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Review Article

ANTINEMIC PROPERTIES OF THE BOTANICALS

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ABSTRACT
Plant parasitic nematodes are ubiquitous, microscopic round worms which affect almost all the agricultural crops of the world and cause substantial yield loss to the farmers. They pave way for the entry of secondary fungal and bacterial pathogens into the plants and nematodes aggravates the disease severity in the plants which ultimately result in death of the plants. Owing to the concern on the environmental protection, botanicals in the nematode management are gaining attention in recent days as they are ecofriendly, cost effective and compatible with other biocontrol agents and agrochemicals. They won't produce any residual effects on their application. Many plants were identified as antagonistic plants against plant parasitic nematodes. These plants exhibit antagonistic nature by the production of secondary volatile and non-volatile exudates from their different parts *viz*., leaf, flower, root and stem. Antinemic properties of various plants and their mechanism involved in the nematode management are discussed in this review.

KEY WORDS: Botanicals, management, nematodes.

INTRODUCTION

Plant parasitic nematodes are microscopic in nature and cause significant damage to almost all the crops. Global crop loss caused by plant parasitic nematodes is estimated to be more than $100 billion annually (Khan *et al*., 2008). Among the 50 per cent of potential crop losses caused by pests, 12.3 percent is estimated to be caused by nematodes and more damage to the crops due to nematode infestation is noticed in the developing countries than in the developed countries (Sasser and Freckman, 1986). Increased use of various chemicals under intensive cultivation practices for the management of nematode has not only contaminated ground and surface water but has also disturbed the harmony existing among the soil, plant and microbial population (Bahadur *et al.*, 2006). There has been growing public concern about the negative impact of nematicides and inorganic fertilizers on the environment and on the safety and quality of food. Due to increasing awareness of the pesticide hazards to the biosphere, organic based materials have created worldwide interest in nematode control which are ecofriendly and biodegradable in nature. In turn, organic matter can be used to promote the healthy population of beneficial organisms in the soil. A number of organic components of plant origin, including oil-seed cakes, chopped plant parts and plant extracts have been used as nematode control agents (Akhtar and Alam, 1993; Tiyagi *et al.*, 2009a, 2009b). In recent days, interest has been shifted in discovering nematostatic compounds of the plant origin (Chitwood, 2002). In nature, plants produce a number of secondary metabolites to defend themselves against various pests, diseases and nematodes. In India, huge numbers of plants are available which have nematicidal properties. These botanicals offer an alternate strategy for the nematode management due to their facile biodegradability, selective toxicity to target organisms and ecofriendly nature. Different plant extracts have been tested by different scientists for their nematicidal properties (Netscher and Sikora, 1990; Akhtar, 1999). Botanical pesticides are readily available in many places and are often cheaper than their synthetic counterparts. Furthermore, crude extracts of the botanicals are easy to prepare by farmers. Addition of organic amendments to the soil stimulates microbial activity and increased accumulation of this matter from plant decomposition and microbial metabolites were deleterious to nematode population in the soil (Chitwood, 2002). Nematicidal properties of the botanicals have already been documented earlier by various Scientists. The plant products *viz*., leaf extracts (Netscher and Sikora, 1990; Akhtar, 1999), oil cakes (Yadav, 2006), plant latex (Siddiqui and Alam, 1990), decomposed products of indigenous medicinal plants and their parts (Goswami and Vijayalakshmi, 1983 & 1986; Jain and Hasan, 1984) are known to have antihelmintic properties. Among the botanicals, *Azadirachta*, *Eucalyptus*, *Chrommelina*, *Sida acuta* and *Tagetes* have been found to be very effective in nematode control (Umar *et al*., 2010).These botanicals not only control nematodes but also improve soil productivity and crop yield by several folds. Botanical extracts that contain alkaloids and flavanoides were found to have ovicicidal property against *Meloidogyne* eggs (Adegbite, 2003).

Botanicals and its products in nematode management

a. Botanical extracts

Aqueous extracts of leaves of Moringa (*Moringa oleifera*), African basil (*Ocimum gratissium*) and neem (*Azadirachta indica*) exhibited pathogenicity effect on *Meloidogyne incognita* race 2 infesting cowpea. All the extracts reduced the egg hatching of *M. incognita* upto 40 - 63.7% per cent enhanced the juvenile mortality from 82 - 93.8 per cent (Cladius-Cole *et al*., 2010). Extracts from Neem (*Azadirachta indica*), Bael (*Aegle marmelos*), Jatropha

(*Jatropha curcas*), Eucalyptus (*Eucalyptus globus*), Sahjan (*Moringa oleifera*), Ber (*Ziziphus mauritiana*), Sarifa (*Annona reticulate*) and Congress grass (*Parthenium argentatum*) were found to be most effective in reducing the population of rice root knot nematode, *Meloidogyne graminicola* in rice. These extracts significantly increased the growth of the plants (Mukesh Dongre and Sobita Simon, 2013). Aqueous extracts of Baker tree (*Milletia-ferruginea*), Bitter leaf (*Vernonia amygodalina*), Parthenium (*Parthenium hysterophorus*), Lantana (*Lantana camara*), Mexican marigold (*Tagetes minuta*), Mexican tea (*Chenopodium ambrosioides*), Neem (*Azadirachta indica*) and Pyrethrum (*Chrysanthemum cinerariafolium*) at 5% concentration recorded nematicidal properties against *M. incognita in vitro.* Mexican marigold leaf, Bitter leaf, Lantana leaf and Baker tree seeds were the most efficacious in nematode control which recorded about 95% inhibition of nematode eggs. In tomato, application of the above botanicals reduced the formation of galls produced by root knot and recorded low nematode population in the soil (Wondimeneh Taye *et al.,* 2013).

Aqueous extracts of tubers of medicinal yam, *Dioscorea floribunda* inhibited the egg hatching of *Meloidogyne incognita* (Nath and Mukherjee, 2000) and killed the juveniles within 4 h of application. Similarly, aqueous extract of *Datura stramonium* was also found to be more effective on the second stage juveniles of *M. javanica* in tomato plants (Al-Saba *et al.*, 2001).

Water soluble fractions of neem exhibit toxic properties against root-knot nematodes and reduced their ability to infect host roots (Khanna, 1991; Kathirvel *et al.,* 1992; Mojumder and Mishra, 1991). Seed and leaf extracts of neem (*Azadirachta indica)* reduced juvenile mortality of the root knot nematodes on potato (Akhtar and Alam, 1991; Khurma and Sing, 1997; Upadhyay *et al*., 2003). Azadirachtin is the major nematotoxic compound present in neem and all other nematotoxic compounds are released through volatilization, exudation, leaching and decomposing of the plant parts (Akhtar, 2000 and Ntalli *et al.,* 2009). Application of Garlic bulb extracts reduced root-knot infection indices on tomato. Garlic extract was found to have greater potential than neem leaf extract in the control of root knot infection in tomato (Agbenin *et al*., 2005). Seed extracts of *Calotropis* (Uma *et al*., 1997) and its leaf extracts (Trivedi *et al*., 1980) were found to reduce the nematode population to a greater extend. In mulberry, leaf extracts of *Datura stramonium, Azadiracta indica, Calotropis procera* and *Crotalaria juncea* reduced the infestation of *M. incognita* among which the highest juvenile mortality (82.8 %) was recorded with neem extract (Vijaya Kumari Nelaballe and Lakshmi Devi Mukkara, 2013). Tomato plants treated with the leaf extracts of *Calotropis gigantea* had highest seed germination with reduced root knot nematode infestation at the time of harvest (Saranavanapriya and Sivakumar, 2005). Extracts of Bitter leaf, *Vernonia amygdalina* significantly reduced nematode populations in the eggplant (Afouda *et al*., 2008). Leaf extracts of *Glyricidia maculata, Ricinus communis, Crotalaria juncea, Glycosmis pentaphylla, Azadirachta indica, Kalanchoe pinnata, Piper betle* and *Moringa oleifera* exhibited nematicidal properties against the *Radopholus similis* (Jasy and Koshy, 1992).

Shoot extracts of *Euphorbia helioscopia*, *Descurainia Sophia*, *Gypsophila pilosa*, *Eruca sativa* and *P. lanceolata* were found to suppress the root galls in tomato plants produced by *M.incognita* and increased the fruit yield of the plant (Hoseinpoor and Kargar, 2012). Stem bark of *Cinnamomum cassia* inhibits temporarily the activity of *M. javanica* and *Pratylenchus vulnus* (Ferris and Zheng, 1999). This is used as crude drugs in many traditional prescriptions in oriental medicine and found to have some nematicidal or nematostatic components in it. Flower extract of the Marigold, *Tagetes erecta* cv. Indian Yellow at 10% concentration effectively reduced the hatching of *M. incognita* eggs (4.75 %) and increased the mortality of its juveniles (100 %) when treated *in vitro* (Sankari Meena *et al*., 2010a) where as in tomato under glass house condition, root extract of *Tagetes erecta* cv. Indian Yellow effectively reduced the root and soil population of *M. incognita* which recorded 79.26 and 92.17 % decrease of root (female) and soil (juvenile) population over control (Sankari Meena *et al*., 2010b). Effectiveness of botanicals increased with increase in their doses. Generally, higher dose was proved to be more effective in improving the plant growth characters and reducing root knot index and final soil nematode population (Tulika Singh *et al*., 2012).

Higher dose (80 ml/m^2) of Dimethyl disulfide (natural biopesticide extracted from *Allium* spp.,) was found to reduce *Meloidogyne incognita* incidence in tomato but did not accelerate vegetative growth of tomato plant whereas low concentration of DMDS (30 ml/m^2) was found appropriate for controlling root knot nematodes of tomato, accelerating saprophytic nematode population in the soil and also enhancing vegetative growth of tomato plant under dry condition of soil (Faruk *et al*., 2011).

b. Botanicals as organic amendments

Application of organic soil amendment has some advantages over chemical control because the former is less hazardous and pollution free. Among various organic materials, application of neem cake (Alam *et al*., 1978) and mustard cake (Gul *et al*., 1990) have shown significant result in the control of nematodes. Soil amendments with oriental herbal medicines such as fruit of *Anethum graveolens*, flower buds of *Syzygium aromaticum*, rhizome of *Cnidium officinale*, rhizome of *Coptis chinensis*, root bark of *Paeonia suffructicosa*, stem bark of *Phellodendron amurense* and stem bark of *Cinnamomum cassia* were found to reduce *Meloidogyne incognita* infestation in tomato. Among them, root bark of *P. suffructicosa* and stem bark of *C. cassia* showed consistent results in reducing root knot nematode galls (Ferris and Zheng, 1999). Application of powder of cocoa bean testa and oil palm fruit fiber as mulches in green house pots against *M. javanica* in tomato reduced nematode population in the plant (Ojo and Umar, 2013). The cocoa bean testa powder probably acted directly on the second stage juveniles in the soil, thus reducing number of juveniles penetrating the roots of tomato plants in the green house. Crude extract of cocoa bean testa was found effective against eggs and juveniles of *M. javanica in vitro.* Dry leaves of *Azadirachta indica, Calotropis procera, Datura stramonium, Crotolarza juncea* and *Vitex negundo* were

effective in reducing root lesion nematode, *Pratylenchus coffeae* infesting banana cultivars Nendran and Rasthali and their application increased yield of the plant (Sundararaju *et al*., 2003). Ground neem seed and tobacco waste dust (Motha *et al*., 2010) and Mustard cake (Khan *et al*., 1996) had significant impact in the control of root knot nematodes. *A. indica* and *C. procera* when applied to okra increased plant growth characters and reduced the population of root-knot nematodes in it (Ramkrishnan *et al.,* 1997). Addition of chopped leaves of *C. procera and R. communis* significantly reduced root knot nematode population in brinjal roots (Nandal and Bhatti, 1990). Reduction in the fecundity of *M. incognita* in pointed gourd was observed due to application of neem (as pure Azadiractin/leaf/cake) (Chakraborti, 2000). Neem cake prepared from crushed neem seeds provides nitrogen in a slow-release form in addition of protecting the plants against parasitic nematodes. It can be mixed with fertilizers such as composted manures, seaweed and kelp to increase its efficacy (Anon, 1998). Neem cake is toxic to plant-parasitic nematodes and not detrimental to beneficial free-living soil organisms. Neem cake contains organic matter and plant nutrients like nitrogen, phosphorus and potassium. Different parts of neem are known to contain over 40 bitter principles which include terpenoid, triterpenoid, limonoid and flavanoids (Thakur *et al.,* 1981). Other limonoids which have been found in traces are meliantriol, salannin, nimbin and nimbidin. Central Insecticides Board of India has approved the registration of 300 ppm oil based and 1500 ppm kernel based neem formulations which can be used against pests (Akhtar, 2000). Application of N coated neem cake reduced the population of lesion nematode, *Pratylenchus coffeae* in banana (Sundararaju and Kumar, 2000). Amendment of soil with neem could affect the movement of nematode juveniles within soil.

Applications of the botanicals *viz*., *Argemone mexicana*, *Calotropis procera*, *Solanum xanthocarpum*, and *Eichhornia echinulata* in combination with normal as well as deep ploughing had significant effect in the reduction of plant-parasitic nematodes and soil-inhabiting fungi in chickpea (*Cicer arietinum* L.) cultivar K-850. Significant reduction was observed in the multiplication of plant parasitic nematodes like *Meloidogyne incognita*, *Rotylenchulus reniformis*, *Tylenchorhynchus brassicae* and *Helicotylenchus indicus* and in the frequency of parasitic fungi such as *Macrophomina phaseolina*, *Fusarium oxysporum*, *Rhizoctonia solani*, *Phyllosticta phaseolina*, and *Sclerotium rolfsii* by the application of botanicals to soil. Frequency of saprophytic fungi *Aspergillus niger*, *Trichoderma viride*, and *Penicillium digitatum* was also significantly increased with the above treatments (Rose Rivzi *et al*., 2012).

c. Botanical oil

Oil based formulation of botanicals was found to be effective against *M. incognita* in vegetables (Sivakumar and Gunasekaran, 2011). Chinaberry and Castor bean oil immobilized *M. incognita* juveniles and reduced the population of the nematode in soil and also increased the longitudinal growth of cucumber plant (Nafiesh Katooli *et al*., 2010). Similarly, volatiles of clove oil exerted a significant potential in the reduction of root knot nematode, *M. incognita in vitro* (Meyer *et al.,* 2008).

Essential oils from various plants like caraway, fennel, applemint, spearmint, syrian oregano and oregano were found to contain the nematicidal compounds like carvacrol and thymol. At very low concentrations (1000 micrograms /litre or 0.001 gm /litre), these oils immobilized the juveniles of root knot nematodes and reduced hatching of the nematode eggs (Oka *et al*., 2000).

Neem oil based formulation, when used as seed treatment and bare root dip controlled the population of root knot nematode, *Meloidogyne incognita* in tomato and chickpea (Akhtar & Mahmood, 1997; Vijayalakshmi and Reshmi Basu, 1999; Javed *et al.,* 2008).

d. Dry powder of botanicals

Dry powder of botanicals also had significant impact in the control of nematode population in soil. Dry powder extracts of *Newbouldia laevis*, when applied to African yam bean plant significantly reduced the galls produced by *M. incognita* in the plant (Ugwuoke *et al*., 2011).

Leaf powder of rock fleabane (*Inula viscose*) at a low concentration of 0.1 per cent reduced the juvenile population of *Meloidogyne javanica* and *Tylenchulus semipenetrans* but had no effect on stem and bulb nematode (*Ditylenchus dipsaci*) (Oka *et al*., 2001).

Dry neem leaves incorporated into the soil reduced root-knot nematode, *Meloidogyne incognita* and significantly enhanced the weight of fruits in eggplants (Khan *et al*., 2012a).Tobacco dust, which is produced as a waste in tobacco processing has nematicidal activity when it was tested in tea plantations. Therefore, tobacco waste dust could be used as a beneficial biopesticide for root knot nematode management in tobacco. Toxic compounds present in tobacco include nicotine, germacrene, anabasine, piperidine and alkaloids which may exhibit the nematicidal properties (Panter *et al*., 1990).

e. Nematicidal principles of botanicals and botanical based biopesticides

Azadirachtin is the major nematotoxic compound present in neem and they are released through volatilization, exudation, leaching and de-composing of the plant parts (Akhtar, 2000 and Ntalli *et al.,* 2009). Tobacco plant contains nicotine, a powerful neurotoxin that is particularly harmful to insects (Panter *et al*., 1990). Asparagus roots contained a certain glycoside which was toxic to the nematode, *Trichodorus Christie* (Rohde and Jenkins, 1958). These glycosides have systemic action in nematode control. Toxic principle of Marigold is terthienyl and bithienyl compounds (Uhlenbroek and Bijloo, 1958 and 1959). Marigold plant significantly lower the galls produced by *M. incognita* on vegetable crops (Yen *et al*., 1998). Allicin derived from garlic, *Allium sativum* exhibited nematicidal activity against the root knot nematode, M. *incognita* even at concentrations less than 0.5 µg / ml (Gupta and Sharma, 1993). Crucifers contain antinemic compounds namely, phenyl isothicyanate which reduced the nematode population *viz*., *Meloidogyne* spp., *Globodera rostochiensis* to a greater extend (Morgan, 1925; Stahmann *et al*., 1943).

Indian farmers without the knowledge of the chemical constituents have been using neem products as a traditional method of pest control for centuries. Increasing interests in neem in recent years have resulted in the development of cheap, safer and ecofriendly nematicides and pesticides. Neem seed constitutes the basic raw

materials for neem products. Currently number of azadirachtin based insecticides are available in India *viz*., Achook, Nemin, Jawan, Repelin, Sunneem etc., Considering safety to the environment, human health hazards and cost of nematode management, botanical nematicides will be much safer and highly practicable. It can easily fit into the integrated nematode management programmes. Neem based formulations, Azadirachtin (Achook® 0.15% EC and Nimbecidine® 0.03% EC) proved highly active against *Meloidogyne incognita* in tomato plants, which reduced nematode population of about 70 per cent. (Agbenin, 2009, Saad *et al.*, 2011& 2012, Khalil, 2013). Appliation of Azadirachtin suppressed root-knot nematode (*Meloidogyne incognita*) on cucumber (Lynn *et al*., 2010) and cyst nematode (*Globodera rostochiensis*) on potato (Trifonova and Atansov, 2011). Margosan-O, Azatin, Superneem 4.5, Neemix and Triact are also some of the neem products registered as a potential insecticides, fungicides and miticides.

TABLE 1. Different plant extracts used against nematodes

Botanicals	Parts used	Target nematode	Reference
A. indica; C. procera; *Melia azedarach*	Leaf	*M. incognita* (eggs and juveniles)	Ramanpreet Singh *et al*.(2001)
Ocimum sanctum; *O. basilicum*	Leaf	*M. incognita* (eggs and juveniles)	Kanta Gill *et al*. (2001)
Bauhinia variegata ; *I. parviflora*; *M. oleifera; T. erecta; A. scholaris; C. pulcherrima; A. Mexicana; B. cambestris*	Flower	*M. incognita* (eggs and juveniles)	Rakesh Pandey *et al*.(2001)
T. patula ; *T. erecta*; *T. minuta*	Root	*M. incognita* (juveniles)	Cannayane and Rajedran (2002)
Catharanthus roseus ; *Crotalaria juncea; C. striata*; *Pueraria phaseoloides, G. maculate*	Plant	*M. incognita* (juveniles)	Sosamma and Jayasree (2002)
Brassica spp.	Oilcake	*Tylenchulus semipenetrans* (juveniles)	Sinha and Neog (2002)
Artemisia vulgaris	Rhizome	*M. megadora* (juveniles)	Doss *et al*.(2003)
Nicotiana tabaccum Bidi tobacco cv.GT5 and GTH 1; *N. rustica*; Chewing tobacco cv.GC1.	Leaf	*Meloidogyne* species (eggs)	Sharma and Patel (2003)
Acorus calamus; *Vitex trifolia; Albizia chineus*; *Parkin roxburghii*	Leaf	*M. incognita* (juveniles)	Joymati *et al*. (2003)
Chrysanthemum coronarium	Flower	*Meloidogyne artiellia* (eggs and juveniles)	Perez *et al*. (2003)
Argemone mexicana; *Lantana camera; A. indica*	Leaf	*M. incognita* (eggs and juveniles)	Patel *et al*. (2004)
Areca catechu; *Carica papaya*; *C. gigantea*	Seed and latex	*M. incognita* (eggs)	Saravanapriya *et al*. (2004)
Tagetes erecta	Flower and root	*M. incognita* (eggs and juveniles)	Sankari Meena *et al*. (2010a & b)
Swietenia mahogany	Seed	*M. incognita* (eggs)	Mohana (2005)
Citrus aurantifolia; *Annona squamosa*; *Psidium quajava*; *Aegle marmelos*	Fruit	*M. incognita* (juveniles)	Ranjana Sexena and Gangopadhya (2005b)
Catharanthus roseus; *Callistemon laceolatus*; *Dandelion* sp.; *Chrysanthemum* sp.	Leaf	*M. incognita* (juveniles)	Ranjana sexena and Lalita (2005)
Arnica montana; *Calendula officinalis*; *Carica papaya*; *A. indica.*	Root	*M. incognita* (juveniles)	Rajendran and Saritha (2005)
Acalypha indica; *Cassia fistula*; *Solanum torvum*	Leaf	*Pratylenchus coffeae* (juveniles)	Sundararaju and Saritha (2006)
Azadirachta indica, Carica papaya;Ocimum sanctum; Ricinus communis;Tagetes patula	Leaves	*M. incognita* (eggs)	Bharadwaj and Sharma (2007)
Datura fastuosa; Ricinus communis;Azadirachta indica; Solanum nigrum;Bougainevillea glabr; Calotropis gigantia; Ocimum sanctum;Allium cepa	Leaves	*M. incognita* (juveniles)	Upadhyay *et al*. (2007)
Clerodendron indicum; C. serratum; Tectona grandis; Mussenda glabra;Melia azadirachta; Xylosoma longifolia;	Leaves	*M. incognita* (eggs and juveniles)	Joymatidevi (2007)
Icornia latifolia;Uvaria kerniyae; Cymbopogon citrates; Tetrapleura	Leaves	*M. incognita* (juveniles)	Ononuju and Kpadobi (2008)

tetraptera; Azadirachta indica.			
Cassia tora and Morus alba	Leaves	*M. incognita* (juveniles)	Tanweer *et al*.(2009)
Nicotiana tobacum; Syzygium aromaticum;Piper betle; Acorus calamus	Leaves	*M. incognita* (juveniles)	Wiranto *et al*.(2009)
Cassia tora; Morus alba; Musa paradisica;Psidum guajava	Leaves	*M. incognita* (juveniles)	Tanweer and Hissamuddin (2010)
Melia azadirachta and *Brassica spp.*	Leaves and seed oil	*M. incognita*- juveniles	Nafiseh katooli *et al*. (2010)
Calotrophis procera; Sesbania surattense;Datura stramonium; Parthenium hysterophorus	Leaves and roots	Reniform nematode (juveniles)	Sunaina *et al*. (2010)
Foeniculum vulgare; Pimpinella anisum;Pistacia terebinthus	Essential oil	*M. incognita* (juveniles)	Nikoletta *et al*. (2010)
Anagallis arvensis; Curcuma longa; Mentha viridis; Moringa oliefera and Ocimum sanctum	Leaves, fruits and seeds	*Tylenchorhynchus Mashhoodi; T. nudus, Hoplolaimus indicus, Helicotylenchus dihystera, Meloidogyne incognita* and *Pratylenchus zeae* (juveniles)	Haidar and Askary (2011)
Castor bean, chinaberry, sweet wormwood and rapeseed	Leaf	*Meloidogyne incognita* (juveniles)	Katooli *et al*. (2011)
Red chili	Fruit	*M. incognita* (eggs and females)	Sajid Aleem Khan *et al*. (2011)
Jatropha curcas; Parkia biglobosas; Newbouldia laevis; Ficus exasperata and *Cassia alata*	Leaf	*Meloidogyne incognita* (juveniles)	Ugwuoke *et al.* (2011)
Murraya koenigii and *Vitex negundo*	Leaf extract	*Rotylenchulus reniformis* (juveniles	Usman and Siddiqui (2013)
Garlic, castor beans and marigold	Bulbs, leaves and flowers	*Meloidogyne javanica* (juveniles)	Tibugari *et al*. (2012)
Tithonia diversifolia; *Azadirachta indica*; *Zanthoxylum zanthoxyloides* and *Datura metel*	Leaves	*Meloidogyne incognita* (juveniles)	Akpheokhai *et al.*(2012)
Glycosmis pentaphylla and *Holarrhena antidysenterica*	Leaf and bark	*M. incognita* (juveniles)	Bhattacharya *et al*. (2012)
Couroupita quianensis; Nepeta cataria and *Pentanema indicum*	Leaf	*Meloidogyne incognita* (eggs)	Pavaraj *et al.* (2012)
Datura stramonium	Leaves	*Meloidogyne javanica* (juveniles)	Kavita Parihar *et al.*(2012)
Chrysanthemum coronarium, Azadirachta indica, Nerium oleander	Leaf and seed	*Meloidogyne javanica* (eggs and juveniles)	Mohammad Reza Moosavi (2012)
Bitter leaf and Cashew	Leaf, seed kernel	*Meloidogyne incognita*	Umar and Aji (2013)
Water hyacinth	Leaves	*M. incognita* (juveniles)	Umar and Mohammed (2013)
Calotropis procera	Fresh leaves	*Meloidogyne incognita* (eggs and juveniles)	Abdul Nazir Chedekal (2013)
Neem	Oil	*Meloidogyne incognita* (eggs)	*Dourado et al.(2013)*
Rauvolfia tetraphylla	Root, leaf and fruit extract	*Meloidogyne incognita* (juveniles)	Tapan Kumar Mandal and Nandi (2013)
Mimusops elengi	Leaf	*Meloidogyne incognita* (eggs)	Azhagumurugan and Rajan (2013)
Calotropis procera	Leaves	Root knot nematode (eggs)	Oluwatoyin Eunice *et al*. (2013)
Garlic (*Allium sativum*) cloves and castor bean (*Ricinus communis*)	Seed	*Meloidogyne incognita* (eggs and juveniles)	Wafaa Mohamed Abd-Elhameed El-Nagdi and Mahmoud Mohamed Ahmed Youssef (2013)
Castor bean	Seed	*Meloidogyne* spp.(eggs and juveniles)	Adomako and Kwoseh (2013)
Hunteria umbellata and *Mallotus oppositifolius*	Leaf	*Meloidogyne incognita* (eggs and juveniles)	Okeniyi *et al.* (2014)

CONCLUSION

Botanicals are the natural plant products when applied to the field enhance the growth of the plants in addition to nematode control. Application of botanicals or botanicals based byproducts to the soil leaves no residues in the field and are economically viable to the farmers. Concerning the environmental safety, now-a-days botanicals are gaining much importance in the integrated nematode management (INM) practices. Many botanical based products are available in the market for the control of pathogens and nematodes. Efficient use of the botanicals will increase productivity of the crop by reducing the insect, pathogen and nematode damage in it which inturn improve the economic status of the farmers. Moreover, application of botanicals to the crops will yield healthy

fruits and vegetables without chemical contamination which results in healthier human generations.

Future prospects

More understanding of the active nematicidal principles of the botanicals will likely to aid in the development of next generation bionematicides with nematode antagonism and improved plant growth and yield attributes.

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