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NEMATODES OF PALMS

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COCONUT

Coconut (*Cocos nucifera* L.) of palm family Arecaceae is cultivated widely throughout the tropics of the world. India is the largest producer of coconuts in the world with an estimated area of 9.1 lakh hectares followed by Indonesia and Philippines. The average productivity of coconuts in the country is 7760 nuts per hectare, nearly 16 per cent of the total world's production.

Coconut is considered to be "kalpavriksha " in view of its versatile contribution to mankind, every part of the tree and its products finding an economic use. It is one of the most important sources of vegetable oil. Nearly 7% of vegetable oil production in the country is accounted for by coconut oil. Coconut contributes about 15 per cent of the annual income and 35 per cent of the agricultural income of Kerala State. The foreign exchange earned by coconut through export is around Rs. 200 crores.

Coconut palm is affected by a large number of diseases and the most prevalent one in Kerala is the root (wilt) disease caused by Mycoplasma-like organisms (MLO). The annual loss due to root (wilt) disease is estimated to be about 968 million nuts. The disease was first reported in 1882 from central parts of Kerala. The disease is non-lethal but debilitating and palms of all groups are affected.

The coconut palms grown under the homestead and plantation situations suffer considerable damage due to infestation by nematodes right from the seedling stage.

Of the 78 nematode species reported on coconut (Govindan Kutty and Koshv, 1979),

the most important endoparasites are red ring nematode *Rhadinaphelenchus cocophilus* and the burrowing nematode *Radopholus similis*.

RHADINAPHELENCHUS COCOPHILUS

Historical Background

The 'Red Ring Disease' of coconut caused by *Rhadinaphelenchus cocophilus* was first reported as occurring in Trinidad by Hart (1905). Later, it was reported in Grenada (Nowell, 1918). It is a major problem faced by the coconut industry in the Caribbean, Central and South America. The disease does not occur in Africa, Southeast Asia, Malaysia, the Pacific Islands, Florida or Cuba (Dean, 1979). *R. cocophilus* was first described by Cobb (1919) as *Aphelenchus cocophilus*. Goodey (1960) designated it as *Rhadinaphelenchus cocophilus* Nowell (1920) and demonstrated its pathogenicity.

Diagnostic Features (Thorne 1961)

Female: Body very slender. Offset head, prominent cephalic framework composed of strong sclerotized arches. Spear with strong basal knob. Median bulb elongated. Vulva covered by a flap of cuticle leading into a curved vagina.

Male: Body slender. Offset head, prominent cephalic framework. Spear with strong basal knobs. Elongated median bulb. Most characteristic feature is the tail, which on death curves to about four-fifths of a circle. Spicules are slightly arcuate and have prominent rostrum. Tail bears a terminal bursal flap. Four pairs of ventrosubmedian papillae are present.

Juvenile: Pre-adult juvenile has conical rounded head, not set off from the body. Tail shorter than that of female with a short sharp terminal bearing a mucron.

Systematic Position

Nematoda, Secernentea, Tylenchida, Aphelenchina, Aphelenchoidea, Aphelenchoididae, Rhadinaphelenchinae, *Rhadinaphelenchus*.

Distribution

At present *Rhadinaphelenchus cocophilus* has been reported from the West Indian Islands of Tobago, Grenada and St. Vincent, and from the Dominican Republic, Venezuela, Guyana, Surinam, French Guyana, Colombia, Ecuador, Mexico. Brazil, Panama, Costa Rica. Honduras and El Salvador. It has not been reported from India. (Dean, 1979).

Hosts

Though *Rhadinaphelenchus cocophilus* is primarily found on coconut and oil palm, it has also been found to occur naturally in the date palm and cabbage palm (Haglay, 1962).

Successful inoculations have been reported in a number of palms (Brathwaite and Siddiqi, 1975; Dean, 1979).

Life Cycle

Life history studies conducted by inoculating immature nuts of coconut palm showed that the nematodes completed one life cycle 9 to 10 days which is probably one of the shortest life cycle reported for plant parasitic nematodes (Blair, 1966, 1970).

Survival

Rhadinaphelenchus cocophilus can survive for sufficient time and move over sufficient distances in soil (Fenwick, 1969). It survived for a maximum of 15 days in soil (Blair, 1964). In fresh water films it survived for 7-8 days and in sea water for 3 days (Dean, 1979). The third stage juvenile is the most persistent form.

Dispersal

Fragments of diseased tissue from contaminated bodies of the palm weevil *Rhynchophorus palmarum* are deposited into the bases of leaf axils of healthy palms. The nematode is carried by weevil larvae, pupae and adults both internally and externally. The nematode persists without change or multiplication through the metamorphosis of the insect. On emergence of the adult insect, large numbers of nematodes located in the region of the ovipositor of the female are injected into the soft tissue of the coconut palm when the insect deposits eggs (Ashby, 1921; Haglay, 1962; Fenwick & Mohammed, 1962; Griffith, 1967, 1968).

Natural cannibalism in the larvae also affects the number of emerging weevils. The bacterium *Micrococcus roseus* Ali-Cohen in cedros wilt diseased palms produces disease in affected palm weevils. Moreover, some ground lizards also feed on the adult insects. The nematode dies in decomposing tissue of diseased palms and an unidentified fungal parasite exists for the nematode (Griffith and Koshy, 1990).

Nature of Damage

Symptoms: Palms of bearing age (5-7 years) are more susceptible to infestation. Primary symptoms are the appearance of yellowing of the lower leaves starting at the tips of distal pinna which progresses towards the base of the pinnae and leaves. The yellowing is succeeded by browning and later by death of the leaf. The inner leaves are also affected and the trees die within 3-4 months of the appearance of the primary symptoms.

Internal symptom of a red-ring nematode infested palm is characteristic. At first, about 2.5 cm beneath the stem surface scattered reddish dots of about 1 mm diameter are seen which eventually coalesce to form an orange-red ring about 3 cm in width. Hence the name 'red-ring disease' and 'red-ring nematode'. The ring extends the whole length of the stem and roots and in petioles it assumes a crescent-like shape. Large number of juveniles

are seen in the centre of the discoloured areas and adults in the periphery (Fenwick, 1969; Brathwaite and Siddiqi, 1975; Dean, 1979). Shedding of green nuts of all sizes takes place. In advanced stages of infection putrefaction of the soft tissues takes place.

Rhadinaphelenchus cocophilus causes little leaf disease of coconut and oil palm in Surinam and Guyana (Hoof and Seinhorst, 1962).

Histopathology

A thermostable phytotoxin was produced due to break-down of coconut tissue (Goberdhan, 1963). Water uptake of infested coconut palms was less due to occlusion of xylem vessels (Goberdhan, 1964; Blair, 1964; Blair and Darling, 1968). In the upper parts of the stem, the nematodes are found intercellularly (Goberdhan, 1964; Blair, 1964). In coconut roots, the nematode attacks cortical tissues.

Losses

At present, most Latin American and Caribbean countries show losses ranging from less than 1 per cent to more than 20 per cent of 2 to 10 year old trees. Thirty-five per cent mortality of young coconut palms has been reported in Trinidad and 80 per cent loss in a single plantation in Tobago (Esser, 1969). Within a span of 10 years, 35 per cent of oil palms died in Venezuela (Oostenbrink, 1963).

Control

Biological: The vector weevil is found to be parasitized by several species of Rhabditidae or Heterorhabditidae throughout Latin America. Since the vector insects can be highly parasitised with the above nematodes selective pressure can be introduced against the vectors. Such measures are being employed in Trinidad with a species of Rhabditidae (Griffith and Koshy, 1990).

Chemical: The leaf axils of diseased palms should be sprayed with 0.1 per cent Lannate (Methomyl) insecticide suspension when early symptoms appear. Then the palm should be poisoned by adding one tablespoon of weedicide "100" in three holes (2 cm diameter and 10 cm deep) bored around the trunk of the tree at a level of 15 cm above the soil. In advanced stages the palms should be cut down and the piece and stumps sprayed with at least 4.5l of 0.1 per cent Lannate suspension.

Guard baskets made of 2 cm mesh wire are used to protect frequent outbreaks of the disease. These baskets are filled with fresh infected tissue and sprayed with 0.1 per cent Lannate suspension. The palm weevils are attracted to the tissues in the basket. After two weeks the tissues in the basket are burnt. One guard basket is used per 0.4 ha of palms.

Integrated: Even though no effective method of control is known at the moment, the following methods are being adopted:

1. Phytosanitation by using arsenic preparations in diseased tree;
2. Leaf axil filling with a granular nematicide;
3. Control of the palm weevil by applying insecticide;
4. Use of resistant varieties with short internodes; and
5. Plant quarantine measures to check its spread to newer areas.

RADOPHOLUS SIMILIS (COBB, 1893) THORNE, 1949

Historical Background

The burrowing nematode, *Radopholus similis* was first described by Cobb (1893) as *Tylenchus similis* from necrotic root lesions of banana *Musa sapientum* received from Fiji in 1891. It was renamed as *Radopholus similis* by Thorne (1949) and Sher (1968), who confirmed it as the type species of the amended genus. The nematode occurs in most tropical and sub-tropical areas of the world.

Diagnostic Features (Thorne, 1961)

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

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.

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

Systematic Position

Nematoda, Secernentea, Tylenchida, Tylenchoidea, Pratylenchidae, Radopholinae, *Radopholus*.

Distribution

Radopholus similis has been reported from coconut palms in Florida, U.S.A., Jamaica, Sri Lanka and India (van Weerdt *et al*, 1959a, 1959b; Weischer, 1967; Koshy *et al*, 1975). Surveys conducted in coconut plantations in South India recorded 24 per cent incidence of *Radopholus similis* in coconut (Sosamma, 1984; Koshy *et al*, 1978).

Hosts

The coconut isolate of *Radopholus similis* has a wide host range which includes many weeds, crops, fruit trees and many palms (Tables 1 and 2). Forty-eight species of

TABLE 1

List of Palms Reported as Hosts of the Burrowing Nematode *Radopholus similis*

Scientific Name	Common Name
Archontophoenix cunninghamiana Wendl. and Drude	Seaforthia alm, Piccabean bunglow palm
Areca (Actinorhytis) calapparia	
Areca catechu Linn.	Betel nut palm
Areca macrocalyx Becc.	
Areca normanbyii	
Areca triandra Roxb.	
Arecastrum romanzoffianum (Cham.) Becc.	Queen palm
Chamaedorea cataractarum Mart.	
Chamaedorea elegans Mart. [*Collina elegans* (Mart.) Liebm.]	Parlor palm, neanthebella palm
Cocos nucifera Linn.	Coconut palm
Elaeis quineensis Jacq.	Oil palm
Phoenix canariensis Chabaud	Canary Island date palm
Phoenix dactylifera Linn.	Date palm
Raphis excelsa	Large lady palm
Roystonea regia	Royal palm

plants belonging to forty-five genera of seventeen families were recorded as hosts in India (Koshy and Sosamma, 1975; Sosamma and Koshy, 1977, 1981; Holdeman, 1986).

Biology

Life Cycle: *Radopholus similis* is a migratory endoparasite and is capable of spending its entire life within roots. All juvenile stages and adult females including gravid females except the fourth stage and adult males are found to be infective. One life cycle was found to be completed within 25 days at a temperature range of 25-28°C (Koshy, 1986; Loos, 1962).

Survival and Dispersal: Burrowing nematode populations survive under field conditions for six months in moist soil (27 to 36°C) and one month in dry soil (29 to 39°C), whereas it survives for 15 months in moist soil (25.5 to 28.5°C) and 3 months in dry soil 27 to 31°C) under greenhouse conditions. The nematode survives in roots of stumps of felled coconut palms up to six months (Sosamma, 1984; Sosamma and Koshy, 1986). Studies conducted at the Central Plantation Crops Research Institute (Regional Station), Kayangulam, Kerala, India, show that adult females are the most persistent form in coconut roots and soil during summer months and caused annual recurrence of infection.

In coconut plantations in Kerala, coconut seedlings are raised by sowing seednuts in the interspaces of coconut palms. The burrowing nematode is widely prevalent in most of the nurseries in Kerala and Tamil Nadu. One-year-old coconut seedlings raised in such infested nurseries harbour large populations of the burrowing nematode within roots both internal and external to the husk (Koshy and Sosamma, 1979). These infested seedlings when distributed to distant places through government as well as private agencies for planting help in the dissemination of the nematode. Moreover, in the present day fast trade between countries for foliage and other ornamental plants such as *Anthurium* spp., *Calathea* spp., etc. chances of dissemination of *Radopholus similis* through these non-conventional hosts are greater (Koshy, 1986).

Biotypes/Pathotypes: Two morphologically indistinguishable races of *Radopholus similis* are known. One is the 'banana race' which parasitizes banana and not citrus and 'citrus race' which parasitizes both banana and citrus (Du Charme and Birchfield, 1956). But, the citrus race has been elevated to species rank and named *Radopholus citrophilus* because it has a haploid number of five chromosomes (n=5) against 4 (n=4) in banana race (*Radopholus similis*) and it differed in protein patterns and pheromone mediated behaviour (Huettel *et al*, 1984). In addition, there is a report of an *Radopholus similis* population in Puerto Rico which has a haploid number of five (n=5) chromosomes not infesting five species of *Citrus* (Rivas and Roman, 1985). The coconut isolate of *Radopholus similis* from Kayangulam and Kasaragod in Kerala, India, is the banana race (Koshy and Sosamma, 1977) with a haploid number of 4 (n=4) chromosomes.

Influence of Environmental Factors: Studies on population fluctuations of the burrowing nematode in coconut plantations in Kerala showed that infested coconut roots

TABLE 2

List of Plants Reported as Hosts of the Coconut Isolate of *Radopholus similis*

No.	Plant Species	Common Name	Family
1.	*Adenanthere pavonia* L.	Manchadi	Leguminosae
2.	*Allium cepa* L.	Onion	Liliaceae
3.	*Amarantus viridis* L.	Green amaranth	Amarantaceae
4.	*Anthurium andraeanum* Linden	Tail flower	Araceae
5.	*Anthurium digitatum* G. Don.		Araceae
6.	*Anthurium veitchill*	King anthurium	Araceae
7.	*Arachis hypogaea* Willd.	Ground nut	Leguminosae
8.	*Areca catechu* L.	Arecanut palm	Arecaceae (Palmaceae)
9.	*Cajanus cajan.* L.	Pigeon pea	Leguminosae
10.	*Careya arborea* Roxb.	Perzhu	Myrtaceae
11.	*Cocos nucifera* L.	Coconut	Arecaceae (Palmaceae)
12.	*Coleus parviflores* Benth.	Chinese potato	Labiatae
13.	*Cucurbita pepo* DC. var. Arkachandan	Pumpkin	Cucurbitaceae
14.	*Curcuma amada* Roxb.	Mango ginger	Zingiberaceae
15.	*Curcuma domestics* Val. (C. longa L.)	Turmeric	Zingiberaceae
16.	*Cyamopsis tetragonoloba* L.	Cluster bean	Leguminosae
17.	*Daucus carota* L.	Carrot	Umbelliferae
18.	*Desmodium tortuosum* DC var.EC.28875		Leguminosae
19.	*Dioscorea esculenta* Burk.	Yam	Dioscoreaceae
20.	*Elaeis quineensis* Jacq.	Oil palm	Arecaceae (Palmaceae)
21.	*Erythrina indica* Lam.	Coral tree	Leguminosae
22.	*Erythrina lithosperma* Blume		Legumonsae
23.	*Ficus religiosa* L.	Banyan tree	Urticaceae
24.	*Glycine max* var. Olso 41.Improved polican, Bragg, Lae and Punjab	Soybean	Leguminosae
25.	*Pennisetum purpurem x P. typhoides* (Hybrid Napier)	Grass	Gramineae

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No.	Plant Species	Common Name	Family
26.	*Ipomoea batatas* Pior	Sweet potato	Convolvulaceae
27.	*Kaempferia galanga* L.	Kacholam	Zingiberaceae
28.	*Lagenaria vulgaris* Ser	Bottle gourd	Cucurbitaceae
29.	*Lathyrus sativus* L.		Leguminosae
30.	*Lycopersicum esculentum* Mill.	Tomato	Solanaceae
31.	*Momordica charantia* L.	Bitter gourd	Cucurbitaceae
32.	*Musa paradisiaca* L.	Plantain	Musaceae
33.	*Myristica fragrans* Houtt	Nutmeg	Myristicaceae
34.	*Oryza sativa.* L.	Paddy	Gramineae
35.	*Phaseolus calcaratus* Roxb.	Rice bean	Leguminosae
36.	*Phoenix dactylifera* L.	Date palm	Palmaceae
37.	*Physalis minima* L.	Njodinjotta	Solanaceae
38.	*Piper betle* L.	Betel pepper	Piperaceae
39.	*Piper nigrum*	Black pepper	Piperaceae
40.	*Polyalthia longifolia* Hook. f. & Thomas	Indian fir	Annonaceae
41.	*Rhaphis excelsa* Walp.		Palmaceae
42.	*Saccharum officinarum* L. CO. 48	Sugar cane	Gramineae
43.	*Scindapsus aureus* Lind and Andre		
44	*Solanum nigrum* L.	Mulaku Thakkali	Solanaceae
45.	*Talinum cuneifolium* Willd.		Portulacaceae
46.	*Tamarindus indica.* L.	Tamarind	Leguminosae
47.	*Trichosanthes anguina* L.	Snake gourd	Cucurbitaceae
48.	*Vicia faba* L. var. E. C. 5063	Broad bean	Leguminosae
49.	*Vigna sinensis* L.	Cowpea	Leguminosae
50.	*Vigna unguiculata* Walp.	Cowpea	Leguminosae
51.	*Xanthosoma sagitifolia*	Tannia	Aracaceae
52,	*Zea mays* L.	Maize	Gramineae
53.	*Zingiber officinale* Rosc.	Ginger	Zingiberaceae

yielded maximum number of *Radopholus similis* during October to November and minimum during March to July. A mean soil temperature below 25°C and light rainfall coupled with availability of tender fleshy roots are favourable for nematode multiplication (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).

Nature of Damage

Symptoms: Burrowing nematode infested coconut palms exhibit general decline symptoms like yellowing, button shedding, reduction in leaf size, yield, etc. which are non-specific.

Symptoms on roots are more specific. *Radopholus similis* on infestation produces isolated elongate orange-coloured lesions on tender and semi-hard roots. Consequent to nematode parasitization and multiplication, these lesions enlarge and coalesce to cause extensive rotting of roots. Tender roots on heavy infestations become spongy in texture. On semi-hard orange coloured roots surface cracks are commonly seen. Lesions are not usually seen on the old, hard, dark brown roots. As high as 4,000 nematodes were recovered from one gram (one inch length) of main roots. 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 (Sosamma, 1984; Koshy and Sosamma, 1987; Koshy and Sosamma, 1996).

The pathogenic effects of *Radopholus similis* on growth flowering and yield of coconut cv. West Coast Tall was established under field conditions. Decrease in growth parameters of inoculated palms was corresponding to the increase in inoculum level and differed significantly from control. All the uninoculated palms came to flowering during 65-83 months after planting compared to 67-132 months in inoculated palms. However, the palms that received an initial inoculum of 1000 nematodes and above did not yield any nuts even after 11 years of planting. The control palms produced a total of 624 nuts compared to 186 nuts by palms that were inoculated initially with 100 nematodes. (Fig. 2). Final populations of nematodes did not differ significantly between treatments. The economic threshold level of *Radopholus similis* on coconut (WCT) is 100 nematodes per seedling in loamy sand under the experimental conditions (Koshy and Sosamma, 1996).

Histopathology: Burrowing nematode penetrates the absorbing region covered by very delicate epidermis behind the root cap by lysis of cells. Such entry points are of 1-2 cells in diameter and surrounded by sclerenchymatous cells to depth of 10-15 cells. The cavities formed in the outer cortex are always surrounded by deeply stained and heavily suberised cells of irregular shape unlike those formed in the inner cortex. Maximum number of nematodes and cavities are seen in the outer cortex. Nematodes are not observed in the stelar region. In the early stage of infection, roots show 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 thus destroying the cortex to a great extent. All stages of the nematode are seen in cavities in longitudinal sections (Koshy and Sosamma, 1987).

Interaction With Other Micro-Organisms

The fungi *Cylindrocarpon effusum*, *Cylindrocarpon lucidum* and *Cylindrocladium clavatum* have been recorded in association with lesions produced by *Radopholus similis* in coconut roots. In pathogenicity studies, *Cylindrocarpon effusum* did not cause any appreciable damage to inoculated seedlings. But when it was inoculated simultaneously with the nematodes, the rate of multiplication of the nematode and damage to coconut seedlings was reduced (Sosamma and Koshy, 1978, 1983; Koshy and Sosamma, 1987).

Losses

Radopholus similis causes heavy crop loss to many fruit, spice and agricultural plantation crops. It is notorious for having wiped out 22 million black pepper vines in the Banka Island of Indonesia within two decades (Christie, 1957). Similarly spreading decline in citrus caused by *Radopholus similis* first observed in Florida (1928) spread to 6000 hectares within 35 years (Kaplan, 1985). It causes root rot, blackhead toppling diseases and decline in banana (Blake, 1972). It causes 30 per cent yield loss in coconut. The threshold inoculum density required to cause significant reduction in various growth parameters of coconut is 100 nematodes/625 cc sandy loam soil over a period of five years under field conditions (Sosamma, 1984; Koshy and Sosamma, 1987).

Nematodes, namely, *Aphelenchoides aligarhiensis, Panagrolaimus rigidus, Rhabditis* sp. and *Trophurus* sp. have been found associated with leaf rot disease affected unopened leaves (spindles) of coconut in root (wilt) affected areas. Investigations are being carried out to prove the role of these nematodes in the etiology, if any, in the incidence of leaf rot disease.

Control

Cultural: The cultural practices which exist in Kerala and Karnataka, such as application of oil-cakes, farmyard manure and growing of sun hemp in the basins and interspaces, and their incorporation as green manure may help in the inhibition of nematode multiplication.

Plant Resistance: Of the 29 exotic and 15 indigenous coconut cultivars and 15 hybrids screened, the dwarf cultivars, Kenthali and Klappawangi and the hybrids such as Java Giant x Kulasekharam Dwarf Yellow, Kulasekharam Dwarf Yellow x Java Giant, Java x Malayan Dwarf Yellow and San Ramon x Gangabondam recorded the least nematode multiplication and lesion indices (Sosamma *et al*, 1980, 1986; Sosamma, 1984).

Chemical: Increased incidence of *Radopholus similis* was noticed in coconut nurseries when banana was used as a shade crop. More than 50 per cent of the seedlings raised in such nurseries failed to establish on transplantation to the main field. Treatment of nurseries with nematicides is the only way to release nematode-free seedlings.

A dip in 1000 ppm DBCP for 15 minutes was found effective in controlling nematode population and to ensure release of nematode-free coconut seedlings from *Radopholus similis* infested coconut nurseries (Koshy and Sosamma, 1979). Soil application of phenamiphos or phorate at the rate of 25 kg a.i./ha during September, December and May in infested coconut nurseries completely eliminated *Radopholus similis* (Koshy and Nair, 1979; Koshy *et al*, 1983; Sosamma *et al*, 1986).

Application of phorate at the rate of 10g a.i./palm in June-July and again in October-November increased 30 per cent yield of *Radopholus similis* infested palms.

Biological: Studies with *Paecilomyces lilacinus, Pasteuria penetrans* and VAM have shown that these micro-organisms can suppress nematode population and may become useful control agents.

The effect of the biocontrol agents *Paecilomyces lilacinus, Trichoderma viridde, Trichoderma harzianum, Verticillium chlamydosporium, Pasteuria penetrans* and VAM on the burrowing nematode was studied in the greenhouse. *Paecilomyces lilacinus* is found to infect the eggs of the burrowing nematode. A virulent strain of *Pasteuria penetrans* which is highly pathogenic to *Radopholus similis* was found to infect all stages of *Radopholus similis*. Experiments conducted in the greenhouse proved that prior colonization of VA mycorrhizae could promote plant growth characters, namely, height, leaf area, shoot weight, root weight and ameliorate the ill-effects of *Radopholus similis* infestation on coconut seedlings. Application of mycorrhizal inoculum in nursery beds enhanced the growth of the seedlings compared to untreated beds.

Integrated: The following measures are suggested for an integrated management schedule for *Radopholus similis* infestation on coconut palms:

1. Application of cowdung farmyard manure, oil cakes and green manure to the basins. *Crotalaria juncea* may be cultivated in the basin and interspaces and used as a green manure;
2. Application of phorate at the rate of 10g a.i./palm in June-July and October-November;
3. Avoid banana as a shade crop in coconut nurseries;
4. Use of nematode-free planting material of coconut and other intercrops; and
5. Use of less susceptible/tolerant cultivars or their hybrids in infested areas.

ARECANUT

Arecanut or betelnut is the common source of masticatory nut obtained from arecanut palm *Areca catechu* Linn.

Arecanut has its origin in the hot damp regions of Asia and the Malay Islands. India is the largest producer of arecanut in the world covering an area of 2,00,000 hectares with an annual production of 2,28,600 tonnes.

Radopholus similis

Distribution: *Radopholus similis* was first reported from soil around arecanut roots in Mysore, India, by Kumar *et al*, 1971. Later, Koshy and Sosamma (1975), Koshy *et al* (1975, 1976) recorded 22 genera of plant parasitic nematodes from the root zone of arecanut during their survey. Among them, *Radopholus similis* was the only endoparasite encountered in more than 50 per cent of the root samples collected (Koshy *et al*, 1978).

Nature of Damage

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. The nematode produces small, elongate, orange-coloured lesions on young, succulent, creamy-white to light-orange coloured portion of the main and lateral roots. Later, 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 become black (Koshy *et al*, 1975).

Histopathology: The burrowing nematodes are found in inter and intracellular positions in the cortex. They do not enter the stelar region (Sundararaju and Koshy, 1988).

Interaction With Other Micro-Organisms: The fungus *Cylindrocarpon obtusisporum* was found in consistent association with lesions caused by *Radopholus similis* in arecanut roots. Though the fungus in combination with the nematode caused more damage, it inhibited the rate of multiplication of the nematode (Sundararaju and Koshy, 1984, 1987).

Losses: *Radopholus similis* on infesting arecanut roots caused reduction in growth parameters. The threshold inoculum level causing significant damage to growth of arecanut was found to be 100 nematodes per seedling or one nematode in 800g laterite soil (Koshy, 1986). Ten-fold increase in yield was recorded by treatment with aldicarb at the rate of 10g a.i./palm, DBCP at the rate of 10ml a.i./palm or fensulphothion 50g a.i./palm (Sundararaju and Koshy, 1986).

Plant Resistance: None of the 46 accessions of arecanut germplasm screened, is immune or highly resistant to *Radopholus similis*. The cultivars Indonesia-6 (VTL-11), Mahuva-B and Andaman-5 (VTL-29e) are tolerant to *Radopholus similis* (Koshy *et al*, 1979; Sundararaju and Koshy, 1982). The cultivar Indonesia-6(VTL-11) and Singapore (VTL-17) are known to yield 50 per cent more nuts over local South Kanara variety.

The hybrid VTL-11 x VTL-17 is highly resistant to *Radopholus similis* (Sundararaju and Koshy, 1988b). Hence, these cultivars could be recommended for *Radopholus similis* infested areas.

Chemical: Application of aldicarb or fensulfothion at the rate of 1g a.i./seedling thrice a year for three years controlled *Radopholus similis* population at the seedling stage. In adult palms reduction in nematode population and 10 fold increase in yield was obtained by aldicarb at the rate of 10g a.i./palm, DBCP at the rate of 10ml a.i./palm or fensulfothion 50g a.i./palm (Sundararaju and Koshy, 1986).

Biological: The effect of the bacterium, *Pasteuria penetrans*, on multiplication of *Radopholus similis* on arecanut was studied. *Pasteuria penetrans* reduced the damaging effect of *Radopholus similis* on arecanut seedling on inoculation of both the organisms simultaneously (Geetha *et al*, 1990).

Integrated: Integrated management of the burrowing nematode infesting arecanut roots can be done as suggested below:

1. Use of nematode-free planting materials of arecanut and other inter/mixed crops;
2. Avoid *Radopholus similis* susceptible inter/mixed crops like black pepper and banana in infested areas; and
3. Apply phorate at the rate of 3g a.i. to the root zones of banana, black pepper and arecanut in arecanut based farming system.

OIL PALM

Oil palm (*Elaeis guineensis* Jacq.) has been recognised as the highest yielding edible oil crop which was introduced to India as early as 1885 as an ornamental plant and regular cultivation was initiated during 1960.

The oil palm has its origin in Central Africa and has been introduced throughout the entire tropics in large groves. It is being cultivated in Kerala, India, on a plantation scale since 1970. In India, it is being cultivated over an area of 5.75 lakh hectares. Among the different plant parasitic nematodes found in the rhizosphere of the oil palm, the most important is *Rhadinaphelenchus cocophilus* (Cobb, 1919; Goodey, 1957, 1960; Sher, 1966; Pizarro, 1968).

Rhadinaphelenchus cocophilus

Distribution: The red ring disease on oil palm caused by *Rhadinaphelenchus cocophilus* was reported from Venezuela (Webster and Gonzeles, 1959). Later, it was reported from Latin America (Malaguti, 1953) and Surinam (Vanhoff and Seinhorst, 1962). It has not yet been reported from India.

Nature of Damage: Diseased palms in young groves are initially found clustered which gradually expand. In older groves, such palms have a random distribution.

In Surinam, 'little leaf' was found to be a prominent symptom in diseased palms (Vanhoff and Seinhorst, 1962), Diseased palms had erect, short and deformed leaves. The top part of the main vein bore suberized patches. The pinnae were shorter wavy and necrotic at the tips and yellow patches were present on the petiole and leaf bases. The diseased palm had a brownish discoloration. *Rhadinaphelenchus cocophilus* was found in discoloured tissue and thrived more in the petioles of young folded leaves than in stem and roots. They were found outside the necrotic zones. A notable feature was that the band of necrotic tissue is always very small. In diseased oil palms an average of less than 500 nematodes was found in one gram of infested tissue. The disease could be produced experimentally (Maas, 1970).

Losses: *Rhadinaphelenchus cocophilus* was found to cause economic loss in oil palms in South Africa. Malaguti (1953) had observed that in a seven year old oil palm grove suffering from little leaf, many trees had died.

Radopholus similis

Radopholus similis was found to infest roots of oil palm on artificial inoculation under greenhouse conditions (Koshy and Sosamma, 1975). Survey carried out in oil palm nurseries and in adult plantations in India indicated the presence of 26 genera of plant parasitic nematodes. The root lesion nematode *Pratylenchus coffeae* was the predominant one. *Radopholus similis* was recorded from Kerala, Karnataka, Andhra Pradesh and Assam. The other major nematode species encountered from the rhizosphere of oil palm were *Helicotylenchus* sp., *Tylenchorhynchus* sp., *Rotylenchulus reniformis* and *Aphelenchoides* sp. (Sundararaju *et al*, 1995).

Aphelenchoides aligarhiensis, Panagrolaimus rigidus, Rhabditis sp. and *Diplogaster* sp. could be isolated from the spindle leaves of spear rot affected oil palms.

DATE PALM

The date palm, *Phoenix dactylifera* L., is dioecious and artificial pollination by man has played a significant role in the historical development of the crop. More than one thirds of all the dates of the world are grown in Iraq. Though the palms will grow throughout the tropics, the number of heat units required from the time of blossoming to ripening should be between 4000 to 5500 for various cultivars. Growth of the palm ceases around 10°C. Suitable climatic conditions occur in the dry parts of California where the palm has been successfully grown on a commercial scale. In this introduced environment the palm has to cope with the new prevailing nematode fauna.

Nematodes of Date Palm

The date palm is affected by numerous pests and diseases wherever it is grown, but

nematodes, with the exception of root knot nematode *Meloidogyne* spp., have not been well studied. However, nematodes have not been found to be a limiting feature in the countries with date as an ancient culture. Date palm is reported as a host for *Radopholus similis* (Koshy and Sosamma, 1975).

Meloidogyne: Root knot nematodes were found in the Coachella Valley of California on date palms in 1925 where they are now known to be widely distributed in commercial date plantings. Buhrer *et al* (1933) first reported the occurrence of root knot nematodes on date, and Jensen (1961) found *Meloidogyne incognita* on roots of date palms in nurseries. Carpenter (1964) reported that root knot nematodes, principally *Meloidogyne javanica* can severely damage or kill date palm seedlings.

Young seedlings of 50 date cultivars were susceptible to infection by root-knot nematodes; more than 90 per cent of the seedlings were killed prior to emergence when seeds were sown in heavily infested soil. Secondary damage by fungi to roots of field-grown palms infested with the nematodes seemed to be an important factor in the deterioration and death of roots. Minz (1958) reported the occurrence of *Meloidogyne arenaria, Meloidogyne hapla, Meloidogyne incognita* and *Meloidogyne javanica* on date palms in Israel. *Meloidogyne* sp. was reported from Sidi Yaia in Algeria (Lamberti *et al*, 1975), and from the Mauritanian oases of Tayaret and Terjitt (Netscher and Luc, 1974).

Other Nematodes: In Algeria, Lamberti *et al* (1975) reported the occurrence of *Pratylenchus penetrans* on date palm roots in the crescent of oases from Beni Ounif to Biskra. *Rhadinaphelenchus cocophilus* is also known to affect the date palm. A specimen in the Botanical Gardens, Trinidad, came down with red ring disease and produced a brownish ring. However, date palm prefers a hot dry environment that limits the activities of the palm weevil, the vector of the red ring nematode.

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