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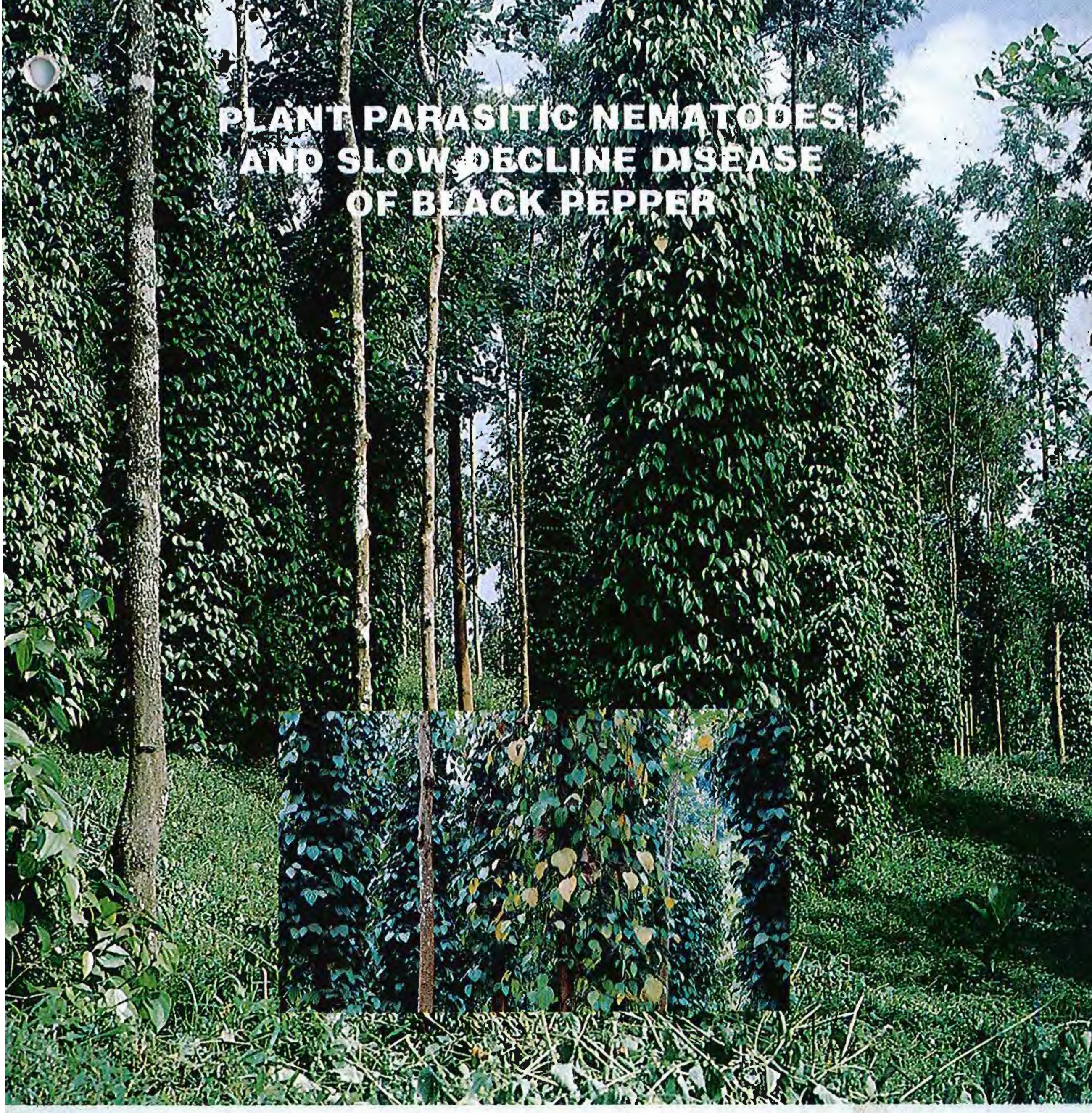

भाकृअनुप
ICAR

NATIONAL RESEARCH CENTRE FOR SPICES
(Indian Council of Agricultural Research)
CALICUT - 673 012, KERALA, INDIA

Technical Bulletin

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Cover: Pure balck pepper plantation (inset) slow decline affected vines

Plant Parasitic Nematodes and Slow Decline Disease of Black Pepper

November 1994

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FOREWORD

Cultivation of black pepper, the 'King of spices', has contributed substantially to the economic uplift and stability of farmers for centuries in all the black pepper growing countries of the world. In India black pepper is mainly cultivated in Kerala and Karnataka and earns about Rs.105 crores annually by export. However, diseases like '*Phytophthora* foot rot' and slow decline are major constraints in black pepper production. 'Slow decline' also known as 'pepper yellows' is caused by nematode infestation. *Radopholus similis* (burrowing nematode) and *Meloidogyne incognita* (root knot nematode) were responsible for the death of millions of black pepper vines in a short span of two decades in the Bangka islands of Indonesia. In India also, this disease is assuming alarming proportions in all the major pepper growing areas.

Though, plant parasitic nematodes are known to infest black pepper for a long time, no systematic and organised research was attempted till late 70's to identify the important nematode species, their role in slow decline disease and to develop effective means to control them in black pepper gardens. Realising the importance of plant parasitic nematodes in black pepper cultivation, a research project (Kerala Agricultural Development Project) under United Nations Development Programme was sanctioned at National Research Centre for Spices during 1979 to carry out research on plant parasitic nematodes of black pepper. Subsequently in 1987 it was merged with the institute projects and the work was continued till 1991.

The project has contributed significantly to the knowledge of nematode problems in black pepper. Major plant parasitic nematodes infesting black pepper were identified and their role in 'slow decline' disease as well as the crop losses were defined. A high yielding black pepper cultivar 'Ottaplakal-1' was identified as resistant to *M. incognita* and recommended for release as 'Pournami'. Vesicular arbuscular mycorrhizae (VAM) having suppressive effects on nematode infestation and multiplication in black pepper were identified, and can be incorporated in nursery to produce nematode free planting material besides forming a component in integrated nematode management in black pepper plantations.

This technical bulletin is compilation of valuable information generated on the role of nematodes in slow decline of black pepper. I hope that the information contained in this will prove useful not only to the scientific community but to all those engaged in black pepper cultivation. I congratulate Dr. K.V. Ramana, Dr. C. Mohandas and Mr. Santhosh J. Eapen for their efforts and I wish them success and good luck.

K.L. Chadha

New Delhi
21 September, 1994

(K.L. Chadha)

DIRECTOR'S INTRODUCTION

National Research Centre for Spices (NRCS), Calicut conducts basic and applied researches on black pepper, cardamom, ginger, turmeric, clove, nutmeg, allspice and cinnamon. Black pepper, being the most important Indian spice, has received special attention in its research programmes. Slow decline, caused primarily by nematodes, is a debilitating disease affecting black pepper in all the phases. The project on "Role of nematodes in the incidence of slow decline (slow wilt disease) of black pepper and screening black pepper germplasm against nematodes", initiated in 1979 was concluded in 1991.

The project revealed that:

1. *Fourteen genera of plant parasitic nematodes are present in the rhizosphere of black pepper in Kerala and Karnataka. From roots of black pepper, two endoparasitic nematodes* Meloidogyne incognita *and* Radopholus similis *and a semi-endoparasitic nematode,* Trophotylenchulus piperis *were isolated.*
2. Radopholus similis *of black pepper was identified as banana race.*
3. R. similis *plays a major role in causing slow decline in black pepper.*
4. *Neem cake is effective against root-knot nematodes. Application of phorate 10G or carbofuran 3G @ 3g. a.i./vine once during May/June and again in September/October is recommended against nematodes.*
5. *Infections by plant parasitic nematodes and fungus like* Phytophthora capsici *result in root degeneration leading to slow decline and this suggests for an integrated disease management.*
6. *Vesicular arbuscular mycorrhizae (VAM) suppress root-knot infestations in black pepper under pot culture.*

A black pepper accession 'Ottaplakal-1' was found tolerant to Meloidogyne incognita. *This line was later released to farmers as "Pournami".*

The present bulletin compiles the information generated in the project concluded in 1991 at a total establishment cost of Rs.8.87 lakhs. I congratulate Dr. K.V. Ramana and Dr. C. Mohandas for conducting successfully the investigation and Mr. Santhosh J. Eapen for compilation. I wish the present bulletin will be a forerunner in a series of bulletins on "Diseases, insect pests and nematodes of spices".

Calicut
5 November, 1994

(K.V. Peter)
Director

Contents

1. INTRODUCTION

Black pepper (*Piper nigrum* L.), the king of spices, is an important spice crop originated in the Western Ghats of India. Its cultivation in India is confined mainly to states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Goa. Now it is being introduced to non traditional areas in Assam and other North Eastern States. Besides India, black pepper is cultivated on a commercial scale in Indonesia, Malaysia, Brazil, Sri Lanka, Thailand, Vietnam, China, Madagascar and Mexico.

Black pepper cultivation is threatened by two diseases, *Phytophthora* foot rot caused by the fungus *Phytophthora capsici* and slow decline mainly due to infestation by plant parasitic nematodes and also in association with *P. capsici*.

Plant parasitic nematodes are small microscopic worms which feed on plant parts, especially the roots. They produce non specific aerial symptoms like stunted growth, foliar yellowing etc. However, roots of such plants show characteristic symptoms like galls, lesions and rotting, which impede uptake of water and nutrients from soil. Further, roots weakened and damaged by nematodes help other soil fungi and bacteria to colonize and accelerate the root decay.

2. PLANT PARASITIC NEMATODES IN BLACK PEPPER GARDENS

Plant parasitic nematodes belonging to 29 genera and 48 species have been reported on black pepper (Sundararaju *et al.*, 1979; Koshy and Bridge, 1990). In surveys conducted during 1980-86, 14 genera of plant parasitic nematodes were found associated with black pepper in Kerala and Karnataka (Table 1). Among these, *Meloidogyne incognita, Radopholus similis* and *Trophotylenchulus piperis* were present in all the districts surveyed (Fig. 1).

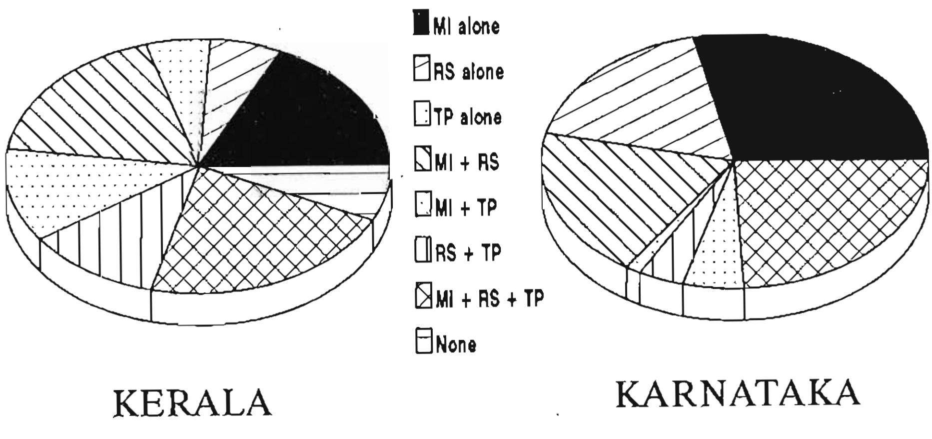

Fig. 1. Occurrence of three major nematode parasites in black pepper gardens of Kerala and Karnataka.

Table 1. Plant parasitic nematodes associated with black pepper.

Nematode species	Incidence (%)*
Acontylus sp.	0.2
Aphelenchus sp.	0.2
Criconemoides sp.	38.5
Helicotylenchus sp.	66.3
Hoplolaimus sp.	13.9
Longidorus sp.	5.8
Meloidogyne incognita	61.2
Pratylenchus sp.	7.6
Radopholus similis	40.9
Rotylenchulus reniformis	56.1
Scutellonema sp.	0.2
Trophotylenchulus piperis	31.9
Tylenchorhynchus sp.	13.2
Xiphinema sp.	22.4

* Incidence is represented as absolute frequencies.

Very high populations of *M. incognita* were seen in several black pepper gardens in Wyanad and Calicut districts of Kerala. In Karnataka, incidence of this nematode was high in Dakshina Kannada district. *R. similis* was more prevalent in Calicut while *T. piperis* was more common in Idukki. In Karnataka, *R. similis* distribution was high in Dakshina Kannada while frequency of *T.piperis* occurrence was very low. The most predominant species with black pepper in India was *M.incognita* followed by *R.similis* and *Helicotylenchus* sp. (Jacob and Kuriyan, 1979; Ramana and Mohandas, 1987 and 1989 a). It was also noticed that black pepper vines trained on arecanut and *Erythrina* sp. supported high populations of *R.similis*.

2.1. Root knot nematode, *Meloidogyne* spp. Goeldi, 1892

The root knot nematode (*Meloidogyne sp.*) was the first nematode to be recorded on black pepper by Delacroix in 1902. Later, Butler (1906) reported root knot nematode infestation on black pepper in Wyanad, Kerala. Two species of root knot nematodes, *M. incognita* and *M. javanica* infest black pepper. Root systems of infested plants show varying degrees of galling due to hypertrophy and hyperplasia. Typical galls or knots are seen on secondary or fibrous roots and elongated swellings on thick primary roots. Adult females with egg masses are generally enclosed deep within these roots. Leaves of such plants turn yellow (inter veinal chlorosis) and drop off easily (Fig. 2).

2.1.1. Nature of damage

Studies conducted at National Research Centre for Spices (NRCS), Calicut

Fig. 2. Symptoms of root knot nematode infestation in black pepper.
(From left) Root galls; Longitudinal section of roots showing egg masses; Foliar yellowing.

showed that *M.incognita* caused considerable reduction in plant height and biomass production, both in seedlings as well as in adult vines. Rooted cuttings of black pepper (Panniyur-1) when inoculated with a series of *M.incognita* inoculum levels, reduced the root proliferation at all higher inoculum levels (>500 nematodes). Root knot indices in these plants ranged from 2.0 to 4.0. However, no significant effects were observed in number of leaves, nodes etc., but shoot length was reduced significantly at the highest inoculum level (2000 nematodes/ cutting).

In adult vines, foliar yellowing and defoliation were the highest in vines inoculated with higher inoculum levels (>10,000 nematodes). Significant reduction in height, number of primary shoots and total biomass was also noticed in these plants (Fig. 3). About 12 to 46.9% yield reduction was found at various inoculum levels, during the first crop season itself. Root systems of these plants showed a corresponding increase in number of galls and root knot nematode level (Mohandas and Ramana, 1991).

2.2. Burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne, 1949

Association of burrowing nematode with black pepper was first reported in India by D'Souza *et al.* (1970). *R. similis* on black pepper in India has been identified as 'banana race' through a host differential study using various species of citrus and through cytological studies (Ramana, 1992; Koshy, 1986). The haploid number of chromosomes of black pepper isolates of *R. similis* from Indonesia and Kerala was found to be n = 4 (Huettel *et al.*, 1984; Koshy, 1986).

High populations of *R.similis* (>250 nematodes/gram of roots) were found in black pepper gardens throughout the year, except during summer months (April to June). The build up of nematode population starts from June/July and

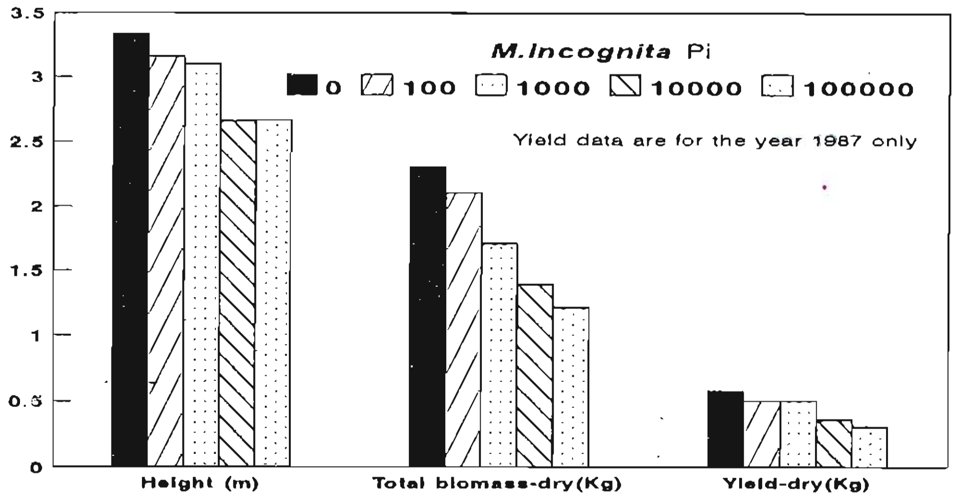

Fig. 3. Effect of *Meloidogyne incognita* on growth and yield of black pepper.

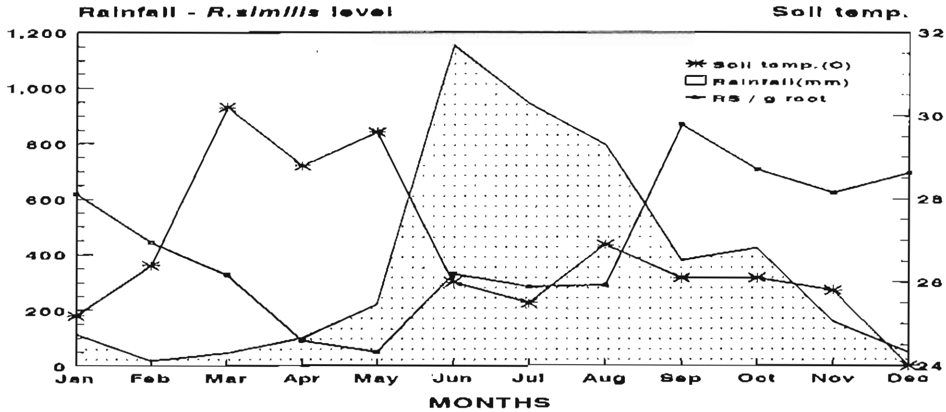

Fig. 4. Seasonal variations in *Radopholus similis* population in black pepper roots.

reaches maximum during September/ October (Mohandas and Ramana, 1988). Population density of *R.similis* in black pepper roots was found to be quite high, compared to other plantation crops. This indicated that black pepper is a more preferred host for *R.similis*. *R similis* population level in black pepper gardens is influenced by rainfall, number of rainy days and their subsequent effects on soil moisture, soil temperature and root proliferation in the host plant (Fig. 4).

2.2.1. Nature of damage

R. similis feeds on cortical tissues and produces elongate, brown to dark brown necrotic lesions on roots at the point of entry. These are more visible in white feeder roots. Subsequently, they merge together and encircle root cortex leading to disintegration of the distal portion of roots. Such infected plants were devoid of feeder roots. Occasionally the nematode infests underground portion of the stem causing dark brown lesions. The aerial symptoms are foliar yellowing and defoliation (Fig. 5).

In a pot culture study, different population levels of *R.similis* were inoculated on black pepper rooted cuttings (var. Panniyur-1). Damage due to nematodes

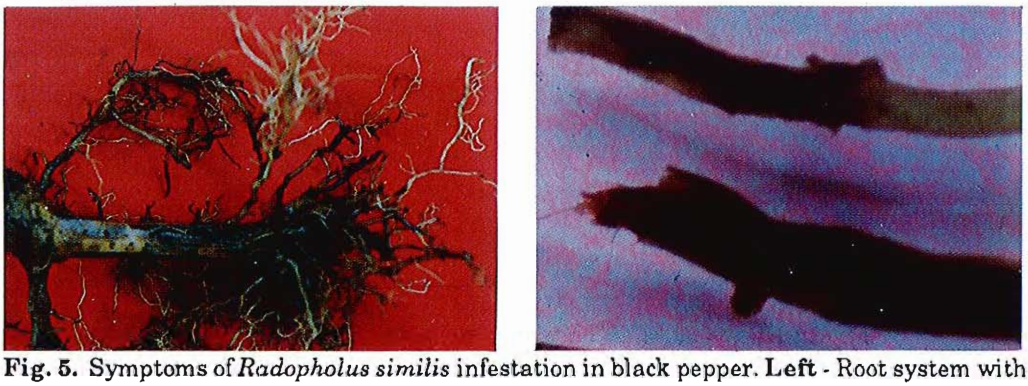

Fig. 5. Symptoms of *Radopholus similis* infestation in black pepper. **Left** - Root system with lesions and rotting. **Right** - Root lesions, a magnified view.

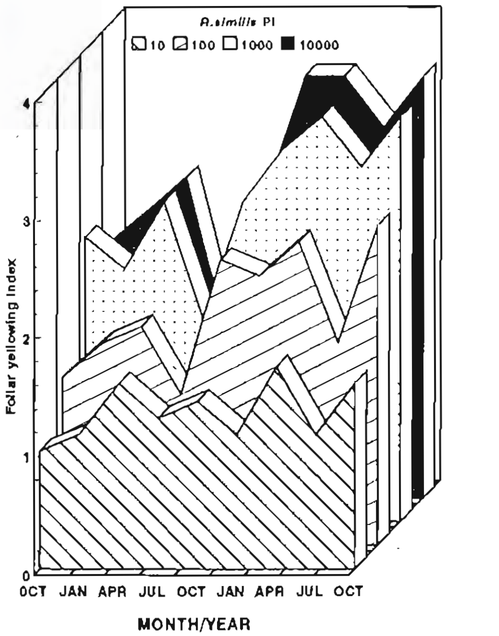

Fig. 6. Foliar yellowing in black pepper plants in relation to inoculum level of *Radopholus similis* and season.

was visible from the third month onwards except for the lowest inoculum level (10 nematodes/pot). Four months after inoculation with *R.similis* (Pi = >50), reduction on shoot length was more than 40% and 25 to 40% each in number of leaves and nodes. *R.similis* reduced root growth by 52.3 to 60.2%. Root lesion index increased correspondingly with increase in the inoculum level and ranged from 1.0 to 3.5. However, the nematode densities in various treatments were on par (182.9 to 238.9/gram of roots) (Ramana, 1992).

Another micro plot study was conducted under simulated field conditions using four population levels (10 to 10,000 nematodes/plant) of *R.similis* during 1984-87. Vines inoculated with high inoculum levels (Pi=1000 and 10,000) exhibited foliar yellowing and defoliation within three months. The symptoms intensified with increase in inoculum level and time (Fig. 6). Plants were stunted and more than 40% reduction in number of primary shoots was recorded in vines inoculated with 100 nematodes or more. Reduction in root mass as well as in total biomass were significant even with Pi = 10 (Fig. 7). The maximum reduction in yield (59.5%) was observed with Pi =

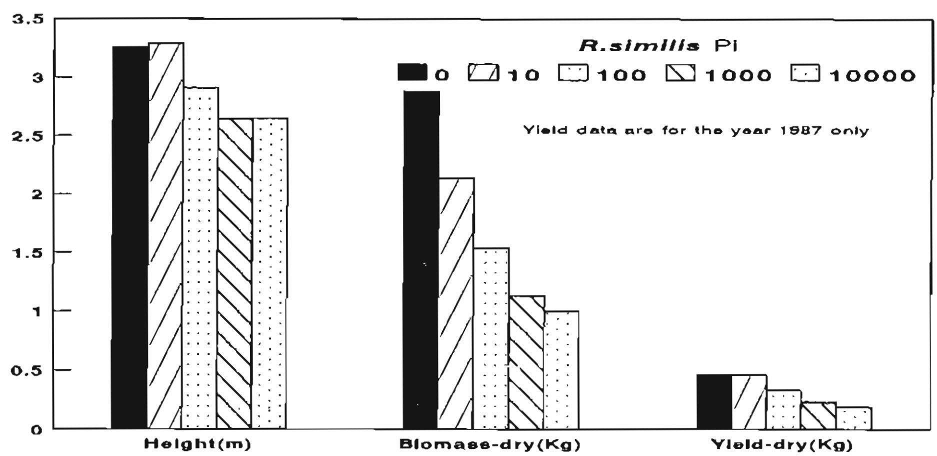

Fig. 7. Effect of *Radopholus similis* on growth and yield of black pepper.

10,000 followed by Pi = 1000 (50.1%) nematodes. Root lesion indices in inoculated plants varied from 1.6 to 3.8 (Mohandas and Ramana, 1991).

2.3. Pepper nematode, *Trophotylenchulus piperis* Mohandas, Ramana & Raski, 1985

Trophotylenchulus floridensis was reported from black pepper for the first time and later it was redescribed as *T.piperis,* a new species (Mohandas and Ramana, 1982; Mohandas *et al.,* 1985). It is a semi endoparasite found on the roots and soil of black pepper. The females are found singly in round, brittle cases, completely enveloping the nematode, except for a small opening closely surrounding the anterior end of the female which protrudes penetrating into the host root (Fig. 8). The cases, brown to dark brown in colour, accumulate in the soil in high numbers. The dark cases persisting in soil are generally empty. However, in cases attached to black pepper roots, 7 to 14 juveniles and 9 to 37 eggs are found together with the adult female. Juveniles are found in soil also, while males are observed very rarely (Mohandas *et al.,* 1985).

Light microscope and SEM studies showed that *T.piperis* is closely related to *T.floridensis* of citrus, in various morphological characters. However, it varies from *T.floridensis* in its smaller size (females-0.29 mm vs 0.44 mm, juveniles-0.26 to 0.33 mm vs 0.41 to 0.48 mm and males-0.35 to 0.39 mm vs 0.41 to 0.58 mm). Moreover, *T.piperis* juveniles have larger depressed area in the circumoral plate at the anterior end and also differs by the indented, digitate outline of the juvenile tail compared to the blunt round tail of *T.floridensis*.

Necrosis and general drying of the root tissues are observed at regions where *T.piperis* females are found attached to pepper roots. Further studies are required to understand the nature of damage and nematode-plant relationship of *T.piperis* and black pepper.

3. SLOW DECLINE DISEASE

Slow decline (slow wilt) disease of black pepper is a debilitating disease, prevalent in all the black pepper growing countries. It was first reported by van der Vecht in 1932 as 'pepper yellows' disease on the islands of Bangka, Indonesia (Mustika, 1990). Death of about 20 million black pepper vines was reported due to this disease over a short period of two decades (Christie, 1957). In Indonesia, the crop losses due to this disease were estimated to be up to 32% (Sitepu and Kasim, 1991). About 30% of vines are damaged annually by this disease in Guyana (Biessar, 1969). Even though exact crop losses due to this disease in

Fig. 8. *Trophotylenchulus piperis* attached to black pepper roots - a magnified view.

India are not available, it is prevalent in all black pepper gardens and is considered as the second major disease of black pepper.

3.1. Symptoms

Mild to moderate foliar yellowing at different regions of the vine are the initial aerial symptoms of the affected vines. However, root necrosis is the primary symptom of the disease. With the advancement of the disease, foliar yellowing intensifies, followed by defoliation and die-back, leading to loss of vigour, yield and finally death of vine (Fig. 9). Vines in early stages of the disease look apparently normal with the onset of monsoon, but foliar yellowing becomes more pronounced with the depletion of soil moisture.

3.2. Role of nematodes

R. similis and *M.incognita* were implicated in the etiology of slow decline of black pepper in India (Nambiar and Sarma, 1977; Ramana, 1986; Venkitesan and Setty, 1977; Ramana *et al.*, 1987a) and also in other black pepper growing countries. Significant correlation was found between infestation levels of *R.similis* and incidence of slow decline in black pepper in India (Ramana *et al.*, 1987a). At NRCS, Calicut an extensive study was conducted during 1984-87, using different levels of *R.similis* and *M.incognita* alone and in various combinations on mature vines of black pepper under field simulated conditions. Foliar yellowing and defoliation indices (FYI and DFI) were always high in vines inoculated with *R.similis* alone or in combination with *M.incognita*. These indices were maximum (3.5 each) in vines simultaneously inoculated with both the nematodes @ 1000 nematodes each/vine.

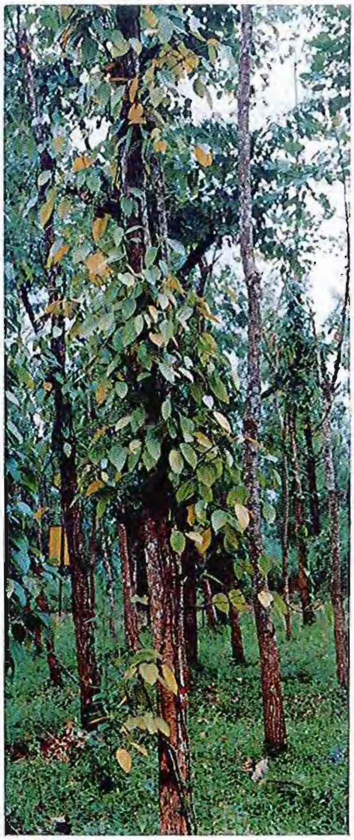

Fig. 9. A black pepper vine showing slow decline symptoms.

R.similis alone (Pi=1000 nematodes) caused the highest reduction in height of the vine (22.0%) (Table 2). All inoculated plants, except with *M.incognita* Pi=500 nematodes alone, showed significant reduction in number of primary shoots. Similarly, root growth and yield were affected by *R.similis*. The yield losses varied from 38.5% to 64.6% in *R.similis* inoculated plants, alone or in combination with *M.incognita*. However, *M.incognita* alone at both levels did not affect the yield. Root knot indices (RKI) were higher when *M. incognita* was inoculated alone. On the contrary, root lesion indices (RLI) were almost same in vines inoculated with *R.similis* alone or in combination with *M.incognita*. The

Table 2. Effect of *Radopholus similis* and *Meloidogyne incognita* on growth and yield of black pepper.

Treatment: Nematode	Pi	Height (m)	Shoot wt. Dry (Kg)	Root wt. Dry (Kg)	RKI	RLI	Yield * Dry (Kg)
Uninoculated		3.46	2.018	0.185	0.0	1.0	0.531
MI alone	500	3.39	1.752	0.184	1.5	1.0	0.509
	1000	3.07	1.519	0.149	3.0	1.0	0.489
RS alone	500	3.09	1.049	0.098	0.0	2.3	0.232
	1000	2.70	0.620	0.055	0.0	3.8	0.207
MI + RS	500	3.22	1.271	0.090	1.3	2.0	0.293
	1000	2.84	0.542	0.054	2.0	3.5	0.188
MI>RS	500	3.09	1.102	0.081	1.5	2.2	0.327
	1000	2.97	0.677	0.046	2.3	3.7	0.238
RS>MI	500	3.16	1.128	0.086	1.2	2.0	0.247
	1000	3.04	0.726	0.052	2.2	3.5	0.221
LSD P=0.05		0.35	0.275	0.029	-	-	0.085

Data are average of six replications. MI - *M.incognita,* RS - *R.similis,* + – simultaneous inoculation and > - 20 days after the first inoculation.
* Yield for the year 1987 only.

final nematode levels in soil and roots also showed similar trends. The root damage by *R.similis* restricts the infestation and multiplication of *M.incognita.* Vines inoculated with *R.similis* alone or in combination with *M.incognita* exhibited typical symptoms of slow decline. The root systems of these plants showed extensive damage due to galls and lesions, leading to gradual degeneration of roots. The fibrous roots are thus lost continuously, which in turn causes poor uptake of water and nutrients. This is reflected as the aerial symptoms of yellowing and defoliation. The study clearly proved that *R.similis* is the primary incitant of slow decline in black pepper (Mohandas and Ramana, 1991).

3.3. Interaction of nematodes with other microorganisms

Though plant parasitic nematodes are primary incitants of slow decline, other microorganisms particularly fungi were reported associated with the disease. Hubert (1957) and Bridge (1978) opined that *R.similis* was responsible primarily for the disease, but an association with *Fusarium sp.* was necessary to cause 'yellows' disease. Winoto (1972) also stated that plants infested with root knot nematodes were more susceptible to *Phytophthora.* Nambiar and Sarma (1979) attributed slow decline in Kerala to fungal-nematode complex, nutritional deficiency and moisture stress. Consistent association of *Fusarium* sp. with roots of diseased plants was also observed (Nambiar and Sarma, 1977). Absence of total remission of symptoms of slow decline affected black pepper vines with application of either carbendazim or phorate or even their combination indicated that *Fusarium* sp. has no role in the disease. However, *P. capsici* caused feeder root damage leading to foliar yellowing symptoms (Ramana et al., 1992).

Micro plot experiments conducted to assess the role of plant parasitic nematodes viz., *R.similis* and *M.incognita* and *P.capsici* alone or in combination in the etiology of the disease indicated that *R.similis* and *P.capsici* alone or in combination or *M.incognita* in combination with either *R.similis* or *P.capsici* or both resulted in root rotting leading to foliar yellowing and decline (Fig.10) (Sarma *et al.,* 1991; Anon., 1992; Ramana *et al.,* 1992). This was further supported as the combined application of nematicide and fungicide gave better control of the disease in black pepper plantations (Anon., 1991). This also indicated that absence of spatial separation of nematodes and *P.capsici* under field situations, which warrants an integrated approach of disease management especially in mixed cropping systems.

4. NEMATODE MANAGEMENT IN BLACK PEPPER GARDENS

Realizing that nematodes cannot be eliminated in a perennial crop like black pepper, the overall goal is to keep the population density as low as possible. Efficient management requires carefully integrated combinations of several practices.

4.1. Use of nematode free planting materials

Studies showed that young black pepper plants (3 and 6 months old) exhibited foliar yellowing and defoliation rather quickly and severely when inoculated with *R.similis,* than older vines (Ramana, 1992). As rooted cuttings are more susceptible and nurseries are more ideal sites for adoption of any nematode management measures, production and distribution of healthy, nematode free planting materials should be given high priority (Sarma *et al.,* 1987). They can establish well, perform better and limit the spread of nematodes. For large scale production of nematode free planting materials, nursery soil mixture should be sterilized with solar heat, steam or soil

Fig. 10. Individual and interactive effects of *Radopholus similis, Meloidogyne incognita* and *Phytophthora capsici* on black pepper. (L to R) control, *P. capsici* (PC), *M. incognita* (MI), *R. similis* (RS), PC + RS, PC + MI, PC + MI + RS.

Table 3. Reaction of black pepper germplasm to *Radopholus similis* and *Meloidogyne incognita*

Test material	*M. incognita*	*R. similis*	Remarks
Cultivated types	178*	204	Ottaplakal - 1 (Acc. No. 812) resistant to *M.incognita*
Wild & related species	77	37	*P.colubrinum* resistant to both nematodes
High yielding Karimunda selections	178	178	All susceptible
Intercultivar hybrids	169	169	-do-
Phytophthora tolerant lines	20	20	-do-
Seedling progenies of popular cultivars	56,000	56,000	-do-

* Data indicate number of lines/accessions screened in each category.

fumigants. Promising isolates of biocontrol agents can be incorporated into the nursery mixture for better establishment. Use of nematicides like phorate 10G (1 gram) or carbofuran 3G (3 grams) is also recommended to bring down the initial nematode load in black pepper rooted cuttings (Mohandas and Ramana, 1987).

4.2. Host resistance

Developing genetically resistant or tolerant black pepper variety is an alternative in nematode management. For this, a good source of resistance/tolerance has to be located by screening the germplasm. Standard methods were developed for screening black pepper germplasm to important plant parasitic nematodes like *R.similis* and *M.incognita* (Ramana and Mohandas, 1989b). An initial inoculum level of 250 nematodes and recording root lesion index five months after inoculation are optimum for studying reaction of black pepper germplasm to *R.similis*. For *M.incognita*, an inoculum level of 1000 second stage juveniles and assessing root knot index four months after inoculation was found optimum. Using these standardized techniques, several black pepper germplasm accessions were tested for their reaction to *R.similis* and *M.incognita* (Table 3).

Piper colubrinum, a wild related species of black pepper, is highly resistant to both the nematodes. The cultivar Ottaplakal-1 (Acc. No. 812) is rated as resistant to *M.incognita* and is recommended for release as 'Pournami' (Fig. 11) (Ramana and Mohandas, 1986, Ramana *et al.* 1987b).

Fig. 11. 'Pournami' (Ottaplakal - 1), a root knot nematode resistant black pepper line.

The reaction of live standards used for trailing black pepper vines in pepper plantations to root knot nematodes and burrowing nematodes is given in Table 4.

Table 4. Reaction of common live standards used in pepper gardens to *Radopholus similis* and *Meloidogyne incognita*.

Plant species	*M.incognita*	*R.similis*
Ailanthes malabaricus	-	NT
Areca catechu (arecanut)	+	+
Artocarpus heterphyllus (jack)	-	NT
A. hirsutus (wild jack)	-	NT
Bombax ceiba (semul)	+	NT
Ceiba pentandra (silk cotton)	+	NT
Cocos nucifera (coconut)	+	+
Erythrina indica	-	+
E. lithosperma (dadabs)	+	+
Garuga pinnata (garuga)	-	NT
Gliricidia maculata (= *sepium*)	+	+
Macaranga peltata	-	NT
Mangifera indica (mango)	-	+
Mesopsis emini	-	NT
Oroxylum indicum	+	NT
Peltophorum pterocarpum	-	NT
Swietenia macrophylla (mahogany)	-	+
Tamarindus indica (tamarind)	-	+

+ indicates susceptible, - means non host and NT not tested.

4.3. Biological control

Biological control measures are major components in the integrated nematode management programmes. Nematodes have many natural enemies including fungi, bacteria and predacious nematodes. Preliminary studies at NRCS, Calicut have shown that *Paecilomyces lilacinus*, a soil inhabiting hypomycetous fungus can significantly reduce the damage due to *R.similis* and *M.incognita* in black pepper (Ramana and Sarma, 1993). However, it showed greater efficacy in suppressing *M.incognita*. Vesicular arbuscular mycorrhizae (VAM), *Glomus mossae*, *G.fasciculatum*, *Acaulospora laevis*, and *Gigaspora margarita* suppressed nematode populations and increased growth of black pepper vines (Anandaraj *et al.*, 1991).

Tagetes patula, a known nematode antagonistic plant, when grown along with nematode infested black pepper plants, inhibited root knot nematode development to some extent, but had no effect on *R.similis*.

4.4. Chemical control

Nematicides are important and reliable means of controlling nematodes. Three granular nematicides viz., aldicarb, carbofuran and phorate (@ 3g a.i./vine, twice a year) were evaluated under field conditions for their efficacy in controlling nematodes of black pepper. Reduction in nematode populations was maximum (82.1%) with phorate followed by aldicarb (81.1%) and carbofuran (57.4%). Combination of phorate with systemic fungicides viz., Ridomil MZ and Akomin gave better protection of feeder roots and enhanced growth of rooted cuttings of black pepper (Anon., 1991).

5. CONCLUSION

Slow decline of black pepper is primarily due to infestation of plant parasitic nematodes. *P.capsici* could induce similar symptoms when the fungal infection is restricted to feeder roots. In order to manage plant parasitic nematodes we have to depend on chemicals till suitable biocontrol agents or resistant lines particularly resistant to *R.similis* are developed. To minimize dependence on nematicides, an integrated approach using clean and healthy planting materials, biocontrol agents like VAM, nematicides at the prescribed dosage and suitable crop combinations may be adopted. The nematode population level in black pepper gardens may be monitored for optimal usage of all existing management techniques.

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