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Chapter 18

Nematode Parasites of Spices

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Spices are strongly flavoured or aromatic substances of plant origin commonly used for seasoning and preserving food stuffs. They consist of rhizomes, barks, leaves, fruits, seeds and other parts of plants. These plants belong to different families, genera and species (Table I). The bulk of the dry matter of their products consist of carbohydrates, volatile oils, fixed oils, proteins, tannins, resins, pigments and mineral elements. These constituents differ in their composition and content in different spices. Most of the spices are crops of the humid tropical regions. India is considered as the home of spices from ancient times and produces a large proportion of all spices. There are innumerable biotic and abiotic problems on spice crops which adversely affect production including plant parasitic nematodes which can cause considerable damage to some of these crops.

Nematode problems of the spices, chilli and garlic are not included as they are discussed under vegetables (Chapter 7). Nematode problems of betel vine (*Piper betle*) and kava (*Piper methysticum*) have also been included in this chapter.

Black Pepper

Black pepper (*Piper nigrum* L.) is a branching and climbing perennial shrub belonging to the family Piperaceae and is cultivated in the hot and humid parts of the world. India, Indonesia, Malaysia and Brazil, contributing 24, 23, 22 and 14% respectively, are the major pepper producing countries in the world today. World production of pepper during 1985–86 was 125 990 t and covered an area of 2 44 250 ha (Anon., 1988). Its origin is considered to be in the hills of south-western India where it is known as the "King of spices". It is used in culinary seasonings, as a preservative for meat and other perishable foods, and in medicine. Piperine, the bite factor of pepper, is used to impart a pungent taste to brandy. Pepper oil is used in perfumery. The pepper vine can be propagated either vegetatively or by seed. Raising plants through cuttings is universally adopted. Two pepper vines entwined about a teak wood or concrete post, set in the field, is known as "pepper tree". In India, live trees are used as supports (standards) for climbing pepper.

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TABLE 1. Important spice crops in the tropics and subtropics.

	Scientific Name	Family	Common Name	Origin	Major Areas of Production
1.	*Allium sativum* L.	Liliaceae	Garlic	Europe	China, Turkey, Spain
2.	*Capsicum frutescens* L.	Solanaceae	Chillies	Tropical America	China, Nigeria, Turkey
3.*	*Trachyspermum ammi* L.	Umbelliferae	Bishop's weed	Egypt	India, Egypt, Iran
4.*	*Cinnamomum cassia* Blume	Lauraceae	Cassia	Egypt	China, Laos, Cambodia
5.*	*C. tamala* (Buch.-Ham) Nees & Eberm	Lauraceae	Tejpat	Egypt	India, Nepal
6.	*C. verum* Presl.	Lauraceae	Cinnamon	Sri Lanka & South India	Indonesia, Sri Lanka, Seychelles
7.	*Coriandrum sativum* L.	Umbelliferae	Coriander	Europe & Asia	Morocco, India, Pakistan
8.	*Cuminum cyminum* L.	Umbelliferae	Cumin	Egypt & Mediterranean	India, Iran, Morocco
9.	*Curcuma domestica* Val.	Zingiberaceae	Turmeric	South-East Asia	India, Bangladesh, Pakistan
10.	*Elettaria cardamomum* Maton.	Zingiberaceae	Cardamom	Indian Peninsula	India, Guatemala, Tanzania
11.	*Eugenia caryophyllus* (Sprengel) Bullock & Harrison	Myrtaceae	Clove	Indonesia	Indonesia, Zanzibar, Madagascar
12.*	*Foeniculum vulgare* Mill.	Umbelliferae	Fennel	Southern Europe	India, Europe, Russia
13.	*Myristica fragrans* Houtt.	Myristicaceae	Nutmeg	Indonesia	Indonesia, Grenada, Sri Lanka
14.*	*Pimenta dioica* (L.) Merrill	Myrtaceae	Allspice	West Indies	West Indies, Guatemala, Honduras
15.*	*Piper longum* L.	Piperaceae	Indian long pepper	India	Indonesia, Singapore, Sri Lanka
16.	*P. nigrum* L.	Piperaceae	Black pepper	India	India, Indonesia, Brazil
17.	*Trigonella foenum-graecum* L.	Leguminosae	Fenugreek	Southern Europe	India, France, Lebanon
18.	*Vanilla fragrans* (Salisb.) Ames	Orchidaceae	Vanilla	Mexico	Madagascar, Indonesia, Comoros
19.	*Zingiber officinale* Rosc.	Zingiberaceae	Ginger	South-Eastern Asia	India, Jamaica, Japan

*No report of nematodes

Nematodes on Black Pepper

Many nematodes have been reported on black pepper (Table 2), but the only two known to cause serious damage to the crop are *Radopholus similis* and *Meloidogyne* spp.

Radopholus similis

Association of the burrowing nematode, *R. similis*, with the yellows disease of pepper was first reported by Van der Vecht (1950), who made extensive field studies and also demonstrated its pathogenicity under laboratory conditions. The nematode is notorious for being associated with the loss of 22 million pepper vines within 20 years in Bangka Island, Indonesia due to "yellows disease" (Christie, 1957; 1959). Subsequently, *R. similis* was reported from black pepper from India (Venkitesan, 1972; Koshy *et al.*, 1978), Malaysia, Thailand (Sher *et al.*, 1969; Reddy, 1977) and Sri Lanka (Gnanapragasam *et al.*, 1985). The nematode is also involved in "slow-wilt" disease of black pepper in India, which is almost identical to pepper yellows in Indonesia (Van der Vecht, 1950; Mohandas & Ramana, 1987*b*; Ramana *et al.*, 1987*a*) hence, they are dealt with together. Intensive surveys carried out on the role of plant parasitic nematodes in the slow-wilt disease complex of black pepper in India showed that high populations of *Radopholus similis* occurred more frequently in slow-wilt disease affected plants than in healthy plants. Discriminate analysis indicated the positive involvement of *R. similis* in slow-wilt disease (Ramana *et al.*, 1987*a*).

Black pepper was introduced to Indonesia from Kerala, India (Nambiar, 1977) and it is quite likely that the burrowing nematode was also introduced along with the rooted cuttings of black pepper.

Symptoms of damage

The primary symptom of the yellows (slow-wilt) disease is the appearance of pale yellow or whitish yellow drooping leaves on the vines. The number of such leaves increases gradually until large numbers of leaves or even the entire foliage becomes yellow (Plate 16A). Yellowing is followed by shedding of leaves, cessation of growth and die-back symptoms (Fig. 1, Plate 16B). The symptoms are well pronounced when soil moisture is depleted. In the very early stage of the disease in India, the symptoms may disappear with the onset of the South-west monsoon resulting in an apparently healthy appearance of such plants in the following years because of new leaf growth and shedding of yellowed leaves. This has often given a mistaken impression of the disease being caused by soil moisture stress rather than nematodes. However, within three to five years of initiation of yellowing all the leaves are shed and death of the vine takes place and hence the name "slow-wilt" disease.

Fig. 1. Black pepper growing on arecanut palms in India showing defoliation and dieback due to *Radopholus similis*.

In bearing vines, shedding of spikes (inflorescences) is a major symptom. Large numbers of shed spikes are seen at the base of affected vines. In large plantations, affected patches become conspicuous initially as yellowed plants (Plate 16C), and later with large numbers of barren standards that have lost the vines, or standards supporting dead vines without any leaves (Plate 16D). Young and old plants are affected and the replanted vines normally die within two years.

The tender thin, white, feeding roots show typical orange to purple coloured lesions. Lesions are not clearly seen on older roots, being brown in colour. The root system exhibits extensive rotting and the main roots are devoid of fine feeder roots that rot quickly. Extensive necrosis of larger lateral roots develops subsequently.

Biology and life cycle

The nematode penetrates roots within 24 hours of inoculation and the cells around the site of penetration become brown (Venkitesan & Setty, 1977). Nematodes do not enter the stelar portions of the root, but plugging of xylem vessels with a gum-like substance has been reported (Freire & Bridge, 1985*a*). It completes its life cycle within 25–30 days, at a temperature range of 21–31°C and the black pepper isolate of the nematode is easily cultured on carrot discs at 25°C (Koshy, 1986*b*). The *R. similis* populations in Indonesia and Kerala (India) have a haploid number (n=4) of four chromosomes (Huettel *et al.*, 1984; Koshy, 1986*b*).

In India, the maximum nematode population in roots of pepper occurs during September-October and minimum during April-June (Ramana, 1986; Mohandas & Ramana, 1987*b*). A low soil temperature coupled with adequate soil moisture and availability of fresh tender roots help in the build up of the population during September-October.

Other hosts

A large number of tree species such as, coconut (*Cocos nucifera*), arecanut (*Areca catechu*), jack fruit (*Artocarpus integrifolia*), mango (*Mangifera indica*), gliricidia (*Gliricidia maculata*), dadap (*Erythrina indica*), garuga (*Garuga pinnata*) and Vatta (*Macaranga indica*) are used as live standards. Among these, coconut and arecanut are good hosts of *R. similis* (see Chapter 11). Crops like banana, ginger and turmeric that are susceptible to *R. similis* are also intercropped with pepper.

Disease complexes

It has been speculated that yellows disease in Indonesia is caused by a nematode – fungus complex (Hubert, 1957; Bridge, 1978) involving *R. similis, Fusarium* spp. and possibly other fungi. There is little direct evidence to support the hypothesis, however, Freire (1982) showed that an Indonesian isolate of *R. similis* predisposed black pepper seedlings to attack by a weakly pathogenic isolate of *Fusarium solani* causing severe root damage.

Economic importance and population damage threshold levels

The slow-wilt disease was first reported from Wynad area in Kerala as early as 1902 and Krishna Menon (1949) reported mortality up to 10% of the vines due to the disease. Reduction in plant growth has been reported in sterile soil when 55-day-old rooted cuttings of black pepper in pots are inoculated with 2300 nematodes.

The onset of yellows disease in Sumatra, Indonesia is correlated with *R. similis* populations of 2/100g of soil and 25/10g of roots, and *Meloidogyne* spp. populations of 47/100g of soil and 305/10g of roots (Mustika, 1978), but Bridge (1978) thought that a low population of less than 310 nematodes/10g roots may not alone cause the disease. A population level of 250 nematodes/g of roots was constantly recorded with slow-wilt affected pepper vines in Kerala (Ramana, 1986).

Control measures

At present there are no effective control measures for control of slow-wilt or pepper yellows. The price of black pepper is known to fluctuate greatly and with the fall in prices, the farmer often loses interest in the crop and tends to neglect adoption of even agronomic practices. Control methods need to be adopted every year for black pepper, being a perennial crop, especially under Indian conditions where live standards are used. The perennial multi-cropping systems involving coconut, arecanut, black pepper, betel vine, banana, ginger, turmeric, etc. that have developed over many years in the west coast of South India are ideal situations where the burrowing nematode multiplies and causes heavy damage to all the susceptible crops (Plate 16E). Black pepper, betel vine and banana are crops that succumb to nematode attack early. In later years, the farmers abandon pepper cultivation in arecanut based farming systems where arecanut is the live standard. Although application of phorate at 3 g a.i./vine twice a year has been found to control *R. similis*, the high density multispecies cropping pattern does not permit use of nematicides, as most of the crops are export oriented and some products are consumed without any processing or cooking, such as banana, betel leaves, etc. This situation is further complicated because arecanut and coconut that are used as live standards are also very good hosts of *R. similis* which warrants higher dosages and more frequent use of nematicides, especially under irrigated conditions.

Cultural practices

Symptoms of slow-wilt/pepper yellows are known to be ameliorated with mulching. Pasril (1976) has recorded 18% reduction in disease incidence in Bangka Island, Indonesia after mulching. He also observed a reduction in disease symptoms after application of nematicide with a corresponding increase of yield in the first year of treatment.

De Waard (1979) suggested application of fertilizers at a dose of 400 kg N, 180 kg P, 480 kg K, 425 kg Ca and 112 kg Mg in combination with a mulch for effective control of yellows disease in Bangka, Indonesia. Further, foliar yellowing and necrosis of distal ends of laminae of slow-wilt affected vines in Kerala, India were attributed to N and K deficiencies respectively (Wahid *et al.*, 1982).

Resistance and tolerance

Eighteen cultivars of black pepper, four *Piper* species and five wild *Piper* collections were screened against *Radopholus similis*. Wild collection Vittal No. 430, *Piper hymenophyllum* and *P. attenuatum*, recorded least (less than 30%) root reduction and minimum (x1.5) nematode reproduction. The hybrid pepper variety Panniyur-I recorded 91.4% root reduction and x7.6 nematode reproduction (Venkitesan & Setty, 1978). However, a local cultivar at Peringamala, Kerala, India was found not to be invaded by *R. similis* (Jacob & Kuriyan, 1979*b*). No resistance or tolerance was found to the nematode in a total of 106 cultivated germplasm, 36 wild related *Piper* spp., 20 intercultivar hybrids, 90 selections of cultivar Karimunda and 12 200 open pollinated seedlings of popular pepper cultivars screened against *R. similis* (Ramana *et al.*, 1987*b*).

Chemical

A number of pesticides have been found effective in reducing *R. similis* populations on black pepper in pot trials as well as in preliminary field trials. Aldicarb sulphone at 8 kg a.i./ha was most effective for control of *R. similis* on pepper in pot trials (Venkitesan, 1976; Venkitesan & Setty, 1979). DD, Vapam, Nemagon, Temik, Furadan, Nemacur, Mocap, Hostathione, Dasanit and Dasudin were found to reduce populations of *Meloidogyne* spp. and *R. similis* on *P. nigrum* in greenhouse trials (Mustika & Zainuddin, 1978). Under Indian conditions, aldicarb/carbofuran/phorate at 3 g a.i./vine applied in May/June and again in September/October results in the remission of foliar yellowing and reduction in nematode populations. Among the above three nematicides, phorate is superior (Ramana, 1986; Mohandas & Ramana, 1987*a*). The chances of rehabilitating the severely affected vines by application of nematicides are slim because of the heavy damage already caused to the root system and the inability of such plants to put out fresh roots for quick rejuvenation.

Although chemicals have been reported to reduce the nematode population and ameliorate slow-wilt symptoms, the cost benefit ratio has not been calculated.

Summary of control measures

Integrated methods of nematode management that can be suggested are:

1. Planting of nematode-free rooted cuttings.
2. Uprooting of affected vines and replanting after a period of 9–12 months.
3. Use of non-living supports or standards.
4. Exclusion of *R. similis* susceptible trees as standards for trailing black pepper vines, and exclusion of susceptible intercrops such as banana, ginger and turmeric.
5. Application of phorate at 3 g a.i./vine with the onset of monsoon and again after three months. The nematicide may be applied after removing the top soil without causing damage to the roots, followed by replacement of the soil. The susceptible intercrops, e.g. banana, may also be treated with nematicides.
6. Application of organic amendments, such as 200 g neem oil cake (*Azadirachta indica*), green foliage (3–5 kg), or farm yard manure (1 kg) per vine.
7. Earthing-up after application of nematicides, NPK fertilizers and organic amendments in September/October.

Methods of diagnosis

Sampling

The presence of nematodes and their association with the disease can be diagnosed by soil sampling at a distance of 25–50 cm from the base of the vine at a depth of 20–30 cm. A soil sample of 200 cm^3 and root sample of 0.5 to 1.0 g thin, tender, feeder roots will yield maximum nematode population (Koshy, 1986*b*, 1987*a*, 1988).

Extraction

Infested roots, showing lesions and rotting, may be split longitudinally and cut to a length of 1 to 2 cm. When such roots are submerged in water contained in Petri dishes or shallow pans and incubated at 20–25°C, 50% of nematodes are released in 72 h. For collecting active nematode populations for culturing and other studies, tease out individual root lesions in water contained in a watch glass under a stereoscopic microscope and quickly transfer the nematodes into fresh water.

Meloidogyne

The root-knot nematode, *Meloidogyne* sp., was the first nematode to be recorded on black pepper (Delacroix, 1902) in Cochin-China. In 1906, Butler reported root-knot nematodes from black pepper in Wynad, Kerala (India). *Meloidogyne javanica* and *M. incognita* have been reported from India, Brazil, Sarawak, Borneo, Cochin-China, Malaysia, Brunei, Kampuchea, Indonesia, Philippines, Thailand and Vietnam (Winoto, 1972; Castillo, 1974; Lordello & Silva, 1974; Ichinohe, 1975; Reddy, 1977; Freire & Monteiro, 1978; Kueh & Teo, 1978; Sundararaju *et al.*, 1979*a*; Ramana & Mohandas, 1983) and *M. arenaria* from Sri Lanka (Lamberti *et al.*, 1983).

Symptoms of damage

A gradual decline characterized by unthrifty growth and yellowing of leaves are the prominent symptoms. Leaves of vines infested with *Meloidogyne* spp. exhibit dense yellowish discolouration of the interveinal areas making the leaf veins quite prominent with a deep green colour, whereas leaves of the vines infested with *Radopholus similis* show uniform pale yellow or whitish discolouration and typical drooping. Root systems become heavily galled. In the cv Panniyur I, the galls are smooth and bigger in size compared to the small galls with exposed egg masses giving a pitted rough appearance to roots of cv Karimunda.

Other hosts

Among the commercially used standards *Oroxylum indicum* Vent., *Erythrina lithosperma* Blume, *Ceiba pentandra* (L.) Gaerth. and *Bombax malabaricum* DC. are highly susceptible to root-knot nematodes, whereas *Garuga pinnata* Roxb. and *Macaranga indica* Wight are not susceptible. The popular live standards, *Erythrina indica* Lank. and *Gliricidia sepium* (Jacq.) Walp. are less susceptible (Koshy *et al.*, 1977). Large numbers of weeds that are found in pepper gardens have been recorded as hosts of the root-knot nematode (Ramana, 1986).

Disease complexes

Meloidogyne spp. do not significantly enhance the susceptibility of pepper vines to foot-rot in Sarawak (Holliday & Mowat, 1963). *M. incognita* and *Fusarium solani* were found associated with black pepper vines in Paraba State, Brazil. Infested plants showed wilting, yellowing of leaves, rotting of stems and roots and cracking of stems; cracked stems 5–10 cm above the soil surface were heavily infected. Both organisms together were found to do more harm than either of them alone (Lopes & Lordello, 1979), but Winoto (1972) reported increased susceptibility of *M. incognita* and *M. javanica* infested pepper cv Kuching to *Phytophthora* infection in Malaysia. *Rotylenchulus reniformis* was found to inhibit the multiplication of *M. incognita* and the resultant damage on black pepper in autoclaved soil in pots under greenhouse conditions in Brazil (Ferraz & Sharma, 1979). The root gall development and population build up of *M. incognita* was suppressed in black pepper on inoculation with *R. similis* in succession in sterile soil under pot conditions (Sheela & Venkitesan, 1981).

Economic importance and population damage threshold levels

As much as 91% root-knot nematode infestation was reported from Para, Brazil (Ichinohe, 1975) and Kerala, India (Ramana *et al.*, 1987*a*; Ramana & Mohandas, 1987*b*). An initial population of ten juveniles per rooted cutting reduces growth by 16%, while, a maximum of 50% reduction is observed at an inoculum level of 100 000 over a period of one year in sterile soil under potted conditions (Koshy *et al.*, 1979*b*). *M. incognita* was found highly pathogenic at 100–10 000 juveniles per seedling (Freire & Bridge, 1985*c*). In Indonesia, yellow symptoms appeared on plants with *Meloidogyne* spp. at population levels of 47/100 g soil and 305/10 g roots (Mustika, 1978).

Control measures

Root-knot infestation in black pepper nurseries has been a serious problem in several government nurseries in Kerala, India. Fumigation of nursery potting mixture with methyl bromide is effective in checking the infestation (Koshy, 1974, 1986*a*; Mohandas & Ramana, 1987*a*).

Cultural

Growing of the non-host cover plant siratro (*Macroptilium atropurpureus*) in the interspace and mulching with Guatemala grass are recommended to reduce populations of *M. incognita* on black pepper in the Amazonian region (Ichinohe, 1980).

Resistance and tolerance

Among the seven popular cultivars screened, the hybrid cultivar, Panniyur-I was the most susceptible and the cultivar Valiakaniakadan was the least susceptible (Koshy & Sundararaju, 1979). The intensity of damage on infestation with *M. incognita* was less in cultivar Karimunda compared with that of Panniyur-I (Mohandas & Ramana, 1983). Of eight cultivars screened against *M. incognita*, Kalluvalli, Balancotta, Karimunda, Narayakodi and Padapan had fewer galls than Panniyur-I, Cheriyakaniakadan and Kottanadan (Jacob & Kuriyan, 1979*a*). A total of 101 cultivars, 74 accessions of wild *Piper* sp. and 140 inter cultivar hybrids were screened against *M. incognita* of which one cultivar, CLT-P-812, was found resistant (Ramana & Mohandas, 1986, 1987*b*; Koshy, 1987*b*).

Infection by nematodes is known to cause biochemical changes in plants. The cv Cingapura recorded high concentrations of total phenols on inoculation with 6000 *M. incognita* juveniles/pot 95 days after planting although no resistance was shown (Ferraz *et al.*, 1984). Changes in levels of amino acids, organic acids and sugars in *M. incognita* infected plants, compared with uninfected plants were reported by Freire and Bridge (1985*b*).

Chemical

Most nematicides have been found effective in reducing root-knot nematode populations on black pepper, but information on their practical use is limited. Under Indian conditions when a live standard is used, the dosage has to be different depending upon the susceptible/resistant reaction of the standard to the root-knot populations. Thus, generalizations on the dosage of nematicides are not possible, and recommendations have to be location specific depending upon the standard, variety of black pepper, rainfall pattern and flowering and harvesting period of black pepper. Green berry yields can be doubled by four applications of carbofuran incorporated into mound soil at 114 g per vine per application in black pepper fields infested with *M. incognita* and *M. javanica* in Malaysia (Kueh & Teo, 1978). Application of Temik 10G at 12.5 g/plant or Furadan 5 G at 50 g/plant twice a year, including at planting around cuttings, can reduce populations of *M. incognita* on black pepper in the Amazonian region (Ichinohe, 1980). Phenamiphos at one per cent a.i./vine followed by carbofuran and ethoprophos was effective in controlling nematodes in cv Kuching in Malaysia (Leong, 1984).

When aldicarb at 1 g a.i./vine applied twice a year (May/June and October/November) is integrated with fertilizers (N=100g, P=40g, K=140g/vine) in two equal split doses, plus earthing up to 50 cm radius at the base of the vines and mulching the vine base with leaves, there is a reduction in foliar yellowing of 83% and *M. incognita* juvenile populations by 33–88% (Venkitesan & Jacob, 1985).

Biological

Nematode-free cuttings could be raised by incorporating a biological control agent in the potting mixture. The only attempt known to have been made in this direction is by Friere and Bridge (1985*d*). However, the rates of infection by *Paecilomyces lilacinus* and *Verticillium chlamydosporium* of *M. incognita* egg masses on black pepper seedlings were only 15 and 12% respectively, and this would be totally inadequate for effective control.

Other nematodes of black pepper

The nematodes that have been found associated with black pepper (Table 2) in various countries (Timm, 1965; Sher *et al.*, 1969; Castillo, 1974; Sharma & Loof, 1974; Ichinohe, 1975; Reddy, 1977; Bridge, 1978; Sundararaju *et al.*, 1979*b*; Rama, 1987; Dasgupta & Rama, 1987; Ramana & Mohandas, 1987*a*) are, apart from *R. similis* and *Meloidogyne* spp., probably of minor economic importance. The nematode that could prove to be damaging to the crop is *Trophotylenchulus piperis*. *T. piperis* has been reported as a widespread parasite of black pepper roots in South India, but its damaging potential has yet to be studied (Mohandas & Ramana, 1982; Mohandas *et al.*, 1985).

Future prospects

Developing cropping systems, avoiding susceptible live supports or standards, incorporating an integrated nematode management system with minimum or no nematicide application, should be the main thrust of research to increase black pepper yield in areas infested with damaging nematodes.

Cardamom

Cardamom is a fruit (capsule) of the plant, *Elettaria cardamomum* Maton, belonging to the family Zingiberaceae. It is a perennial plant having an underground stem (rhizome) with aerial shoots. A mature cardamom plant may measure about 2 to 4 m in height. Flowers are borne on panicles which emerge directly from the swollen base of the aerial shoot. The fruits are small, trilocular capsules containing 15 to 20 seeds. Cardamom, known as the "Queen of spices", has its origin in the evergreen rain forests of South India and is basically a shade loving plant. India and Guatemala are the main producers and exporters of cardamom. Tanzania, Sri Lanka, El Salvador, Vietnam, Laos, Kampuchea and Papua New Guinea are also cardamom growers. The area under cardamom cultivation in India during 1985–86 was 95 370 ha and the total world production was 10 660 t (Anon., 1988). Cardamom is used for flavouring various food preparations, confectionery, beverages, liquors and medicines. Cardamom can be propagated through seedlings as well as suckers. Suckers are better suited for gap filling and multiplication of selected high yielding types.

Nematodes on Cardamom

Nematological investigations on this crop have been undertaken in India, where a number of plant parasitic nematodes have been found with cardamom (Table 2). The most important nematode problem is caused by the root-knot nematodes, *Meloidogyne* spp., although the lesion nematode, *Pratylenchus coffeae* and the burrowing nematode, *Radopholus similis*, are also known to cause root rotting (D'Souza *et al.*, 1970; Kumar *et al.*, 1971; Khan & Nanjappa, 1972; Viswanathan *et al.*, 1974; Sundararaju *et al.*, 1979*b*).

Meloidogyne

Widespread occurrence of root-knot nematodes, *Meloidogyne incognita* and *M. javanica* has been reported in cardamom nurseries and plantations in India (Kumar *et al.*, 1971; Koshy *et al.*, 1976; Ali, 1982, 1986).

Symptoms of damage

Heavy root-knot nematode infestation in mature plants in a plantation causes stunting, reduced tillering, yellowing, premature drying of leaf-tips and margins, narrowing of leaf blades, a delay in flowering, immature fruit-drop and reduction in yield. Unlike several other plant species, galling of roots is not a conspicuous symptom on mature plants. The infested roots, however, exhibit a "witches broom" type of excessive branching (Plate 16E).

In the primary nurseries, more than 50% of the germinating seeds do not emerge as a consequence of infection of the radicle and plumule by the second stage juveniles of the root-knot nematode. The infested seedlings at the two-leaf stage show marginal yellowing and drying of leaves and severe galling of roots. On transplantation to a secondary nursery, they exhibit curling of the unopened leaves. These leaves mostly emerge after the breaking open of the pseudostem. Up to 40% of such seedlings do not establish in the secondary nursery. In secondary nurseries, the infested plants are stunted and yellowed with poor tillering, drying of leaf-tips and margins, and heavy galling of roots (Ali & Koshy, 1982).

Survival and means of dissemination

The heavily shaded, hot, humid atmosphere and continuous availability of soil moisture prevalent in cardamom plantations are congenial conditions for the multiplication of root-knot nematodes. The nematodes are disseminated through infested seedlings and rhizomes used for propagation. Most plantations have their own permanent nursery sites situated in areas having easy access to water sources like forest streams.

Other hosts

A large number of annual weeds present in the cardamom plantations and the common shade trees, *Erythrina indica* and *E. lithosperma*, are hosts of root-knot and help in the build up of nematode populations.

Disease complexes

The incidence of rhizome rot and damping-off diseases caused by the fungus, *Rhizoctonia solani* increases in the presence of *M. incognita* in the nurseries (Ali, 1986; Eapen, 1987).

Economic importance

A yield loss of 32–47% due to root-knot has been reported from the results of a nematicide experiment (Ali, 1984, 1986). An initial population level of 100 nematodes per plant causes discernible damage to cardamom (Eapen, 1987).

Control measures

Nematological investigations have helped in creating a general awareness among the planters as well as administrators in India that the root-knot nematode is a major factor. However, planters have not yet adopted recommended control measures. No resistance to root-knot nematodes has been found and the popular cardamom cultivars, Malabar, Mysore and Vazhuka are all susceptible.

It is advisable to change nursery sites every year, but this is not always practicable in view of the difficulties involved in getting suitable sites having facilities for irrigation. Hence, disinfestation of the nursery beds need to be carried out every year. Disinfestation of nursery beds with methyl bromide at 500 g/10m^2 is effective in controlling root-knot infestation in both primary and secondary nurseries.

It has been demonstrated that application of aldicarb at 5 kg a.i./ha, three times, every three months, results in increased growth and vigour of seedlings both in primary and secondary nurseries (Koshy *et al.*, 1979*a*; Ali, 1986). Aldicarb, carbofuran, phorate at 5, 10 or 15 kg a.i./ha respectively, have been applied in primary nurseries of cardamom for control of *M. incognita*. None of the nematicide treatments totally prevented nematode infestation but there was significant reduction in root-knot densities. Aldicarb at the very high level of 15 kg a.i./ha reduced nematode numbers by 90% (Ali, 1987). Application of aldicarb/carbofuran/phorate at 5g and 10g a.i./plant and neem oil cake at 500g and 1000g/plant twice a year increases yield of cardamom plants infested with *M. incognita* from 47 to 88%. Maximum yield was obtained from the plants receiving neem oil cake at a rate of 1000g/plant followed by 500g/plant (Ali, 1984).

Ginger

Ginger is the rhizome or underground stem of *Zingiber officinale* Rosc., a herbaceous perennial, belonging to the family Zingiberaceae. Although the country of origin is not known with certainty, it is presumed to be either India or China. It is grown in many countries of the tropics and subtropics and is used widely in food, beverages, confectionery and medicines. India is the largest producer and exporter of dry ginger. The total area in India under cultivation during 1986–87 was 52 460 ha. India contributes (127 000 t) nearly half of the worlds production. The other ginger producing countries are Jamaica, Sierra Leone, Nigeria, Southern China, Japan, Taiwan and Australia (Anon., 1988).

Ginger is propagated by seed rhizomes or setts. Seed rhizomes are cut into small pieces of 2.5 to 5 cm length, weighing 20 to 25 g each, having one or two good buds. It is grown either as a monocrop or as an intercrop in many farming systems. In India, mulching of ginger beds with green leaves is a traditional practice to enhance the germination of seed rhizomes and conservation of soil moisture. The first mulching is done at the time of planting itself, with green leaves at 10 to 12 t/ha and repeated with 5t/ha, 40 and 90 days after planting, immediately after weeding and application of fertilizers.

Nematodes on Ginger

Although a large number of nematode species have been recorded from ginger (Table 2) (Colbran, 1958; Reddy, 1977; Sundararaju *et al.*, 1979*b*; Rama & Dasgupta, 1985; Kaur, 1987) the most important parasites are *Meloidogyne* spp., *Radopholus similis* and *Pratylenchus coffeae*.

Meloidogyne

Nagakura (1930) in Japan was the first to report *Meloidogyne* sp. on ginger and subsequently the species *M. arenaria, M. hapla, M. incognita* and *M. javanica* have been reported as parasites of ginger in various countries.

Symptoms of damage

The root-knot nematodes cause galling and rotting of roots and underground rhizomes. The second stage juveniles of *M. incognita* invade the rhizome through the axils of leaf sheaths in the shoot apex. In fibrous roots, penetration occurs in the area of differentiation and, in fleshy roots, the entire length of root is invaded. In both fleshy and fibrous roots the nematode develops to maturity in 21 days but in rhizomes it requires 40 days at 30°C (Cheng & Tu, 1979). Galls are formed on the fibrous roots. Abnormal xylem and hyperplastic parenchyma are observed in all infested tissues except rhizome meristems. Extensive internal lesions are formed in the fleshy roots and rhizomes. Wound cork around the lesions is suberized only in old rhizomes after harvest (Huang, 1966; Shah & Raju, 1977). Infested rhizomes have brown, water-soaked areas in the outer tissues, particularly in the angles between shoots. Nematodes continue to develop after the crop has matured and been harvested and induce breakdown of the seed rhizomes. Heavily infested plants are stunted and have chlorotic leaves with marginal necrosis. Infested rhizomes serve as a source of infection and means of dissemination.

Disease complexes

The fungus *Pythium myriotylum* is antagonistic to *M. incognita* on ginger in the rhizosphere, although concomitant infection by the two organisms does not affect the soft rot disease syndrome (Lanjewar & Shukla, 1985).

Other hosts

Most of the weeds that are present in ginger growing areas are known hosts of root-knot nematodes.

Economic importance and population damage threshold levels

In Queensland, Australia severe infestation of rhizomes reduces yields by 57% as determined by fumigation (Pegg *et al.*, 1974). Treatment of infested soil with DD before planting nematode-free seed rhizomes has increased yields by 80%. A reduction of 74% rhizome weight has been recorded with an initial inoculum level of 10 000 nematodes per plant over a period of six months under potted conditions and significant reduction in yield can be expected with a population of one juvenile/30g of soil (Sukumaran & Sundararaju, 1986).

Both *M. incognita* and *M. hapla* cause significant reduction in shoot length and shoot and root weight following inoculation with 50 juveniles/100 cm^3 soil in pots whereas, 2 juveniles/cm^3 of soil is required to produce measurable effects when ginger is grown in soil naturally infested with *M. incognita*. At higher initial inoculum levels, *M. incognita* and *M. hapla* cause partial or complete withering of aerial shoots, and typical symptoms of drying and twisting of leaves are observed with *M. arenaria* (Kaur, 1987).

Significant damage is noticeable at 0.5 and 1.25 nematodes/g of soil and above in sterilized soil under potted conditions. The fibrous roots are very much reduced at two nematodes/g soil (Parihar, 1985; Routaray *et al.*, 1987*a*).

Control measures

Pegg *et al.* (1974) suggested the following control measures for root-knot nematodes in Queensland:

1. Production of nematode-free planting material by:
   a) Selecting an area where ginger has not been grown in the previous season and has no history of severe nematode infestation.
   b) Preparation of land and fumigation with DD or EDB 15 at 330 l/ha in August. Application of fumigants at a depth of 20 cm in rows, 30 cm apart. The time interval between fumigation and planting should be at least two weeks.
   c) Selection of nematode-free planting material and treatment in hot water at 40°C for 20 min. It is followed by cooling the rhizomes before cutting and dipping in benomyl. Seed should be planted within one week of hot water treatment.
   d) Growing under sawdust mulch. If sawdust is not available, nemacur granules should be sprinkled over the soil between the plants at 11 kg/ha in mid-November and again in mid-January. The rhizomes should be held for planting in the following season. Seed rhizomes with external symptoms of nematode infestation should be discarded.
2. Fumigation of land two or more weeks before planting.

In Fiji, hot water treatment of ginger seed material at 50°C for ten minutes has been recommended (Anon., 1971).

The efficacy of granular nematicides such as Mocap, Nemacur, Vydate and Temik was assessed in Queensland against *M. javanica*. Nemacur was found to be the most effective, increasing rhizome yield by up to 15%. Split and late applications at 22.4 kg/ha are more promising than higher doses applied early in the season (Colbran, 1972). A high level of control of root-knot nematodes has been obtained with sawdust mulching at a depth of 5–7.5 mm, combined with post-plant application of Nemacur. The control schedule for *M. javanica* involving the use of clean seed and a ginger-taro-fallow rotation has been recommended in Fiji (Haynes *et al.*, 1973).

In India, the traditional practices of applying well decomposed cattle manure or compost at 25–30 t/ha, neem cake at 2 t/ha, and mulching with green leaves at 10–12 t/ha at planting and repeating the mulching during the growth period help in reducing nematode multiplication. Application of phenamiphos at 3 kg a.i./ha has resulted in a 70 to 144% increase in yield of ginger in fields infested with *M. incognita* and *Pratylenchus coffeae* either singly or in combination (Kaur, 1987).

Radopholus similis

Parasitism of ginger by the burrowing nematode, *R. similis*, was first reported by Hart (1956) in Florida, USA. Later, Butler & Vilsoni (1975) reported heavy infestation of ginger by *R. similis* in Fiji and its further spread through infested seed rhizomes. Occurrence of *R. similis* along with *M. incognita*, *Pratylenchus* sp. and *Helicotylenchus* sp. has also been reported from roots of ginger in India (Charles, 1978; Charles & Kuriyan, 1979).

Symptoms of damage

Infected plants exhibit stunting, reduced vigour and tillering. The topmost leaves become chlorotic with scorched tips. Affected plants tend to mature and dry out faster than unaffected healthy plants. Incipient infections of the rhizomes are evidenced by small, shallow, sunken, water-soaked lesions (Vilsoni *et al.*, 1976; Sundararaju *et al.*, 1979*a*). The nematodes migrate intracellularly through tissues producing large infection channels or galleries within the rhizomes.

Means of dissemination

R. similis infestation in Fiji of ginger fields appears to have originated through bananas as the areas once used for banana cultivation have been used for growing ginger (Vilsoni *et al.*, 1976). The coconut isolate of *R. similis* in Kerala (India) also reproduces well on ginger (Koshy & Sosamma, 1975, 1977). The perpetuation and dissemination of the nematode is through infested seed rhizomes used for planting.

Economic importance and population damage threshold levels

In Fiji, *R. similis* has been reported from more than 50% of the total area with a rate of infection ranging from 10–50% resulting in yield reductions of about 40%. An initial inoculum level of 10 000 nematodes per plant has been reported to cause 74% reduction in rhizome weight and an initial inoculum level of ten nematodes per plant-reduced shoot weight, root weight and rhizome weight by 43, 56 and 40% respectively, in a pot experiment (Sundararaju *et al.*, 1979*c*).

Control measures

Few studies have been done on the control of *R. similis* on ginger, but the measures suggested for control of root-knot nematodes could help in reducing the loss.

Pratylenchus coffeae

The lesion nematode, *P. coffeae* is widely distributed in ginger in Kerala (Charles & Kuriyan, 1979) and Himachal Pradesh, India. The nematode is highly pathogenic to 15 day old ginger seedlings even with an initial inoculum level of ten nematodes in sterilized soil (Kaur, 1987).

Future prospects

Systematic nematode surveys have not been carried out in most of the ginger growing areas of the world except for stray reports. The burrowing nematode, root-knot nematode and the lesion nematode are well-known potential pathogens that can cause considerable reduction in yield of ginger.

Turmeric

Turmeric (*Curcuma domestica* Val.) is best known as a condiment although the plant has uses in the social and religious lives of people in South-east Asia, its probable origin. The commercial turmeric is the processed rhizomes of *C. domestica*. It is grown mostly in India, and to a small extent in China, Indonesia, Peru and Jamaica. In India, the total area under cultivation during 1986–87 was 102 500 ha with a production figure of 280 600 t (Anon., 1988). It is cultivated either as a monocrop or an intercrop in many farming systems.

It is indispensable in the preparation of curry powder, and is an important source of natural yellow dye. It is also used as a colouring matter in the drug, confectionery and food industries. The rhizomes of *C. aromatica* Salisb., a close relative of *C. longa*, is also a source of turmeric.

Nematodes on Turmeric

A number of species of plant parasitic nematodes have been reported in association with turmeric in India (Table 2) (Nirula & Kumar, 1963; Sundararaju *et al.*, 1979*b*; Dasgupta & Rama, 1987; Gunasekharan *et al.*, 1987; Rama, 1987; Routaray *et al.*, 1987*b*) of which *Meloidogyne* spp., *Radopholus similis* and *Pratylenchus coffeae* are of economic importance. *M. incognita* has also been recorded as an important parasite of turmeric in China (Chen *et al.*, 1986).

Meloidogyne

Two species of root-knot nematodes, *M. incognita* and *M. javanica*, have been reported on turmeric, but most investigations have been concerned with *M. incognita*.

Symptoms of damage

Turmeric plants infested with *M. incognita* have stunted growth, yellowing, marginal and tip drying of leaves and reduced tillering with galling and rotting of roots. In the field, high densities of *M. incognita* cause yellowing, and severe stunting and withering in large patches. Plants die prematurely leaving a poor crop stand at harvest. Infested rhizomes tend to lose their bright yellow colour (Mani *et al.*, 1987).

Economic importance and population damage threshold levels

Significant reductions in length of shoot and leaf, width of lamina, number of leaves and weights of shoot, root and rhizome have been recorded at > 1000 juveniles/plant over uninoculated plants. A 76.6% reduction in the rhizome weight has been recorded with an initial inoculum level of 100 000 nematodes/plant after six months in pots (Sukumaran *et al.*, 1986).

Control measures

Resistance and tolerance

The cultivars and breeding lines 5379–1–2, 5363–6–3, Kodur, Cheyapuspa 5335–1–7, 5335–27, Ca–17/1, Cli–124/6, Cli–339, Armoor, Duggirala, Guntur–1, Guntur–9, Rajampet, Sugandham and Appalapadu have been reported as resistant to *M. incognita* (Mani *et al.*, 1987; Gunasekharan *et al.*, 1987). The species *C. zedoaria* is more resistant to *M. incognita* than *C. domestica* in China (Chen *et al.*, 1986).

Physical

Immersing turmeric rhizomes in hot water at 55°C for 10 min or 45°C for 50 min can kill *M. incognita* inside rhizomes (Chen *et al.*, 1986) and this could be used for establishing nematode-free multiplication plots but is unlikely to be economic for large scale field use.

Chemical

Application of DBCP at 15 l a.i./ha 15 days prior to planting results in a yield increase of 253–270% compared with 59–187% increase in yield with application of phenamiphos at 2.5 kg a.i./ha one day before planting (Patel *et al.*, 1982). Aldicarb and carbofuran applied at 1 kg a.i./ha increased yield by 71% and 68% respectively over control, with a cost benefit ratio of 1:6 in aldicarb and 1:2 in carbofuran treatments (Gunasekharan *et al.*, 1987). Carbofuran at 4 kg a.i./ha applied in rows to a 4-month-old turmeric crop has resulted in a 81.6% reduction in root-knot nematode population as against 45% increase in untreated plots (Mani *et al.*, 1987)

Radopholus similis

Symptoms of damage

Roots of turmeric damaged by *R. similis* become rotted and most of these decayed roots retain only the epidermis devoid of cortex and stelar portions. The infested plants show a tendency to age and dry faster than healthy plants. Infested rhizomes are of a yolk yellow colour compared with the golden yellow colour of healthy rhizomes and have shallow water-soaked brownish areas on the surface. The scale leaves harbour *R. similis* (Sosamma *et al.*, 1979).

Survival and means of dissemination

The nematodes are disseminated through infested planting material. Populations of *R. similis* from coconut are known to infest turmeric (Koshy & Sosamma, 1975) and the use of turmeric as an intercrop in *R. similis* infested coconut and arecanut based farming systems should be avoided.

Economic importance and population damage threshold levels

Pathogenicity studies show that an initial inoculum level of ten nematodes per plant can cause a reduction of 35% of the rhizome weight after four months and 46% reduction at the end of the season (8 months). With 100 000 nematodes, the extent of reduction in rhizome weight is 65 and 76%, after 4 and 8 months respectively (Sosamma *et al.*, 1979).

Control measures

Control has not been studied under field conditions. However, use of clean, nematode-free rhizomes for planting should be the first step in developing an integrated management system for the burrowing nematode on turmeric.

Pratylenchus coffeae

P. coffeae, has been reported to be associated with discolouration and rotting of mature rhizomes of 'wild turmeric', *C. aromatica*. In advanced stages of infection, the rhizomes become deep red to dark brown in colour, less turgid and wrinkled with dry-rot symptoms. The fingers are more severely affected than the mother rhizomes. Internally the affected rhizomes show dark brown necrotic lesions (Sarma *et al.*, 1974).

Future prospects

Turmeric has received very little input in terms of nematological research, although *M. incognita*, *M. javanica*, *R. similis* and *P. coffeae* are known to damage the crop. Detailed investigations including surveys, pathogenicity experiments and control through resistant/tolerant cultivars, cultural, chemical and biological methods are warranted.

Other Spices

Although a number of spice crops including tree spices and seed spices (Table 1) are cultivated over large areas in the tropics and subtropics, there is very little information available on the damage and yield loss caused by plant parasitic nematodes on some of these crops. This is not to say that nematode problems do not exist on these crops but only that there has been a lack of nematological investigations. The plant parasitic nematodes that have been reported in association with these crops in surveys and host range studies are given in Table 2. Nematodes have been found associated in clove (Ghesquiere, 1921; Goodey *et al.*, 1965; Sharma & Loof, 1974; Bridge, 1978; Sundararaju *et al.*, 1979*b*), nutmeg (Goffart, 1953; Goodey *et al.*, 1965; Kumar *et al.*, 1971; Sundararaju *et al.*, 1979*b*; Chawla & Samathanam, 1980), cinnamon (Goffart, 1953; Goodey *et al.*, 1965; Sundaraju *et al.*, 1979*b*; Chawla & Samathanam, 1980; Dasgupta & Rama, 1987; Rama, 1987), cumin (Swarup *et al.*, 1967; Verma & Prasad, 1969; Shah & Raju, 1977; Shah & Patel, 1979; Patel *et al.*, 1986), fenugreek (Krishnamurthy & Elias, 1967; Chandwani & Reddy, 1967; Mathur *et al.*, 1969; Khan & Khan, 1969, 1973; Rashid *et al.*, 1973; Khan, 1975), coriander (Krishnamurthy & Elias, 1967; Chandwani & Reddy, 1967; Sen & Dasgupta, 1977; Das & Sultana, 1979), vanilla (Orton Williams, 1980; Stier, 1984 in Bridge, 1988). All these spices are hosts of *Meloidogyne* spp., and roots of cumin can be severely galled by *M. incognita* and *M. javanica* (Patel *et al.*, 1986). *Pratylenchus brachyurus* is reported to be a parasite of vanilla in the Pacific island of Tonga causing reduced growth of vines (Stier, 1984 in Bridge, 1988).

TABLE 2. Plant parasitic nematodes found associated with spices.

Nematodes	Spice Crops									
	Black pepper	Cardamom	Ginger	Turmeric	Clove	Nutmeg	Cinnamon	Cumin	Fenugreek	Coriander	Vanilla
Caloosia spp.			+		+						
Criconema spp.		+									
Criconemella spp.	+			+	+		+				
Crossonema tylatum		+									
Discocriconemella limitanea	+										
Dolichodorus sp.	+				+						
Helicotylenchus microcephalus											+
Helicotylenchus multicinctus		+		+							
Helicotylenchus spp.	+	+		+	+						+
Hemicriconemoides gaddi		+									
Hemicriconemoides mangiferae	+										+
Hemicycliophora spp.		+	+								
Hoplolaimus columbus	+			+							
Hoplolaimus indicus			+	+			+		+		
Hoplolaimus seinhorsti	+		+								
Hoplolaimus sp.		+			+	+					
Longidorus sp.	+			+							
Meloidogyne arenaria	+		+								
Meloidogyne hapla			+								
Meloidogyne incognita	+	+	+	+	+	+		+	+	+	
Meloidogyne javanica	+	+	+	+				+	+	+	
Meloidogyne sp.							+				+
Ogma taylatum		+									
Paratrichodorus spp.		+							+		
Paratylenchus sp.						+					
Pratylenchoides sp.	+										
Pratylenchus brachyurus			+								
Pratylenchus coffeae	+	+	+	+							
Pratylenchus exilis										+	
Pratylenchus indicus			+								
Pratylenchus pratensis			+								
Pratylenchus zeae	+						+				
Pratylenchus sp.					+						
Radopholus similis	+	+	+	+		+					
Radopholus williamsi											+
Rotylenchulus reniformis	+	+	+	+	+	+	+	+	+		+
Rotylenchus spp.		+		+		+	+				
Scutellonema siamense	+										
Trichodorus sp. (*s.l.*)	+				+						
Trophotylenchulus piperis	+										
Tylenchorhynchus spp.	+		+	+	+			+	+	+	
Xiphinema spp.	+	+	+	+	+	+	+				

Related Crops

Betel Vine

The betel vine, *Piper betle* L. is a perennial, dioecious, semi-woody creeper, probably native of Malaysia. Its leaves are used for chewing, extraction of essential oils like methyl eugenol and in traditional herbal (ayurvedic) medicines and religious ceremonies. It is grown throughout Asia also in Africa, the Philippines, Indonesia and the Pacific islands. The area under betel vine cultivation in India is about 30 000 ha with an annual turnover of Rs. 7 000 million. The yield varies from 7.5–22.5 million leaves/ha/year (Shenoy, 1985).

Its cultivation is labour intensive and requires heavy investment. Betel vine is propagated by cuttings of three to five nodes, from two-year-old vines. It is trailed on coconut, arecanut or other straight stemmed plants like *Sesbania grandiflora* Pers., *Moringa oleifera* Lam and *Erythrina variegata* L. Non-living standards like bamboo, wooden poles or granite stone supports are also used. The crop is usually heavily manured with farm yard manure, oil cakes, fish manure, sheep manure, etc.

Nematodes on Betel Vine

Numerous plant parasitic nematodes have been reported associated with the betel vine in India and elsewhere (Timm, 1965; Reddy, 1978; Ganguly & Khan, 1983; Sivakumar & Marimuthu, 1984; Sivakumar & Muthukrishnan, 1985; Jagdale *et al.*, 1986). Nematodes known to cause damage to the crop are *Meloidogyne incognita*, *Radopholus similis* and *Rotylenchulus reniformis*.

Meloidogyne incognita

M. incognita has been reported to be associated with betel vine decline from all areas in India (Dhande & Sulaiman, 1961; Venkata Rao *et al.*, 1973; Mammen, 1974; Sivakumar & Marimuthu, 1984; Jagdale *et al.*, 1986).

Symptoms of damage

Infested plants exhibit poor growth, yellowing of leaves, reduced vigour and wilting with heavy galling and rotting of roots (Jagdale *et al.*, 1986).

Disease complexes

Association of *M. incognita* with severe wilt symptoms of betel vine was reported from India (Mammen, 1974) and *M. incognita* is known to predispose betel vine to root-rot caused by *Phytophthora palmivora* (Sivakumar *et al.*, 1987).

Economic importance and population damage threshold levels

The root-knot nematode is pathogenic to betel vine at an initial inoculum level of 100 juveniles/plant in sterile soil in pots (Jagdale *et al.*, 1985*a*).

Control measures

Cultural

A crop rotation of betel vine – rice – banana – rice is helpful in reducing *M. incognita*, *Helicotylenchus* sp. and *Rotylenchulus reniformis* populations on betel vine crop raised in rice fields (Sivakumar & Marimuthu, 1986*a*; Sivakumar *et al.*, 1987). Considerable reduction in nematode populations in the soil and number of galls on roots has been reported after application of 50–75 kg K_2O/ha (Jagdale *et al.*, 1985*b*).

Application of neem oil cake at 1 t/ha and sawdust at 2 t/ha can reduce nematode populations.

number of galls and increase the number of leaves harvested significantly (Jagdale *et al.*, 1985*c*). Significant reduction (60%) in the nematode population has been observed in beds amended with chopped and shade dried leaves of *Calotropis gigantea* R. Br. at 2.5 t/ha followed by neem oil cake and poultry manure (44.4 and 40.9% respectively). Beds amended with *C. gigantea* leaves yielded 14.2 kg/4840 leaves and with neem oil cake yielded 12.1 kg/4220 leaves. Soil amendment with sawdust at 2 t/ha + NPK (3638 leaves) and neem oil cake at 2 t/ha is effective in reducing nematode numbers and increasing yields (Sivakumar & Marimuthu, 1986*b*).

Resistance and tolerance

The cvs Kakair, Bangla, Karapaku, Gachipan, Aswani pan and Berhampuri are reported to be tolerant to root-knot (Anon., 1987). The cv Karpoori is highly susceptible and cv Kuljedu had the lowest root-knot index and number of egg masses per plant (Jagdale *et al.*, 1985*a*; Sivakumar *et al.*, 1987).

Physical

Solarization by mulching the land with black and white polythene (100 gauge) before planting for 15 days was found to reduce plant parasitic nematode populations in India (Sivakumar & Marimuthu, 1987).

Chemical

Application of aldicarb and carbofuran at 0.75 kg a.i./ha reduces nematode populations by 71 and 55%, respectively, resulting in increased yields. The granules, at both the levels, degraded to non-detectable levels 41 days after application (Sivakumar *et al.*, 1987). Aldicarb, carbofuran and benfurocarb applied at 1.5, 3.0, 5.0 kg a.i./ha, respectively, in furrows on either side of the rows can reduce *M. incognita* populations in soil and galling of the roots significantly (Dethe & Pawar, 1987). However, use of aldicarb and carbofuran is generally not recommended for betel vine as the leaves are picked continuously and consumed directly without any processing.

Because of the residue problem in leaves, it is preferable to manage root-knot nematode infestation on betel vine by adopting the following non-chemical measures:

1. Crop rotation wherever possible.
2. Use of resistant/tolerant cultivars.
3. Use of dead or non-living standards or nematode-resistant live standards for supports.
4. Solarization by mulching the land with clear polythene (100 gauge) before planting.
5. Application of organic amendments such as leaves of neem and *Calotropis*, and sawdust at 2 t/ha.
6. Supply of nitrogen through neem oil cake at 2 t/ha.

Radopholus similis

The burrowing nematode, *R. similis* has been reported to cause yellows/slow wilt disease of betel vine in India. The symptoms produced on betel vine are akin to the symptoms caused by *R. similis* on black pepper vines (Koshy & Sosamma, 1975; Sundararaju & Suja, 1986; Eapen *et al.*, 1987).

The integrated management schedules suggested for control of nematodes on black pepper, other than application of nematicides, can be largely adopted with modification to suit the local conditions for controlling *R. similis* on betel vine.

Rotylenchulus reniformis

Acharya and Padhi (1987) found *R. reniformis* to be pathogenic to betel vine. At inoculum levels of 1000 and 20 000 nematodes per cutting the reduction in number of leaves was 20 and 60% respectively.

Kava

Kava or Yaqona (*Piper methysticum* Forst.) provides a popular narcotic drink for the peoples of the Pacific islands. The drink is made from the thick roots of this bushy shrub.

Nematodes of Kava

Root-knot nematodes, *Meloidogyne* spp., have been found associated with a serious disease of kava and the nematodes alone can greatly decrease growth of plants in Fiji and Tonga (Stier, 1984 in Bridge, 1988) (Plate 16F). *M. incognita* is reported causing severe root galling of *P. methysticum* in Western Samoa (Fliege & Sikora, 1981).

Other potentially damaging parasitic nematodes that have been found with kava include *Rotylenchulus reniformis, Pratylenchus coffeae* and *Radopholus similis* (Kirby *et. al.*, 1980; Orton Williams, 1980). None of these have as yet been shown to damage the crop.

Further investigations are necessary to determine the economic importance of nematodes, particularly *Meloidogyne* spp., and their means of control.

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