

6. DISEASES OF TURMERIC (*CURCUMA LONGA* LINN.)

Foliar diseases of turmeric are only next to rhizome rot in their importance, since the loss of active photosynthetic area of the leaves affects the yields considerably. The diseases were reviewed earlier (Joshi and Sharma, 1982).

6.1 *Taphrina* Leaf Spot

The disease is widely distributed in the southern states and the Gangetic plains in Uttar Pradesh and Bihar. This was first reported from Gujarat, Saharanpur (UP) and Rangpur (East Pakistan) (Butler, 1911).

6.1.1 Crop Losses

Though precise crop loss figures are not available, the foliar destruction it causes would reduce the yields considerably especially when the disease starts in its early stages of crop growth (Butler, 1918).

6.1.2 Symptoms

The disease starts as small scattered oily looking translucent spots on the lower leaves when the plants are in 3-4 leaf stage. The leaf spots later turn dirty yellow and deepens to colour of gold and some times to bay shade. The adjacent individual leaf

Nematodes in Plantation Crops

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1. INTRODUCTION

Plant parasitic nematodes cause considerable losses to plantation crops. However, systematic nematological investigations on the nematodes associated with the plantation crops were started only during 1970s. The nematode problems relating to plantation crops are not easy to tackle because of the perennial nature of the crops. Most of these plants have deep and very elaborate root systems. Therefore, the studies relating to the pathogenicity of suspected nematode species, enumeration of nematode population that would cause debilitation in plant growth and yield and application of nematicides in to the soil and evaluation of the same do not yield quick results. In spite of all these difficulties, considerable work has been done on the nematode problems of plantation crops which is presented in this chapter.

2. PLANT PARASITIC NEMATODES

Plant parasitic nematodes are elongate worms ranging in length from about 0.3 mm to over 5.0 mm; bilaterally symmetrical, unsegmented, colourless and circular in cross section. The anterior end tapers to a rounded lip region, the body proper is more or less cylindrical and the posterior part tapers to a terminus which may be pointed to hemispherical. Females of some species like cyst and root-knot nematodes have greatly expanded bodies sometimes nearly spherical, but always with a distinct neck. The adult males are always slender worms. There are usually no external appendages. The body is covered with a cuticle which may be smooth or may exhibit various kinds of transverse and longitudinal grooves. Underneath the cuticle lies the hypodermis which produces the cuticle and a muscle layer that allows the undulating movements of nematodes in a dorso-ventral plane. Since their ability to force a passage by moving soil particles is limited, nematodes must make their way through pore spaces of the soil. Nematode movement is possible only when water is present. Movement is inhibited in soil which is near the wilting point for plants. They have well defined digestive system with the mouth opening followed by a mouth cavity or stoma which is armed with a conspicuous protrusible spear or stylet which is used to puncture plant cells. The stylet is hollow and forms the path of food intake.

They have well defined excretory, nervous and reproductive systems but organs or structures associated with circulatory and respiratory systems are not known. Both circulatory and respiratory processes are apparently associated with movement of fluids of the body cavity.

The life cycle of a plant parasitic nematode is simple with five distinct stages—adult, egg and four juvenile stages with four moults. The first stage juvenile develops in the egg and the first moult occurs within the egg shell giving rise to the second stage juvenile which emerges free into the soil or plant tissue. On feeding, the second stage juvenile grows, develops and moults three times and becomes an adult. Upon maturity, the female deposits eggs and the life-cycle is repeated. Nematodes as a rule are dioecious existing as separate females and males. Some forms are parthenogenetic.

Important nematode problems on plantation crops are the burrowing and root-knot nematodes.

3. NEMATODES ON COCONUT

Many nematode species belonging to 44 genera have been reported on coconut in India (Kutty and Koshy, 1979; Koshy, 1986 a, b) and among them the burrowing nematode is the most important. The red ring disease of coconut caused by *Rhadinaphelenchus cocophilus* transmitted by the black palm weevil *Rhynchophorus palmarum* prevalent in Caribbean and Latin American countries is not known to occur in India as well as in South-East Asia.

3.1. Radopholus *similis* (Cobb, 1893) Thorne, 1949

The burrowing nematode was reported from coconut palms in Kerala, India by Weischer in 1967. Surveys conducted in coconut plantations in South India recorded 24 per cent incidence of *R. similis* in coconut (Koshy, 1986a).

3.1.1 Diagnostic Features

3.1.1.1 Female : Vermiform, migratory, endoparasitic, lip region rounded, strong well-developed stylet and oesophagus. Two outstretched ovaries, tail conoid to blunt, rounded terminus.

3.1.1.2 Male: Vermiform, migratory, not parasitic. Lip region sub-spheroid, offset, slender stylet, degenerated oesophagus, single testis, spicules paired with bursa extending two-thirds length of the tail.

3.1.1.3 Juveniles : Vermiform, migratory, parasitic. Lip region rounded, well-developed stylet and oesophagus.

3.1.1.4 Systematic position : Nematoda, Secernentea, Tylenchida, Tylenchoidea, Pratylenchidae, Radopholinae, Radopholus.

3.1.2 Biology

3.1.2.1 Life cycle : All juvenile stages, females including gravid females except the adult and fourth stage males are infective and endoparasitic. Life cycle is completed in 25 days at a temperature of 25-28°C (Koshy, 1986b).

3.1.3 Culturing

The *R. similis* population from coconut is easily cultured axenically on carrot discs placed on one per cent water agar (Koshy and Sosamma, 1980). It can also be cultured within the mesocarp of growing tender coconut without affecting the size or quality of the nuts (Koshy and Sosamma, 1982).

3.1.3.1 Survival and dispersal : Burrowing nematode populations survive under field conditions for six months in moist soil and one month in dry soil. The nematode survives in roots of stumps of felled coconut palms upto six months (Sosamma and Koshy, 1986). Adult females withstand adverse conditions better than all other stages and cause annual recurrence of infection.

Infested coconut seedlings help in the dissemination of the nematode to distant places. Apart from coconut, infested planting materials of intercrops such as arecanut, banana, pepper, ginger, turmeric etc. also serve as sources of inoculum.

3.1.3.2 Pathotypes : The coconut isolate of *R. similis* has a haploid number of four chromosomes ($n = 4$) and do not infest any of the *Citrus* spp. and *Poncirus trifoliata*. (Koshy and Sosamma, 1977).

3.1.3.3 Population fluctuation : Roots of infested coconut palms yield maximum number of *R. similis* during October to November and minimum during March to July (Koshy and Sosamma, 1978). The burrowing nematode multiplies well on coconut in loamy sand followed by riverine alluvium and least in 'Kari' soil and causes maximum plant damage in riverine alluvium and least in laterite soil (Sosamma and Koshy, 1985).

3.1.4 Hosts

Burrowing nematode has a wide hostrange and among the 115 plant species tested 48 are hosts which include several crops and weeds in coconut gardens (Koshy and Sosamma, 1975; Sosamma and Koshy, 1977; 1981).

3.1.5 Symptoms

Burrowing nematode infested coconut palms exhibit general decline symptoms such as stunting, yellowing, reduction in leaf number and size, delayed flowering and reduced yield. Symptoms on roots are very specific. *R. similis* infestation produces small, elongated, orange coloured lesions on tender creamy white roots. Consequent to nematode parasitisation and multiplication, these lesions enlarge and coalesce to cause

extensive rotting of roots (Fig. 1). On merging of lesions, cracks develop on the epidermis of the semi-hard orange coloured main roots. Lesions and rotting are confined to the tender portion of roots. Lesions are not conspicuous on the secondary and tertiary roots as they are narrow and rot quickly on infestation. Lesions are not usually seen on the old, hard, dark brown roots. As high as 4000 nematodes were recovered from one gram (one inch length) of main roots. Tender roots of coconut seedlings on heavy infestation become spongy in texture. The nematode also attacks the plumule, leaf bases and haustoria of seedlings. The drastic reduction in the number and mass of tertiary feeder roots on parasitisation by the nematode limits plant growth (Koshy and Sosamma, 1987).

3.1.6 Histopathology

Burrowing nematodes do not enter hardened or suberised epidermis of coconut roots; but they penetrate the absorbing region behind the root cap covered by very delicate epidermis by lysis of cells. Such entry points or holes are of 1-2 cells in diameter and surrounded by sclerenchymatous cells to a depth of 10-15 cells. The cavities that form in the outer cortex are always surrounded by deeply stained and heavily suberised cells of irregular shape, whereas those found in the inner cortex do not have any such deformed darkly stained border cells. Maximum number of nematodes and cavities are seen in



Fig. 1 : Shows lesions and rotting on coconut roots infested by the burrowing nematode, *Radopholus similis*.

the outer cortex. Nematodes have not been observed in the stelar region or in closely packed 4-6 layers of cells outside the strongly suberised endodermis even in heavily infested roots. The endodermis and the 4-6 layers of cells around it appear to serve as an effective barrier against the invasion of the stele. In the early stage of infection, roots have cavities of independent origin separated by several cells. Consequent to nematode multiplication and lysis of cytoplasm and cell walls, adjacent cavities merge with each other. Multiple cavities and their coalescence destroy the cortex to a great extent. The stelar tube remains intact even in heavily infested roots in transverse and longitudinal sections. Eggs and all stages of nematodes with different orientations are seen in cavities in longitudinal sections (Koshy and Sosamma, 1987).

3.1.7 Losses

The pathogenic threshold level of *R. similis* is 100 nematodes per seedling or one nematode in 576 cm³ or 800 g sandy loam soil. At an inoculum level of 62,500 nematodes per seedling 48,21,76 and 79 per cent reduction over control in height, girth, shoot and root weight respectively was recorded. It causes up to 30 per cent reduction in yield of coconut on heavy infestation.

3.1.8 Control

3.1.8.1 Nursery: Application of phorate or phenamiphos at 25 kg ai/ha during September, December and May in infested coconut nurseries completely eliminated *R. similis* (Koshy *et al.*, 1985). Avoiding banana as a shade crop in coconut nurseries is helpful in reducing nematode multiplication.

3.1.8.2 Plantations : (a) Apply cowdung, farm yard manure, oil cakes, green manure (*Glyricidia maculata*) etc. to the basins and *Crotolaria juncea* and grow *crotolaria juncea* in the basins and interspaces and use as green manure in the basins and interspaces and use as green manure. (b) Apply phorate @ 10 g ai/palm and at 3 g ai/seedling in June-July and in September-October. (c) Use nematode-free planting materials of coconut and other intercrops. (d) Use tolerant or less susceptible cultivars or their hybrids in infested areas. (e) Apply phorate at 3g ai/plant to intercrops such as banana, black pepper and arecanut in June-July and September-October in infested gardens.

3.1.9 Method of Diagnosis

Soil and root samples for detection of *R. similis* should be collected in October-November at a distance of 100 cm from the bole of the palm to a depth of 50-100 cm. Fifty gram of tender, creamy-white to orange coloured, semi-hard, main roots showing lesions and rotting should be collected. These may be peeled and sliced longitudinally into four to eight pieces of 3-5 cm length. Sliced root bits may be submerged in water contained in petridishes or in shallow pans at a temperature range of 20-25°C for 72 hrs for collecting active nematode population and for population assessment, such processed root bits should be stained and blended.

4. NEMATODES ON ARECANUT

Twentyeight genera of plant parasitic nematodes have been recorded from the root zone of arecanut (Koshy et al., 1975, 1976; Sundararaju and Koshy, 1982). Among them, *Radopholus similis* was the only endoparasite encountered in more than 50 per cent of the root samples collected.

4.1 *Radopholus similis*

The burrowing nematode was first reported from soil around roots of arecanut palm in **Mysore** by Kurnar et al., (1971).

4.1.1 Symptoms

Burrowing nematode infested areca palms exhibit non-specific above ground symptoms like general yellowing, and visible reduction in growth, vigour and yield. The most conspicuous symptom is the appearance of lesions and rotting of roots. On nematode infestation young, tender, creamy white main and lateral roots produce small, elongate, orange coloured lesions. The adjoining lesions coalesce and cause extensive root rotting. The thick primary **roots** produced from the bole region of the palm **exhibit** large, oval, sunken, dark lesions. Unlike in **coconut** the tips of lateral and tertiary roots on infestation becomes black.

Nematodes feed inter and intra **cellularly in the** cortex but do not enter the stelar tissues.

4.1.2 Biology

The burrowing nematode takes 25-30 days to complete one **life** cycle (J_2 - J_2) on arecanut seedlings at a temperature range of **21-31°C** under greenhouse **conditions**. Many arecanut isolates of *R. similis* have a haploid number of four chromosomes ($n = 4$) (Koshy, **1986b**). Maximum population of *R. similis* occur during October to November and minimum during March to June (Koshy and Sosamma, **1978a**).

4.1.3 Losses

R. similis was recorded from 32 per cent root samples collected from Kerala, **Karnataka** and Tamil Nadu with a maximum population of 440 nematodes per gram of root. *R. similis* occurred in **55, 45, 44, 30** and 11 per cent root samples from plantations intercropped with banana, black pepper, cardamom, coconut and cacao respectively **compared** to 25 per cent from plantations monocropped with arecanut (Sundararaju, 1984). The population damage threshold level on arecanut seedlings is 100 **nematodes/** plant or **one/800** g of **laterite** soil. Ten fold increase in yield was recorded by treatment with **aldicarb** at 10 g **ai/palm**, DBCP at 10 **ml ai/palm** or fensulfothion at 50 g **ai/palm** (Sundararaju and Koshy, 1986).

4.1.4 Control

4.1.4.1 Resistance/tolerance : Cultivars VTL-11 and VTL-17 are high yielding as well as tolerant to *R. similis*. The hybrid VTL-11 x VTL-17 is highly resistant to *R. similis*. The variety VTL-3 (Mangala) is highly susceptible to *R. similis* (Koshy *et al.*, 1979; Sundararaju and Koshy, 1982, 1988).

4.1.4.2 Integrated : (a) use **tolerant/resistant** varieties; (b) use nematode free planting materials of arecanut and other intercrops; (c) avoid *R. similis* susceptible varieties of inter crops like black pepper and banana; (d) Apply 5-10 kg of green manure per palm preferably *Glyricidia* or *Crotolaria* ; (e) apply 1 kg of neem oil **cake/palm/year**; and (f) apply phorate at **3g ai/plant** to the root zone of arecanut, banana and black pepper in June-July and in September-October in arecanut based farming systems.

5. NEMATODES ON OIL PALM

Though a number of species of plant parasitic nematodes have been recorded from the root zone of oil palm, none of them appear to be a serious problem at the moment. *R. similis* has been reported from the roots of a few seedlings. Intensive survey is required to identify nematode problems, if any.

6. NEMATODES ON COCOA

From the limited survey carried out no major nematode problem has been identified on cacao in India (Sosamma *et al.*, 1979).

7. NEMATODES ON BLACK PEPPER

Of the 36 species of nematodes reported on pepper, the two most important ones are *Radopholus similis* and *Meloidogyne incognita* (Sundararaju *et al.*, 1979 a; Ramana and Mohandas, 1987a).

7.1 *Radopholus similis*

In Kerala and Karnataka, the burrowing nematode causes the slow wilt disease which is identical with the pepper yellows of **Bangka** Island in Indonesia. (Van der Vecht, 1950; Mohandas and Ramana, 1987b; Ramana *et al.*, 1987a).

7.1.1 Symptoms

The primary symptom of burrowing nematode infestation (slow wilt) is the appearance of a few, pale yellow drooping leaves whose number gradually increases and within a year or two, the entire foliage may become yellow. This is followed by shedding of leaves, cessation of growth and die-back symptoms. In the **very** early stage, the symptoms may disappear with the on set of South-West **monsoon** because of the shedding of yellowed leaves and the appearance of new flush. This makes the farmers

to attribute the yellowing to drought and lack of nutrients. However, the symptoms reappear in September and within three to five years of initiation of yellowing all the leaves are shed and death of the vine occurs. In bearing vines spike shedding is a major symptom. In large plantations, affected patches are conspicuous with many barren standards and vines with different intensities of yellowing and shedding of foliage. Young and old plants are affected.

The **tender**, thin, white, feeder roots show typical orange to purple coloured lesions. The feeder and lateral roots rot quickly and the root system gets crippled to large necrotic main roots. *R. similis* do not enter the **stelar** portion of roots and are found in inter and **intracellular** positions within the cortex (Venkitesan, 1976).

7.1.2 Hosts

Crops involved in coconut and arecanut based farming systems such as banana, ginger, turmeric, cardamom, etc. are hosts of the burrowing nematode. In infested areas pepper trailed on to arecanut do not survive for more than 10-15 years. Establishing replants is also difficult specially under irrigated **conditions** with banana as an intercrop. Application of heavy doses of phorate to all crops involved may be necessary for this.

7.1.3 Losses

A population level of 250 nematodes per gram of root was constantly recorded with slow wilt affected pepper vines in **Kerala** (Ramana, 1986). **Menon** (1949) reported **mortality** up to ten per cent of the vines due to the disease.

7.1.4 Control

7.1.4.1 Plant resistance: A total of 106 **cultivated** germplasm, 36 wild related *Piper* spp., 20 intercultivar hybrids, 90 selections of **cv Karimunda** and 12,200 open pollinated seedlings of popular pepper cultivars were screened against *R. similis* and found no **resistance/tolerance** in any of them (Ramana *et al.*, 1987b).

7.1.4.2 Chemical: Aldicarb sulphone at 8 kg ai/ha gave best control of *R. similis* followed by fensulfothion and DBCP (Venkitesan, 1976). Aldicarb/carbofuran/phorate at 3g ai/vine (applied in **May/June** and in **September/October**) result in the remission of **foliar** yellowing and reduction in nematode population. Among these phorate was found superior to others (Ramana 1986; Mohandas and Ramana, 1987a). But studies on **cost-benefit** ratio and residue analysis of these chemicals have not been carried out.

7.1.4.3 Integrated : For heavily infested areas the following integrated method of management is suggested.

- a) Use non-king standards and exclude *R. similis* susceptible trees as standards for trailing black pepper vines and avoid infested planting **materials** of intercrops.

- b) Uproot affected vines and replant after 9-12 months with nematode free rooted cuttings of high yielding tolerant variety and protect with phorate @ 1 g ai/vine at planting itself.
- c) Apply phorate @ 3g ai/vine in May/June and September/October. If the vine is trailed on to a susceptible tree like arecanut, phorate is to be applied @ 6g ai/standard.
- d) Apply 5 kg green manure (*Glyricidia*, *Crotolaria*), 1 Kg FYM, along with the recommended dosages of NPK, neem oil cake @ 200g/vine, nematicides as above and earth up to 50 cm radius.
- e) Avoid susceptible intercrops like banana, ginger, turmeric etc. or treat banana with phorate @ 3g ai/plant twice a year and turmeric and ginger with phorate @ 1 g ai/ha at planting.

7.2 *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949.

The occurrence of **root-knot** nematode on black pepper from Wynad in Kerala (Butler, 1906), is the second report of a plant parasitic nematode in India.

7.2.1 Diagnostic Features (Jepson, 1987)

7.2.1.1 Female : Body white, globular to pear shaped, 295-4250 / μ m long, sometimes elongate, usually with short neck, cuticle thin, annulated with characteristic terminal striations forming perineal pattern around vulva and anus. Head has cuticular framework with a 10-20 / μ m long robust **stylet**. Gonads are paired, elongate, and convoluted. Eggs are laid in gelatinous matrix secreted by rectal glands.

7.2.1.2 Male : Vermiform, migratory with a length about 700-1900 μ m. Strong cephalic framework. Robust 13-30 / μ m **stylet**. **Metacarpus weakly** developed. Tail bluntly rounded with paired spicules. One or two testes.

7.2.1.3 Second-stage juveniles : Vermiform, infective, migratory, of about 250-600 / μ m long. Head with labial cap, robust **stylet**. Tail tapering narrow with rounded tip and hyaline **terminal** portion.

Third and fourth stage juveniles swollen, **sedentary** within roots, without **stylet** and within cuticle of second stage **which** retains the tail spike.

7.2.2 Systematic Position

Nematoda, Secernentea, Tylenchida. Tylenchina, .**Heteroderoidea**, Meloidogynidae, Meloidogyninae, Meloidogyne.

7.2.3 Biology

The eggs are laid in a gelatinous matrix. Its contents undergo a series of determinate cleavage giving rise to the second stage juvenile which hatches out. The J₂ juveniles penetrate host plants above the meristematic zone and orient parallel to the stele. It starts feeding on the pericycle cells for several weeks gradually swelling. A series of three moults occur in quick succession. Reproduction may be **parthenogenetic** or bisexual with a female laying 400-500 eggs. Egg laying is completed within a week. The life cycle under optimum condition takes 3-4 weeks.

7.2.4 Symptoms

On infestation by root-knot nematode, black pepper vines show unthrifty growth and yellowing of leaves. The **interveinal** areas on leaves of such vines become dense yellow thereby the leaf veins appear quite distinct with a deep green colour, whereas leaves of the vines infested with *Radopholus similis* show uniform pale yellow or whitish discolouration and typical drooping. In variety 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. Histopathological studies of infested roots of var. Panniyur I revealed the presence of the nematode in the cortex as well as in the stelar region. A maximum of six giant cells were recorded in the vascular region at one site. In most of the cases egg masses were found 5-10 cells below the epidermis (Koshy and Sundararaju, 1979; Koshy *et al.*, 1979; Koshy and Bridge, 1990).

7.2.5 Losses

An initial **inoculum** level of ten second stage juveniles per rooted cutting was found to reduce growth by 15 percent while at a level of 1,00,000 juveniles 50 per cent reduction in growth was **observed** over one year period (Koshy *et al.*, 1979a). Root-knot nematode infestation is a major problem in black pepper in several agricultural departmental nurseries in Kerala and more than 50 per cent death of transplants occur in field planting.

7.2.6 Other Hosts

The naturally occurring hosts, *Oroxylum indicum* Vent, *Erythrina lithosperma* Blume, *Ceiba pentandra* (L.) Gaerth, and *Bombax malabaricum* DC are highly susceptible to root-knot nematode whereas *Garuga pinnata* Roxb and *Macaranga indica* Weight are not susceptible. The popular live standards *Erythrina indica* Lank and *Glyricidia 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).

7.2.7 Control

7.2.7.1 Resistance/tolerance: Among the seven popular cultivars screened, the cultivar **Panniyur I** was the most susceptible and Valiyakani akada the least (Koshy and Sundararaju,

1979). The intensity of damage on infestation with *M. incognita* was less in cultivar Karimunda compared to the variety Panniyur I (Mohandas and Ramana, 1983). The cultivars **Kalluvally**, Balankotta, Narayakodi and Padapan had fewer galls when compared with Panniyur I (Jacob and Kuriyan, 1979). Of the **101 cultivars**, 74 accessions of wild Piper sp and 140 intercultural hybrids screened, one cultivar CLT-P-812 was found resistant to *M. incognita* (Ramana and Mohandas, 1986, **1987b**; Koshy, **1987b**).

7.2.7.2 Chemical : Application of **aldicarb** at 1 g **a.i./vine** twice a year (**May/June** and **October/November**) integrated with fertilizers (N = 400 g, P = **40g**, K = **140g/vine**) in two equal **split** doses, earthing **upto** 50 cm radius at the base of the vines and mulching the base of the vines with leaves reduced **foliar** yellowing by 83 per cent and *M. incognita* larval population by 33-88 per cent (**Venkitesan** and Jacob. 1985).

7.2.7.3 Integrated: The integrated management practices suggested against *R. similis* on black pepper is effective against *M. incognita* also as both the nematodes occur mostly together on the same plant.

8. NEMATODES ON CARDAMOM (**ELETTARIA** CARDAMOMUM (L) **MATON**)

The **most important** nematode problem on cardamom is the root-knot nematode, *Meloidogyne incognita* and *M. javanica* (D'souza et al., 1979; **Kumar et al.**, 1971; Viswanathan et al., 1974; **Sundararaju et al.**, **1979a**) occurring in nurseries and plantations in Kerala, Karnataka and Tamil Nadu (Koshy et al., 1976; **Ali**, 1982, 1986).

8.1 Symptoms

Mature plants on heavy infestation in a plantation show stunting, reduced tillering, yellowing, premature drying of leaf tips and margins, narrowing of leaf blades, delay in flowering, immature capsule drop and reduction in yield. Unlike in seedlings, galling of roots is not a conspicuous symptom on mature **plant**. The infested roots, however, exhibit a "witches **broom**" type of excessive branching.

In the primary nurseries more than 50 per cent 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 the secondary nursery, they show curling of the unopened spindle leaf. Up to 40 per cent of such seedlings do not establish in the secondary nursery. In the secondary nursery **the** infested plants show stunting, yellowing, drying of leaf tips and margins, poor tillering and heavy galling of roots (Ali and Koshy, 1982).

Increased incidence of rhizome rot and damping off disease is noted in **root-knot** nematode infested nurseries (Ali, 1986; Eapen, 1987).

8.2 Survival and Distribution

The nematodes are disseminated through infested seedlings supplied by nurseries of Spices Board and plantations. Though methods for fumigation of nursery beds with methyl bromide formalin and treatment with nematicides are available, they have not been adopted by various agencies involved.

8.3 Other Hosts

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

8.4 Losses

An yield loss of 32-47 per cent due to root-knot nematode has been reported (Ali, 1984, 1986). An initial population of 100 nematodes per plant causes discernible damage to cardamom (Eapen, 1987).

8.5 Control

Disinfecting nursery beds with methyl bromide @ 500 g/110m² is effective in controlling root-knot nematode in cardamom nurseries. Seed beds can also be drenched with two per cent formalin to a depth of 20-30 cm and covered with polythene sheets for three to seven days. Seeds can be sown two weeks after formalin application when the soil is free from formalin fumes. Application of aldicarb at 5 kg ai/ha three times after every three months results in increase in growth and vigour of seedlings both in primary and secondary nurseries (Koshy et al., 1979; Ali, 1986). Application of aldicarb carbofuran/Phorate at 5 g and 10 g a.i./plant and neem oil cake at 500 g and 1000 g/plant twice a year increases yield of cardamom plants infested with *M. incognita* from 47-88 per cent. Maximum yield was obtained from the plants receiving neem oil cake at a rate of 1000 g/plant followed by 500 g/plant (Ali, 1984).

9. NEMATODES ON GINGER (*ZINGIBER OFFICINALE*, ROSC.)

Among the large number of nematode species reported on ginger the root-knot and burrowing nematodes are the most important (Sundararaju et al., 1979a; Rama and Dasgupta, 1985; Routaray et al., 1987b; Kaur, 1987).

9.1 *Meloidogyne* spp.

9.1.1 Symptoms

Heavily infested plants show stunting and have chlorotic leaves with marginal necrosis. Roots and underground rhizomes exhibit galling and rotting. Infested rhizomes have brown, water-soaked areas in the outer tissues especially in angles between shoots. Such rhizomes serve as a source of infection and means of dissemination.

9.1.2 Losses

Under potted conditions an initial inoculum level of 10,000 **nematodes/plant** over a period of six months resulted in 74 per cent reduction in rhizome weight. A population level of one infective juvenile/130 g of soil can cause significant reduction in yield (Sukumaran and 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 cm³** soil in pots whereas two juveniles/cm³ 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). At an inoculum level of two **nematodes/g** of soil the fibrous roots are very much reduced (Parihar, 1985; Routaray et al., 1987a).

9.1.3 Control

The traditional practice of application of well decomposed cattle manure or compost at 25-30 **tonnes/ha**, neem **cake** at two tonnes/ha and mulching with green leaves at 10-12 **tonnes/ha** at planting and mulching again during the growth period help in reducing nematode population. Application of phenamiphos at 3 Kg **a.i./ha** resulted in a 70 to 144 per cent increase in yield of ginger in fields infested with *M. incognita* and *Pratylenchus coffeae* either singly or in combination (Kaur, 1987).

9.2 *Radopholus similis*

Occurrence of *R. similis* along with *M. incognita*, *Pratylenchus* sp. and *Helicotylenchus* sp. was reported from Kerala by Charles and Kuriyan (1979). The coconut isolate of *R. similis* was found to reproduce well on ginger (Koshy and **Sosamma**, 1975, 1977).

9.2.1 Symptoms

R. similis infection in ginger cause stunting, loss of vigour and poor **tillering**. The topmost leaves become **chlorotic** with scorched tips. Affected plants tend to mature and dry out faster than unaffected healthy plants. Rhizomes on infection produce small, shallow, sunken, water soaked lesions (**Sundararaju et al., 1979b**).

9.2.2 Losses

An initial inoculum level of 10,000 nematodes per plant caused 74 per cent reduction in rhizome weight (Sundararaju et al., 1979c).

9.2.3 Control

The measures suggested for the control of root-knot nematode could be adopted till studies are conducted for the control of burrowing nematodes.

10. NEMATODES ON TURMERIC

Of the many species of plant parasitic nematodes **reported** on turmeric (**Nirula and Kumar, 1963; Sundararaju et al., 1979b; Dasgupta and Rama, 1987; Gunasekharan et al., 1987; Rama, 1987; Routaray et al., 1987b**) of which *Meloidogyne* spp., *Radopholus similis* and *Pratylenchus coffeae* are of economic importance.

10.1 *Meloidogyne incognita*

10.1.1 Symptoms

Affected plants show stunted growth, yellowing, marginal **and** tip drying of leaves, reduced **tillering** and galling and rotting on roots. 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).

10.1.2 Losses

An initial inoculum level of 1,00,000 nematodes/plant caused 76.6 per cent reduction in rhizome weight under pot conditions (Sukumaran et al., 1986).

10.1.3 Control

Among 60 germplasm collections screened against *M. incognita*, 5379-1-2, 5363-6-3, Kodur, Cheyapasupu, 5335-1-7, 5335-27, Armour, Duggirala, Guntur I, Guntur-9, Sugandham and Appalapadu have been reported as resistant. (Mani et al., 1987; Gunasekharan et al., 1987).

Aldicarb and carbofuran applied at 1 kg ai/ha increased yield by 71 and 68 per cent respectively over control with a cost benefit ratio of 1:6 in aldicarb and 1:2 in carbofuran treatments (Gunasekharan et al., 1987).

10.2 *Radopholus similis*

10.2.1 Symptoms

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

10.2.2 Losses

Pathogenicity studies in **pots show** that an initial inoculum level of ten nematodes per plant can cause a reduction of 35 per cent of rhizome weight **after four** months and

46 per cent at the end of the season (8 months). With 1,00,000 nematodes, the extent of reduction in rhizome weight is 65 and 76 per cent after 4 and 8 months respectively (Sosamma *et al.*, 1979).

10.3 *Pratylenchus coffeae* (Zimmerman, 1878) Filipjev and Sch. Stek, 1941

P. coffeae causes discolouration and rotting of rhizomes of *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).

10.4 Other Spices

There have never been any serious nematological investigations on tree and seed spices, though these crops are cultivated over large areas in India. Root-knot and reniform nematodes have been reported to cause damage to coriander, (Krishnamurthy & Elias, 1967; Chandwani & Reddy 1967; Sen and Dasgupta, 1977; Das and Sultana, 1979; Midha and Trivedi, 1988 a, b), cumin (Swarup *et al.*, 1967; Verma and Prasad, 1969; Shah and Raju, 1977; Shah and Patel, 1979; Patel *et al.*, 1986) and fenugreek (Krishnamurthy and Elias, 1967; Chandwani and Reddy, 1967; Mathur *et al.*, 1969; Khan and Khan 1969, 1973; Rashid *et al.*, 1973; Khan, 1975; Sharma *et al.*, 1988). A number of ectoparasitic nematodes have been reported from the root zone of nutmeg, clove and cinnamon (Sundararaju *et al.*, 1979a).

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