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RADOPHOLUS SIMILIS, THE BURROWING NEMATODE OF COCONUT*

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ABSTRACT

The burrowing nematode, *Radopholus similis* causes considerable damage to coconut. The nematode has been reported from coconut palms in Florida, Jamaica, Sri Lanka, India and Western Samoa of Pacific Ocean Islands. In India, the nematode is reported on coconut from Kerala, Karnataka, Tamil Nadu and Lakshadweep Islands. The burrowing nematode population parasitising coconut is also known to infest and cause considerable damage to the intercrops in infested coconut plantations. The infestation of nematode causes heavy root rotting, loss of vigour, stunting, yellowing of fronds, delay in flowering, button shedding and reduction in yield. *R. similis* infestation produces small, elongate, orange-coloured lesions on tender creamy-white roots. Infested coconut roots yield maximum number of *R. similis* during October to November and minimum during March to July. The threshold inoculum density required to cause significant reduction in various growth parameters of coconut is 100 nematodes per seedling or one nematode in 576 cm^3 or 800 g sandy loam soil over a period of five years under field conditions. Control of *R. similis* is known to increase coconut yield by 30 per cent. Information available on the biology and life cycle, population fluctuation, symptoms, pathogenicity, host range, methods of diagnosis and control of nematodes etc. are reviewed.

INTRODUCTION

The coconut palm is affected by large number of insects, fungi and nematodes than most other cultivated plants. The first plant parasitic nematode reported on coconut is *Rhadinaphelenchus cocophilus* (Cobb, 1919) which causes the red ring disease. At present the red ring disease has a restricted distribution and has only been reported from West Indies (Trinidad, Tobago, Grenade and St. Vincent) and Latin America (Dominican Republic, Venezuala, Guyana, Surinam, French Guyana, Colombia, Ecuador, Peru, Mexico, Brazil, Panama, Nicaragua, Costa Rica, Honduras, Belize and El Salvador). It is also reported that red ring disease occurs in Guatemala, but does not occur in northern Caribbean Islands, Florida, Cuba or other parts of the world (Dean, 1979; Griffith and Koshy, 1990). There is a strict embargo on import of seednuts to India from the countries where the disease is known to occur.

Govindankutty and Koshy (1979) reviewed the nematodes associated with coconut palm and reported 78 species belonging to 56 genera of nematodes from coconut, but most records are of nematodes extracted from soil collected around coconut palm. In India, from an extensive survey carried out during 1973 – 1982 39 genera of plant parasitic nematodes were reported (Koshy, Sosamma and Sundararaju, 1979;

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Sosamma, 1984). Of these *Longidorus saginus*, *Hoplolaimus seinhorsti* and *Dolichodorus pulvinus* have been encountered from various depths within the root zone of coconut. They have also been found to multiply on roots of coconut seedlings on inoculation. Later, twelve species of plant parasitic nematodes and four species of saprophytic nematodes have been added to the list (Darekar and Khan, 1980; Valdez, 1980; Raski et al., 1980; Orton Williams, 1980; Sharma and Loof, 1982; Raski, Koshy and Sosamma, 1982:; Luqman and Khan, 1985, Khan, 1986; Rashid, Geraert and Sharma, 1987; Khan and Saeed, 1988; Maggenti et al; 1983; Siddiqi, 1984; Ahamad and Jairajpuri, 1984). Recently *Xiphinema radicicola* and *X. elongatum* have been found associated with coconut decline at the District Agricultural Farm, Anchal, Quilon District, Kerala, India.

Second to *R. cocophilus* that causes the red ring disease, the burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne, 1949 causes maximum damage to coconut palms. This paper reviews the research work carried out on this nematode on coconut.

Economic importance

The burrowing nematode is very serious and it wiped out more than 20 million pepper vines over a short period of two decades in the Bangka Island of Indonesia (Christie, 1957). More than 15 thousand acres of citrus in Florida are reported to be infested with *R. similis*. Reduction in yield from 50 to 80 per cent for grapefruit and from 40 to 70 per cent for oranges are reported (Poucher et al., 1967). In Central America, Wehunt and Edwards (1968) reported that the uninfested banana plots yielded upto 17,000 lbs. more fruits per acre per year than the nematode infested plots. Besides citrus and banana, the nematode attacks large number of crops and the estimated loss for ornamental crops is up to five per cent (O'Bannon, 1977). In India no data is available on loss due to *R. similis* infestation on any crop, though the nematode was recorded as early as 1966 from banana in Kerala (Nair, Das and Menon, 1966) and known to parasitize several crops.

Measurements and description

Female:

(n = 20) L: 624.44–747.93 (684.51) μ: body width = 18.66–27.99 (23.68); a = 23.21–32.23 (28.65), b = 7.00 — 8.06 (7.56); b' 3.80–4.60 (4.16); c = 8.79 — 10.60 (9.47); c' 2.99–4.41 (3.63); v = 53.81 – 61.94 (57.27); spear = 16.79–18.66 (17.68) μ; excretory pore from head = 81.55–116.50 (99.84) μ; tail length — 69.90–81.55 (72.59) μ; H = 7.46–12.13 (9.74) μ; phasmids from tail terminus = 43.85–55.05 (50.49) μ; anterior gonad = 130.62 – 180.74 (147.10) μ; posterior gonad = 110.09–170.57 (141.30) μ: Head height = 2.80–4.67 (3.87) μ; head width = 8.39–10.26 (9.47) μ.

Body straight to slightly arcuate ventrally, cuticle distinctly annulated, vermiform, lip region low, hemispherical, sometimes offset, usually with 3 annules,sclerotization strong, lips 6, almost equal. Spear with well developed round basal knobs which are usually indented anteriorly. Median oesophageal bulb well developed,round to oval valvular apparatus prominent. Oesophageal glands three in separate lobes, overlapping intestine dorsally and dorso-laterally. Hemizonid 3 annules long, just anterior to excretory pore which is at or just behind the level of oesophago-intestinal valve. Vulva prominent just post equatorial. Reproductive organs paired, opposed, outstretched. Spermathecae spherical, usually packed with small rod-shaped sperms.

Ovaries generally with a single row of oocytes. Intestine filled with spherical granules, indistinctly overlapping rectum. Tail tapering rounded variable terminus with or without annulation. Lateral field with four incisures, coalescing to three incisures near middle of tail.

Gravid females:

(n = 20) L = 643.08 – 829.48 (765.54) μ; body width = 28 – 37.32 (34.52) μ; a = 20.30 – 24.19 (22.63); b = 8.23 – 10.14 (9.31); b' = 4.05–5.08 (4.56); c = 9.27–11.16 (9.36); c' = 2.88–4.49 (3.65); v = 54.22–59.45 (56.07); spear = 17.73–19.59 (18.66) μ; excretory pore from head = 83.88–102.52 (94.95) μ; tail length = 69.90–90.87 (82.13) μ; H = 7.46–13.06 (9.19) μ; phasmids from tail terminus = 44.78–65.30 (57.57) μ; anterior gonad = 186.60–405.86 (300.82) μ; posterior gonad = 148.35–320.95 (248.69) μ; head height = 3.73–4.67 (4.25) μ; head width = 9.33.

Similar to female except for increase in body length and width.

Male:

(n–20) L = 559.20 – 710.65 (642.61) μ; body width = 15.86 – 21.45 (19.17) μ; a=28.88 – 38.08 (33.43); c = 7.82–9 (8.49); c' = 4.66–6.53 (5.34); spear = 11.19–14.92 (12.73) μ; excretory pore from head = 86.21–102.52 (96.35) μ; tail length = 69.90–83.88 (76.42) μ; Spicules = 16.79–18.66 (18.05) μ; Gubernaculum = 9.33–12.11 (10.12) μ; testis length = 175.40–237.91 (199.24) μ; H=5.59–9.33 (6.62) μ; Phasmids to tail terminus = 43.85–63.44 (52.29) μ; head height = 4.66–6.53 (5.45) μ; head width = 6.53–8.40 (7.83) μ.

Vermiform, lip region elevated, hemispherical, 4–lobed with lateral lips considerably reduced,distinctly set off, with four annules in the posterior region, not strongly sclerotized. Oesophagus and spear degenerate,median bulb and valular apparatus indistinct, spear without distinct knobs. Hemizonid just anterior to excretory pore which is usually 2–3 body widths behind median oesophageal bulb. Single testis, outstretched anteriorly; spermatocytes in 3 rows followed by 5; spermatozoa rod-like. Bursa coarsely crenate, enveloping about 2/3 of tail. Spicules strongly cephalated, with pointed distal ends. Gubernaculum rod-like, protrusible.

Juveniles:

4th stage ♀: (n = 20) L = 470.66 – 594.15 (533.53) μ; body width = 20.53–24.26 (22.90) μ; a = 19.46–27.24 (23.49); 3.61–4.76 (4.01); c = 5.79–9.19 (7.17); c' = 3.25–4.37 (3.86); spear = 14.93–18.66(17.59) μ; excretory pore from head = 74.56–97.86 (90.52) μ; tail length = 60.58–81.55 (69.88) μ; head height = 3.73–4.67 (4.02) μ; head width = 8.4 μ; anterior gonad = 80.24–120.02 (96.02) μ; posterior ovary = 89.25–128.16 (110.30) μ.

4th stage ♂: (n=20) L = 454.62 – 596.20 (505.55) μ; body width = 22.39 – 24.26 (23.23) μ; a = 19.21–27.70 (22.49); b' = 3.55–5.01 (4.23) μ; c=5.62–8.82 (6.69); c'= 3.33–4.86 (3.98); spear = 16.79–18.66 (17.56) μ; excretory pore from head = 64.38 – 88.34 (73.75) μ head height = 2.80 – 3.73 (3.31) μ; head width – 7.46–9.33 (8.12) μ; tail length = 65.24 – 88.54 (77.12) μ; length of testis = 190.48–216.24 (203.05) μ.

3rd stage juvenile:

(n=20) L=421.48–457.12 (440.34) μ; body width = 14–18.66 (17.69) μ; a = 20.91–26.86 (24.85); b'=2.82–4.22 (3.36); c=7.28–10.00 (8.19); c'=3.33–5.02 (4.16); spear = 12.13–15.86 (14.84) μ; excretory pore from head =

areas like Gujarat (Sethi, Siyanand and Srivastava, 1981), Maharashtra (Darekar et al., 1981), Goa (Koshy and Sosamma, 1988); and Lakshadweep Islands (Koshy et al, 1978; Sundararaju, 1990).

Since many years, one year-old coconut seedling raised in the interspaces of coconut plantations are being sent from Kerala to various coconut growing states in India. Seedlings raised in nematode infested nurseries harbour large populations of the nematodes in roots internal and external to the husk. Such seedlings when distributed help in disseminating nematodes over long distances. Surveys conducted have revealed the widespread infestation of burrowing nematode in coconut nurseries at Palghat, Nileshwar, Valiathura, Kazhakootam, Karunagappally, Mavelikkara and Vyttila in Kerala (Anonymous, 1986), and at Manavalakurichi, Agastheeswaram, Kovilpatty, Ponneri, Korimedu, Erode and Salem in Tamil Nadu.

Methods of diagnosis

Sampling:

Soil and root samples for detection of *R. similis* should be collected during October - November when maximum population of the nematode occur. Maximum population of *R. similis* is found in the root zone of coconut at a distance of 100 cm from the bole of the palm and at a depth of 50–100 cm. Tender, creamy-white to orange coloured, semi-hard, main roots showing lesions and rotting should be collected to obtain live populations in large numbers.

Extraction:

The semi-hard, orange coloured, main root bits are peeled and sliced longitudinally into four to eight pieces of three to five cm length. These sliced root bits are submerged in water contained in petri dishes at a temperature range of 20–25°C, which is ideal for increased extraction from polyphenol rich coconut roots (Koshy et al., 1975; Koshy, 1986). After every 24 hours of incubation, the water needs to be changed. Fifty per cent of the poulation is extracted within 72 hours. Rest of the nematodes are recovered within four to seven days.

Symptoms of damage:

The burrowing nematode causes non-specific general decline symptoms such as stunting, yellowing, reduction in number and size of leaves and leaflets, delay in flowering, button shedding and reduced yield which is otherwise generally attributed to lack of nutrition, drought etc. *R. similis* infestation produces small, elongate, orange-coloured lesions on tender creamy white roots. Consequent to nematode parasitization and multiplication, these lesions enlarge and coalesce to cause extensive rotting of the roots (Fig. 1) and surface cracks develop on the epidermis of semihard orange coloured main roots. Lesions and rotting are confined to the tender portions of the root. Lesions are also not conspicuous on the secondary and tertiary roots since these are narrow and rot quickly on infestation. Tender roots of coconut seedlings with heavy infestation become spongy in texture.

As many as 4000 nematodes are known to occur in one g (2.5 cm length) of main roots. The nematode also attacks the plumule, leaf bases and haustoria of seedlings. The above ground symptoms being non-specific, the only definite method to identify an infested palm is to look for characteristic lesions on fresh, creamy-white to orange-coloured tender main roots.

R. similis does not enter a hardened or suberised epidermis of coconut roots but does penetrate the absorbing region behind

72.23–81.55 (77.24) μ; tail length = 48.48–60.50 (55.94) μ; Genital primordium length = 16.46–23. 32 (20.30) μ; breadth = 7.46–9.33 (7.84) μ; head height = 2.8–3.7 (3.03) μ; head width = 7.46–8.40 (7.98) μ.

Second stage juvenile:

(n=20) L = 233–310.26 (274.89) μ; body width = 10.26 – 14(13.11) μ; a = 19.14–23.24 (20.47); b' = 2.50–3.18 (2.79); c = 6.74–8.41 (7.53); c' = 3.67–4.25 (3.85); spear = 10.26 – 13.06 (11.52) μ; excretory pore from head = 58.25–68.88 (61.64) μ; tail = 28.92–39.61 (36.56) μ; genital primordium length = 5.60–10.26 (8.49) μ; breadth = 3.73–5.60 (4.58) μ; head height = 1.8–2.8 (2.65) μ; head width = 5.60–6.53 (6.16) μ.

First stage :

(n = 20) L = 220.68–268.72 (242.54) μ; body width = 12.13–14 (13.02) μ; spear = 9.33–12.13 (10.83 μ), excretory pore from head = 48.93–55.98 (53.20) μ.

Egg:

(n=100); L = 56.91 – 77.43 (67.64) μ; breadth = 24.25–37.32 (30.41) μ

Juveniles similar to female except for three incisures in the lateral field and shorter hyaline area in tail terminus. For taking measurements the first stage juveniles were forced out of the eggs by applying slight pressure on the cover slip placed over eggs mounted in a drop of water on a microscopic slide.

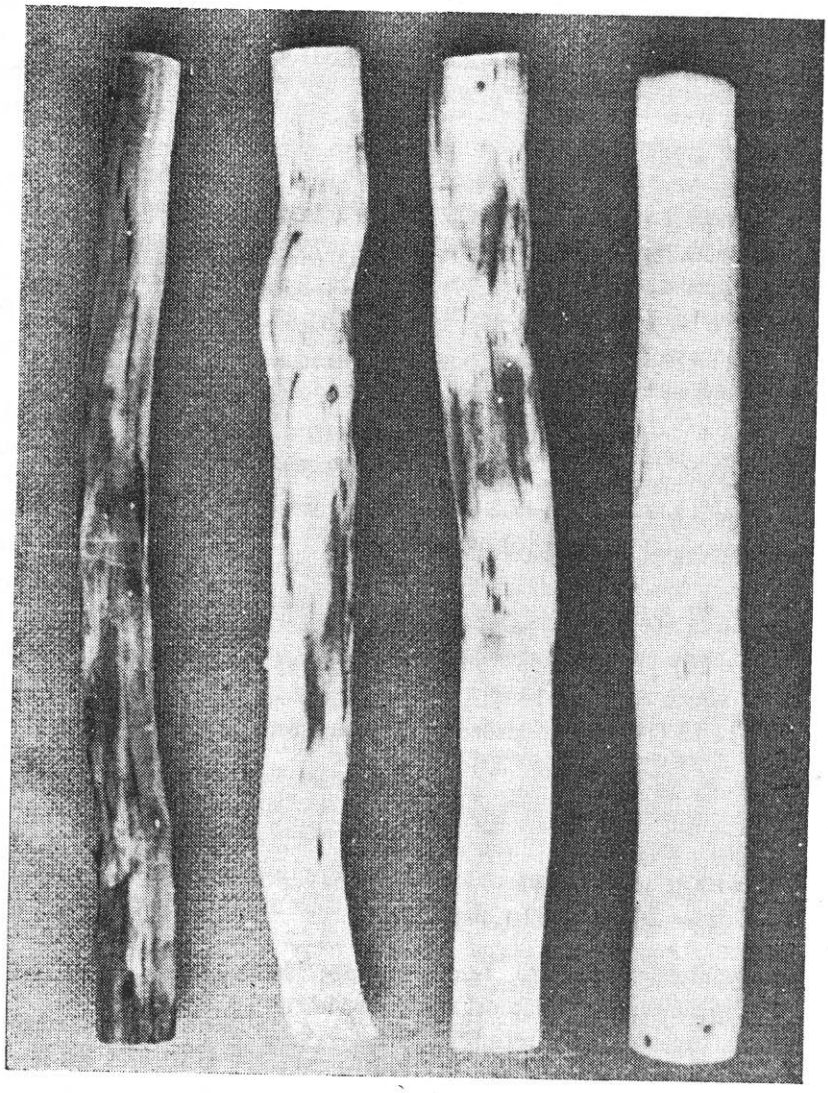
Type habitat and locality:

From roots of coconut palm (*Cocos nucifera*) of palm No. 72 of Block II at the Central Plantation Crops Research Institute, Kayangulam, Alappuzha District, Kerala, India.

Distribution and spread

The burrowing nematode, *R. similis* occurs in most tropical and sub-tropical areas of the world where bananas are produced with a notable exception of the Jordan valley, Israel (Minz, Ziv and Strich-Harari, 1960) and Taiwan (Huang, 1972). The nematode has been reported from coconut palms in association with lethal yellowing in Florida and Jamaica and with leaf scorch decline in Sri Lanka and from Western Samoa of Pacific Ocean Islands (van Weerdt, Martinez and Esser, 1959; Latta, 1966; Ekanayake, 1964; Orton Williams, 1980). In India, the burrowing nematode was reported for the first time from roots of banana (Nair et al, 1966) and later from coconut (Weischer, 1967; Mathen, 1969; Mathen, Kurian and Lal, 1970; Koshy, Sosamma and Nair, 1975). Extensive surveys carried out comprising 965 samples each of soil and root from Kerala (836), Tamil Nadu (116) and Karnataka (13) during 1973 to 1982 revealed the widespread occurrence of the burrowing nematode on coconut (Koshy, Sundararaju and Sosamma, 1978). Koshy (1986) suggested the co-evolution of the nematode along with black pepper or certain local cultivars of banana in the Western hills of South India as the nematode occurs in roots of wild black pepper deep inside the forests and is widespread on a number of crops like coconut, arecanut, black pepper, banana, betelvine, ginger, turmeric etc. in South India. The most important means by which *R. similis* is introduced into new geographical areas is through the infested planting materials. The wide distribution of *R. similis* is due to the transference of infected planting material especially banana rhizomes from country to country (O' Bannon, 1977). The unrestricted movement of banana suckers without observing the minimum plant protection measures have helped in its spread from Kerala to

Fig. 1. Tender roots of coconut with various intensities of lesions and rotting on infestation by *Radopholus similis*



the root-cap covered by very delicate epidermis by lysis of cells. The cavities that form in the outer cortex are always surrounded by deeply stained and heavily suberised cells of irregular shape, whereas those formed in the inner cortex do not have any such deformed darkly stained border cells. Maximum number of nematodes and cavities are seen in the outer cortex. Nematodes have not been observed in the stelar region or in the closely packed four to six layers of cells outside the endodermis even in heavily infested roots. In the early stages of infection, individual cavities developed on feeding by nematodes are small and well defined which later enlarge and merge with each other consequent to multiplication of nematodes.

Multiple cavities and their coalescence destroy the cortex to a great extent, but the stelar tube remains intact. Eggs and all stages of nematodes with different orientations are seen in the cavities in longitudinal sections (Fig. 2)(Koshy and Sosamma,1982a; 1987; Koshy, 1986).

Biology and life cycle

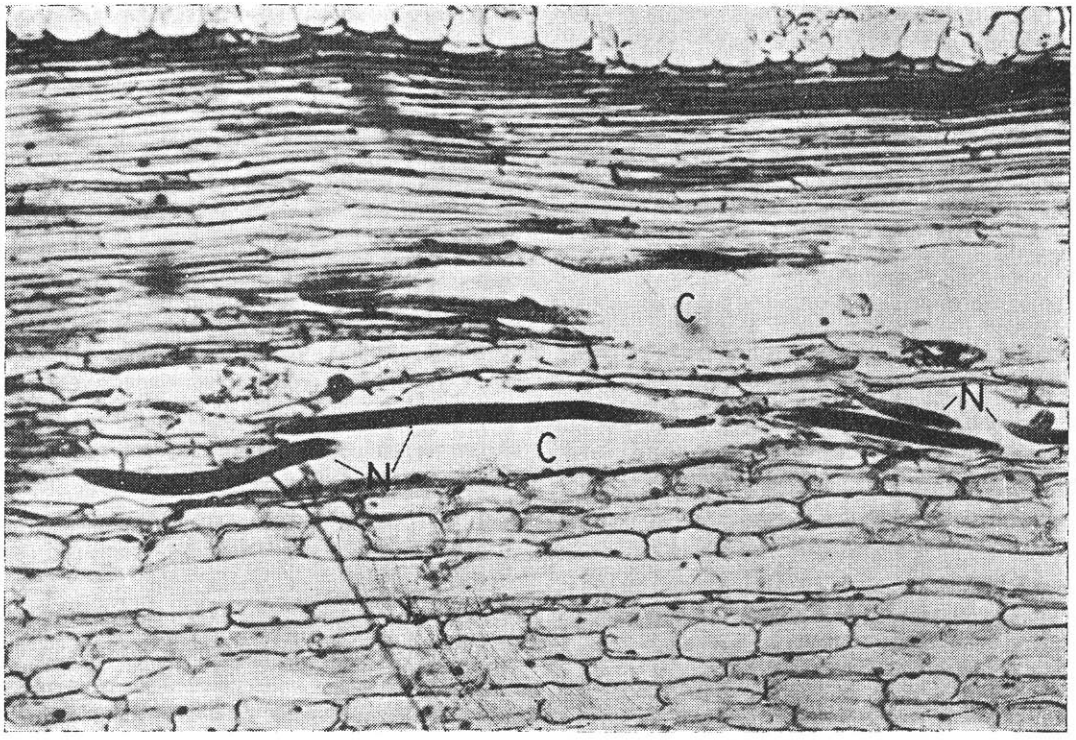
The burrowing nematode is a migratory endoparasite and is capable of spending its entire life within the roots. All juvenile stages, adult and gravid females except adult and fourth stage males are infective. The nematode is known for its sexual dimorphism. Fertilization is usual but parthenogenesis does occur. In coconut the nematode takes 25 days at a temperature range of 25–28°C to complete one life cycle (J_2 to J_2) on inoculation to tender roots of coconut seedlings with second stage juveniles (Koshy, 1986).

The *R. similis* population of 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 coconuts without affecting the size or quality of the nuts (Koshy and Sosamma, 1982b).

Occurrence in different soil types

The percentage occurrence of *R. similis* on coconut was maximum in sandy loam soil (37.8%), followed by red loam (16.5%), clay (13.4%), laterite (10.7%) and riverine alluvium (8.2%) under field conditions (Koshy et al., 1978). The nematode was found to multiply well on coconut in loamy sand followed by riverine alluvium but the

Fig. 2. Longitudinal section of coconut root showing *Radopholus similis* in cavities formed in the cortex
N – nematode C – cavity



least in 'Kari' type soil and it caused maximum plant damage in riverine alluvium and the minimum in lateritial soil (Sosamma and Koshy, 1985).

Population fluctuation

The *R. similis* population in coconut roots were found to fluctuate between samples, palms, groves, months and years in Kerala. However, there were definite periods for occurrence of maximum and minimum populations within a year. Highest populations were recorded during October-November and lowest or nil during May to July. Though populations were low during August to September and January to February, they were around the detectable level of four nematodes per gram of root. Nematode population in individual palms vary considerably during the low and high peaks depending upon the age, availability of tender roots, variety and condition of the palms infected. Ecological conditions such as rainfall, temperature and availability of moisture and susceptible roots play their own roles in the population build up but low soil temperature was found to have a more decisive effect as compared to others (Koshy and Sosamma, 1978).

Survival and means of dissemination

Studies conducted on survival of *R. similis* revealed that annual recurrence of burrowing nematode infestation was brought about by the persistence of adult females during summer months under field conditions. The burrowing nematode survived under field conditions for six months in moist soil (27 to 36°C) and one month in dry soil (29 to 39° C); and under greenhouse it survived for 15 months in moist soil (25.5 to 28.5°C) and three months in dry soil (27 to 31° C). The nematode survived in roots of stumps of felled coconut palms for upto six months (Sosamma, 1984; Sosamma and Koshy, 1986). Adult females were found to survive adverse conditions better than other stages.

Host range and biotypes

The burrowing nematode is polyphagous. The coconut isolate of *R. similis* has a wide host range including several economically important plants, weeds and trees. Of the 115 plant species tested, 48 species belonging to 45 genera in seventeen families were recorded as hosts (Koshy and Sosamma, 1975; Sosamma and Koshy, 1977; 1981).

The coconut isolate of *R. similis* from Kayangulam and Kasaragod, Kerala, India were identified as the "banana race" as they did not infest *Citrus* spp. and *Poncirus trifoliata*, but infested and multiplied on banana plants inoculated concurrently (Koshy and Sosamma, 1977). The coconut isolate of *R. similis* has a haploid number of four chromosomes (n=4) (Koshy, 1986).

Pathogenicity

The pathogenicity of coconut was studied in pots under field conditions over a period of five years. The initial inoculum levels ranged from 100 to 62,500 nematodes per seedling. At the highest initial inoculum level of 62,500 nematodes per seedling caused 48, 22, 76, 18, 25, 40, 48 and 79 per cent reduction respectively with respect to plant height, girth at collar region, shoot weight, number of leaves, number of leaflets/leaf, leaflet length, lamina length and root weight over control plants. The threshold inoculum density required for causing significant reduction of various growth parameters was 100 nematodes per seedling or one nematode in 576 cm^3 or 800 g sandy loam soil in cement pots under field conditions over a period of five years (Koshy and Sosamma, 1987).

Though the pathogenicity experiments have clearly established the pathogenic potential of the nematode on coconut, the role of the nematode in delaying flowering and causing yield reduction could not be established as the plants got pot bound. To facilitate normal growth of the plant, to flower, yield and exhibit the effect of nematode under natural conditions a detailed pathogenicity trial was initiated in October, 1982, in 1.8m x 1.8 m x 1.2 m field tanks (microplots) filled with sandy loam soil fumigated with methyl bromide. On establishment, the seedlings were inoculated with fungus and different levels of nematode inoculum *viz.*, 100 to one million nematodes per seedling. This experiment, first of its kind on a perennial crop has clearly brought out the damage potential of the burrowing nematode on coconut. After seven years an initial inoculum level of 10 nematodes/35640 cm^3 of soil (1,000 nematodes/seedling) caused 13, 13 and 24 per cent reduction over control with regard to height, number of leaves and girth respectively compared to 17, 14 and 35 per cent reduction with an initial inoculum of 100 nematodes / seedling (one nematode in 35640 cm^3). The average field population is 26 nematodes per 35640 cm^3 of soil. At a higher inoculum level of one nematode in 3.5 cm^3 (1,000,000 nematodes/seedling) of soil, the percentage reduction over control in height, number of leaves and girth was 44,30 and 51 respectively. All the five uninoculated control palms have flowered with earliest recorded in December, 1987, whereas three out of five palms that received an initial inoculum of 100 nematodes have flowered much later with the earliest recorded in June, 1988. On an average, the first inflorescence appeared in the axil of 42nd leaf of five control palms, compared to the appearance of inflorescence in the axil of 44th leaf of the three inoculated palms. The average number of inflorescences produced by the five control palms was 16, whereas it was only 7.6 in the case of three palms which received 100 nematodes per seedling. The average number of nuts produced by the first five inflorescences of the two control palms is 23.5 against 19.5 of two palms which have received 100 nematodes. If the total number of nuts produced so far by the five control palms are taken into account against the palms that received 100 nematodes per palm, the reduction in yield is 58 per cent (Anonymous, 1990). The infestation of the nematodes caused heavy root rotting, yellowing, loss of vigour, stunting, delay in flowering and reduction in yield (Anonymous, 1989).

Disease complexes

The fungi *Cylindrocarpon effusum*, *C. lucidum* and *Cylindrocladium clavatum* have been recorded in association with lesions produced by *R. similis* in coconut roots (Sosamma and Koshy, 1978; 1983). However, the *C. effusum* has been associated more often with lesions. The pathogenic effect of the fungus *C. effusum* and nematode *R. similis* was studied singly and in combination with each other in pots under greenhouse conditions. An initial inoculum level of 100,000 nematodes caused 40, 55, 20, 62, 71, 57 and 51 per cent reduction over control with regard to height, shoot weight, number of leaves, leaf area, number of lateral roots, volume and root weight respectively over a period of one year. The fungus *C. effusum* did not cause any appreciable damage to inoculated seedlings. The fungus when inoculated simultaneously with the nematode, reduced the rate of multiplication of the nematode and damage to coconut seedlings. The pathogenic threshold level of *R. similis* is 1000 nematodes per plant or one nematode per 10 cm^3 of sandy loam soil under green house conditions over a period of one year (Koshy and Sosamma, 1987).

Problems in coconut based cropping systems

The important nematode problems in coconut based farming systems other than the burrowing nematode are the root-knot nematode, *Meloidogyne incognita* and lesion nematode, *Pratylenchus coffeae*. The burrowing nematode causes root rotting on coconut as well as on the other component crops like arecanut, black pepper, banana, betelvine, ginger and turmeric (Koshy and Bridge,1990). On black pepper and betelvine the above ground symptoms are similar which is called slow wilt in India and pepper yellows in Indonesia. *R. similis* infested ginger and turmeric, plants exhibit stunting, reduced vigour and tillering. They mature and dry out faster than healthy plants. The top most leaves become chlorotic with scorched tips. The infested ginger rhizomes exhibit small, shallow, sunken, water soaked lesions. Infested turmeric rhizomes tend to lose their characteristic bright yellow colour and show brown discolouration when cut across (Sundararaju, Sosamma and Koshy, 1979; Sosamma, Sundararaju and Koshy, 1979).

Control

Control of the burrowing nematode on a perennial palm like coconut with a massive root system is difficult, especially under the high density multispecies cropping system that exists along the West Coast of South India involving susceptible crops like arecanut, banana, black pepper, betelvine, ginger, turmeric etc.

Chemical:

Thirty per cent increase in yield was obtained by application of phenamiphos or phorate @ 10 g a.i. per palm in June/ July and October/November. However, unlimited use of nematicides for the control of the burrowing nematode may cause problems of insecticide residues in coconut water and meat. Application of Aldicarb @ 10 g a.i. per palm showed residues in coconut water and meat after 45 days of application (Habeebullah et al, 1983).

A dip in 1000 ppm DBCP for fifteen minutes is effective in controlling *R. similis* in seedlings (Koshy and Sosamma, 1979). Complete control of *R. similis* can be obtained with soil application of phenamiphos or phorate @ 25 kg a.i/ ha during September, December and May in infested coconut nurseries (Koshy et al, 1985). Apart from this, application of nematicides to coconut in high density multi-species cropping system may lead to residual toxicity in the products of the intercrops. Therefore, control of nematodes by field application of nematicides alone is not a practical proposition.

Cultural:

The cultural practices existing in Kerala and Karnataka (India) such as growing of crotolaria in the basins and interspaces and incorporating into soil at flowering and application of oil cakes, farm yard manure and green foliage (Glyricidia etc.) to the coconut basins and growing of cacao that enriches the soil with sizeable quantities of shed foliage which helps in the build up of beneficial organisms, may inhibit nematode multiplication. Thirty per cent yield increase has been obtained by the application of Marotti (*Hydnocarpus*) oil cake @ 4 kg per palm in June-July and in October-November (Koshy, 1986).

Resistance and tolerance:

All the coconut cultivars (29 exotic, 15 indigenous and 15 hybrids) screened for resistance to *R. similis* in India were found susceptible in varying intensities. The dwarf cultivars, Kenthali and Klappawangi, recorded the least nematode multiplication and lesion indices. Similar reactions were

noticed in hybrids such as Java Giant X Kulasekharam Dwarf Yellow, Kulasekharam Dwarf Yellow X Java Giant, Java Tall X Malayan Dwarf Yellow and San Ramon X Gangabondam (Sosamma, Koshy and Bhaskara Rao, 1980; 1988; Sosamma, 1984).

Integrated nematode management

The following measures are suggested towards developing an integrated management schedule for *R. similis* infestation on coconut palms :-

1. Avoid use of bananas as a shade crop in coconut nurseries.

2. Use nematode free planting material of coconut and other inter-crops.

3. Use tolerant/less susceptible cultivars or hybrids of coconut and other intercrops in infested areas.

4. Avoid use of susceptible crop combinations like coconut, banana, black pepper ginger, turmeric etc.

5. Apply 50 kg cowdung/farm yard manure, 2 kg oil cake and 25 kg green manure to the basins and growing *Crotolaria juncea* in the basins and interspaces and incorporate into soil at flowering as a green manure.

6. Grow *Glyricidia maculeata* on the borders of coconut plantations and in the interspaces as a standard for black pepper and use leaves and tender twigs for green manuring of coconut and black pepper.

7. Application of phorate @ 10 g a.i/ palm and @ 3 g a.i./plant to banana and black pepper if grown in interspaces in June/ July and in October/November.

Future areas of research

1. Screening of coconut cultivars and their hybrids against *R. similis*

2. Identification of effective biocontrol agents for *R. similis*

3. Developing an integrated nematode management schedule for the coconut based farming systems involving susceptible crops like arecanut, black pepper, banana, ginger turmeric etc.

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