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NEMATODE MANAGEMENT IN BLACK PEPPER

K.V. RAMANA, Y.R. SARMA
and
M. ANANDARAJ
National Research Centre for Spieces, Calicut-673 012, Kerala, India

Black pepper *(piper nigrum L.)* the 'King of Spice ' is an important spice crop originated in the Western Ghats of Kerala, India. In India, its cultivation is confined largely to sub-tropical regions of Kerala and Karnataka. Besides India, black pepper is cultivated on commercial scale in Indonesia, Malaysia, Brazil and Lanka.

In India, black pepper cultivation is seriously affected by two diseases,. *'Phytophthora* foot rot' caused by *Phytophthora capsici* and slow decline (Slow wilt/pepper yellows) mainly due to infestation by plant parasitic nematodes viz, *Radopholus similis* (burrowing nematode) and *Meloidogyne incognita* (root- knot nematode).

Status of Slow decline

Nematode infestations assume alarming proportions leading to *slow decline* in plantations. Root-knot nematode *(Meloidogyne sp.)* is the first nematode species recorded on black pepper in Cochin- china (Delacroix 1901). *Radopholus similis* infestation was reported for death of 22 milion black pepper vines over a period in Bangka Island, Indonesia (Christie 1957) resulting in a major economic disaster for the Island's inhabitants. The problem still remains serious in Bangka and Belitung where almost all the pepper vines are infested and losses up to 32% in pepper production are reported (Sitepu and kasim 1991). In Guyana about 30% vines are demaged annually due to the disease (Biessar 1969). Though exact figure on crop loss in India is not available the disease is rampant in all major black pepper growing areas in Kerala and Karnataka (Ramana 1992).

As early as in 1906, Butler reported root-knot nematode infestation in black pepper in Wynad, Kerala (Butler 1906). Association of burrowing nematode with black pepper in India was first reported from South- West India (D'Souza et al. 1970). Besides *M. incognita* and *R. similis*, a semiendoparasitic nematode, *Trophotylenchulus piperis* was found infesting roots of black pepper in India (Mohandas et al. 1985), the role of which in pepper culture has to be established. Though 48 species of plant parasitic nematodes belonging to 29 genera are reported in association with black pepper (Sundararaju et al. 1979), large scale surveys conducted in all major black pepper growing areas in India showed that out of 14 genera recorded, *M. incognita, R. similis, T. piperis* and *Helicotylenchulus* spp. are predominant (Ramana and Mohandas 1987, 1989b).

Etiology

Besides establishing pathogenicity of *M. incognita* and *R. similis* on black pepper, of these nematodes in the incidence of slow decline and consequent effects on growth of pepper vines have been demonstrated (Holiday and Mowat 1963; Winoto 1976; Venkit and Setty 1977; Mustika 1978; Ferraz and Sharma 1979; Jacob and Kuriyan 1979b; Kosh al. 1979; Lamberti et al. 1983; Mohandas and Ramana 1983; Mustika 1984; Ramana et al. 19 Mustika 1990). de Waard(1969) attributed 'pepper yellows' in Sarawak to nutritional deficien cy and he was also of the view that the disease could be controlled effectively by applicatio of fertilizers.

In India, pathogenicity studies conducted under simulated field conditions in microplots showed that both the nematode species are highly pathogenic to black pepper and caused significant reduction in growth and yield. The affected foliar yellowing with time leading to varying degress of defoliation and die back (Mohandas and Ramana 1991).

Slow decline is primarily attributed to infestations by *R. similis* and *M. incognita* (Van der Vecht 1950; Christie 1957; Hubert 1957; Ting 1975; Ichinohe 1976; Nambiar and Sarma 1977; Venkitesan and Setty 1977; Bridge 1978; Mustika 1978). Ramana et al. (1987) also found significant correlation between infestation levels of *R. similis* and incidence of slow decline in black pepper plantations in India. However, Hubert (1957) and Bridge (1978) opined that though *R. similis* is primarily responsible for the disease, an association with fungi like *Fusarium* is necessary to cause 'yellows' disease. Nambiar and Sarma (1979) stated that slow decline in India is complex in nature involving nematode-fungal interaction coupled with nutrient deficiency and soil moisture. Consistent association of *Fusarium* sp. with roots of slow decline affected vines was also reported (Nambiar and Sarma 1977). The possible role of *Fusarium* in the disease in India could not be established from the results of large scale field trials using Bavistin, a fungicide highly effective in controlling *Fusarium* spp. alone and in combination with phorate and neem cake (Ramana et al. 1990). Mustika (1990) reported that *R. similis* alone or in combination with *M. incognita* and *Fusarium solani* caused foliar yellowing with stiff droop of leaves. Similarly Mohandas and Ramana (1991) observed foliar yellowing, defoliation and die back only in the vines inoculated with *R. similis* alone or in combination with *M. incognita*.

Winoto (1972) stated that plants infested with root-knot nematodes are more susceptible to *Phytophthora* infections. Anandaraj et al. (1991a) reported that damage caused to feeder roots due to *P. capsici* infections also lead to the expression of declining symptoms similar to that of nematode infestation. This was corroborated from the results of large scale field trials for the control of slow decline using phorate, Bavistin and neem cake in different combination in areca-pepper mixed cropping system (Ramana et al. 1990). The results showed that though nematode population in roots of black pepper vines treated with phorate/neem cake was significantly reduced, there was no corresponding decrease in disease symptoms and improvement in the health of vines. Further, the disease manifested severely during the course of 3 years of experimentation leading to death of vines ranging from 16.6 to 58.3% in different treatments. The highest mortality of the vines was in Bavistin treatment. This might be due to the fact that Bavistin could suppress fungi like *Fusarium* only and not *Phytophthora*. All the diseased vines also gave positive isolation of *P. capsici* irrespective of treatments indicating the role of *P. capsici* in roots damage andé subsequent expression of declining symptoms (Ramana et al. 1990).

A study under simulated field condition in microplots on the etiology of slow decline, wherein black pepper vines were inoculated with *R. similis, M. incognita* and *P. capsici* alone and in various combinations is in progress at National Research Centre for Spices, Calicut. Vines inoculated with *R. similis, P. capsici* alone and their combination expressed similar symptoms. Thus feeder root damage caused either by *R. similis, P. capsici* individually or their combinations lead to declining symptoms (Anon. 1991).

Since plant parasitic nematodes cause extensive damage to feeder roots leading to slow decline either independently or in association with certain fungi, nematode management in black pepper acclaims a prime place to boost up health, vigour and productivity of vines.

Disease Management

Nematode management is comparatively difficult because of their soil borne nature and infestation on root system that goes unnoticed for a longer period before plants express foliar symptoms. Further, unlike in annual crops relationship between nematode populations and the resultant effects on plant growth and production are more complex in perennial crops. Used of chemicals is one of the important components for control of plant parasitic nematode. However, their high cost, diffculty in handling, health hazards, environmental pollution due to continuous application pose a challenging problem to nematologists to search alternatives to chemicals. Since eradication of nematodes in intensive cropping systems particularly in plantation crops is impossible, the concept of living with nematodes and aiming at managing crop losses by integrating various methods involving cultural practices such as use of organic amendments, growing resistant/tolerant cultivars and also biocontrol agents with minimal use of chemicals assume importance.

Different approaches attempted for management of nematodes in black pepper can be broadly divided into 4 groups viz., (1) cultural practices, (2) plant resistance, (3) biological control and (4) chemical control.

(1) Cultural Practices

Cultural practices generally aim at bringing down nematode populations by manipulating certain crop husbandry practices like summer ploughing, flooding fields, applying manures and soil amendments crop rotation etc. However, many of these practices cannot be adopted in cultivation of black pepper since the crop is pernnial and grown as mixed crop with a variety of crops, particularly in India.

Plant hygiene - Planting nematode free rooted cutting is important since nematode infested material leads to incidence of slow decline in course of time in plantations. Nematode free rooted cutting can be produced using fumigated nursery mixture and frequent application of nematicides to soil in bags containing rooted cuttings, particularly when planting materials are continuously produced and maintained in nurseries for longer periods as in the case of rapid multiplication technique (Sarma et al. 1987).

Organic amendments - Application of organic manures and soil amendments such as oil cakes are known to improve soil texture and enhance growth of useful microorganisms suppressive to pathogens. Among different oil cakes, neem cake attracted a lot of attention and proved to be highly effective on various crops (Alam et.al. 1977; Siddique and Saxena 1987a, b). Nematicidal properties of neem cake are attributed to several chemicals naturally occurring in neem such as nimbidin, thionemone, azadirachtin, nimbin, nimbidic acid etc. Ramana et al. (1990) conducted large scale field trials for control of slow decline in black pepper using phorate, Basvistin and neem cake and results showed that application of neem cake @ 2 kg/vine twice a year was highly effective in bringing down *M. incognita* population and this was comparable to that of phorate. It was not however, effective against *R. similis*.

Litzenberger and Lip (1961) reported that mulching with *Chromolaena odorata (Eupatorium odoratum)* eliminated nematodes and controlled 'yellows' and root rot disease complex in pepper in Cambodia. It was found however that under Indian conditions mulching with *C. odorata* did not suppress *M. incognita* infestation and multiplication in black pepper in pot culture experiments.

Live standards (supports for trailing black pepper vines) - In India, a variety of plant species are used as live standards for trailing black pepper vines. Susceptibility of these live standards to nematodes is also important as susceptible plant species contribute to population build up of nematodes. *Artocarpus heterophyllus, A. hirsutus Ailanthus malabarica, Mesopsis emini, Peltophorum pterocarpum, Swietenia macrophylla* and *Tamarindus indica* are some of the resistant plants to *M. incognita* (Ramana, 1986). It was also reported that *Garuga pinnata* and *Macaranga indica* are not susceptible and *Erythrina indica* and *Glyricidia sepium* are less susceptible to root-knot nematode(Koshy et al. 1977).

Crop combination - In India, black pepper is grown mostly as a mixed crop. Nematode build up in plantation greatly varies depending upon the cropping system and susceptibility of crops involved in mixed cropping system to plant parasitic nematodes. Areca-pepper and coconut-pepper cropping systems are popular in India. Incidentally both arecanut and coconut are highly susceptible to *R. similis*. Ginger, turmeric, elephant-foot yam and banana which are highly susceptible to both *R. similis* and *M. incognita* are also commonly grown in black pepper plantations. This type of crop combinations become ideal for population build up of these nematodes and black pepper may become more vulnerable to infestation in such cropping systems. This aspect is more important in management of nematodes in black pepper.

(2) Plant Resistance

Growing nematode resistant/tolerant plants is probably the most enconomical, effective and practical method of management. It is known that availability of resistance in crop plants is more common for sedentary endo and semi-endoparasites (Roberts 1982). It is true that two of the predominant nematode species infesting black pepper viz., *M. incognita* and *T. piperis* belong to this category. However, *R. similis*, a more serious pathogen is migratory endoparasite.

To identify genotypes resistant/tolerant to nematodes, assembling of large gemplasm consisting of a wide range of cultivated and wild types is of utmost importance. Standardisation of screening techniques is another factor since designation of host susceptibility i.e., degree of susceptibility or resistance is subjective. Due to different methods used in screening host plants, such as nematode inoculum level and period of exposure of test plants to pathogen, a cultivar categorised as moderately resistant in one study could be rated differently in another study. Development of a standard method based on nematode reproduction and damage to roots at particular inoculum level is necessary for uniformity in host resistance designation. Ramana and Mohandas (1989a) standardised screening techniques for black pepper and suggested for *M. incognita*, an inoculum of 1000 freshly hatched second stage juveniles and assesing root-knot index (0-5 scale) 4 months after inoculation and for *R. similis*, an inoculum of 250 nematodes and recording root-lesion index (1-5 scale) 4 months after inoculation.

Attempts are made to identify resistant/tolerant genotypes of black pepper to nematodes without success (Vekitesan and Setty 1978; Koshy and Sundararaju 1979; Jacob and Kuriyan 1979a). Ramana and Mohandas (1986) identifield a cultivar resistant to *M. incognita* which has good yield potential, but no cultivar was found resistant/tolerant to *R. similis* (Ramana et al. 1987). However, one variety PW 14 was reported totally immune to *R. similis* from Sri Lanka (Gnanapragasam 1989). A wild related species, *P. colubrinum* was resistant to both *M. incognita* and *R. similis* (Anon. 1990). As it was shown earlier that resistance could be transferred to a susceptible cultivar through biotechnology, efforts should be made to identify gene(s) responsible for resistance to nematode in *P. colubrinum* and transfer to high yielding cultivar through genetic engineering to solve the nematode problems in black pepper to a greater extent.

(3) Biological Control

Efficacy of biolgical control as the sole means of nematode managment has remained debatable. The present consensus is that it should form an integral part of an overall management approach with other methods. A variety of microorganisms inhabit rhizosphere along with plant parasitic nematodes and some of these organisms are known to parasitise or predate on nematodes. According to Sewell (1965) biological control is "the induced or natural, direct or indirect limitations of a harmful organism or its effects by another organism or group of organisms". This aspect has not been fully exploited for control of nematodes in black pepper. Researches on these lines are initiated at National Research Centre for Spices, Calicut, India.

Vesicular arbuscular mycorrhizae (VAM) -The beneficial effects of VAM fungi on growth of various crop plants are well documented. Earlier studies on interactions between VAM fungi and nematodes suggest the possibility of using VAM fungi as agents of biological control (Sikora 1978; Smith et al. 1986). Report on occurrence of VAM fungi on roots of black pepper (Manjunath and Bagyaraj 1982) evoked interest on these fungi . Shivashanker and Iyer (1988) and Bopaiah and Khader (1989) found beneficial effects of VAM fungi on black pepper.

Anandaraj et al. (1991b) tested the efficacy of *Glomus mosseae, Acaulospora la*
Glomus fasciculatum and *Gigaspora margarita* in suppressing *M. incognita* in black pep
VAM fungi significantly increased growth parameters and reduced root-knot index. Lo
root-knot index of 0.75 (0-5 scale) was observed in plants colonized with A. laevis.
suppressive effects of VAM fungi on nermatodes were comparable with that of phorate
enhanced growth in VAM inoculated plants may be due to increased uptake of nutrients
well as suppression of nematode infestations.

Attempts are also being made to test the efficacy of VAM fungi in suppressing
similis, *M. incognita* and *P. capsici* since all these pathogens occur together under natural fie
conditions. Pot-culture studies indicated that inoculation of black pepper rooted cutting wit
VAM fungus, *G. fasciculatum* prior to challenge by the pathogens afforded better protectio
of the root- system. Population of both *R.similis* and *M. incognita* were less in VAM
inoculated vines (Anon. 1991). The possibility of incorporating VAM fungi in nursery mixture
is suggested since these fungi help in enhancing growth of plants and also reduce root damage
by suppressing nematode and fungal pathogens.

Paecilomyces lilacinus - Among several nematode destroying fungi, *P. lilacinus* is the
subject of many researchers for exploiting its biocontrol potential against nematodes. This
fungus controls effectively root-knot nematodes on various crops (Jatala 1986). The fungus
parasitises eggs and larvae of root-knot nematode (Lysek 1966; Jatala et al. 1979; Morgan-
Jones et al. 1984; Freire and Bridge 1985; Jatala 1985, 1986). Important qualities of the fungus
are its ability to colonize rapidly nematodes' reproductive structures, capacity to survive host
free periods and easy to culture in laboratory. Efficacy of this fungus in suppressing *M.*
incognita than *R. similis* (Ramana and Sarma, Unpublished). However, the recent report
that the fungus is a human pathogen (Kerry 1987) limits its usage as a biocontrol agent for
nematode control.

In view of the above, studies are in progress to isolate other microorganism hyper-parasitic or antagonistic to the two nematodes as a part of integrated disease management programmes.

Antagonistic plants - Many plant species are known to possess antagonistic activity against plant parasitic nematodes and serve as useful biocontrol agents. Tagetes is one such antagonistic plant. Among different species of Tagetes, *T. patula* has nematicidal effect to polyphagous nematodes (Vissar and Vythialingam 1959; Daulton and Curtis 1963; Varma et al. 1978; Indra Rajvanshi et al. 1985). Subramanian and Selvaraj (1988) reported nematicidal property of leaf extract of *T. patula* on *R. similis*. In black pepper when plants inoculated with *M. incognita* were grown along with *T. patula* in pots, root-knot index was less (2.8) compared to the index in plants grown without marigold (3.5) indicating *T. patula* had inhibited root-knot nematode development to some extent. But *T. patula* had no effect on *R.similis* (Ramana 1992). However, these studies are preliminary and more detailed studies in vivo are warranted to determine efficacy of marigold as an useful antagonistic plant for control of nematodes in black pepper.

(4) **Chemical Control**

Nematicides are chemicals used to kill or stall the activity of nematodes. They are of two groups viz., soil fumigants and systemic nematicides. Most of the systemic nematicides are translocated from root to above ground plant parts except a few which have basipetal translocation. Though a variety of nematicides are found excellent in controlling nematodes on various crops, adoption at the farmers' level is limited to a certain cash crops because of several limitations. But in black pepper, since nematodes are serious problem, use of nematicides cannot be avoided totally till effective alternate methods are found.

Various nematicides like phenomiphos @ 20 g/vine (Nambiar and Sarma 1979), aldicarb sulphone@ 8 kg/ha (Venkitesan and Setty 1979), phorate and DBCP (Venkitesan and Carles 1979) were found effective in controlling nematodes in black pepper in India.

In Malaysia, carbofuran @ 114 g/vine (Kueh and Teo 1978), phenomiphos and oxamyl (Kueh 1979) were found effective. Similarly in Indonesia, Shell DD, Vapam EC, Nemagon 75 EC, Temik 10 G, Furadan 3 G, Nemacur 5 G, Mocap 10 G, Hostaltion 5 G, Dasanit 5 G and Basudin 60 EC were all effective to control nematodes in black pepper (Mustika and Zeinuddin 1978). In Brazil, Ichinohe (1980) found application of Temik 10 G @ 12.5 g or Furadan 5 G@ 50 g/plant twice a year reduced nematode population and improved growth of vines.

Observation trials under pure black pepper cropping system were conducted in two plantations, one predominantly infested with *M. incognita* and the other plantation where *R. similis* was predominant, to test the efficacy of 3 granular nematicides viz., Temik 10 G (aldicarb), Thimet 10 G (phorate) and Furadan 3 G (carbofuran) @ 3 g a.i./vine applied twice in a year at National Research Centre for Spices, Calicut, India. Application of nematicides significantly reduced nematode population and improved health of vines. However, Thimet was found superior in suppressing *R. similis* population (Anon 1985; Mohandas and Ramana 1987).

In view of the inseparable nature of plant parasitic nematodes and *P. capsici* under field condition and also damage caused to feeder roots by nematodes or *P. capsici* lead to declining symptoms, a pot culture experiment was conducted to study efficacy of nematicides and fungicides. Combination of phorate with systemic fungicides viz., Ridomil ZM, Ridomil MZ and Akomin gave better protection to feeder roots and enhanced growth of black pepper cuttings compared to either of the fungicides treated separately (Anon. 1991). It is suggested that a combination of nematicide and fungicide would offer a better control of the disease. However, location specific decision needs to be taken based on involvement of these pathogens in a given situation to reduce plant protection cost. In view of this large scale disease management trials involving fungicides and nematicides are in progress.

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