) were also noticed to control *M. incognita* **[31]**. The effect of 3, 4-dihydroxybenzoic acid (3,4-DHBA) extracted from *Terminalia nigrovenulosa* Pierre, bark caused for increasing J2 mortality of *M. incognita* **[32]**. The toxicity of aqueous extract of *Artemisia annua* L. on targeted *M. incognita* population and its components i.e., caffeic acid, chlorogenic acid, artemisinin and the related semi-synthetic artesunate were used against *M. incognita*. The extract of *A. annua* consisting of various active phytochemicals has the potential for development of new nematicidal formulates **[33]**. *C. procera, A. indica*, *Clerodendrum inerme* (L.) and *Lantana camara* L. caused the inhibition of egg hatching by preparing aqueous extract in which maximum in *C. procera* (99.83%) and the least in *L. camara* (77.88%). Most mortality of 2nd stage juveniles was observed in leaf extracts of *A. indica* (90.17%) and least in *C. procera* (60.33%) **[34]**. The nematicidal property and chemical characterization of essential oils and aqueous extracts of three mint species were also observed **[35]**. The impact of baker tree, bitter leaf, parthenium, lantana, Mexican marigold, Mexican tea, neem, and pyrethrum were evaluated on *M. incognita* in tomato plant under laboratory and pothouse. Mexican marigold and Lantana were

promising botanicals **[36]**. Two 4-quinolone alkaloids, waltherione E (1), a new alkaloid, and waltherione A (2), were isolated from *Triumfetta grandidens* Hance (Tiliaceae) and applied to control *M. incognita*, with second-stage juveniles (J2s) and resulted in mortality of 100% at 500 µg/mL at 48 h post-exposure **[37]**. A few essential oils and methanol extract of aerial parts of *Petroselinum crispum* (Miller) were characterized chemically and tested their activity against *M. incognita*. The most abundant furanocoumarin compounds in the methanolic extract were xanthotoxin, psoralen, bergapten and oxypeucedanin and showed the nematicidal property and enhanced plant growth **[38]**. The impact of 11 leaves of trees and shrubs in the form of aqueous extract in vivo and in vitro as dry leaf powder against *M. incognita* were evaluated. Maximum inhibition of egg hatching was found in *Aegle marmelos* (L.) **[39]**. The volatilome of rucola (*Eruca sativa*) (L.) acted as a powerful natural nematicidal agent against the *M. incognita*. Testing of the nematicidal activity of rucola volatile compounds revealed that erucin, pentyl isothiocyanate, hexyl isothiocyanate, (E)-2-hexenal, 2-ethylfuran, and methyl thiocyanate were the most active **[40]**. The biopesticidal activity of essential oils and phenylpropanoids from *Foeniculum vulgare* Miller var. vulgare (bitter fennel) towards the *M. javanica* and trans-Anethole shown acute nematicidal action after 24 and 48 h and estragole indicated effectiveness against *M. javanica* hatching and juveniles after 15 days (about 2 weeks) **[41]**. Suppression of RKN (Root knot nematodes) egg hatch and J2 activity by extracts from pomegranate fruit rinds and roselle leaves indicate that these plant-derived products are probable important components for future studies of nematode-antagonistic compounds **[42]**. The nemato-toxic activities of seven plants viz: garlic, ginger, cinnamon, neem, castor bean, nerium and eucalyptus were recorded against juveniles' stage of *Meloidogyne sp.* after 48 hours from exposure in concentration 5% and 10%. The maximum percentage of nematode mortality was in eucalyptus extract (100%) followed by cinnamon (97.1%), nerium (95.6%), ginger (92.7%), neem (91.3%), castor bean (81.1%) and garlic (65.2%) as compared with control (13.0%) in concentration 10% **[43]**. Leaf extracts of *Argemone Mexicana* L., six different weeds and *Achyranthes aspera* L. were very toxic against the root-knot nematode **[44]**. Carvacrol, a phenolic monoterpene used as a nematicide while conducting an experiment to control *M. javanica* **[45]**. The influence of

aqueous extracts of seed of Canavalia *ensiformis* (L.) toward the infective stage (J2) of *M. incognita* were noticed. The aqueous crude extract of *C. ensiformis* displayed the premier nematicidal activity. Responsible compounds were d-glucose, l-canavanine, xanthotoxin, cis-aconitic acid, trans-aconitic acid, malic acid, citric acid, palmitic acid and S-carboxymethylcysteine **[46]**. In some studies, it is proclaimed (E)-cinnamaldehyde as a potential compound against *M. incognita* **[47]**. In vivo and in vitro trials were recorded to check the nematotoxic potential of neem plants against *M. incognita*. Neem extracts were lethal to second-stage juvenile (J2) and egg hatching, and a maximum 250% growth increment was detected in the length of tomato roots **[48]**. The effectiveness of *M. azedarach* preparations against *Meloidogyne sp*. in a tomato greenhouse, by root gall examination and soil J2 enumeration and reported the increase in mortality and plant growth parameters in tomatoes **[49]**. In some observation, α-terthienyl extracted from marigold roots has the nematicidal property to control *M. incognita* **[50]**. The nematicidal efficacy of extracts of *Waltheria indica* L. in the regulation of *M. incognita* were observed. 3, 4-quinolone alkaloids, 5′-methoxywaltherione A, waltherione A and waltherione C, were isolated and characterized as nematicidal metabolites. 5′ Methoxywaltherione A and waltherione A caused high mortality in juveniles of *M. hapla*, *M. arenaria* and *M. incognita* **[51]**. Some botanicals such as Chia as a host to *M. incognita* and chia shoots and roots produce compounds active against a nematode **[52]**. EOs (Essential Oil) from *S. aromaticum*, *C. flexuosus* and *Cymbopogon martini* (Roxb.) were extracted by hydro distillation method and analyzed by GC-FID and GC-MS (Gas Chromatography Mass Spectrometry). Results showed that palmarosa oil possessed the highest mortality followed by lemongrass and clove oils due to the occurrence of their major compounds **[53]**. The nematicidal activity of three Echinacea species were conducted against *M. incognita*, *E. angustifolia* activity was best among these **[54]**. In some studies, the nematicidal activity of flavonoids isolated from *Tagetes patula* L. were conducted. In flavonols the most effectual compounds were found to be fisetin, galangin, morin, isorhamnetin, and myriceti. These flavonoids exhibited 100% mortality of 2nd stage juveniles after 24 h of incubation. Whereas, among flavones that showed the same excellent activity parameters, were simple flavone, 6-hydroxy flavone, chrysin, 6-methoxy apigenin, apigenin-7-O-glucoside and 6-methoxy

luteolin **[55]**. At the same time, garlic essential oil to control *M. incognita* in Tomato plants were observed. The main components of the oil, according to GCMS, are diallyl trisulphide (66.7%) and diallyl disulphide (21.3%), which presented lethal concentrations to 50% J2 **[56]**. The evaluation of different extracts of garden cress (*Lepidium sativum*) entire plants, seeds, and the combination of other top extracts as a biological control agent against *M. incognita* infected tomato transplants in pots experiment were used. The acetone-based extract from the whole plant among all extracts gave the strongest activity, which showed 91% mortality and 73% egg inhibition at 1000PPM **[57]**. Saponins extracted from five different *Medicago* species exerts a nematicidal property against the (PPN) *M. incognita*, *Xiphinema index* Thorne & Allen and *Globodera rostochiensis* (Wollenweber) **[58]**. Neem was the most reliable product found in the study among jatropa, neem kachnar, bel & eucalyptus against *M. javanica* **[59]**. The nematicidal property of *Aspergillus flavus* Link *Penicillium chrysogenum* Thom and *Pochonia chlamydosporia* (Goddard). Zare, as culture filtrates applied individually and in combination in vitro and planta greenhouse and field studies against *M. incognita* using cucumber cultivar and found *A. flavus, P. chrysogenum* and *P. chlamydsporia* could be used alone or in different combinations in integrated pest management (IPM) as an effective strategy for *M. incognita* **[60]**.

CONCLUSION:

The status of (PPN) with special reference to India was reviewed in the present document. *Meloidogyne* sp. seems to be the most destructive species. Thus, the focus of the review was oriented towards popular and environmentally safe strategies applied to manage this species. During the present study, the most visible outcome was the role of specific plant/ mycorrhizae /compounds, which control a particular species of Meloidogyne at variable rates. For the management of *M. hapla* and *M. gaminicola*, *Petroselinum crispum* and *Waltheria indica* were most effective. The activity of these was due to the presence of Xanthotoxin, psoralen, bergapten and oxypeucedanin, quinolone alkaloids, methoxywaltherione, waltherione A and waltherione C. The best controlling agents for *M. javanica* found by various authors were Phenolic monoterpene, Essential oil (EO), *Inula viscose, Myrtus communis*, neem and *Foeniculum vulgare*. The nematicidal property of these was assumed due to the occurrence of Carvacrol, Costic acid, Isocostic acid, EO

Phenylpropanoids, trans-Anethole and estragole. *M. incognita* was reflected as the most damage causing species of *Meloidogyne.* Lantana, Mexican marigold, *Calotropis procera, Ricinus communis, Ficus elastic,* neem, *Artemisia annua, Calotropis gigantea, Tagetes Patula, Ocimum sanctum,* Dinbera, Cucumis, *Eucalyptus microtheca, Acacia nilotica, Chenopodium album, Lepidium sativum, Verticilium chlamydosporium*+Corbofuran+neem, marigold, *Triumfetta grandidens, Cinnamomum cassia, garlic, Crotalaria virgulata, p. suffructicosa, Punica granatum, Thymus vulgaris*, *Artemisia absinthium, E. angustifolia, Eruca sativa, Aspergillus flavus+Penicillium chrysogenum+Pochonia chlamydosporia, O. vulgare, O. dictamnus, M. pulegium, M. officinalis, Paecilomyces lilacinus*+neem, Argemone, *Couroupita quianensis, Nepeta cataria, Agastache rugosa, Melia azedarach, Canavalia ensiformis, P. lanceolata, Pomegranate,* Chia, Medicago *etc.* were observed most effective in the reduction of the population of this species **(Table 1)**. The possible cause for activity related to active compounds present in these sources. In the future researchers may exploit the combination/s of these active compounds in an appropriate ratio and can develop a strong eco-friendly, highly efficient, and cost-effective nematicidal formulation as a sustainable solution to farmers against *Meloidogyne sp.*

Table 1: List of some most efficient plant species against *Meloidogyne* sp

Species	Most effective	Actual Compound
M. gaminicola	***P. fluorescens*, Neem cake and Carbofuran**	**-**
***M. hapla*.**	***P. crispum* & *W. indica***	**Xanthotoxin, Psoralen, Bergapten, Oxypeucedanin quinolone, alkaloids, methoxywaltherione, waltherione A &C**
M. arenaria	***P. crispum* & *W. indica***	**Xanthotoxin, Psoralen, Bergapten Oxypeucedanin Quinolone & Alkaloids**
M. javanica	**Neem, jatropa, kachnar, bel, eucalyptus Phenolic monoterpene, Essential oil, *I. viscose*, *M. communis*, neem & *F.vulgare***	**Neem, Carvacrol, Costic acid, Isocostic acid, Phenylpropanoids, Anethole & Estragole**
Meloidogyne species	***M. azedarach* eucalyptus, neem,.garlic bulb, Palmarosa oil, *C. procera* Linseed, Mustard oil, *A. mexicana, A. aspera,* Prosopis, neem+Corbofuran & *C. flexuosus***	**Eugenol, Citral, Geraniol & Geranyl acetate**
M. incognita	**Lantana, Mexican marigold, *C. procera, R. communis, F. elastic,* neem, *A. annua, C. gigantean, T. Patula, O. sanctum, Dinbera*, *Cucumis*, *E. microtheca*, *A. nilotica*, *C, album*, *L. sativum, Verticilium chlamydosporium*+Corbofuran+neem, marigold, *T. grandidens, C. cassia,* garlic, *C. virgulata, P. suffructicosa*, *P. granatum*, *T.vulgaris*, *A. absinthium, E. angustifolia, E. sativa, A. flavus+P. chrysogenum+P. chlamydosporia, O. vulgare*, *O. dictamnus*, *M. pulegium*, *M. officinalis*, *P. lilacinus*+neem, Argemone, *C. quianensis, N. cataria, A. rugosa, M. azedarach, C. ensiformis, P. lanceolata,* Pomegranate, Chia, Medicago, *A. marmelos.***	**Caffeic acid, Chlorogenic acid, Artemisinin, Artesunate, Fisetin, Galangin, Isorhamnetin, Morin, Myricetin, Flavone, Terthienyl, Alkaloids, Cinnamaldehyde, Diallyl sulphide, Erucin, Pentyl isothiocyanate, Hexyl isothiocyanate, Hexenal, Ethylfuran, Methyl thiocyanate, Phenylalanine ammonia lyase, Polyphenol oxidase, Peroxidase, Essential Oils, Terpenes, Lantanillic acid, Camaric acid, Oleanolic acid, Eugenol, Methyleugenol, Glucose, Canavanine, Xanthotoxin, Aconitic acid, Malic acid, Citric acid, Palmitic acid & Carboxymethylcysteine.**

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