NEMATODE PESTS OF SPICES AND THEIR MANAGEMENT

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INTRODUCTION

Spices play an important role in the economy of many countries. India is known as 'Home of Spices' since large varieties of species originated and are grown in the country. Spices production, productivity and quality are affected by several factors. Phytonematodes are one of the factors responsible for low production in species. Generally, spice growers consider nematodes and nematode diseases as subtle and mysterious due to non-descript above ground symptoms and these symptoms are usually confused with the aberrations due to abiotic factors like nutrient deficiency, mositure stress etc. Further, nematode problems are difficult to identify, demonstrate and control because nematodes are invisible and live in an inaccessible and secluded environment. Nematodes, besides feeding and damaging the host plant roots, are also responsible for rendering the plants susceptible to attack by several bacterial and fungal pathogens leading to disease complexes. The type of crops grown and the intensity of cultural practices are important determinants of nematode species and populations. Nematode problems become more severe when good host crops are grown continuously on the same land. Plant parasitic nematodes are either ecto-parasites or endo-parasities and are also either sedentary or migratory depending on their parasitic habits.

MAJOR NEMATODES ASSOCIATED WITH SPICE CROPS

The economic importance of phytonematodes in spices cultivation is now well recognized by spice producing countries. Among the several plant parasitic nematodes associated with spice crops, a few species like *Meloidogyne* spp. (root knot nematodes), *Radopholus similis* (burrowing nematodes), *Pratylenchus* spp. (lesion nematodes) are economically important in spices cultivation.

Meloidogyne spp. (Root knot nematodes)

Root knot nematodes are of great economic importance and are prevalent throughout tropical and subtropical countries. These nematodes occupy unique position in spices cultivation since almost all spice crops are attacked by them.
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Among several species of root knot nematodes, *Meloidogyne incognita, M. javanica, M. arenaria* and *M. hapla* are known to infest several spice crops, while *M. incognita* is the most predominant species. Root knot nematodes have highly developed complex relationships with the host plants. These nematodes are sedentary endo-parasites feeding on vascular tissues and due to hypertrophy and hyperplasia of the tissues, characteristic galls or knots are produced on the infested roots. Second stage juveniles emerging out of the eggs infest the roots and after establishing the feeding sites in the vascular tissues the nematodes develop further and the adult nematodes lay eggs in a gelatinous matrix. The galled roots attract several soil borne fungal and bacterial pathogens, resulting in rotting and disintegration of the roots. Due to the damage to roots, the infested plants express symptoms like stunted growth, foliar yellowing, wilting etc.

Radopholus similis (Burrowing nematodes)

Burrowing nematodes are more important and destructive nematodes pests of several important horticultural and plantation crops and are prevalent throughout tropical and warm temperate regions. These are migratory endoparasites and cause extensive damage to root cortical tissues. The nematodes are small and all mobile stages, except adult males, are infective. The nematodes can infect all succulent under ground plant parts, but prefer root tips. Nematode feeding activity is restricted to cortical tissues. Dark brown lesions, a characteristic symptom of the burrowing nematode infestation, develop on roots at the point of nematode entry. These lesions enlarge as nematodes feed and move inter and intra-cellularly in the cortical tissues and attract invasion by other microorganisms resulting in root rot. Thus, the burrowing nematodes cause extensive damage to roots, depriving the plants nutrients and water from the soil. Foliar yellowing, defoliation, wilting, reduced growth, reduction in yield and in some cases total loss of the plants are accompanied symptoms with the burrowing nematode infestations in several crop plants.

Pratylenchus spp. (Lesion nematodes)

Species of *Pratylenchus* are generally known as lesion or meadow nematodes and are tropical and subtropical in distribution. Like the burrowing nematodes, these are

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also migratory endo-parasites. The damage roots by direct feeding and also through destructive secretions. Root injury is aggravated by the attack of other soil borne microorganisms. All the stages of the nematodes from second stage juvenile are infective. The nematode feeds on cortical tissues forming cavities or galleries consisting of all stages of the nematode. The root parts where these nematodes multiply assume dark red or brown colour due to necrosis of the invaded cells. The nematodes also infest the under ground plant parts like rhizomes leading to rotting and direct loss to the produce as in the case of ginger, turmeric etc. The symptoms produced on the above ground plant parts are similar to that of caused bythe burrowing nematodes.

NEMATODE PROBLEMS IN SPICE CROPS

Black pepper

Phytonematodes belonging to 30 genera and 54 species are reported in association with black pepper throughout the world. Among these, very few species like *Meloidogyne incognita*, *Radopholus simiis*, *Trophotylenchulus piperis*, *Helicotylenchus* spp., *Rotylenchulus reniformis* are predominantly associated with the crop in India. Among these also root knot and burrowing nematodes are of economic importance as they are found infesting the crop in all pepper growing countries and are involved in 'slow decline' disease, a major constraint in pepper cultivation. The disease is prevalent in India, Malaysia, Indonesia, Brazil, Thailand, Sri Lanka etc. It is a debilitating disease over a period of time. The diseased plants exhibit yellowing of leaves, defoliation, die back, loss in vigour and productivity (Fig.1). These plants some times recover with the onset of monsoon when the plants put forth-new roots. However, these plants succumb to the disease in due course of time when root regeneration can not compensate root loss due to nematode damage (Ramana, 1992).

Though, nematodes are incitants of the disease, other soil borne pathogens aggravate the onset and severity of the disease. Feeder root damage caused either by nematodes or the fungus, *Phytophthora capsici* or their combined interaction leads to the development 'slow decline' disease (Anandaraj, Ramana and Sarma, 1996a, 1996b, Ramana, Sarma and Mohandas, 1992).

Three species of root knot nematodes viz., *M. incognita, M. javanica* and *M. arenaria* are reported on black pepper. Among these, *M. incognita* is the most widely distributed nematode in black pepper gardens in all pepper growing countries. Barber followed by Butler in 1906 and Ayyar in 1926 first reported the occurence of this nematode in India on black pepper. Subsequently surveys revealed the predominant occurrence of this nematode in all pepper gardens in Kerala (69.8%) and Karnataka (53.8%) (Ramanan and Mohandas, 1987, 1989). The nematode infests all types of roots. On thick primary roots, due to multiple infection by the nematodes, the whole length of the root turn into a gall

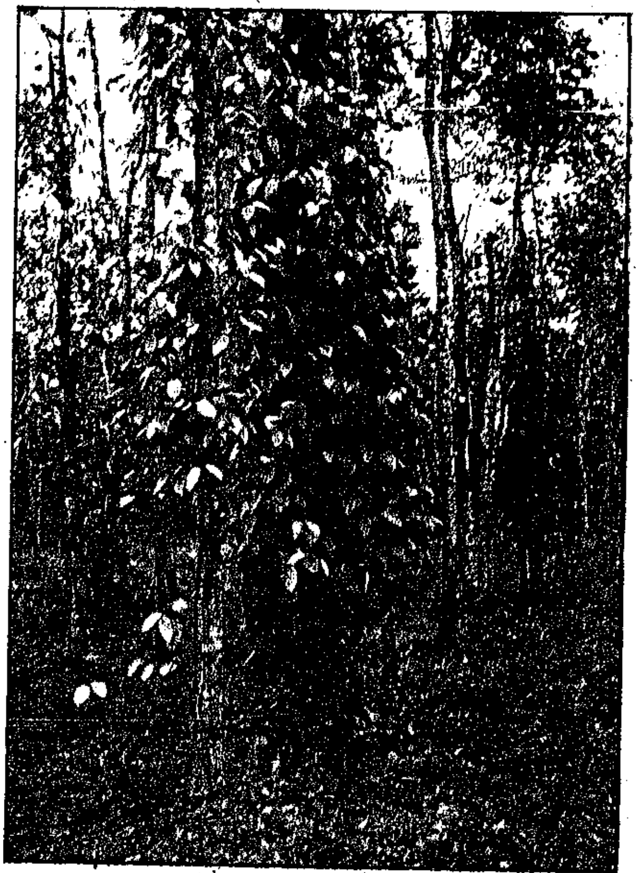

Fig.1 A black pepper vine affected with 'slow decline' disease.

while typical galls or knots are present on the fibrous roots. When the galled root is split opened longitudinally, many adult females with egg masses can be seen. In the nursery, infested rooted cuttings are stunted, leaves show yellowing or interveinal chlorosis, with reduction in total root mass and left with a few galled roots (Ramana, Mohandas and Eapen, 1994). The major means of dissemination of nematodes is through infested planting materials. In plantations nematode infested vines show stunted growth, yellowing of leaves and decline in vigour and productivity. In severely infested vines, leaves show dense yellowing of inter venial areas with deep green veins. Pathogenicity tests conducted under simulated conditions on grown up vines showed that nematodes caused significant reductions in all growth parameters and yield (37 to 46%) (Mohandas and Ramana, 1991). Root knot nematode population in black pepper plantations reaches maximum during December/January. Pepper being a perennial crop, nematodes can survive well in the agro-ecosystem. Other inter crops and common weeds in the plantation are also good hosts of root knot nematodes thus helping the survival and multiplication of the nematode to economic injurious levels.

The burrowing nematode is a serious nematode pest of black pepper and was first reported by Goodey in 1936. A disease known as 'yellows' which was responsible for the death of 20 million vines in Bangka Islands in Indonesia, was due to severe infestation by *R. similis*. In India, surveys showed its wide distribution in all pepper growing areas in

Kerala and Karnataka (Ramana and Mohandas, 1987, 1989). Nematodes move inter and intra cellularly in the cortical root tissues producing large necrotic areas and tunnels/cavities in the cortical tissues. There is complete loss of fibrous roots and in severe infestations, the plants loose almost all-vital roots and are left with a bunch of decayed root mass. As a result the roots are not able to absorb water and nutrients from the soil medium and the plants express above ground symptoms such as foliar yellowing, defoliation and retarded growth. Nematode infestation to rooted cuttings in the nursery results in the poor growth of the cuttings with leaves completely turning pale yellow (Fig. 2). These rooted cuttings fail to establish in the plantation and the infested planting materials are the main source of nematode spread. Pathogenicity tests conducted under simulated field conditions on grown up vines showed that the nematode caused typical symptoms of 'slow decline' disease viz., foliar yellowing, defoliation, die back and severity of the disease depended in the initial nematode inoculum. Nematode caused significant reduction in height, number of primary shoots, dry matter production and yield (Mohandas and Ramana, 1991).

Banana, coconut, arecanut which are highly susceptible to the burrowing nematodes are generally grown in pepper plantations either as inter crops or pepper vines are trailed on coconut or arecanut palms. These crops help in the population build up of the nematodes. *R. similis* populations are maximum during September/October and minimum during April to June in pepper plantation (Ramana, 1992).

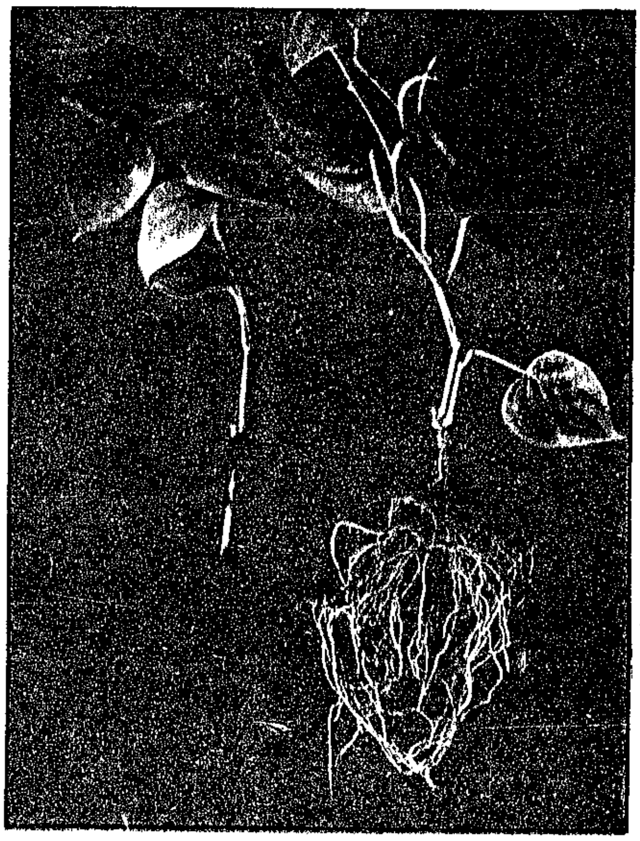

Fig.2 A black pepper rooted cutting attacked by burrowing nematodes (left) and a healthy cutting (right)

Cardamom

Phytonematodes belonging to 20 genera are reported on cardamon. Among these, the most important and more widely distributed are root knot nematodes, *Meloidogyne* spp. Other nematodes of commón occurrence are *Helicotylenchus* spp. and *Rotylenchulus reniformis. Radopholus similis* and *Pratylenchus coffaea* are other two important nematodes, generally found in mixed plantations of cardamom with arecanut and coffee respecively (Eapen, 1995). Root knot nematodes are widely distributed in most of the cardamom plantations and nurseries in Kerala and Karnataka. Out of the 3 species viz., *M. incognita, M. areneria* and *M. javancia, M. incognita* is the most predominant species. Typical root galls are produced in seedlings in the nursery. Poor germination, patchy and stunted growth, weak and unhealthy appearance of seedlings are characteristic symptoms of nematode infestation in the nursery (Fig.3).

Fig.3 Cardamom seedlings in a nursery attacked by root - knot nematodes

These seedlings fail to establish in the plantation. In mature plants/suckers, though root galling is not prominent, suppression of secondary root production and abnormal branching are common (Fig. 4). Stunted growth, poor tillering, narrowing and yellowing of leaves, drying of leaf tips and margins are some of the aerial symptoms attributed to root knot nematode infestation in the plantation. About 32 to 40% loss in yields was observed in plantations infested with the nematodes. Studies under simulated conditions also showed 46.6% loss in the yield (Eapen, 1994) Besides, root knot nematodes predispose plants to fungal pathogens like

Rhizoctonia solani leading to disease complexes like rhizome rot and damping off. Root knot nematode populations are maximum during December/January in cardamom plantations (Eapen, 1993).

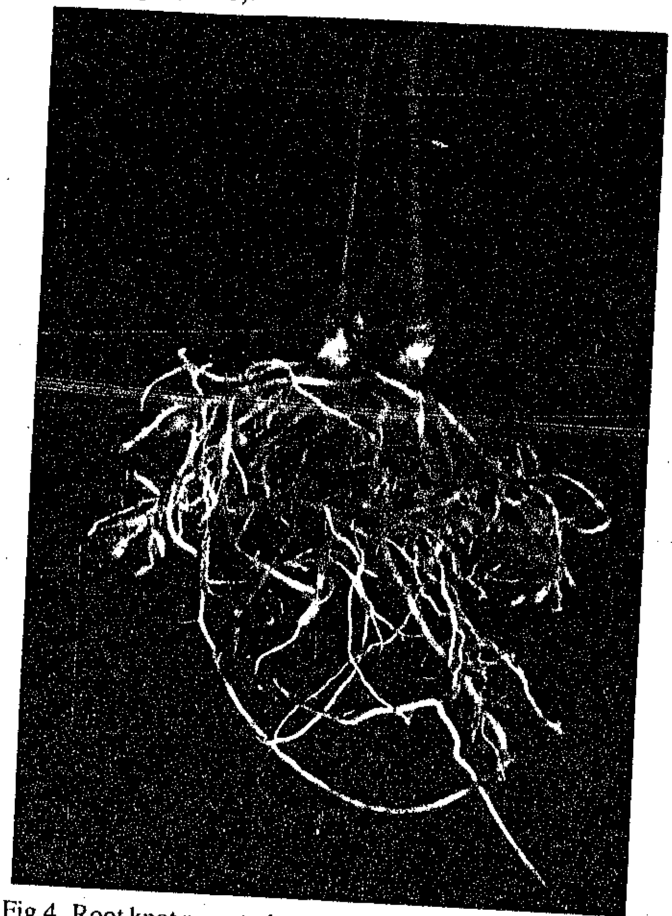

Fig.4 Root knot nematode symptoms in Cardamom

Fig. 5 Root Knot nematode symptoms in turmeric

Ginger and Turmeric

Photonematodes belonging to 17 to 20 genera was reported on ginger and turmeric, respectively. Among them, root knot nematodes and burrowing nematodes are major problems. Among three species of root knot nematodes infesting ginger and turmeric, M. incognita is predominant compared to the occurrence of M. hapla and M. arenaria. Root knot nematodes are widely distributed in ginger and turmeric fields in Kerala and Andhra Pradesh and these nematodes causes significant yield losses. A population of 2 nematodes per gram of soil is the economc threshold level.

Nematode infestation causes characteristic galls on the roots of both the crops (Fig. 5). In ginger fresh roots are invaded throughout the length but gall production is more promient on the fibrous roots (Fig. 6). Nematodes also infest the rhizomes, survive in the seed rhizomes and are carried to the field. The infested rhizomes of ginger show brown, water soaked areas in the outer tissues while in turmeric, rhizomes loose bright yellow colour due to nematode infestation. The common above ground symptoms are stunting, chlorosis, poor tillering and necrosis of leaves. The affected plants mature, dry fast and die prematurely than the healthy ones.

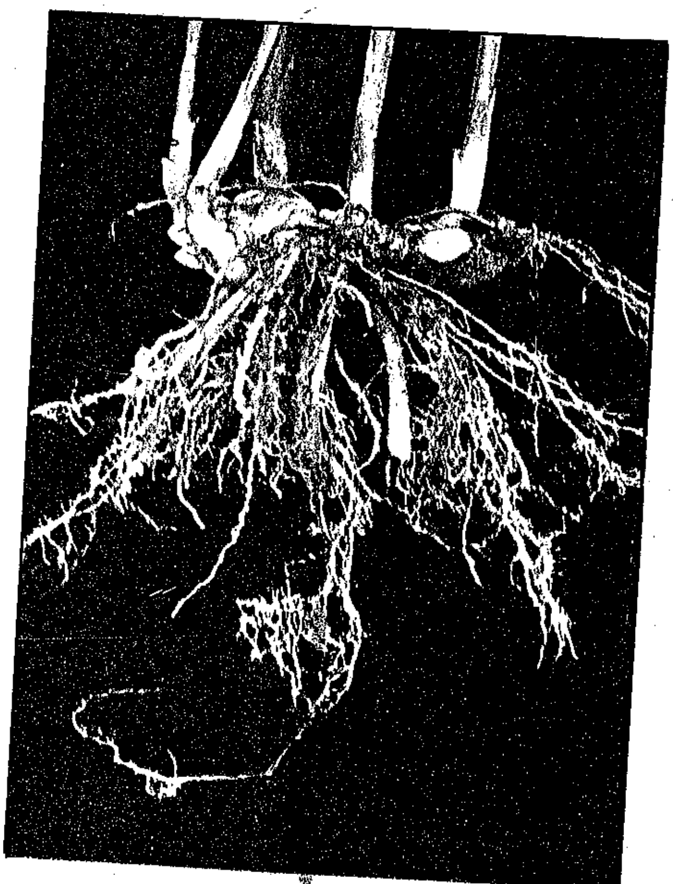

Fig. 6 Ginger roots infested with root knot nematodes

Burrowing nematodes are another important pests of ginger and turmeric. An initial level of 10 nematodes per plant caused 39.8% and 35 to 46% reductions in the rhizome weight in ginger and turmeric, respectively. The nematode causes small, shallow, shrunken water soaked lesions on roots resulting in the rotting and most of these decayed roots retain only the epidermis lacking cortex and stelar portions. The nematode also infests the rhizomes, migrate intra cellularly producing large infection channels or galleries within the rhizomes. Infested turmeric rhizomes are yellow in colour compared to golden yellow colour of the healthy ones. Infested rhizomes are the main source of nematode inoculum and aid in the dissemination. Nematode infested plants show above ground symptoms such as poor tillering, stunted growth and loss of vigour.

Several species of the lesion nematode namely, *P. coffeae, P. brachyurus, P. indicus, P. pratensis* and *P. zeae* are reported on ginger and turmeric. P. coffeae is reported to cause ginger yellows disease in Himachal Pradesh (Kaur and Sharma, 1990). Severe infestation by *Pratylenchus* sp. in rhizomes of ginger from Sikkim and turmeric from Andhra Pradesh were observed. The incidence of these nematodes in rhizomes is of great concern as it leads to wide spread distribution through seed rhizomes. Nematodes enter the root, move in the root tissues piercing, sucking and leaving behind a trail of cell killing metabolites. Cell death results in brown lesions on the roots. Lesions begin on one side, but many encircle a root and thereby girdle it. The overall effect is a weak, shallow root system with a lot of dead areas. Nematode infestation in ginger rhizomes leads to dry rot. Dark brown necrotic lesions are produced in the rhizomes (Fig. 7).

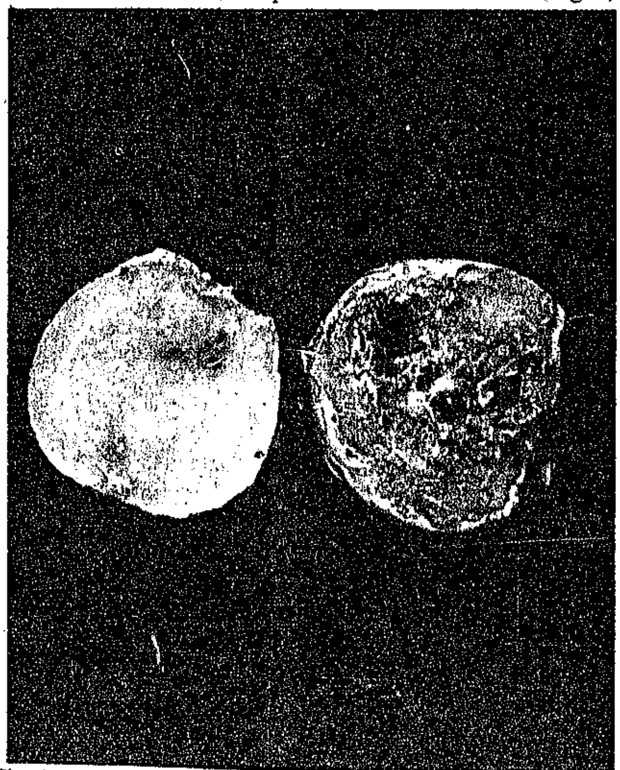

Fig. 7 Ginger rhizomes showing necrosis and rotting due to attack by lesion nematodes (*Pratylenchus* sp.)

In turmeric, in the advance stages of infestation, rhizomes are discoloured, less turgid with dry rot symptoms. Symptoms expressed by the infested plants are yellowing of leaves and stunted growth. Nematode infestation in ginger leads to increased incidence and severity of fungal disease, soft rot or rhizome rot caused by *Pythium aphanidermatum* and bacterial wilt caused by *Ralstonia solanacearum.*

Seed spices

Several genera of phytonematodes are reported on seed spices like coriander (11), fenugreek (10), celery (11), dill(12), cumin (5), fennel (2) and caraway (3). Root knot nematodes attack all these crops and are of much economic importance. Root knot nematodes, *M. incognita* causes significant reductions in yield of coriander (52%), cumin (43%) and fennel (42%). Characteristic galls are produced on the roots of these plants infested with root knot nematodes and plants are stunted and show wilting symptoms with the depletion of soil moisture. In celery, plant parasitic nematodes like *Aphelenchoides* spp., *Aphelenchus* sp., *Paratylenchus* spp. and *Pratylenchus penetrans* are also important and cause severe crop losses if the plants are infested in the early stages of growth. Fenugreek is highly susceptible to *Pratylenchus zeae* (Ramana and Eapen, 1998).

Tree spices

Not much is known about the nematode pand their damage in tree spice crops, except a few reports on the occurrence of nematodes on these crops. However, presence of root knot nematodes on cinnamon, nutmeg and clove; *Pratylenchus* sp. on clove and cinnamon and *R. similis* on nutmeg has to be viewed seriously. They have to be studies intensively particularly in the nurseries for production of healthy and nematode free planting materials (Ramana and Eapen, 1998).

NEMATODE MANAGEMENT

In any given situation it is impracticable to eliminate nematodes from the agricultural soil, particularly in plantations, as these crops are perennial or grown continuously. The aim should be to bring down the nematode populations below economic injury levels. In the cultivation of many spice crops, planting materials are produced in the nurseries. Nurseries are the main sources of spread of these pests. Planting materials infested with nematodes do not establish in the plantations. Hence, management of nematodes should start from the nurseries. Various methods developed for management of nematode pests in spice crops can be grouped into 1) cultural practices, 2) host resistance, 3) biological control and 4) chemical control. There is seldom a single method to alleviate the nematode problems. Hence, integration of several methods both in the nurseries and plantations is the right choice for an effective management of these pests.

Cultural practices

Cultural practices are extremely useful for bringing down the nematode populations in spice crops. Several inter crops and live standards commonly used in pepper gardens are also very good hosts of nematodes and hence these crops should be avoided.

Nematode free planting materials : In spices, planting materials of black pepper, cardamom and tree spices are generally multiplied in the nurseries. Healthy, nematode free planting materials can ensure a better establishment of the crop in the plantation. This can be achieved by raising the planting materials in denematized soil mixture or seedbeds by soil solarization or fumigation with chemicals. Soil solarization is a simple pre-sowing technique. Nursery mixture with sufficient moisture can be made into beds of convenient length and height, but not more than 2 feet height and covered with transparent polythene sheet (100-400 gauge) in such a way that it remains air tight in an open area during hot season for about 30-45 days. During this period soil gets heated up and nematodes die due to rise in temeperature. By following this method, planting materials like black pepper rooted cuttings, seedlings or grafts of tree spices like clove, cinnamom, nutmeg etc. can be produced without nematode infestation. Similarly, seedbeds for raising cardamom seedlings can be solarized. In cardamom there was 10% increase in germination, increased growth and vigour of the seedlings resulting in a considerable increase in the number of transplantable seedlings due to soil solarization (Eapen, 1995). This method can be applied to fields also and it was found effective for the control of soil borne diseases in ginger and turmeric. Soil solarization, apart from controlling nematodes, significantly reduces weed growth. Deep ploughing and exposing nursery soil to solar heat, burning straw or other plant residues on nursery beds also help in reducing nematode populations. Retention of nurseries continuously at the same site accumulates pests and diseases. Rotation and fallowing of nursery sites should be followed.

Phytosanitation : Phytosanitation means a wide range of cultural practices, including weed control, crop residue destruction and several other hygienic practices. Production and distribution of nematode free propagation materials deter the spread of nematodes. Using planting materials from known, nematode free sources and selecting healthy propagation materials without symptoms of nematode infestation, particularly in selectingthe runner shoots of black pepper are important. Before planting the runner shoot of balck pepper for rooting, these should be washed thoroughly and nodal roots trimmed to avoid introduction of nematodes into the nurseries. Manual removal of nematode infested roots in cardamom seedlings is advisable to prevent the entry of nematodes to the main plantations. It is advisable to destroy severely affected vines along with their root systems to exclude the surce of nematode inoculum in pepper plantations. Replanting can be done after treating the planting pit with nematicides and leaving it fallow for a period of minimum one year. Similarly, in ginger and turmeric, using the seed materials collected from healthy fields and also treating the rhizomes in hot water at 50-55^0 C for 10 minutes can minimize nematode problems.

Host resistance

Use of resistant or tolerant varieties is the best solution to most of the nematode problems. In black pepper, a germplasm collection, Ottaplakal-1 (Pournami), was found resistant to root knot nematodes and is recommended for cultivation in the areas where root knot nematode is a serious problem. A few varieties in turmeric (Armoor, Duggirala, Guntur-1, Guntur-9, Rajampet, Sungandham and Upplapadu), fenugreek (VLM-112, 227, 67, 113, 24, 9, NLM TG 2336, UM 34, 35), coriander (CO-1, CO-2), cumin (CVT-R-S-1, CVT JC-1, CVT JC-2, CVT JC-3, CVT VC-43, CVT VC-159) were found resistant to root nematodes. In ginger and cardamom so far knot no variety has been found resistant to nematodes.

Biological control

Biological control of plant parasitic nematodes is in the early stages of its development in spice crops. It has the potential to form an integral part of a complete management programme. Tropical soils under perennial cropping systems are fertile sources of potential antagonists of nematodes. A good degree of natural control already exists in these soils. A large number of biocontrol agents have been identified in recent years that have very good potential for suppressing nematode populations in spice crops (Fig. 8).

Fig. 8 A root knot nematode egg parasitized by a fungal biocontrol agent (*Fusarium* sp.)

VAM fungi *(Glomus fasciculatum, G. mossae, Giaospora margarita), Paecilomyces lilacinus, Trichoderma* spp. *Verticillium chlamydosporium* and *Pasteuria penetrans* are having high potential as biocontrol agents in spice crops. Incorporation of these biocontrol agents into the nursery soi mixture and nursery beds is recommended to produce nematode free planting materials (Eapen and Ramana, 1996).

Paecilomyces lilacinus : It is an opportunistic fungus present in many soils. In black pepper rooted cuttings, root damage and root rotting due to nematode infestation were significantly reduced by incorporating the fungus into the soil mixture (Ramana, 1994). However, this fungus is more effective against root knot nematodes than the burrowing nematodes. In cardamom nurseries, application of this fungus multiplied on coffee husk or neem oil cake reduced root knot nematode populations by 74.2% and also rhizome rot disease by 19.7% (Fig. 9) (Eapen and Venugopal, 1995).

Fig. 9 A cardamom nursery treated with the biocontrol agent, *Paecilomyces lilacinus*

***Trichoderma* spp :** *Trichoderma* spp. are hypomycetous fungi widely used against several disease causing fungi. Among several species of *Trichoderma, T. harzianum, T. logibrachiatum, T. koningii, T. viride and Gliocladium virens* are better colonizers of eggs of root knot nematodes of black pepper and suppress nematode multiplication. Incorporation of *Trichoderma* isolates into the nematode sick cardamom nursery beds reduced root knot nematode population by more than 60% and also the incidence of rhizome rot. These fungi are broad-spectrum biocontrol agents, can be easily multiplied and used in spices nurseries and plantations (Eapen and Venugopal, 1995).

Vesicular arbuscular mycorrhizae (VAM) : The symbiotic association of these fungi with host plant roots increases the plants ability to absorb water, phosphorus and other elements. VAM fungi also offer increased host tolerance to nematode infection due to the improved 'P' status of the host or by competition or antagonism between nematodes and the fungus. Incorporation of *Glomus fasciculatum ,Acaulosopora laevis, Gigospora margarita* into the soil significantly reduced root knot nematode population and increased growth of black pepper rooted cuttings. *G. fasciculatum* also reduced root rot caused by nematodes and the fungus, *Phytophthora capsici* in black pepper (Anandaraj, Ramanan and Sarma, 1991). In cardamom also incorporation of *G. fasciculatum, G. margarita* suppressed *M. incognita* infection and resulted in the production of healthy and nematode free seedlings.

Verticillium chlamydosporium : This fungus, a known biocontrol agent of cyst and root knot nematodes, was isolated recently from black pepper gardens in Kerala. This fungus parasitized root knot nematode eggs and suppressed their hatching (Sreeja, Eapen and Ramana, 1996). It is a potential biocontrol agent in spice crops and further work is in progress.

Pasteuria penetrans : This bacterial biocontrol agent has been encountered in some spice plantations. Addition of this biocontrol agent to the nursery mixture and nursery beds reduced nematode populations in black pepper and cardamom. respectively and enhanced growth of the plants.

Soil amendments : A wide range of soil amendments is being used for the control of plant parasitic nematodes. It is attributed to the nematicidal byproducts released during their breakdown and also the associated enhancement of indigenous microflora. Use of various organic cakes has been recommended for nematode control in spice crops. In black pepper and cardamom, neem oil cake application reduced nematode populations particuarly root knot nematodes and increased the yields. Application of well decomposed cattle manure or compost or saw dust or green leaves or neem oil cake helps in reducing nematode multiplication in ginger.

Chemical control

Nemtadoes can be eliminated from the nursery mixture or nursery beds through soil fumigation with chemicals. Soil fumigation withmethyl bromide (500/10M^2) or ethylene di-bromide (20 l/ha) or durofume (30 l/ha) was found highly effective in cardamom nurseries. Nursery soil mixture can be fumigated with methyl bromide @ 500 g / 100 cft soil. Drenching 2% formaldehyde is also effective in killing the nematodes in the nurseries. Fumigated nursery mixture can be used for raising planting materials of black pepper and tree species. Fumigants perform well in less clayey soils with not much organic matter. Fumigants are highly toxic and only trained persons should handle these chemicals. However, several fumigants are either banned or for restricted use only because of environmental pollution.

Although, a number of chemicals for the control of nematodes in spice crops are effective and are being used for many years without apparent problems, it is now known that there are serious health and environmental risks associated with these chemicals. Many of these chemicals have been withdrawn from the market. However, they are the immediate choice for rapid kill of nematodes in the absence of other effective control measure. Many nematicides, volatile and non-volatile were tested for their efficacy to control nematodes in spice crops. In black pepper, application of phorate or carbofuran @ 3 g a.i/vine, twice in a year gives good control of nematodes. In nurseries, application of phorate @ 0.1 g/bag is recommended (Ramana, 1992). In cardamom root knot nematodes can be kept under check by application of phorate @ 2.5 - 5.0 g a.i/plant or carbofuran @ 5.0 g a.i./plant, twice a year with significant increase in yields. In cardamom nurseries also application of these nematicides is highly affective in reducing nematode infestation apart from soil fumigation (Eapen, 1995). Application of carbofuran reduced root knot nematode populations by 81.6% in turmeric. However, use of nematodes in annual crops like ginger, turmeric and seed spices should be with utmost care to avoid any residues in the produce.

FUTURE PROSPECTS

Plant parasitic nematodes incude some of the most damaging pest species of spices. But as they do not provide clear symptoms, growers often underestimate their economic effects. In order to have a durable control of plant parasitic nematodes, integrated nematode management schemes are essential in which cultural measures, natural resistance and nematicides will have a continuing role. Developments in the field of biological control can supplement such schemes to make nematode control sustainable.

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