NEMATODES ASSOCIATED WITH THE TUBER CROPS IN KERALA

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Nematodes associated with the tuber crops in Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "Nematodes associated with the tuber crops in Kerala" is a record of research work done independently by Sri. REMESH KUMAR, V. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

Second to cereals, tuber crops are the most important group of staple food in the tropics and sub tropics. They form an important part of the diet in many regions like East and West Africa, Caribbean Island, South America, India and South East Asia. Industrial use and export potential of these crops have added to their importance.

Kerala State has a wealth of tubers which are grown as pure crop, intercrop or as vegetables in home-steads year after year. These include tapioca (Manihot esculenta), sweet potato (Ipomoea batatas), yams (Dioscorea spp.), taro (Colocasia esculenta), tannia (Xanthosoma spp.), elephant foot yam (Amorphophallus companulatus) and coleus (Coleus parviflorus). Except for coleus which is seasonal, tuber crops can be seen in the field throughout the year.

Continuous cultivation may cause complex pest problems. Insect pests and diseases of these tuber crops have been studied. Researche on nematode pests of these crops have gone a long way in other countries where vast acreage are under tuber crops. Information on nematodes affecting these crops are scanty in India, especially in Kerala.

Meloidogyne incognita (Kofoid and White, 1919) Chitwood, 1949 had been reported as a serious pest of *Coleus parviflorus* in Kerala (Satyarajan *et al*., 1964). Nadakal and Thomas (1964) reported *M. incognita* on amorphophallus and colocasia in Kerala. Root knot nematode were encountered in high numbers in amorphophallus and coleus while population of nematode were found lower in cassava, sweet potato and Xanthosoma (Mohandas *et al*., 1988). Mohandas *et al*. (1988) also recorded *Pratylenchus* sp. and *Hoplolaimus* sp. in *Dioscorea alata*. No systematic survey of nematode pests affecting these crops has so far been done in Kerala.

The present studies have been carried out with the objectives of collecting information on the plant parasitic nematodes associated with tuber crops in Kerala, the nature and extent of damage caused by different levels of nematode population on the crops and also assessment of the influence of irrigation on the development of nematodes.

Review of Literature

1. REVIEW OF LITERATURE

A brief review of literature on plant parasitic nematodes associated with tuber crops, assessment of damage caused to them, development of nematodes under conditions of water stress, histopathology of *M. incognita* infested roots, keeping quality of nematode infested tubers under storage is presented below.

1.1. Plant parasitic nematodes associated with tuber crops and assessment of damage

Several plant parasitic nematodes are reported on the tuber crops.

1.1.1. Nematodes on aroid species

Important edible aroids include cocoyams (*Xanthosoma spp*) and taro (*Colocasia esculenta*). Species of root knot nematode particularly *Meloidogyne javanica* (Treub, 1885) Chitwood 1949 and *Meloidogyne incognita* (Kofoid and White, 1919), Chitwood 1949 are the most widely reported nematode pests of both *Colocasia* and *Xanthosoma* (Mc Sorley, R 1980).

Root knot nematode was first reported from *C. esculenta* by Byars (1914) in Florida. Root knot nematode species from colocasia has also been reported from Hawaii (Parris, 1940), Kerala (Nadakal *et al.*, 1964), Tongo (Bridge, 1978) and South Pacific (Williams, 1980).

M. javanica on C. esculenta was reported from India (Srivastava et al., 1969), East Africa (Whitehead, 1969), Florida (M.C. Sorley, 1980) and Hawaii (Jackson, 1980).

M. incognita was reported on colocasia from Trinidad (Brathwaite, 1972), Fiji (Kirby, 1977) and Niue Island (Williams, 1980).

Reports on root knot nematodes on Xanthosoma are limited. Meloidogyne spp. had been reported on X. sagittifolium in Trinidad (Brathwaite, 1972), Puerto Rico (Roman, 1978) and M. arenaria and M. javanica on X. sagittifolium in Florida (Mc Sorley, 1980).

Martin (1959) reported root knot nematodes on related aroid species. They were Meloidogyne arenaria (Neal, 1989), Chitwood 1949 and M. incognita on Alocasia macrorrhiza and M. javanica, M. arenaria and M. incognita on other Alocasia species.

Brathwaite (1972) observed high nematode numbers Rotylenchulus reniformis Linford and Oliviera, 1840 of 100-1000/100 cm^3 soil associated with colocasia in Trinidad. Orton Williams (1980) found R. reniformis in two third of the sites covered in a survey in Fiji and in one out of six sites in Tonga.

Ayala (1969) reported X. sagittifolium as a host of R. reniformis.

Brathwaite (1972) observed the spiral nematode *Helicotylenchus sp.* in soil samples collected from ground crops including *C. esculenta* in Trinidad. In a survey done by Orton Williams (1980), the common spiral nematodes *H. dihystera* and *H. macronatus* were seen in 50 per cent of the sites examined in Western Samoa while the latter was present in all the six taro areas checked in Niue (120/100 ml soil). *Helicotylenchus spp.* were found in about 65 per cent of the sites in Fiji, 80 per cent of the 20 plots in Western Samoa and 100 per cent areas in Tonga.

Kumar and D'Souza (1969) reported *Pratylenchus mutabilis* Colbian from the roots of colocasia in India. Orton Williams (1980) observed *Pratylenchus* sp. in about a quarter of the samples collected from Fiji.Mortimer *et al*. (1981) reported that *P. coffeae* occasionally infested taro corms in Solomon islands.

Tandon and Singh (1974) found *Aphelenchoides colocasia* and *A. buckleyi* in roots of *C. esculenta* var. *antiquorum* at Lucknow, India.

A survey conducted by Orton Williams (1980) on taro revealed a moderate population of *R. similis* in Western Samoa, *Macroposthonia onoensis* and *M. denoyodeni* in Fiji, *Xiphinema sp.* in Fiji, *X. brevicolle* in Niue and *Tylenchus* sp. in Upolu.

Mortimer *et al*. (1981) described *Hirschmanniella sp* as an endoparasitic nematode in corms of *C. esculenta* in Solomon islands.

1.1.1.a. Damage on aroids

MC Sorley (1980) observed that severity of crop damage due to *Meloidogyne spp* on aroids varied widely depending on the plant cultivar, growing conditions, nematode population and geographical locations.

M. javanica infestation on taro resulted in yellowing, dieback of infested plants, whitish round root galls (2-15 mm diameter) and deformed corms. Heavy infestation resulted in galls on corms, which reduced the quality and market value of the produce and accelerated rotting during storage (Srivastava *et al*., 1969). Onwueme (1978) reported that the severity of root knot nematodes was more on upland taro (*C. esculenta* var. antiquorum). Gall like swellings also had been reported by Jackson (1980) which resulted in crop failure in Hawaii. Mc Sorley (1980) reported that *M. javanica* infection in Florida on colocasia showed mature egg masses on roots.

M. incognita infection on taro resulted in plentiful females in larger roots of the plant while galling was confined to the feeder roots (Brathwaite, 1972). Slight galling was reported from Fiji and the cultivar somoa was considered as moderately susceptible (Kirby, 1977). Severe galling and damage by *M. incognita* on taro was reported from Niue island (Williams, 1980).

Yellowing, stunting and galling at root tips on the damaged plants was reported on *Xanthosoma* due to *Meloidogyne* infection (Roman, 1978). Acosta (1979) observed rough appearance and galls on the cortex in the tannier corms infected by *Meloidgyne* sp. Preplant populations of 500 *M. incognita* (race - 2)/100 cm^3 of soil was found to cause a significant reduction in corm weight, but *X. sagittifolium* was observed as a poor host, since *M. incognita* could not maintain its population levels on the crop (Caveness *et al*., 1981).

Small root lesions were evident due to heavy infestation of *R. reniformis* on taro (Brathwaite, 1972) and numerous mature females could be seen (Mc Sorley, 1980). With the preplant population of 56 *R. reniformis*/100 cm^3 of soil and final populations of about 400/100 cm^3 of soil, a reduction of 26 per cent in marketable dry corm weight of *X. caracu* was observed but the yield of *X. atrovirens* was not affected (Mc Sorley *et al*., 1983). Very high population of *R. reniformis* on colocasia was also observed (Mc Sorley *et al*., 1983).

1.1.2. Nematodes on sweet potato

Many genera of plant parasitic nematodes were seen with sweet potato in the field. Thirteen genera and 12 species were recorded on sweet potato from Philippines (Gapasin, 1979). Important genera observed were *Meloidogyne* and *Rotylenchulus* (Prasad *et al*., 1964; Gapasin, 1979).

Species of *Meloidogyne* infesting sweet potato were *Meloidogyne hapla* Chitwood 1949; *M. arenaria*, *M. incognita* and *M. javanica* (Clark and Meyer, 1988).

Other important genera were the migratory endoparasites *Pratylenchus* (Huan and Xu, 1985) and Brown ring nematode *Ditylenchus* (Ding and Lin, 1982; Yin and Zhang, 1983).

Various species of *Pratylenchus* were reported from Japan, the principal species being *P. coffeae* (Zimmerman, 1898) Goodey 1951. In U.S. *P. brachyurus* (Godfrey, 1979). Filipev & S. Stekhoven 1941 was most common (Clark and Meyer, 1988) and in China, *Pratylenchus penetrans* (Cobb, 1917) Filipjev & Stekhoven, 1990; *P. vulnus*, Allen and Jensen, 1951; *P. convallariae* and *P. zeae* Graham, 1951 were seen (Huan and Xu, 1985).

Brown ring or stem and bulb nematode *Ditylenchus destructor* Thorne, 1945 is the dominant pathogenic species on sweet potato reported from China (Ding and Lin, 1982; Yin and Zhang, 1983).

The spiral nematode, _Helicotylenchus spp_. has been found in association with sweet potato in the field more than any other genera of ectoparasites (Gapasin, 1979).

Several genera of ectoparasites, _Belanolaimus_ - the sting nematode, _Trichodorus_ - the stubby root nematode, _Tylenchorynchus_ - the semi-endoparasite and several species of lance nematodes - _Hoplolaimus_ were seen associated with sweet potato. Finally several genera of migratory ectoparasites have been found in association with sweet potato. These include _Aphelenchoides_, _Aphelenchus_, _Criconema_, _Criconemella_, _Hemicycliophora_, _Longidorus_, _Paratylenchus_, _Quinisulcus_, _Radopholus_, _Scutellonema_, _Tylenchus_ and _Xiphinema_ (Clark and Meyer, 1988).

1.2.2.a. Damage on sweet potato

The root knot nematode is one of the destructive nematodes on sweet potato, enjoying a wide distribution. It reduces the yield and quality of fleshy storage roots. Spindle shaped swellings (galls) on roots occurred on infected fibrous roots. Small necrotic flecks or lesions developed on roots infected by certain species or populations of root knot nematode (Clark and Meyer, 1988).

Out of 52 varieties tested for resistance, 28 were resistant to *M. incognita* and 47 to *M. javanica*. Resistance rating was significantly and positively correlated with numbers and indices of egg masses and root galls as well as with root nematode population (Gapasin, 1984). Out of 408 clones of sweet potato tested 67 were highly resistant to *Meloidogyne spp*. and 66 showed some resistance in the Pacific Islands (Shiga and Takemata, 1981). At high inoculum levels of *M. incognita* more eggs and juveniles were recorded from susceptible variety of sweet potato than from varieties moderately susceptible (Lawerence *et al*., 1986). *M. incognita* was not successful in infesting sweet potato variety 'Sree Vardhini' in a pathogenecity trial (Mohandas *et al*., 1988).

Four months after inoculation with *M. incognita* plants were stunted and roots were galled with several egg masses. On the surface lesions, necrosis and rotting were observed (Gapasin and Valdez, 1979). Infected feeder root system are usually shorter and had fewer secondary roots and root hairs. Additional symptoms, such as reduction in the vine growth, yellowing, flagging (transient wilting of foliage) may also caused (Clark and Meyer, 1988).

Longitudinal cracks were formed on tubers by *M. incognita* (Thomas and Clark, 1983). Decrease in root, tuber and top weights were observed with corresponding increase of level of inoculum in pot experiments with *M. incognita* and *M. javanica*. Tuber production in pots at initial population of 20000 eggs/pot of *M. incognita* and *M. javanica* were 47.7 per cent and 50.6 per cent respectively (Gapasin and Valdez, 1979). Inoculum levels were found negatively correlated with number of marketable roots and root weight and positively with total cracked roots, percentage of cracked roots and cracking severity (Lawrence *et al*., 1986). Occasionally bumps or blisters were seen on the surface of infected fleshy roots (Clark and Meyer, 1988).

The reniform nematode *R. reniformis* was found to be a destructive pathogen of sweet potato affecting both yield and quality of the crop. Roots were shorter and had fewer secondary roots when nematode densities were high but when population was low root growth was stimulated early in the season. Later fibrous roots turned necrotic. Damage to secondary roots caused stunting of vines, yellowing of foliage and transient wilting (Clark and Meyer, 1988).

Decrease in root, tuber and top weights were observed with corresponding increase in levels of inoculum in pot experiment. Tuber reduction in pots at initial populations of 5000 larvae of *R. reniformis* was 60.6 per cent (Gapasin and Valdez, 1979). Gapasin (1987) also reported that reduction in tuber production may range from 13.4 to 60.6 per cent. Cracking of tubers was found increased due to R. reniformis (Thomas and Clark, 1983).

Reproduction of R. reniformis on ten sweet potato selections was not found related to the reduction in yield. Least reproduction was in the variety goldrush while it was not affected by the nematode. Variety 'white centennial' supported high reproduction but was least affected. Yields were found significantly reduced when initial population was high (Clark and Wright, 1983). Water stress delayed the egg hatchability of R. reniformis on sweet potato (Thomas and Clark, 1983).

Mc Sorley (1980) reported that all cultivated varieties were hosting 228-408 R. reniformis/100 cm^3 of soil in Florida. Juveniles were usually found in the soil surrounding the infected plants and it reached density levels as high as 100,000/500 cm^3 soil (Clark and Meyer, 1988).

The nematode had not been reported within enlarged fleshy roots of sweet potato, but it had been observed on small storage roots prior to significant centripetal enlargement (Clark and Meyer, 1988).

The lesion nematode _Pratylenchus_ _spp_. caused a disease of sweet potato known as root lesion or nematic root rot. In U.S. _Pratylenchus_ was not often associated with sweet potato and green house test indicated the nematodes did not reproduce well on it. But cultivars grown in Japan supported increased multiplication of the nematodes in the field. When sweet potato was planted in nematode infested fields, the nematodes typically caused small necrotic root lesions from which nematodes at various stage could be extracted. Fibrous root necrocis led to some stunting of vines and a significant reduction in the quality of fleshy storage roots. Secondary fungi and bacteria invaded lesion incited by the nematode and increased the extend of necrocis or decay. Small brown to black, necrotic lesions were seen on storage roots which made the roots unmarketable (Clark and Meyer, 1988). Clark and Meyer (1988) described the pathogenecity of _D_. _destructor_ initially consisted of scattered sunken areas on storage roots. When they were cut open, a brown to brownish black layer was revealed in the cortex beneath the periderm. Eventually the entire root became decayed and nematodes and myceilia of secondary fungal invaders spread through out it. The periderm then shrunk and became crinkled. The disease was primarily a storage disorder rather than a field disease and the nematode was not seen infecting growing vines.

The spiral nematode *Helicotylenchus spp.* reproduced rapidly on sweet potato. Low densities were found to stimulate root growth but higher densities had no effect on the growth of fibrous roots or the weight of fleshy storage roots (Lopez *et al.*, 1981).

Sting nematodes *Belanolaimus longicaudatus* Rau 1958 caused significant stunting of sweet potato vines, some of which may died prematurely and caused lower yields of storage roots. The feeder roots were short and often swollen just behind the root tips. The roots proliferated above feeding sites. Minute discoloured, shrunken lesions developed at feeding sites (Clark and Meyer, 1988).

The stubby root nematodes *Paratrichodorus* and *Trichodorus spp.* normally fed ectoparasitically near the tips of fibrous roots causing cessation of root elongation. Affected root systems were shortened and had fewer lateral roots and the roots were swollen at the ends, no necrosis was noticed. Stubby root nematode reduced both growth and yield of sweet potato (Roberts and Scheuerman, 1984).

1.1.3. Nematodes on *Coleus parviflorus*

M. incognita was recorded as a serious pest of coleus from different parts of India (Satyarajan *et al.*, 1966; Hrishi and Mohan Kumar, 1976).

1.1.3.a. Damage on Coleus

Heavy root galling was observed on coleus due to nematode infection (Pushkarnath and Roy Chowdhary, 1958; Satyarajan *et al*., 1966; Patnaik and Das, 1986; Sosamma, 1988). In an inoculation with 10 juveniles/pot 29 per cent reduction in root length was observed in 60 days inoculation with nematodes. This was considered as the damage threshold level. An increase in dry weight of roots for inoculation levels upto 1000 second stage juveniles per pot (100%) was also observed (Patnaik and Das, 1986). Sosamma (1988) reported rotting of roots by third month and at harvest no healthy root was present in infected plants.

Chlorotic leaves (yellowing) on infected plants have been reported in coleus (Pushkarnath and Roy Chowdhary, 1958; Patnaik and Das, 1986). Shoot lengths and shoot weight of plants infected by *M. incognita* was found to be less than that of uninfected plants (Pushkarnath and Roy Chowdhary, 1958; Sosamma, 1988). Number of leaves were also less in infected plants (Sosamma, 1988). Patnaik and Das (1986) reported a decrease in shoot dry weight in infected plants. Wilting and drooping of leaves and other premature symptoms of ageing were also observed (Pushkarnath and Roy Chowdhary, 1958).

Coleus tubers infected with *M. incognita* became malformed and hypertrophied due to heavy galling and became unsuitable for consumption and marketing (Pushkarnath and Roy Chowdhary, 1958; Satyarajan *et al*., 1966; Sosamma, 1988). Patnaik and Das (1986) observed 46.5 per cent reduction in tuber weight at 1000 second stage juveniles per pot. Sosamma (1988) also reported high yield reduction of tubers in infested plants.

Infected coleus tubers when stored developed dark patches on the surface which spread inwards covering the whole of the internal tissue within nine days and by the twelth day the internal contents had turned into a dark brown heavy liquid with a bad odour. The peel of the tuber did not show rotting (Sosamma, 1988).

1.1.4. Nematodes on Yams (*Dioscorea spp.*)

Important yams include water yam (*D. alata*), white yam (*D. rotundata*) and yellow yam (*D. cayannensis*). *Meloidogyne spp.*, (Steiner & Lettew, 1933), *Scutellonema bradys* Andrassy, 1958 and *Pratylenchus spp.* had been identified as the serious nematode pests on yams in Africa (Acosta, 1974; Adesiyan and Odihiran, 1975a, Adesiyan, 1977).

In a survey conducted in Nigeria it was found that 10-90 per cent of water yam, 3-70 per cent white yam were infected by nematodes while yellow yam showed no symptoms (Adesiyan and Odihiran, 1975a). M. incognita, M. javanica (Adesiyan and Odihiran, 1975b) M. arenaria (Barros Lee and Ponte, 1979) were found infesting yam causing heavy damage. M. incognita had been reported on yams in Florida (Smart and Perry, 1968), in roots of D. alata in Puerto Rico (Ayala and Acosta, 1971), West Indies (Kermarrec and Anais, 1973) and Antilles, Africa (Kermarrec, 1974).

Pratylenchus coffeae had been reported as a migratory endoparasite of yam roots and tubers (Bridge, 1973; Brathwaite, 1977). P. brachyurus found causing damage to yams in Nigeria (Bridge, 1973); Florida (Smart and Perry, 1968) and P. striatus in Ivory coast (Smitt, 1971). Other reports of Pratylenchus spp. on yams include of those from West Indies (Kermarrec and Anais, 1973), Anitilles, Africa (Kermarrec, 1974) and Kerala (Mohandas et al., 1988).

S. bradys was recorded as a migratory endoparasite of yam roots and tubers in Florida (Smart and Perry, 1968) and Nigeria (Bridge, 1973). S. bradys found infesting D. alata (Ayala and Acosta, 1971; Degras and Kermarrec, 1976), on guinea yam (Acosta and Ayala, 1976), D. cayannensis and D. alata (Kasasiyan et al., 1978).

Other reports include Tylenchus pratensis on Dioscorea in West Africa (Steiner, 1931); Rotylenchulus reniformis, Helicotylenchus dihystera, Aphelenchoides sp., Aphelenchus spp. on Dioscorea alata in Puerto Rico (Ayala and Acosta, 1971); Helicotylenchus sp., Tylenchorynchus sp. Rotylenchus sp. and Criconemoids on D. trifida in West Indies (Brathwaite, 1972); Aphelenchoides besseyi Christei, 1942, Helicotylenchus sp. and Rotylenchulus sp. on yams in West Indies (Kermarrec and Anais, 1973), A. besseyi, Helicotylenchus sp. and Rotylenchulus sp. on yams in Antilles, Africa (Kermarrec, 1974) and Hoplolaimus sp. on D. alata in Kerala (Mohandas, 1988).

1.1.4.a. Damage on yams

A low population of M. incognita stimulated the development of tops, roots and tubers of D. rotundata (Ayala and Acosta, 1971). Adesiyan and Odihiran, (1975b) found that an inoculum level of 5000 nematodes per plant significantly reduced the yield of D. alata. Meloidogyne sp. found occurred in the galled tubers of D. alata (Adesiyan and Odihiran, 1975b, Degras and Kermarrec, 1976) and M. arenaria in D. cayannensis tubers (Barros Lee and Ponte, 1979). But Kasasiyan et al. (1978) did not observe survival and reproduction of M. incognita in stored Dioscorea tubers.

M. incognita did not cause cracking of tuber cortex (Ayala and Acosta, 1975).

An initial population of 600 *M. incognita* per plant caused dry rot of yam (Ayala and Acosta, 1975). Atu *et al.* (1983) found tubers from pots inoculated with more than 1250 nematodes per plant were so heavily galled that the market value was reduced by 40 per cent. Economic threshold level and economic injury level of *M. incognita* had been fixed as 250 and 1250 nematodes per plant at a soil temperature of 28°C on *D. rotundata*.

Atu *et al.* (1984) also reported that in South Eastern Nigeria all except *D. dumetorum* and *D. alata* cv. abuneuyi were found susceptible to *M. incognita* race-2.

Low population of 200 larvae of *S. bradys* stimulated the development of tops, roots and tubers of *D. rotundata* (Ayala and Acosta, 1975). Suppression to the extent of 21 per cent was caused to top growth of guinea yam (Acosta and Ayala, 1976).

S. bradys was found associated with dry rot of yam tubers in storage and it caused 80 to 100 per cent tuber losses in Nigeria (Adesiyan and Odihiran, 1975a) The nematodes were restricted to the outer 1-2 cm of tuber, in the peridermal and sub peridermal layers. They fed intracellularly in the tissues causing cell destruction and necrocis. The nematode caused dry rot symptoms in the absence of other organisms but nematode damage did predispose tubers to secondary pathogens particularly fungi and bacteria.

Significant amount of water loss from the *D. rotundata* and *D. cayannensis* during 12 weeks storage between healthy tubers and tubers infected with *S. bradys* was found but no significant weight loss was evident. Infection of each of the species of yam with *S. bradys* was associated with marked reduction in the size of edible portions (Adesiyan and Odihiran, 1975a) An initial population of 600 *S. bradys* caused dry rot of yam (Ayala and Acosta, 1975). Storage root quality was found reduced to the extent of 20 per cent by *S. bradys* on guinea yam (Acosta and Ayala, 1976). *S. bradys* was found to survive and reproduce in stored dioscorea tubers (Kasasiyan *et al*., 1978).

Low population of 200 larvae of *P. coffeae* was found to stimulate the development of tops, roots and tubers of *Dioscorea rotundata* (Ayala and Acosta, 1975). Suppression of top growth to the extent of 29 per cent was caused by *P. coffeae* on Guinea yam (Acosta and Ayala, 1976). *P. coffeae* was found causing quality deterioration of yam tuber in Puerto Rico by causing dry rot of yam. An initial population of 600 *P. coffeae* was high enough to induce dry rot of yam tuber (Acosta and Ayala, 1975). Storage root quality was reduced by 72 per cent on guinea yam (Acosta and Ayala, 1976).

P. coffeae were found concentrated mainly in the outer 6 mm of tissues, but penetration upto 15 mm was found in the guinea yams. The oldest portion adjacent to the stem contained the highest population while the distal portion the least (Acosta, 1974). Kasasiyan *et al.* (1978) found that *P. brachyurus* could survive and reproduce on stored dioscorea tubers. *P. brachyurus* in large numbers were also reported from storage roots of *D. floribunda* affected with dry rot (Roman, 1978).

Low populations of 200 larvae of *R. reniformis* stimulated the development of tops, roots and tubers of *D. rotundata*. *R. reniformis* did not cause cracking of the tuber cortex (Ayala and Acosta, 1975). Kasasiyan *et al.* (1978) also reported *R. reniformis* from the dioscorea tubers.

1.1.5. Nematodes on Cassava

Meloidogyne javanica (Nirula and Kumar, 1963) and *Meloidogyne spp.* (Hoggen, 1971) were reported as pests of cassava in India. Survey conducted in Philippines (Gapasin, 1979) observed the occurrence of 13 genera and 17 species in cassava. *Meloidogyne spp.* was abundant and widespread. *Rotylenchulus* and *Helicotylenchus* were widely distributed but population densities were low.

McSorley *et al.* (1983) observed that the plant parasitic nematodes most frequently found associated with cassava throughout the world were *Pratylenchus brachyurus*, *Rotylenchulus reniformis*, *Helicotylenchus spp*., *Scutellonema sp*. and *Meloidogyne spp*. But only *Meloidogyne spp*. and *P. brachyurus* were considered economically important.

Other reports of nematodes from cassava include *Diplocapter rhizophillus*, *Cephalobus rigidus*, *C. elongatus*, *Isonchus radicicola*, *Tylenchus dipsaci* in Brazil (Gilbert Rahn, 1982), *Helicotylenchus abunaamai*, *M. incognita*, *P. brachyurus* from plant and soil *Heterodera digitatus*, *H. indicus*, *Hirschmanielia sp*., *Hoplolaimus seinhorstei*, *Longidorus sp*., *Macroposthomia sp*., *Pratylenchus zeae*, *Rotylenchulus reniformis*, *Tylenchorynchus martini* and *T. darainei* from soil samples in Thailand (Thongjiem, 1983), *Coslenchus sp*., *Criconemella onoensis*, *Pratylenchus zeae*, *Tylenchorynchus annulatus* in Trinidad (Bala, 1984).

1.1.5.a. Damage on cassava

Damage due to *Meloidogyne spp*. depended on the population level though differences in responses of various cassava cultivars to *Meloidogyne spp*. was observed (McSorley *et al*., 1983). Varietal resistance had been reported (Ponte *et al.*, 1980) for *M. incognita* and *M. javanica*. Nineteen cultivars were seen immune out of 24 cultivars tested and three were highly resistant as assessed by the index of galling after sixty days. Freitas *et al.* (1986) reported cv. Mandiocal was found resistant to both *M. javanica* and *M. incognita* while cv. white retroz 1 and retroz 4 were resistant to *M. incognita*. Varietal reaction on the production of galls also varied. Marketable yield of the cultivars 'senorita' and 'Mantiqueira' were similar in plots having a sub-threshold level of *M. incognita* but 'senorita' showed more galling than 'mantiqueira'.

Seedling heights increased in the lower inoculum levels of 500 and 1000 larvae per plant (Caveness, 1977). In greenhouse trials plant height increased upto 10 per cent under light nematode infestation but the plant height was reduced as much as 52 per cent with heavy infestation (Caveness, 1982). The root knot nematodes *M. incognita* and *M. javanica* significantly reduced stalk height, stalk weight and storage root weight of two cassava cultivars viz. TMe 30555 and TMe 30572, after a 15½ month growing period in the tropical reinforest zone of southern Nigeria (Cavensis, 1982).

Galling increased root weights at inoculum levels of 500, 1000 and 2000 *M. incognita* larvae per plant (Caveness, 1977) but heavy infestation reduced the weight of root system (Caveness, 1982). Tuber weights were reduced at inoculation levels of 500, 1000 and 2000 larvae per plant inoculum levels of *M. incognita* (Caveness, 1977). Population of *M. incognita* inversely correlated with the yield (McSorley *et al.*, 1983) and root galling (Mc Sorley and Parrado, 1985). Freitas *et al.* (1986) reported that storage roots did not present any root knot symptoms.

1.2. Development of nematodes under water stress condition

Population of *Rotylenchulus reniformis* markedly increased when sweet potato was irrigated during the whole of the vegetative period but decreased greatly when irrigation was applied only during 60th to 110th day after planting (Rodriguez and Caraballo Llosus, 1981). Thomas and Clark (1983) observed water stress delayed the egg hatchability and larval movement of *R. reniformis*.

Damage to sweet potato by *R. reniformis* was enhanced by moderate drought stress during the growing season which occur frequently on sandy soils. It was attributed to the combined effect of reduced availability of water and the reduced capacity of infected roots to take up water (Clark and Meyer, 1988).

The nematological surveys of irrigated projects in Eastern Nigeria showed that the availability of irrigation during the dry season and rainfall during the rainy season favoured Meloidogyne build up (Onyenobs, 1985). Root knot nematode damage was more under conditions of moderate drought, because of combined effect of reduced availability of water and the reduced capacity of the infected roots to take up water. When soil moisture was maintained at an adequate level for the growth of sweet potato during the growing season, the nematode had less effect on growth or yield of the crop (Clark and Meyer, 1988).

Water stress had no effect in M. incognita on the egg hatchability and larval movement (Thomas and Clark, 1983). But root knot was more serious in sandy textured soils and the factor according to Clark and Meyer (1988) was related to the size of pore spaces and the greater mobility of nematode in water in larger pore spaces.

Irrigation during summer maintained relatively large population of Trichodorus viruliferous whereas in unirrigated plots populations declined over 50 per cent and economic threshold level for T. viruliferous on sugarbeet were fixed as 700/1 in unirrigated soil and 300/1 in irrigated soil (Cooke, 1984). McKenry and

Kretsch (1987) observed that peach tree under high irrigation regime suffered detrimental effect of root knot nematodes.

1.3. Histopathology of roots inoculated with *M. incognita*

Penetration of root knot larvae was directly through the root epidemis near the root tips destroying some epidermal cells during penetration (Krusburg and Nielson, 1958). Reaching cortex the larvae migrated intra cellularly. Formation of characteristic giant cells on susceptible plants due to infection by *M. incognita* have been reported by several workers (Crittenden, 1958; Dropkin and Nelson, 1960; Litrell, 1966; Kozhokaru, 1985; Fawole, 1988 and Sosamma, 1988). According to Litrell (1966), the giant cells originated from the provascular strand while other workers (Birchfield, 1964; Taylor, 1976) reported that giant cells were formed from phloem. Some workers found the formation of giant cells from xylem and phloem parenchyma (Molina and Nelson, 1983), while some noted giant cell formation from the xylem alone (Taylor, 1976; Jacob, 1977; Fawole, 1988). Crittenden (1958) reported that giant cells occurred generally in the region of the pericycle. Giant cells were generally found adjacent to the head of the nematode (Crittenden, 1958; Ferver and Crittenden, 1958; Dropkin and Nelson, 1960; Litrell, 1966; Taylor, 1976; Kozhokaru, 1985).

The number of giant cells initiated by *M. incognita* in different crops showed variations (Orr and Morey, 1978). In pepper 4 to 6 giant cells were observed (Jacob, 1977), while in vegetables 8-9 giant cells were usually seen (Kozhokaru, 1985) and in coleus 4 giant cells were seen (Sosamma, 1988). Giant cells were observed to be larger than surrounding cells and they had very dense cytoplasm with a large number of nuclei (Crittenden, 1958; Dropkin and Nelson, 1960; Birchfield, 1964; Taylor, 1976; Molina and Nelson, 1983; Sosa Moss *et al*., 1983; Kozhokaru, 1985; Fawole, 1988).

Increase in size of giant cells was reported to be due to incorporation of surrounding parenchyma cells (Dropkin and Nelson, 1960; Birchfield, 1964; Litrell, 1966).

Birchfield (1964) observed progressive cell wall dissolution in advance of the nematode which was followed by the formation of thick walls around the feeding area. The nuclei of dissolved cells aggregated within cyncytia and maintained nuclear membrane intact.

According to Litrell (1966), multinucleate cells were noted in plants 72 hours after inoculation with the nematode. He also observed mitosis without cell division. A similar observation was made by Johns and Payne (1978) who also found that cell plate alignment in the giant cells proceeded normally, but cytokinesis was unsuccessful. They did not find any evidence of wall break down. Electron microscope studies by Kozhokaru (1985) showed that the nuclei of giant cells had lobate contours. Root knot nematodes were found with its head embedded in the stele and body in the cortex (Ferver and Crittenden, 1958; Krusburg and Nielson, 1958). Aggregation of granular cytoplasm towards the head region of the nematode was observed (Sosamma, 1988).

Enlargement of stele and cortex due to infection by M. incognita was reported by several workers (Ferver and Crittenden, 1958; Krusburg and Nielson, 1958; Taylor, 1976; Vovlas et al., 1986; Sosamma, 1988). Hyperplasia also occurred in the pericycle (Litrell, 1966; Dropkin and Nelson, 1960). In infected roots, vascular tissue differentiation was not observed (Dropkin and Nelson, 1960). Prominent disruption in the stele, cortex and pericycle were observed due to extensive hypertrophy and hyperplasia in roots infected by M. incognita (Ferver and Crittenden, 1958; Dropkin and Nelson, 1960; Birchfield, 1964; Taylor, 1976; Sosa Moss et al., 1983; Vovlas et al., 1986; Sosamma, 1988).

Akhthar et al. (1983) found that certain enzymes were secreated by the nematodes which reduced the concentration of lignin in the cell facilitating the movement of the nematode within the host.

In late stages of root infection by *M. incognita* normal development was severely disturbed so that only remnants of the xylem and pholoem remained (Dropkin and Nelson, 1960). Abnormal xylem formation in infected root cells was reported (Dropkin and Nelson, 1960 ; Litrell, 1966; Orr and Morey, 1978).

According to Krusburg and Nielson (1958) as the nematodes matured after oviposition, it either died or stopped feeding as the giant cell cytoplasm often disintegrated and disappeared especially in young enlarging roots where the giant cells usually collapsed. Studies by Birchfield (1964) showed that older syncytia became necrotic, hard and crumbly. Necrocis was observed in the cortex 30 days after infection (Dropkin and Nelson, 1960). Dropkin and Nelson (1960) found that the cortex in galls of older roots sloughed off, galls observed in mature soybean plant contained little or no cortex tissue.

Large cavities were observed four months after inoculation of *M. incognita* in coleus root tissue, which were caused by the deterioration of giant cells and the death of adult females within the tissues. Tissue differentiation was not observed even after five months in coleus roots infected by *M. incognita* (Sosamma, 1988).

1.4. Keeping quality of tubers infested by nematodes

Respiration and weight losses of tubers increased with temperature during storage (Dambroth, 1970).

Srivastava *et al.* (1969) reported that colocasia tubers heavily infected by *M. javanica* showed accelerated rotting during the storage. Destruction of infected tubers under storage due to rotting had been reported by Adesiyan *et al.* (1975) on yam. Coleus tubers infected by nematodes rotted but those uninfected tubers could be stored for long periods (Sosamma, 1988; Mohandas, 1988). Sosamma (1988) also found that highly infected tubers could not be stored for more than 12-15 days by which the tubers completely rotted rupturing the peel giving a foul smell, but the peel remained unaffected.

Materials And Methods

2. MATERIALS AND METHODS

A study was conducted for collecting information on plant parasitic nematodes affecting tuber crops in Kerala at College of Agriculture, Vellayani, Thiruvananthapuram during the period 1988-1990. The study included a survey of the plant parasitic nematodes associated with tuber crops in Kerala followed by crop loss assessment and the assessment of the influence of water stress on nematode development. The crops included for the study were coleus *Coleus parviflorus* Benth, sweet potato *Ipomoea batatas* (L.) Poir, yam *Dioscorea alata* L., cassava *Manihot esculenta* Crantz and aroids (taro-*Colocasia esculenta* (L.) Schott and tania - *Xanthosoma spp*). Most prevalent species of nematode *Meloidogyne incognita* was used for the crop loss assessment and nematode development studies.

2.1. Survey on the incidence of nematode pests on tuber crops in Kerala

A survey of nematode pests of above mentioned tuber crops was conducted during the period December 1988. Stratified multistage random sampling technique was adopted for the study. Five NARP zones were considered as the five strata. The primary units were five panchayats selected at random from each NARP zone. From each panchayat four holdings were selected randomly as secondary units for each crop namely coleus, sweet potato, tapioca, dioscorea and colocasia or Xanthosoma. Representative samples of 500 g soil and 50 g roots were collected in polythene bags adopting standard procedure from each of these holdings. The samples were properly labelled and brought to College Laboratory for analysis. Samples were processed immediately.

2.1.1. Extraction of nematodes

2.1.1.a. From soil sample

Nematodes were extracted from soil samples following Cobb's decanting and sieving technique as modified by Christie and Perry (1951). The soil samples weighing 100 g was transferred to a plastic basin and mixed throughly with three times water. This was passed through a twenty mesh sieve to remove larger extraneous matter. The materials in the mesh were discarded. After proper mixing supernatent liquid in the basin was then passed through a sixty mesh sieve and the materials were collected in the sieve. Sediments in the basin were discarded. The filtrate was then allowed to stand for a few minutes and then decanted and passed through a series of 100, 200 and 325 mesh sieves. The fine silt and nematodes collected in sieves were washed down into a beaker with minimum quantity of water.

Nematode suspension obtained from the soil samples processed was poured gently into a double layered tissue paper kept in position on wire gauze and that was placed in a petriplate filled with water. The level of water was so adjusted that the under surface of wire gauze containing tissue paper just touched on the surface of water. This was kept undisturbed for twenty four hours.

2.1.1.b. From root samples

Nematodes were extracted from root samples following the petriplate method. The roots were throughly washed in water. Roots weighing 5 g was taken and chopped very finely and placed on the double layered tissue paper supported on the wiregauze kept in a petriplate containing water and water level was so adjusted that the underside of wiregauze just touched the water level. This was kept undisturbed for fortyeight hours.

2.1.2. Fixing and preservation of nematodes

The nematode suspensions obtained from the drawings from petriplates were allowed to settle and the volume was reduced. To this equal quantity of boiling formalin 10 per cent was added to kill the nematodes.

2.2. Identification and estimation of the nematodes

The preserved suspensions of the nematodes were directly counted under a binocular stereo microscope. Population of different genera were directly counted for thinly populated suspensions. In the case of dense suspensions small samples were examined and from the count number of different genera in the total sample was estimated.

2.3. Assessment of crop loss

A series of pot experiments were carried out to find out the nature and extent of damage caused by different levels of nematodes.

2.3.a. Preparation and sterilisation of pot mixture

Pot mixture was prepared by mixing sieved field soil (red loam), seived sand and well decomposed farmyard manure in the ratio 2:1:1. The soil was taken in cement tanks. It was then denematized by applying formalin at the rate of 160 ml per m^2. The fumigant was poured in holes made in the pot mixture. The holes were closed and the soil surface was covered with polythene sheets to prevent escape of fumigant and was kept undisturbed for 30 days. The denematized pot mixture was stored in pots and kept free from nematode contamination for use in the experiment. Prior to the using of pot mixture samples were examined for the presence of nematodes if any.

2.3.b. Culturing root knot nematodes in Laboratory

Pure culture of *M. incognita* was raised and maintained on ornamental coleus roots. Subculturing and multiplication was done periodically to ensure the availability of sufficient larval population for various experiments.

At the time of inoculation, egg masses were collected from these plants, and hatched in distilled water. One day old larvae were released to the root zone by pouring required quantities of the suspension in holes made around the plants. The holes were then covered with soil.

2.3.1. Pathogenecity of *M. incognita* on *Colocasia esculenta*

Thirty earthern pots of ten litre capacity were taken and filled with denematized pot mixture. Pest free tubers (variety local) weighing 30-35 g were planted in each pot. Crop was raised as per recommendations in package of practices, KAU 1986. Each plant was inoculated with nematodes 15 days after germination of tubers. Inoculation was done @ 0 (T_0), 500 (T_1), 1000 (T_2), 2000 (T_3), 4000 (T_4) and 8000 (T_5) nematodes per plant. The experiment was laid out in CRD with five replications.

Biometric observations such as plant height, girth of the plant and number of leaves were recorded at monthly intervals. At the time of harvest shoot weight, root weight, weight of tubers, root knots per ten centimetre root nematode population in soil, roots and tubers and percentage (weight) of galls in roots were recorded. The percentage (weight) of galls in roots were obtained by the following formula.

$$\text{Percentage (weight) of galls in roots} = \frac{\text{Weight of infected root}}{\text{Total weight of root}} \times 100$$

Data relating to the biometric observations were analysed in split plot design taking periods of observation as minor factor and treatments as major factor. Observation taken at harvest were analysed in CRD.

2.3.1.a. Assessment of keeping quality of tubers obtained from different treatments

Samples of tubers (500 g) taken from each treatment were stored in glass jars covered with muslin cloth and kept in store. Samples from the uninoculated pots were stored separately. Weekly observations were taken on the weight of spoiled tubers which became unconsumable at each observation was recorded. From the data, percentages of the weight of spoiled tubers in each treatment compared to the weight of tubers in control during the corresponding period of observations were worked out.

2.4. Effect of water stress on the attack of *M. incognita* on crops

Three sets of controlled experiments were carried out to find out development of *Meloidogyne incognita* under condition of water stress. Water stress condition was created by increased time lapse between the successive irrigations considering the water requirement of the crop.

2.4.1. On sweet potato

Twenty four 1 x 1 x 0.5 m concrete pots were filled with the denematized pot mixture. Fifteen centimetre long cuttings of sweet potato vine (variety Kanjangad local, five numbers) were planted in each of the pots. Nematodes were inoculated @ 5000 per plant fifteen days after planting in twelve of the concrete basins. Fertilisers and other operations were given as recommended by package of practices, KAU, 1986. Experiment was laid out in CRD with five replications.

Treatments

T_1 Irrigated once in two days + 0 nematodes per plant

T_2 Irrigated once in two days + 5000 nematodes per plant

T_3 Irrigated once in seven days + 0 nematodes per plant

T_4 Irrigated once in seven days + 5000 nematodes per plant

Plants were uprooted at fortnightly intervals starting from the 14th day after inoculation of nematodes and the observations were recorded.

Observations were taken on vine length, number of leaves, shoot weight, root weight, weight of tuberous roots, population of nematodes in roots, soil and tuberous roots, root knots per 10 centimetre root and percentage (weight) of galls on roots.

2.4.2. On Coleus parviflorus

In this experiment ten litre capacity earthern pots were filled with denematized soil and planted with 10 cm long tops of coleus. Nematodes were inoculated fifteen days after planting the tops @ 5000 per plant. Fertilisers and other cultural operations were given as recommended. Experiment was laid out in CRD with five replications.

Treatments

T_1 Irrigated daily + 0 nematodes per plant
T_2 Irrigated daily + 5000 nematodes per plant
T_3 Irrigated once in 4 days + 0 nematodes per plant
T_4 Irrigated once in 4 days + 5000 nematodes per plant

Plants in each treatment were uprooted at fortnightly intervals, starting from 14th day after inoculation of nematodes and the observations recorded.

Observations taken were on number of leaves, number of branches, shoot length, shoot weight, root weight, population of nematodes in soil and roots, root knots per 10 cm root and percentage infection of the roots. Since the experiment was conducted during February to July tuber formation was poor.

2.4.3. On Dioscorea alata

Required number of ten litre capacity earthern pots were filled with denematized soil and they were planted with cut pieces of (100 g) pest free D. alata Yam (local variety). Nematodes were inoculated @ 5000 per plant fifteen days after the germination of the tubers. Fertilisers and other cultural operations were given as recommended. Experiment was laid out in CRD with five replications.

Treatments

T_1 Irrigated once in two days + 0 nematodes

T_2 Irrigated once in two days + 5000 nematodes per plant

T_3 Irrigated once in ten days + 0 nematodes per plant

T_4 Irrigated once in ten days + 5000 nematodes per plant

Plants were uprooted at 6 weekly intervals commencing from 45th day after inoculation for taking observations.

Observations were recorded on number of leaves, shoot weight, root weight, weight of tubers and nematode populations in soil, roots and tubers. Root-knot production was meagre and was not characteristic as on other tuber crops.

2.5. Histopathology of roots inoculated with *M. incognita*

Roots of colocasia having galls of different stages were cut and fixed in F.A.A. The fixed roots were then processed for microtomy (Johanson, 1940). The sections were examined under microscope and micro photographs were taken to study the changes. Root from uninoculated pots served as control.

Results

3. RESULTS

3.1. Survey of plant parasitic nematodes of tuber crops

A survey of nematode pests on five tuber crops was conducted in twenty five panchayats of five agroclimatic zones of Kerala.

3.1.1. Nematodes associated with tapioca

The data related to this aspect are presented in Table 1. *Meloidogyne sp.* could be seen in soil samples collected from all panchayats while only 10 panchayats showed the presence of the nematode in root samples. The mean population per 100 ml of soil varied from 6.32 to 10.77 and 0.15 to 2.0 in 5 g of root samples in the five zones. There was no significant difference in the soil population or in root population among five zones or among five panchayats within the zones.

Rotylenchulus sp. could be observed in soil samples collected from all panchayats while it could be isolated from root samples collected from 19 panchayats. The mean population of *Rotylenchulus sp.* varied from 6.90 to 17.90 and 0.85 to 4.05 in soil samples (100 ml) and root samples (5 g) respectively. There was no significant difference in the soil populations or root populations among different zones or among five panchayats within each zone.

Table 1. Incidence of plant parasitic nematodes on tapioca in the different agroclimatic zones of Kerala

NARP Zones	Panchayats	Meloidogyne sp.		Rotylenchulus sp.		Helicotylenchus sp.		Tylenchorynchus sp.		Radopholus sp.		Pratylenchus sp.		Tylenchus sp.	
		S	R	S	R	S	R	S	R	S	R	S	R	S	R
High ranges	Ambalavayal	1.00	-	22.15	5.50	2.75	-	0.75	-	-	-	-	-	-	-
	Thirunelly	1.61	-	8.39	-	-	-	-	-	2.25	-	0.75	-	-	-
	Santhampara	14.21	2.00	14.73	2.50	1.75	-	-	-	1.00	-	0.50	-	-	-
	Karunapuram	23.95	7.25	9.12	-	-	-	-	-	-	-	1.75	-	-	-
	Rajakumari	12.49	0.75	9.12	1.50	-	-	1.75	-	0.75	-	-	-	-	-
	Mean	10.77	2.00	12.70	1.80	0.90	-	0.50	-	0.85	-	0.60	-	-	-
Problem zone	Pandalam	3.68	1.00	9.84	-	1.75	-	3.00	-	1.75	-	3.25	-	-	-
	Ambalapuzha	8.72	-	7.91	3.00	2.75	-	1.75	-	-	-	-	-	-	-
	Shertallai South	14.01	-	6.16	2.00	2.50	-	-	-	-	-	-	-	-	-
	Ochira	8.58	0.75	5.84	2.00	1.75	-	-	-	0.50	-	-	-	-	-
	Mannanchery	5.63	-	17.66	6.25	0.75	-	-	-	0.50	-	4.00	-	-	-
	Mean	8.12	0.35	9.49	2.65	1.90	-	0.95	-	0.55	-	1.95	-	-	-
Northern zone	Nileswar	6.79	-	21.10	-	0.75	-	2.75	-	-	-	0.75	-	-	-
	Chengala	6.63	-	11.82	3.25	-	-	-	-	-	-	3.50	-	-	-
	Chaliyar	5.37	0.50	12.09	4.25	0.50	-	1.75	-	4.75	-	-	-	-	-
	Puzhakkattiri	14.34	3.25	18.52	6.00	3.25	-	-	-	-	-	1.75	-	-	-
	Periye	2.28	-	9.24	3.25	0.75	-	-	-	2.75	-	-	-	-	-
	Mean	7.08	0.75	14.55	3.35	1.05	-	0.90	-	1.50	-	1.20	-	-	-
Central zone	Kongad	5.80	-	23.27	4.00	0.75	-	-	-	-	-	2.25	-	1.75	-
	Mundur	9.22	-	10.27	5.00	3.50	-	3.50	-	-	-	-	-	-	-
	Madakkathara	5.38	2.25	17.42	4.50	4.25	-	-	-	-	-	-	-	-	-
	Kizhakkanchery	4.60	-	15.24	3.50	-	-	2.75	-	-	-	-	-	-	-
	Ongallur	6.60	2.25	17.32	3.25	4.50	-	-	-	-	-	-	-	-	-
	Mean	6.32	0.90	17.90	4.05	2.60	-	1.25	-	-	-	-	-	-	-
Southern zone	Kalliyoor	3.65	-	4.14	0.50	1.75	-	2.25	-	-	-	-	-	-	-
	Mangalapuram	2.27	-	8.50	-	2.75	-	-	-	3.27	-	1.75	-	-	-
	Kulakada	10.85	-	1.61	-	-	-	0.25	-	-	-	-	-	-	-
	Sreekaryam	9.51	-	11.18	2.25	-	-	3.25	-	-	-	-	-	-	-
	Mayyanad	7.46	0.75	7.09	1.50	4.75	-	2.75	-	-	-	-	-	-	-
	Mean	6.75	0.15	6.90	0.85	1.85	-	1.70	-	0.65	-	0.35	-	-	-

Mean number of nematodes obtained from 100 ml of soil and 5 g roots

S = Soil R = Root

Data did not show significant variations among zones and among panchayats

Helicotylenchus sp., *Tylenchorynchus* sp., *Radopholus* sp. and *Pratylenchus* sp. could be obtained in soil samples from 18, 12, 9 and 10 panchayats respectively. These four nematodes were absent in root samples. *Tylenchus* sp. was seen in soil sample collected from one panchayat in central zone.

3.1.2. Nematodes associated with sweet potato

Data relating to the incidence of plant parasitic nematodes on sweet potato are presented in Table 2. *Meloidogyne* sp. could be obtained from soil samples from all the panchayats surveyed while they were seen in the root samples collected from 21 panchayats only. The mean soil population varied in different zones and it ranged from 4.32 to 9.02 per 100 ml soil and 0.63 to 3.39 per 5 g root. There was no significant difference either in soil population or root population among five zones or among panchayats within zones.

Presence of *Rotylenchulus* sp. was observed in the soil samples collected from all panchayats while two panchayats alone had no population of the nematode in root samples. Their mean population varied from 5.02 to 8.77 per 100 ml soil and 1.49 to 4.15 per 5 g root. No significant difference in soil population and root population of nematodes could be seen among five zones or among panchayats within the zones.

Table 2. Incidence of plant parasitic nematodes on sweet potato in the different agroclimatic zones of Kerala

NARP Regions	Panchayats	Mean number of nematodes obtained from soil (100 ml) and roots (5 g)													
		Meloidogyne sp.		Rotylenchulus sp.		Helicotylenchus sp.		Tylenchorynchus sp.		Radopholus sp.		Pratylenchus sp.		Heterodera sp.	Tylench sp.
		S	R	S	R	S	R	S	R	S	R	S	R	S	S
High ranges	Ambalavayal	16.70	4.27	4.17	2.49	0.25	-	1.75	-	1.00	-	0.50	-	-	-
	Thirunelly	8.17	1.83	6.47	5.39	-	-	-	-	1.00	-	1.75	-	-	-
	Santhampara	5.32	-	3.94	0.99	4.25	-	-	-	0.75	-	-	-	-	-
	Karunapuram	5.15	1.73	4.71	3.68	0.25	-	-	-	1.50	-	-	-	2.75	3.50
	Rajakumari	2.74	0.39	5.79	2.48	1.00	-	-	-	-	-	-	-	-	-
	Mean	7.62	1.64	5.02	3.01	1.15	-	0.35	-	0.85	-	0.45	-	0.55	0.70
Problem zone	Pandalam	5.20	0.99	11.87	2.48	1.50	-	-	-	-	-	3.00	-	0.50	-
	Ambalapuzha	9.56	0.65	6.88	2.20	2.75	-	-	-	0.75	-	-	-	-	-
	Shertallai South	8.06	2.37	2.70	-	-	-	-	-	1.25	-	-	-	-	-
	Ochira	6.02	1.38	4.53	3.54	0.25	-	-	-	1.25	-	-	-	-	-
	Mannancherry	6.34	0.99	17.85	12.53	2.25	-	-	-	0.50	-	-	-	-	-
	Mean	7.04	1.28	8.77	4.15	1.35	-	-	-	0.75	-	-	-	-	-
Northern zone	Nileswar	1.95	1.12	11.86	2.21	1.00	-	-	-	0.50	-	-	-	-	-
	Chengala	8.81	1.37	0.86	-	2.50	-	-	-	1.00	-	-	-	-	-
	Chaliyar	14.82	7.80	5.71	2.21	-	-	-	-	0.25	-	-	-	-	-
	Puzhakkattiri	11.84	5.61	7.03	1.30	0.25	-	-	-	-	-	-	-	-	-
	Periye	7.78	1.05	3.29	1.73	2.25	-	-	-	-	-	-	-	-	-
	Mean	9.04	3.39	5.75	1.49	1.20	-	-	-	0.35	-	-	-	-	-
Central zone	Kongad	1.37	-	20.31	10.95	-	-	2.50	-	0.75	-	-	-	-	-
	Mundur	16.87	6.24	10.38	2.66	1.00	-	-	-	-	-	-	-	-	-
	Madakkathara	2.17	0.56	4.40	1.73	4.25	-	-	-	-	-	-	-	-	-
	Kizhakkanchery	9.44	1.62	4.67	0.40	-	-	-	-	-	-	1.70	-	-	-
	Ongallur	12.22	2.73	2.49	1.25	-	-	-	-	-	-	-	-	-	-
	Mean	8.41	2.23	8.37	3.40	1.05	-	-	-	-	-	3.40	-	-	-
Southern zone	Kalliyoor	8.58	1.93	6.22	2.38	4.50	-	-	-	0.50	-	4.00	-	-	-
	Mangalapuram	5.11	-	4.62	0.86	1.25	-	-	-	1.00	-	-	-	-	-
	Kulakada	0.22	-	4.69	2.28	1.75	-	-	-	-	-	-	-	-	-
	Sreekaryam	2.38	0.71	11.45	6.03	0.75	-	-	-	-	-	-	-	-	-
	Mayyanad	5.29	0.99	2.80	3.59	-	-	-	-	-	-	-	-	-	-
	Mean	4.32	0.63	5.96	3.03	1.65	-	-	-	0.30	-	0.80	-	-	-

S = Soil R = Root

Data did not show significant variations among zones and among panchayats

Helicotylenchus sp. and *Radopholus* sp. were observed in soil samples collected from 18 and 14 panchayats respectively. *Pratylenchus* sp., *Tylenchorynchus* sp. and *Tylenchus* sp. also were obtained from soil samples of 6, 2, 2 and 1 panchayats surveyed respectively.

3.1.3. Nematodes associated with yam (*Dioscorea* sp.)

Data on the incidence of plant parasitic nematodes on dioscorea in Kerala are presented in Table 3. *Meloidogyne* sp. could be observed from soil samples collected from all panchayats while in root samples it could be extracted from 15 panchayats only. Mean population varied from 3.61 to 5.81 per 100 ml soil while in roots it was between 0.35 to 2.0 per 5 g sample. There was no significant difference in the soil population and root population among five zones or among panchayats within the zones.

Rotylenchulus sp. could be extracted from soil samples collected from all panchayats while it was not present in root samples from three panchayats. No statistical significance could be observed in the variations among the mean population of nematodes in soil and roots in five zones or among panchayats within zones. The mean soil population varied between 5.44 to 8.22 per 100 ml soil

Table 3. Incidence of plant parasitic nematodes on dioscorea in the different agroclimatic zones of Kerala

NARP Regions	Panchayats	Mean number of nematodes obtained from 100 g soil and 5 g of roots											
		<u>Meloidogyne</u> <u>sp.</u>		<u>Rotylenchulus</u> <u>sp.</u>		<u>Helicotylenchus</u> <u>sp.</u>		<u>Hoplolaimus</u> <u>sp.</u>		<u>Radopholus</u> <u>sp.</u>		<u>Pratylenchus</u> <u>sp.</u>	
		S	R	S	R	S	R	S	R	S	R	S	R
High ranges	Ambalavayal	11.16	4.50	16.72	5.40	0.75	-	3.00	-	1.75	-	5.75	6.00
	Thirunelly	1.72	0.25	5.52	1.00	-	-	3.00	-	1.00	-	-	-
	Santhampara	5.29	-	5.83	0.75	0.50	-	0.50	-	2.75	-	4.75	3.50
	Karunapuram	1.95	2.00	9.17	2.75	1.50	-	-	-	-	-	18.25	8.00
	Rajakumari	7.27	3.25	4.18	0.25	-	-	1.50	-	1.75	-	-	-
	Mean	5.48	2.00	8.22	2.03	0.55	-	2.00	-	1.45	-	5.75	3.50
Problem zone	Pandalam	1.37	-	4.76	1.00	1.75	-	1.50	-	1.25	-	-	-
	Ambalapuzha	3.37	0.25	15.07	4.50	-	-	2.50	-	2.00	-	-	-
	Shertallai South	4.60	0.75	6.47	2.75	-	-	0.75	-	-	-	-	-
	Ochira	5.52	1.00	2.38	0.75	1.00	-	0.25	-	-	-	-	-
	Mannanchery	3.20	-	10.51	2.50	0.25	-	3.75	-	-	-	-	-
	Mean	3.61	0.50	7.84	2.30	0.60	-	1.75	-	0.65	-	-	-
Northern zone	Nileswar	4.16	-	9.96	4.75	2.25	-	4.00	-	1.75	-	-	-
	Chengala	4.60	0.50	9.73	6.25	0.75	-	2.25	-	0.50	-	-	-
	Chaliyar	6.25	1.00	4.76	1.25	-	-	1.25	-	2.75	-	-	-
	Puzhakkattiri	1.72	-	4.19	1.00	0.25	-	0.75	-	1.25	-	-	-
	Periye	5.93	0.50	3.24	-	-	-	2.25	-	0.25	-	-	-
	Mean	4.53	0.50	6.38	2.05	0.65	-	2.10	-	1.30	-	-	-
Central zone	Kongad	1.95	-	9.84	3.00	3.75	-	4.75	-	2.25	-	-	-
	Mundur	4.40	-	7.85	3.75	1.00	-	3.50	-	1.50	-	-	-
	Madakkathara	6.19	0.50	6.01	-	-	-	3.25	-	-	-	-	-
	Kizhakkanchery	8.76	2.25	7.79	5.25	-	-	-	-	1.75	-	-	-
	Ongallur	3.98	-	9.05	7.50	2.00	-	4.50	-	-	-	-	-
	Mean	4.96	0.55	8.11	3.90	1.35	-	2.80	-	1.10	-	-	-
Southern zone	Kalliyoor	11.02	1.00	8.01	2.50	0.75	-	6.00	-	2.25	-	-	-
	Mangalapuram	3.36	0.25	1.43	-	0.25	-	1.00	-	0.50	-	-	-
	Kulakada	9.52	0.30	10.45	5.50	2.00	-	3.75	-	0.75	-	-	-
	Sreekaryam	1.43	-	3.68	3.00	-	-	-	-	1.75	-	-	-
	Mayyanad	3.73	-	3.59	1.00	0.50	-	1.50	-	-	-	-	-
	Mean	5.81	0.35	5.44	3.00	0.70	-	2.45	-	1.10	-	-	-

S = Soil R = Root

Data did not show significant variations among zones or among panchayats

while in roots it ranged between 2.03 to 3 per 5 g.

Helicotylenchus sp., *Hoplolaimus sp.* and *Radopholus sp.* were seen in soil samples collected from 16, 21 and 18 panchayats respectively while they were absent in root samples. Population of *Hoplolaimus sp.* was found to vary from 1.75 to 2.80 per 100 ml soil among five zones. *Pratylenchus sp.* could be extracted from soil and root samples collected from 3 panchayats in High ranges and their mean population in 3 panchayats found to vary from 4.75 to 18.25 per 100 ml soil and 3.50 to 8.0 per 5 g of root sample collected.

3.1.4. Nematodes associated with colocasia/xanthosoma

The related data are presented in Table 4. *Meloidogyne sp.* was observed in soil samples collected from all panchayats surveyed while 22 panchayats showed the presence of the nematode in root samples. The mean population varied from 4.23 to 15.80 per 100 ml soil while in roots it was between 1.58 to 7.01. There was no significant difference in mean soil and root populations among five zones or among the panchayats within each zones.

Rotylenchulus sp. was seen in soil samples collected from 22 panchayats and in root samples from 20 panchayats.

Table 4. Incidence of plant parasitic nematodes on colocasia/xanthosoma in the different agroclimatic zones of Kerala

NARP zones	Panchayats	Mean number of nematodes obtained from 100 g soil and 5 g roots													
		Meloidogyne sp.		Rotylenchulus sp.		Helicotylenchus sp.		Radopholus sp.		Pratylenchus sp.		Heterodera sp.		Tylenchorynchu sp.	
		S	R	S	R	S	R	S	R	S	R	S	R	S	R
High ranges	Ambalavayal	19.34	3.54	-	-	-	-	-	-	5.75	1.75	3.25	0.75	-	-
	Thirunelly	1.61	0.71	2.48	1.72	3.25	-	-	-	-	-	-	-	-	-
	Santhampara	1.84	0.56	5.83	0.56	8.25	-	3.25	-	6.75	1.00	-	-	-	-
	Karunapuram	7.14	1.91	5.71	1.95	0.75	-	-	-	-	-	-	-	-	-
	Rajakumari	9.05	3.61	6.44	1.95	2.75	-	-	-	-	-	-	-	4.00	-
	Mean	7.80	2.07	4.09	1.24	3.00	-	0.70	-	2.50	0.55	0.65	0.15	0.80	-
Problem zone	Pandalam	30.08	17.31	-	-	1.00	-	-	-	5.75	-	-	-	0.75	-
	Ambalapuzha	7.80	-	9.36	5.83	3.50	-	-	-	-	-	-	-	-	-
	Shertallai South	8.95	1.42	2.48	0.99	2.25	-	-	-	-	-	-	-	-	-
	Ochira	27.18	16.89	2.89	1.95	3.50	-	-	-	2.75	-	-	-	-	-
	Mannanchery	6.99	-	7.31	3.12	5.25	-	-	-	-	-	-	-	0.25	-
	Mean	15.80	7.01	4.41	2.38	3.10	-	-	-	1.70	-	-	-	0.20	-
Northern zone	Nileswar	2.48	-	6.78	1.43	1.00	-	-	-	5.75	-	-	-	-	-
	Chengala	2.27	1.12	11.14	3.29	1.75	-	-	-	-	-	-	-	-	-
	Chaliyar	4.44	1.76	2.89	0.56	2.25	-	-	-	-	-	-	-	-	-
	Puzhakkattiri	5.71	1.61	5.92	1.12	2.50	-	1.75	-	-	-	-	-	-	-
	Periye	6.23	3.39	9.58	5.39	-	-	-	-	-	-	-	-	-	-
	Mean	4.23	1.58	7.27	2.36	1.50	-	0.35	-	1.25	-	-	-	-	-
Central zone	Kongad	9.96	7.26	4.38	2.42	-	-	-	-	-	-	-	-	-	-
	Mundur	8.33	3.98	3.39	0.99	3.25	-	-	-	3.25	-	-	-	-	-
	Madakkathara	14.84	5.72	10.17	5.08	5.50	-	-	-	7.00	3.00	-	-	-	-
	Kizhakkanchery	9.17	1.27	11.69	6.23	0.75	-	-	-	-	-	-	-	1.50	-
	Ongallur	18.40	6.06	12.65	3.98	4.25	-	1.75	-	-	-	-	-	-	-
	Mean	12.14	4.85	8.46	3.74	2.75	-	0.35	-	2.05	0.60	-	-	0.30	-
Southern zone	Kalliyoor	6.89	2.48	6.75	1.72	3.25	-	-	-	-	-	-	-	0.75	-
	Mangalapuram	12.14	1.84	3.65	-	1.75	-	-	-	3.25	-	-	-	3.50	-
	Kulakada	10.39	1.61	1.61	-	2.25	-	-	-	-	-	-	-	1.75	-
	Sreekaryam	4.19	1.12	-	-	0.25	-	-	-	-	-	-	-	-	-
	Mayyanad	12.09	4.85	1.84	1.12	2.25	-	-	-	-	-	-	-	-	-
	Mean	9.13	2.38	2.77	0.57	1.95	-	-	-	0.65	-	-	-	1.20	-

S = Soil R = Root

Data did not show significant variations among zones or among panchayats

The mean soil population and root population varied from 2.77 to 8.46 and 0.57 to 3.74 respectively while significant differences in the soil and root population among five zones or among five panchayats within the zones were lacking.

Helicotylenchus sp., *Radopholus sp.* and *Tylenchorynchus sp.* could be recovered from soil samples collected from 22, 3 and 7 panchayats respectively while no root population of any of these nematodes could be observed.

Presence of *Pratylenchus sp.* was seen in soil samples collected from 8 panchayats while root samples from 3 panchayats also showed the presence of nematodes. The mean population in soil varied from 1.25 to 7 per 100 ml soil while in roots it was between 1.0 to 3.0 per 5 g of root in different panchayats. *Heterodera sp.* also was obtained from soil (3.25/100 ml) and root (0.75/5 g) samples from one panchayat in high ranges.

3.1.5. Nematodes associated with *C. parviflorus*

Related data are presented in Table 5. Samples relating to this could not be collected from Northern zone.

Meloidogyne sp. could be obtained in soil samples and root samples collected from all the twenty panchayats

Table 5. Incidence of plant parasitic nematodes on <u>Coleus parviflorus</u> in the different agroclimatic zones of Kerala

NARP zones	Panchayats	Mean number of nematodes obtained from 100 ml of soil and 5 g roots												
		Meloidogyne sp.		*Rotylenchulus* sp.		*Helicotylenchus* sp.		*Radopholus* sp.		*Pratylenchus* sp.		*Tylenchorynchus* sp.		*Heterc* sp
		S	R	S	R	S	R	S	R	S	R	S	R	S
High ranges	Ambalavayal	14.29	7.16	8.61	0.56	3.50	-	1.75	-	1.00	-	-	-	-
	Thirunelly	4.53	1.37	8.71	0.56	-	-	-	-	-	-	0.50	-	-
	Santhampara	30.14	13.83	2.17	-	5.00	-	0.75	-	2.75	-	-	-	-
	Karunapuram	16.12	6.21	2.42	-	-	-	-	-	-	-	1.50	-	-
	Rajakumari	14.99	5.33	15.82	7.12	-	-	4.25	-	0.75	-	5.00	-	-
	Mean	16.01	6.78	7.55	1.65	1.70	-	1.35	-	0.90	-	1.40	-	-
Problem zone	Pandalam	10.75	3.29	2.90	1.61	-	-	-	-	-	-	-	-	-
	Ambalapuzha	26.73	9.81	1.61	-	3.00	-	3.25	-	-	-	-	-	-
	Shertallai South	23.63	13.23	3.49	1.49	4.75	-	-	-	-	-	-	-	-
	Ochira	10.85	7.47	7.14	2.66	-	-	-	-	-	-	-	-	-
	Mannanchery	26.26	9.98	14.07	3.41	-	-	-	-	4.00	-	-	-	-
	Mean	19.64	8.66	5.84	1.87	1.56	-	0.65	-	1.00	-	-	-	-
Central zone	Kongad	21.57	6.38	1.84	-	4.25	-	-	-	-	-	0.75	-	-
	Mundur	28.20	15.76	2.71	0.59	-	-	-	-	-	-	-	-	-
	Madakkathara	57.06	22.22	15.35	3.73	6.25	-	-	-	-	-	-	-	-
	Kizhakkanchery	10.60	4.60	7.70	5.17	-	-	-	-	3.00	-	-	-	-
	Ongallur	23.59	16.94	14.91	4.13	0.75	-	4.00	-	-	-	0.50	-	-
	Mean	28.04	13.18	8.50	2.80	2.25	-	0.80	-	0.60	-	0.10	-	-
Southern zone	Kalliyoor	27.58	11.84	5.16	1.86	2.50	-	-	-	-	-	-	-	-
	Mangalapuram	14.01	5.44	7.87	2.99	-	-	-	-	-	-	-	-	-
	Kulakada	20.17	11.45	4.39	1.25	2.25	-	4.25	-	0.75	-	-	-	-
	Sreekaryam	15.47	4.29	-	-	5.00	-	-	-	-	-	3.25	-	3.50
	Mayyanad	39.93	17.58	2.28	1.25	-	-	-	-	-	-	-	-	5.75
	Mean	23.49	10.12	3.90	1.49	2.00	-	0.85	-	0.15	-	0.65	-	1.85

S = Soil R = Root

Data did not show significant variations among zones or among panchayats

surveyed. The mean population varied from 16.01 to 28.04 per 100 ml of soil while in roots it varied between 6.78 to 13.18 per 5 g of root among four zones. Significant differences in mean soil or root population among zones or among panchayats within the zones were lacking.

Rotylenchulus sp. was observed in 19 panchayats in soil samples and 15 panchayats in roots collected. Their mean population varied between 3.90 to 8.50 per 100 ml soil among four zones while in roots it was between 1.49 to 2.80 per 5 g of root. But there was no statistical significance in the variations in soil or root population in four zones or among panchayats within the zones.

Other nematodes observed from soil samples were *Helicotylenchus sp.*, *Radopholus sp.*, *Pratylenchus sp.* and *Tylenchorynchus sp.* They were seen in 10, 6, 6 and 6 panchayats respectively. *Heterodera sp.* could be observed from soil samples collected from two panchayats in Southern zone.

3.2. Crop loss studies

3.2.1. The effect of different levels of population of *M. incognita* on *C. esculenta*

M. incognita larvae were found to affect *C. esculenta* adversely. The different parameters like number of leaves,

Table 6. Effect of different levels of *M. incognita* on the height of *C. esculenta*

Number of nematodes inoculated	Mean plant height (cm) observed at different intervals after inoculation (month)					Mean
	1	2	3	4	5	
0	42.00	89.20	119.80	127.60	122.60	100.24
500	40.00	83.60	114.80	123.60	119.00	96.32
1000	44.00	75.40	108.80	112.80	106.00	89.52
2000	42.00	75.40	105.40	109.00	101.00	86.56
4000	43.60	76.40	97.80	96.40	92.00	80.92
8000	42.47	75.20	100.20	94.40	88.80	80.44
CD			6.76			4.43

plant height and plant girth at the base, were recorded at monthly intervals and at harvest shoot weight, root weight, weight of tubers, nematode population in soil (100 ml), roots and tubers (5 g each), root knots per 10 cm root and percentage (weight) of galls on roots.

3.2.1.a. Plant height

Uninoculated check recorded the maximum mean plant height (100.24 cm) (Table 6). It was on par with the treatment in which 500 nematodes were inoculated (96.32 cm) but both were significantly higher than the rest of the treatments. The treatments in which plants were inoculated with 1000 and 2000 nematodes were on par in mean plant heights (89.52 and 86.56 cm). Both were significantly higher than the heights at inoculation levels of 4000 and 8000 nematodes per plant but the latter two treatments were on par (80.92 and 80.44 cm).

Plant heights in the uninoculated treatment in all monthly observation were on par with the treatment in which the plants were inoculated with 500 nematodes, and both these were found significantly higher than the rest of the treatments except in the first month, where they were on par, with the rest of the treatments. In the first and second months the treatments in which plants were inoculated with 1000 to 8000 nematodes, plant heights

Table 7. Effect of different levels of *M. incognita* on the girth of *C. esculenta*

Number of nematodes inoculated	Mean plant girth (cm) observed at different intervals after inoculation (month)					Mean
	1	2	3	4	5	
0	7.00	11.58	14.48	14.78	13.10	12.13
500	6.64	11.16	14.52	14.26	12.26	11.60
1000	6.38	10.44	13.88	14.00	11.80	11.30
2000	6.78	10.90	13.00	13.34	10.80	10.96
4000	6.10	9.86	11.32	10.80	10.70	9.98
8000	6.48	9.88	10.40	10.40	9.86	9.33
CD			0.81			0.44

remained on par. From third to fifth month plant heights in the treatments inoculated with 1000 and 2000 nematodes were on par while they were found significantly higher than the treatments inoculated with 4000 and 8000 nematodes per plant. But the plant heights in the latter two treatments were on par. (Fig. 1a).

3.2.1.b. Plant girth

Uninoculated treatment recorded the highest mean plant girth (12.13 cm) which was found significantly higher than that of rest of the treatments (Table 7). Mean plant girth of the treatments in which plants were inoculated with 500 nematodes and 1000 nematodes were on par (11.60 and 11.30 cm) but the former was significantly higher than all other inoculated treatments while the latter was on par with the treatment in which plants were inoculated with 2000 nematodes. Mean plant girth (9.98 cm) was significantly higher in treatment inoculated with 4000 nematodes than in plants inoculated with 8000 nematodes (9.33 cm) and both were significantly lower than the girth in treatment inoculated with 2000 nematodes (10.96 cm).

Plant girth in all treatments were found on par in the first month. During the second month the plant girth in uninoculated check (11.58 cm) which was on par with

Fig. 1. Effect of different levels of *M. incognita* on the plant height, plant girth and leaf number of *C. esculenta*

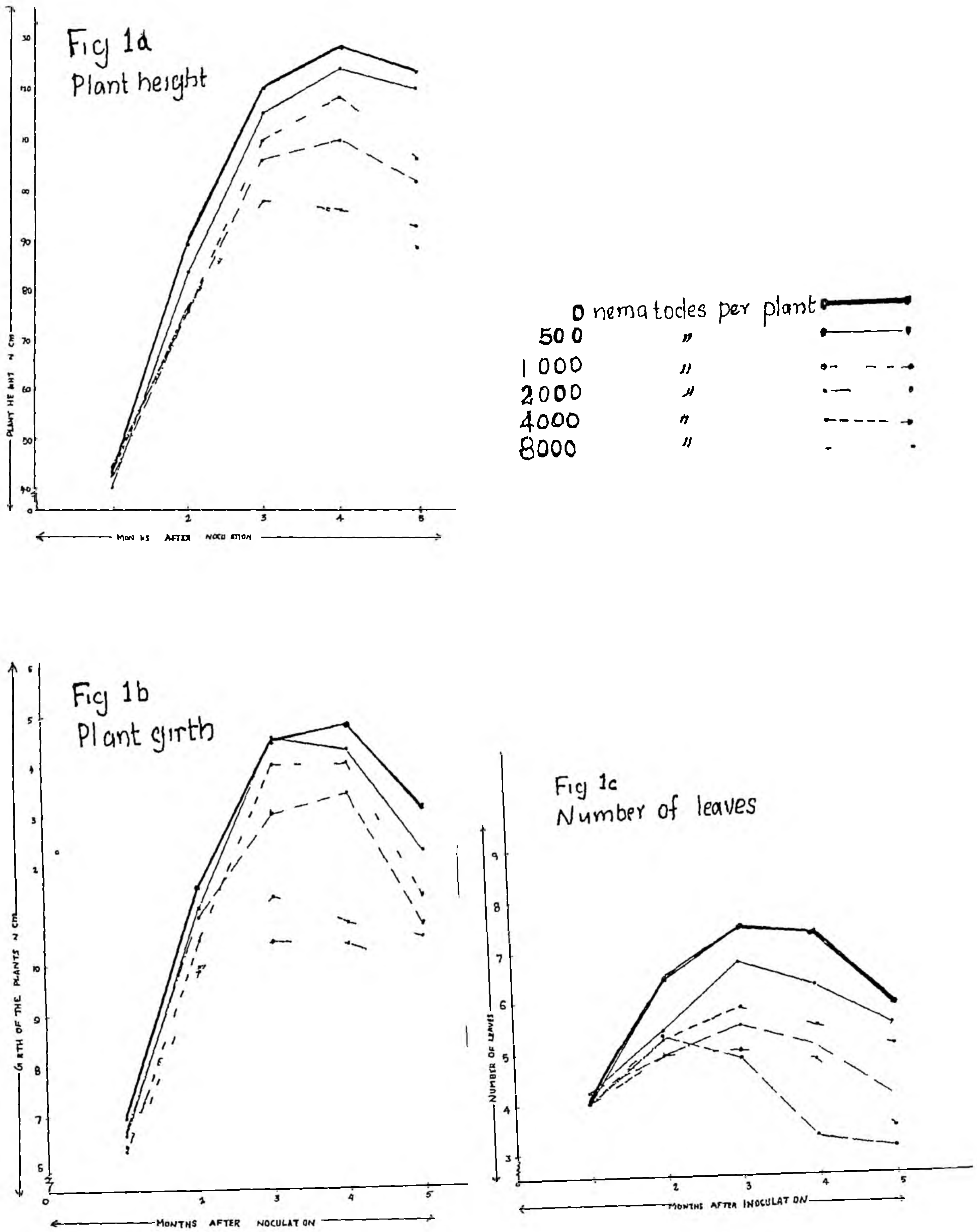
Fig 1a
Plant height
Fig 1b
Plant girth
Fig 1c
Number of leaves
0 nematodes per plant
500 "
1000 "
2000 "
4000 "
8000 "
MONTHS AFTER NOCULAT ON
MONTHS AFTER INOCULAT ON
NUMBER OF LEAVES

Fig 1

the treatment in which 500 nematodes were inoculated (11.16 cm) and the former was significantly higher than those in rest of the treatments, but latter was on par with treatments inoculated with nematodes 1000 and 2000 per plant (10.44 and 10.90 cm). Treatments inoculated with nematodes 4000 and 8000 (9.86 and 9.88 cm) were on par while they were significantly lower than that of treatments inoculated with 2000 nematodes (10.90 cm). During the third month the plant girth in uninoculated check (14.40 cm) was on par with the treatment in which 500 nematodes (4.52 cm) but both were significantly higher than that of rest of the treatments except that inoculated with 1000 nematodes (13.88 cm). Plant girth found significantly lowered in the inoculated treatments from 1000 to 8000 nematodes (13.88, 13.0, 11.32 and 10.40 cm). During the fourth month uninoculated check (14.78) was significantly higher in all treatments except in two treatments inoculated with nematodes 500 and 1000 (14.26 and 14.00 cm) while the latter found significantly higher than the rest of treatments. Plant girths in treatments 4000 and 8000 nematodes per plant, were on par (10.80 to 10.40 cm). During the fifth month the plant girth in uninoculated check (13.10 cm) was significantly higher than rest of the treatments. Treatments in which plants were inoculated with 500 nematodes plant girth was

Table 8. Effect of different levels of *M. incognita* on number of leaves of *C. esculenta*

Number of nematodes inoculated	Mean number of leaves observed at different intervals (month)					Mean
	1	2	3	4	5	
0	4.0	6.4	7.4	7.2	5.8	6.12
500	4.2	5.4	6.7	6.2	5.4	5.60
1000	4.0	5.2	5.8	5.4	5.0	5.04
2000	4.2	4.8	5.4	5.0	4.0	4.76
4000	4.0	4.8	4.8	4.6	3.4	4.28
8000	4.2	5.3	4.6	3.2	3.0	3.96
CD			0.69			0.37

Fig. 2. Effect of different levels of *M. incognita* infestations on the shoot, root and tubers of *C. esculenta*

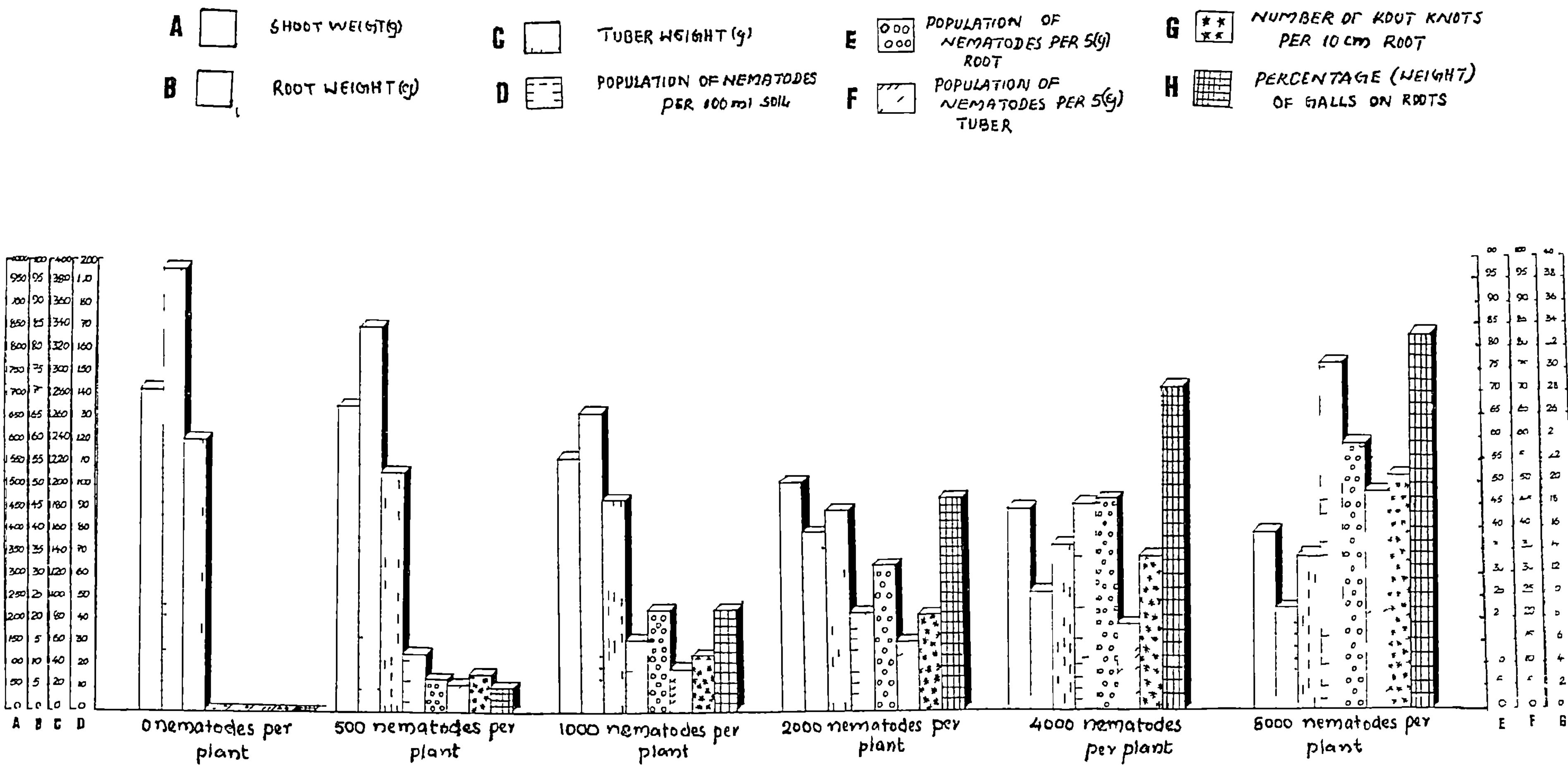
A SHOOT WEIGHT(g)
B ROOT WEIGHT(g)
C TUBER WEIGHT (g)
D POPULATION OF NEMATODES PER 100 ml SOIL
E POPULATION OF NEMATODES PER 5(g) ROOT
F POPULATION OF NEMATODES PER 5(g) TUBER
G NUMBER OF ROOT KNOTS PER 10 cm ROOT
H PERCENTAGE (WEIGHT) OF GALLS ON ROOTS
0 nematodes per plant
500 nematodes per plant
1000 nematodes per plant
2000 nematodes per plant
4000 nematodes per plant
8000 nematodes per plant

Fig. 2

significantly higher than rest of the inoculated treatments. Plant girth in the treatments which received 2000 and 4000 nematodes were on par (10.80 and 10.70 cm) while both the treatments were significantly higher than that of the treatment which received 8000 nematodes (9.86 cm). (Fig. 1b).

3.2.1.c. The number of leaves

The mean number of leaves in the uninoculated check (6.12) was significantly higher compared to all other treatments (Table 8). In treatment which received 500 nematodes per plant number of leaves were higher (5.6) than that of the treatment in which plants were inoculated with 1000 nematodes (5.04) but the latter was on par with the treatment which received 2000 nematodes per plant (4.76). Number of leaves in treatments which were inoculated with 4000 and 8000 nematodes per plant (4.28 and 3.96) were on par but the both were significantly lower than the treatment 2000 nematodes per plant (4.76).

One month after inoculation with nematodes, number of leaves in uninoculated treatment was found on par with the rest of the treatments. Two months after inoculation, uninoculated control was significantly higher (6.4) than that of rest treatments while among the inoculated treatments they were on par. Number of leaves in uninoculated check (7.4) was significantly higher than the rest of the treatments, three months after the inoculation. The number of leaves in the treatments which received 500 and 1000 nematodes differed significantly (6.7 and 5.8) but the latter were on par with the rest of the treatments (5.4, 4.8 and 4.6).

Four months after inoculation with nematodes the number of leaves in uninoculated check (7.2) was significantly higher than that of the treatment which received 500 nematodes per plant (6.2) and both were significantly higher than the rest of the inoculated treatments (5.4, 5.0, 4.6 and 3.2) but they were on par among them except in case of treatments in which 4000 and 8000 nematodes per plant were inoculated (4.6 and 3.2). Five months after inoculation with nematodes the number of leaves in the uninoculated check (5.8) was on par with the treatment 500 nematodes (5.4) but was significantly higher than rest of treatments. Number of leaves in the treatments in which 1000 and 2000 nematodes per plant were inoculated the former was significantly higher than the rest of treatments (4.0, 3.4 and 3.0) while the latter was significantly higher only with the treatment which received 8000 nematodes per plant (3.0). (Fig. 1c).

3.2.1.d. Shoot weight

A significant reduction in the mean shoot weight

Table 9. Effect of different levels of *M. incognita* on the shoot weight, tuber yield and root weight of *C. esculenta*

Treatments		Shoot weight (g)*/plant	Root weight (g)/plant	Weight of tuber (g)/plant
Number of nematodes inoculated/plant	0	710.00	97.80	243.00
do	500	685.40	85.20	213.20
do	1000	565.00	66.80	188.20
do	2000	513.00	40.20	179.90
do	4000	441.80	26.40	163.00
do	8000	392.20	22.40	134.40
CD		78.41	13.49	27.52

was noticed in the different treatments at the time of harvest as the inoculum of nematode increased (Table 9). The highest mean shoot weight of 710.60 g/plant was recorded in control and it was significantly higher than the weight recorded in other treatments. Shoot weight of the treatments in which plants were inoculated with 500 nematodes (685.40 g) was found superior to all other inoculated treatments, but it was on par with the control. The shoot weight in treatment inoculated with 1000 nematodes per plant (565.0 g) was found on par with the treatment inoculated with 2000 nematodes (513.0 g) while the former was found superior to the treatments in which plants were inoculated with 4000 and 8000 nematodes (441.8 and 392.2 g) and the latter was superior to the treatment inoculated with 8000 nematodes. The treatments in which nematodes were inoculated at 4000 and 8000 were on par (Table 9). (Fig. 2).

3.2.1.e. Root weight

A significant reduction in the mean root weight was noticed in the different treatments at the time of harvest as the inoculum of nematodes increased (Table 9). The maximum root weight of 97.80 g/plant was observed in control plants and it was significantly higher than the weights recorded in other treatments but it was on par

Plate 1. Effect of different levels of *M. incognita* on the roots of *C. esculenta*

Plate 1

with the treatment in which plants were inoculated with 500 nematodes (85.20 g). The root weights of plants inoculated with 500, 1000, 2000, 4000 and 8000 nematodes were significantly different (85.20, 66.80, 40.2, 26.4 and 22.4 g respectively). The last two treatments were on par and significantly lower than the rest. The reduction in root weights of plants inoculated with different levels of nematodes were not proportionate (vide Plate 1).

3.2.1.f. Weight of tubers

Data related to the experiment is presented in Table 9. The mean tuber yield obtained from the uninoculated plants (243 g/plant) was significantly higher than those of inoculated treatments (134.4 to 213.20 g). The yield in treatment in which plants were inoculated with 500 nematodes (213.20 g) was significantly higher than other inoculated treatments. The differences in tuber yields of plants inoculated with 1000, 2000 and 4000 were not statistically significant. The tuber yield in treatments with 4000 and 8000 nematodes were significantly different (163.0 and 134.4 g).

3.2.1.g. Population of nematodes in soil at harvest

Soil population varied in different treatments at harvest. The population levels were not proportional to the levels of initial inoculum (Table 10). The treatment receiving 500 nematodes per plant recorded the least mean soil population (26.4 per 100 ml soil) but it was on par with treatments received 1000 and 2000 nematodes per plant (31.8 and 44.2). But the treatments which received 2000, 4000 and 8000 nematodes were found to differ significantly (44.2, 90.8 and 151.8 respectively). Plants in control pot did not show any nematodes.

3.2.1.h. Population of nematodes in roots at harvest

The root population in different treatments were related to the initial inoculum of nematodes but they were not proportional. A population of 58.8 nematodes per 5 g of roots was recorded in plants given an inoculum of 8000 nematodes. The mean population of 7.4 nematodes was recorded in plants given an inoculum of 500 nematodes, which was significantly lower than all other treatments. The treatments in which plants were given 1000 and 2000 nematodes were on par (23.2 and 33.4) and likewise the treatments in which plants were given 4000 and 8000 nematodes were also on par (46.8 and 58.8).

3.2.1.i. Population of nematodes in tuber at harvest

The population of nematodes in tuber also varied in different treatments but the variations were not

Table 10. Population of *M. incognita* in soil and plant parts at harvest when inoculated at different levels at 15 days after planting

Number of nematodes inoculated/ plant	Population of nematodes at harvest observed in			Number of root knots observed per 10 cm root harvest*	Percentage (weight) of galls in roots
	soil(100) ml*	root(5 g)*	tuber(5 g)*		
0	0(1)	0(1)	0(1)	0(1)	0(0)
500	26.4(5.19)	7.4(2.79)	6.6(2.47)	3.4(2.06)	5.9(13.37)
1000	31.8(5.53)	23.2(5.30)	9.4(3.03)	5.0(2.43)	22.5(28.29)
2000	44.2(6.53)	33.4(5.81)	15.4(3.90)	8.6(3.02)	47.5(43.57)
4000	90.8(9.42)	46.8(6.79)	19.2(4.25)	13.8(3.83)	71.1(57.47)
8000	151.8(12.16)	58.8(7.71)	48.0(6.78)	20.6(4.60)	82.6(65.37)
	(2.15)	(1.31)	(1.79)	(0.68)	(6.59)

* Figures in parenthesis are $\sqrt{x+1}$ transformed values

** Figures in parenthesis are angular transformed values correlated with the initial inoculum (Table 10). A mean population of 6.6 per 5 g of tuber was recorded in the treatment in which plants were given 500 nematodes and 48 per 5 g of root in the treatment received 8000 nematodes per plant. Plants in the control pot did not show any infection. The treatments in which plants were inoculated with 500, 1000, 2000 and 4000 the mean population of nematodes were on par (6.6, 9.4, 15.4 and 19.2 respectively) but these were significantly lower than the treatment in which plants were given 8000 nematodes.

3.2.1.j. Number of root knots per 10 cm root

Lowest numbers of root knots 3.4 was observed in plants given 500 nematodes which was on par with the treatment, given 1000 nematodes per plant (5) and the latter was in turn on par with the treatment given 2000 nematodes per plant (8.6). In the treatments given 2000, 4000 and 8000 the values (8.6, 13.8 and 20.6 respectively) found to differ significantly. Result showed the unproportionate increase compared to the increase in initial inoculum.

3.2.1.k. Percentage (weight) of galls on root

Mean number of galls in the treatments also varied significantly. Percentage (weight) of galls in treatments

Table 11. Keeping quality of tubers harvested from different treatments in the pot experiment (500 g each)

Number of nematodes inoculated/ plant	Weight (g)/percentage of tubers rendered unfit for marketing at different intervals after storage (weeks)					
	1	2	3	4	5	6
500	27.5/5.56	52.5/10.69	95.0/19.63	-	-	-
1000	25.0/5.06	60.5/12.32	135.5/28.00	160.0/34.41	189.5/42.11	-
2000	88.0/17.76	124.0/25.25	160.5/33.16	215.5/46.34	284.0/63.11	-
4000	69.5/14.05	155.0/31.57	295.5/60.95	347.0/74.62	399.0/88.67	-
8000	127.5/25.78	196.0/39.92	428.0/88.42	-	-	-
	Weight of tubers from control observed (g) at different intervals after storage (weeks)					
	494.0	491.0	484.0	465.0	450.0	448.0

given 500, 1000, 2000, 4000 and 8000 nematodes per plant were 5.9, 22.5, 47.5, 71.1 and 82.6 respectively. The gall development in different treatments were in the same proportion at which the initial inoculum levels were given.

3.2.1.i. Keeping quality of tubers harvested from different treatments in the pot experiment

The data relating to the experiment are presented in Table 11. Uninfected tubers could be stored without deterioration in quality for a period of six weeks and the reduction in weight during the period was 52 g from the original weight of 500 g. The tubers were fully fit for consumption or marketing even after six weeks of storage.

The percentage of spoiled tubers by weight compared to uninfected tubers ranged from 5.50 to 25.78 after first week of storage in different treatments and it ranged from 10.69 to 39.92 after two weeks. More than 60 per cent tubers were found spoiled by third week after storage in the treatments given an inoculum of 4000 and 8000 nematodes per plant (60.95 and 88.42 per cent) while in other treatments it ranged between 19.63 to 33.18 per cent. Spoilage was not seen thereafter in treatments given 500 and 8000 nematodes/plant. By the end of four weeks of storage 34.41, 46.34 and 74.62 per cent tubers were found spoiled

Fig. 3. Spoilage of tubers obtained from *C. esculenta* plants infested by varying population of *M. incognita* when kept in store

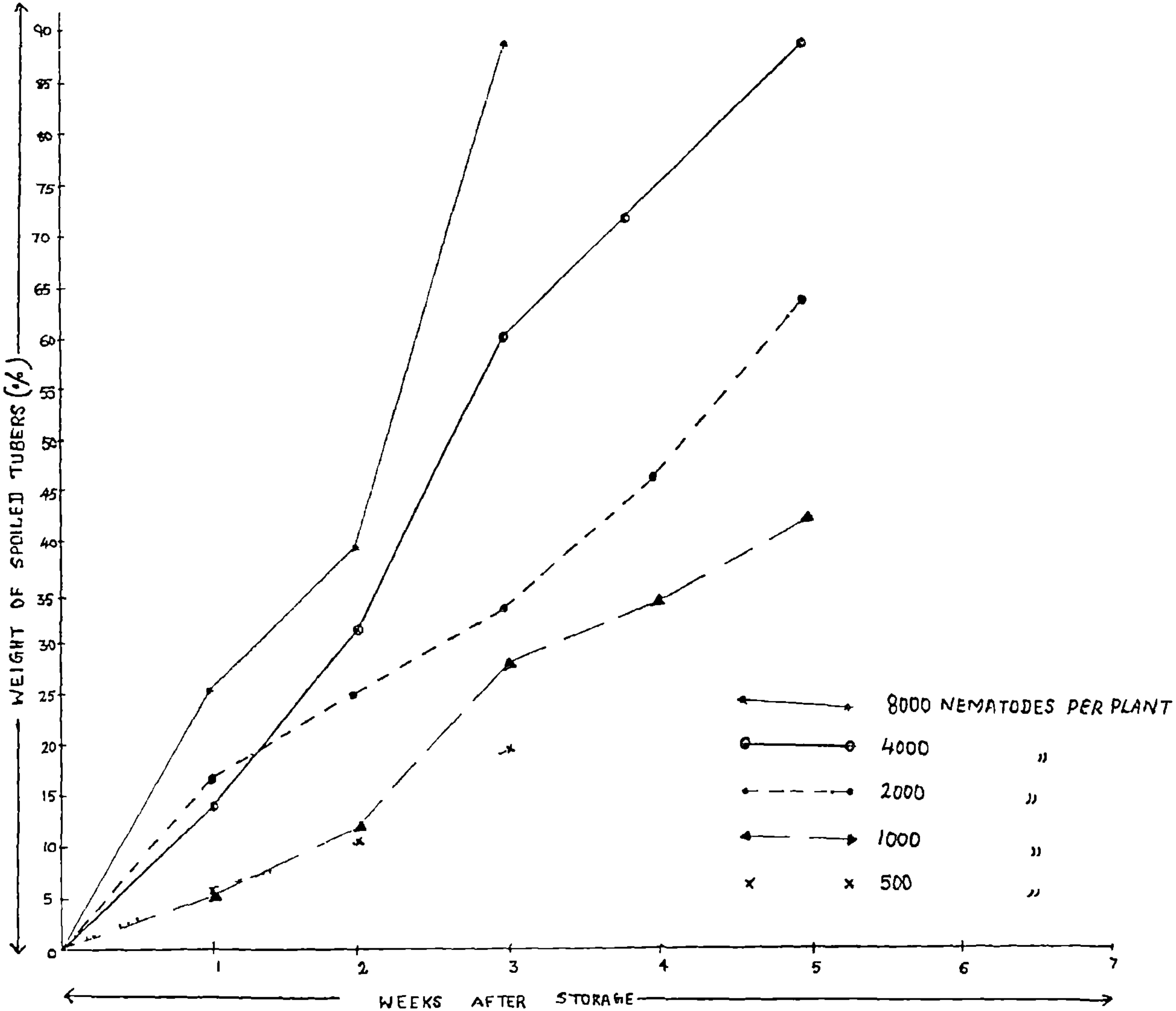
WEIGHT OF SPOILED TUBERS (%)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
1
2
3
4
5
6
7
WEEKS AFTER STORAGE
8000 NEMATODES PER PLANT
4000 "
2000 "
1000 "
500 "

Fig 3

and it was 42.11, 63.11 and 88.67 per cent in treatments given 1000, 2000 and 4000 nematodes per plant respectively when a period of five weeks was completed (Fig. 3).

3.2.1.2. Histopathology of colocasia roots infected by *M. incognita*

Sections of root of healthy and galled coleus were examined under the microscope.

In the uninfected colocasia roots the exodermis, cortex, endodermis, pericycle, xylem and phloem could be observed clearly. Xylem strands are arranged alternating with phloem. Protoxylem is seen towards the periphery and metaxylem towards the interior. The cortical cells has a hexagonal shape while cells in the pericycle region shows quadrangular or oval shape (Plate 2).

Sections of galled root showed mature female nematodes and associated egg masses in the regions of cortex (Plate 3a), pericycle (3b) and stele (3c). In all the cases the head of the nematode was seen directed towards the stele. Giant cells were observed adjacent to the head of the nematodes. The giant cells were conspicuous.

Infection in the cortex and pericycle regions caused modification of tissues due to hypertrophy and hyperplasia (3d). The cells of cortex and pericycle

Plate 2. Cross section of a healthy colocasia root

Plate 3. Cross section of an infected colocasia root showing *M. incognita* infection at different regions

Plate 4. Section of infected colocasia root showing *M. incognita* in the stele

Plate 5. Section of infected colocasia root showing advanced stage of infection

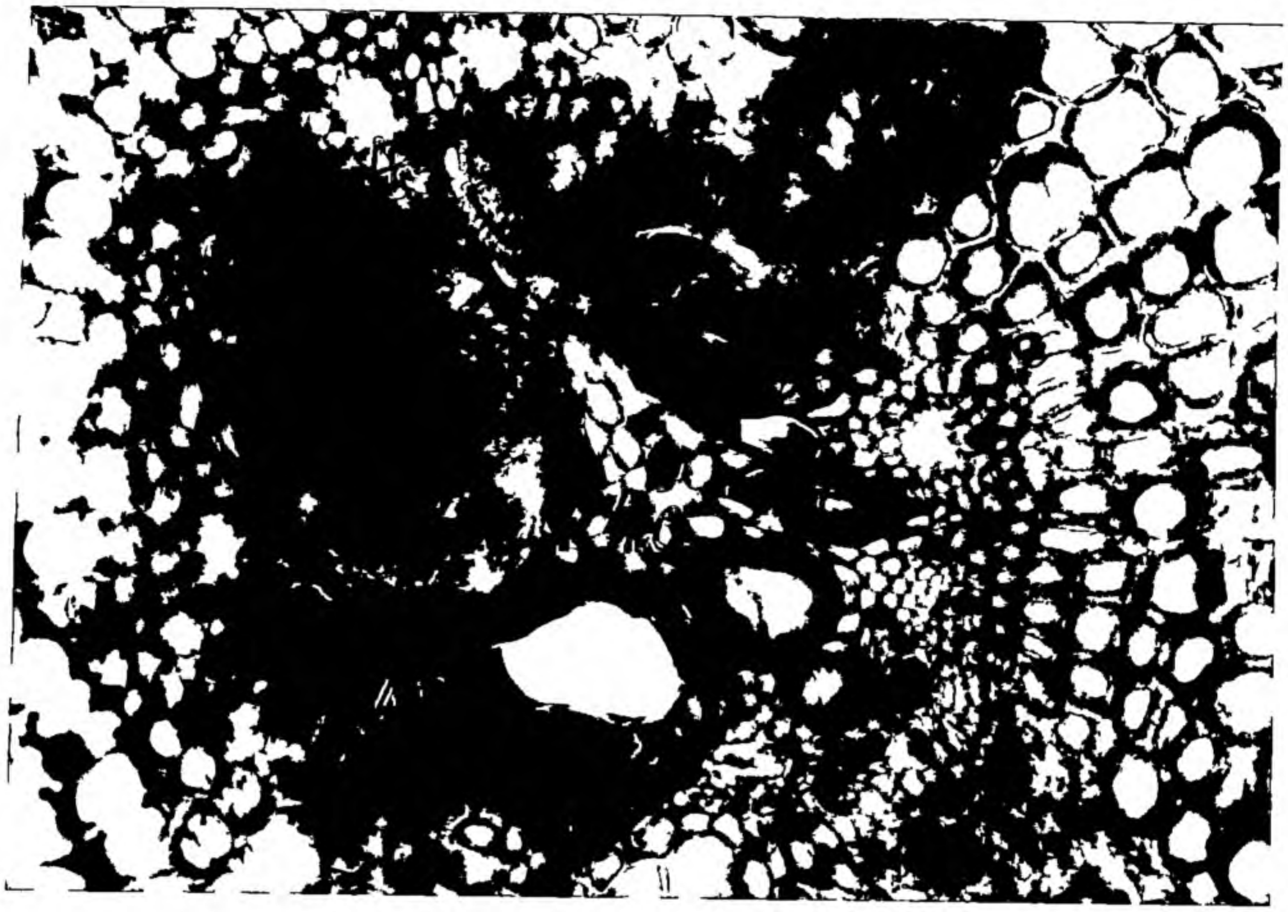

Plate 4

Plate 5

regions lose regular shape, size and arrangement. The infection in the stelar region compresses the adjacent cells and cause their distortion (Plate 4a).

The number of cells in the infected region of the root was seen higher compared to the healthy roots. Systematic arrangement of xylem (4b) and phloem (4c) were seen distorted in the infected area. Endodermis was not fully distinguishable around the stele.

In the advanced stages cortex was grossly malformed due to intensive proliferation of cells (Plate 5a). In the stelar region xylem and phloem lose their identity. The spots occupied by the nematodes developed into prominent cavities by the disintegration of giant cells, egg masses and adult females. Necrocis of root tissue was also observed in an extensive scale. This in course of time get decayed and rotten (Plate 5).

3.2.2. The effect of water stress on the attack of M. incognita on sweet potato

In this study different parameters like vine length, number of leaves, shoot weight, root weight, weight of tuberous roots, population of M. incognita in soil (100 ml), roots (5 g) and tuberous roots (5 g), number of root knots per 10 cm root and percentage (weight)

Table 12. Effect of water stress on the attack of *M. incognita* on sweet potato

Treatments	Observations recorded at different intervals (fortnight)						Mean	Observations recorded at different intervals (fortnight)						Mean
		2	3	4	5	6		1	2	3	4	5	6	
	Vine length (cm)							Population of nematodes in soil (100 ml)*						
Irrigation once in two days + 0 nematodes/plant	66 40	87 00	114 80	142 00	150 60	169 60	121.67							
Irrigation once in two days + 5000 nematodes/plant	68 60	89 10	106 00	114 80	126 60	128.20	107 27	24 08 (5 01)	50 76 (7 19)	70 37 (8 47)	123 55 (11.16)	123 95 (10 72)	159 32 (12 66)	90 34 (9 20)
Irrigation once in 7 days + 0 nematodes/plant	61 00	71 60	86 40	94.20	100.80	115.80	88 30							
Irrigation once in 7 days + 5000 nematodes/plant	56 00	66 00	83 20	86 60	92 80	99.30	80.20	20 11 (4.59)	35 45 (6 03)	47 87 (6 99)	69 58 (8 40)	79 27 (8 96)	105 21 (10 36)	59 58 (7 55)
CD			12 54				5.12			1 49				0 61
	Number of leaves							Population of nematodes in roots (5 g)*						
Irrigation once in two days + 0 nematodes/plant	111 60	196 10	253 80	326.20	329 80	312.80	255 80							
Irrigation once in two days + 5000 nematodes/plant	107.40	179 60	213 20	277.20	289.60	245.80	218.80	22 68 (4 87)	24 29 (5.03)	32 85 (5 82)	43 49 (6 67)	68.50 (8 34)	61 85 (7 92)	50 73 (6 44)
Irrigation once in 7 days + 0 nematodes/plant	84.60	143.20	180 40	225.20	246 20	215.20	182 47							
Irrigation once in 7 days + 5000 nematodes/plant	81 60	127 80	141.00	201.80	176.00	182.00	151 73	18 36 (4.40)	17 76 (4.32)	24.01 (5.00)	25 83 (5.15)	34 26 (5.95)	31 76 (5 73)	30 47 (5 09)
CD			9.97				11.34			0.48				0.20
	Shoot weight (g)							Population of nematodes in tuberous roots (5 g)*						
Irrigation once in two days + 0 nematodes/plant	177.40	218 60	247.20	371.60	389.20	265 20	293.50							
Irrigation once in two days + 5000 nematodes/plant	170 40	194 20	217 00	299.80	345.60	296.60	252 27	-	6 53 (2 74)	11 70 (3 56)	12 62 (3.69)	15 95 (4.12)	22 67 (4 87)	13 97 (3 80)
Irrigation once in 7 days + 0 nematodes/plant	127 40	167 40	182 00	220.20	265.80	266.00	204 20							
Irrigation once in 7 days + 5000 nematodes/plant	122 60	157 20	166.40	205 40	224.40	264.20	181 70	-	5 90 (2 63)	9 10 (3.12)	11 13 (3 48)	9.10 (3 18)	14 66 (3 96)	9 [illegible] (3 29)
CD			10.07				4 11			1.14				0 51
	Root weight (g)							Number of root knots/10 cm root*						
Irrigation once in two days + 0 nematodes/plant	11 76	15 32	18 40	2[illegible].20	22 90	23.24	18 80							
Irrigation once in two days + 5000 nematodes/plant	1[illegible] 52	14 72	14 40	16 36	20.48	20.50	16 75	-	3.24 (2.06)	8.16 (3 03)	11 15 (3 48)	16 95 (4 13)	18 01 (4 36)	11 50 (3 41)
Irrigation once in 7 days + 0 nematodes/plant	9 [illegible]4	1[illegible] 80	13 76	16 70	17 66	[illegible]7 50	14 [illegible]1							
Irrigation once in 7 days + 5000 nematodes/plant	9.64	11 08	12.09	12 54	14.80	16.38	12 75	-	3 12 (2 03)	7 99 (2 99)	6 97 (2 83)	13 65 (3 83)	13 63 (3 82)	9 07 (3 10)
CD			1.69				0 69			1 14				0 32
	Weight of tuberous roots (g)							Percentage (weight) of galls in roots**						
Irrigation once in two days + 0 nematodes/plant	0.0	23 40	37.40	72 40	309.0	615.40	211.52							
Irrigation once in two days + 5000 nematodes/plant	0.0	22 40	35 40	59 20	263 60	490.40	174 24	-	7 30 (17 40)	11 05 (19 41)	17 95 (25 06)	19 80 (26 45)	32 40 (34.10)	17 70 (29 90)
Irrigation in 7 days + 0 nematodes/plant	0.0	10.10	28.20	49.80	181.00	364.20	128 46							
Irrigation once in 7 days + 5000 nematodes/plant	0.0	10.80	28 40	49 00	166.40	326.00	118 00	-	9 95 (15 69)	9 90 (18 36)	11 10 (19 50)	17 90 (25 01)	19 40 (26 15)	13 61 (26 24)
CD			45 45				20 73			5 64				2 52

of galls on roots were observed at fortnightly intervals. Data related to the experiment are presented in Table 12.

3.2.2.a. Vine length

The mean vine length of sweet potato inoculated with 5000 Meloidogyne larvae per plant and irrigated once in two days (107.27 cm) was significantly lower than the vine length in corresponding control (121.67 cm). At a lower level of irrigation (once in 7 days) also the vine length in control (88.30 cm) was significantly higher than that of the nematode infested crop (80.20 cm). The percentage reduction in the vine length in treatments over control were 11.86 and 9.18 at the two levels of irrigation respectively.

At the higher frequency of irrigation the data on the vine lengths in treatments and control were on par during first, second and third fortnights while at lower frequency of irrigation they remained on par upto the fifth observation.

3.2.2.b. Number of leaves

The mean number of leaves in the inoculated treatments and corresponding control given higher and lower frequencies of irrigation were significantly different (255.80 and 218.80, 182.47 and 151.73 respectively). The reduction observed in the treatments compared to corresponding control given higher and lower frequencies of irrigation were 14.47 and 17.14 per cent respectively.

At the higher and lower levels of irrigation the data on the number of leaves in treatments and control were found on par during first period of observation while in the remaining fortnights significant reduction in number of leaves were observed in treatments compared to corresponding controls.

3.2.2.c. Shoot weight

The mean shoot weight in the inoculated treatments and corresponding control given higher and lower frequencies of irrigation showed significant difference (293.5 and 252.27, 204.20 and 181.70 g respectively) and the reduction in the treatments compared to corresponding controls were 14.05 and 11.02 per cent respectively.

In the shoot weights at the higher and lower frequencies of irrigation observed in different fortnights showed that the treatments and corresponding controls were on par during first fortnight while there were significant reductions in treatments during remaining fortnights.

3.2.2.d. Root weight

The mean root weight in the inoculated treatments and corresponding controls given higher and lower frequencies of irrigation showed significant differences (18.80 and 16.75, 14.51 and 12.75 g respectively) and the reductions in the treatments compared to corresponding controls were 10.91 and 12.13 per cent respectively.

In the higher frequency of irrigation the data on the root weights in treatments and control were on par during first and second fortnights while at lower frequency of irrigation they remained on par during first, second, third and sixth fortnights of observation.

3.2.2.e. Weight of tuberous roots

The mean weight of tuberous roots of sweet potato inoculated with 5000 larvae/plant and irrigated once in two days (174.24 g) was significantly lower than that in the corresponding control (211.52 g). But at a lower level of irrigation (once in 7 days) the mean weight of tuberous roots in control (128.46 g) did not show significant difference than that of the nematode infested crop (118.0 g). The percentage reduction in the mean weight of tuberous roots were 17.63 per cent at higher level of irrigation while it was only 8.15 per cent in the lower level of irrigation.

Observations at the higher frequency of irrigation on the weight of tuberous roots in treatments and control were on par during second, third and fourth fortnights while at lower frequency of irrigation they remained on par throughout.

3.2.2.f. Population of nematodes in soil (100 ml)

A significant reduction of 34.05 per cent was observed in the treatment given 5000 nematodes per plant in the lower frequency of irrigation compared to the treatment given higher frequency of irrigation.

Soil population of nematodes were significantly lower in the lower level of irrigation than in the higher level of irrigation in all the six fortnights.

3.2.2.g. Population of nematodes in roots (5 g)

The treatment with the lower frequency of irrigation had significantly lower mean root population than in the higher level of irrigation and the reduction was 39.94 per cent.

The population of nematodes in roots were found significantly lower in the lower frequency of irrigation than in higher frequency of irrigation in all the fortnightly observations.

3.2.2.h. Population of nematodes in tuberous roots (5 g)

Significant reduction in the population of nematodes in tuberous roots was observed in the lower irrigation level compared to the population in higher level of irrigation (28.49 per cent).

The population of nematodes in tuberous roots showed significant reduction in the lower level of irrigation than in the higher level of irrigation in all the observations recorded at fortnightly intervals except during the second fortnight.

3.2.2.i. Number of root knots/10 cm root

The mean numbers of root knots were found reduced significantly in the treatment given lower frequency of irrigation than in the treatment with higher level of irrigation (21.14 per cent).

Significant reduction also shown in the number of root knots/10 cm root in the treatment given irrigation once in 7 days than in the other treatment during fourth, fifth and sixth fortnights.

3.2.2.j. Percentage (weight) of galls in roots

The mean percentage (weight) of galls in roots was significantly higher in the treatment given higher

Table 13. Effect of water stress on the attack of *M. incognita* on *C. parviflorus*

Treatments	Observations recorded at different intervals after inoculation (fortnight)										Mean
	1	2	3	4	5	6	7	8	9	10	
					Number of leaves						
Daily irrigation + 0 nematodes/plant	44.2	174.6	288.6	374.4	482 6	557.6	613.6	671.6	568.6	557.6	433 32
Daily irrigation + 500 nematodes/plant	48.2	169.0	249.2	318.2	367.8	498 6	498.2	514 6	429.6	286 6	349 84
Irrigation once in 4 days + 0 nematodes/ plant	39.2	148.6	196.6	242.2	300.8	417.4	464.8	440.4	358.8	299.0	290 78
Irrigation once in 4 days + 5000 nematodes/plant	37.6	129.0	169.0	220.0	269.2	374 8	377.0	310.0	255 8	203.8	234.70
CD					53.13						16 82
					Number of branches						
Daily irrigation + 0 nematodes/plant	2.4	9.0	9.2	18 4	21.2	23.8	26.6	24.2	21.0	16.2	17.20
Daily irrigation + 500 nematodes/plant	2.6	9.0	9.0	15.8	19.4	21.6	22 4	20.0	14 0	11 4	14 58
Irrigation once in 4 days + 0 nematodes/ plant	2.4	7.4	8.6	13.6	18 2	18.8	20.8	17.2	13.4	14.2	13.46
Irrigation once in 4 days + 5000 nematodes/plant	2.0	8.0	7.6	12 6	15.1	18.3	19.6	21.3	19.1	15.4	12 75
CD					3.37						1 07
					Shoot length (cm)						
Daily irrigation + 0 nematodes/plant	24.4	33.0	44.8	58 0	71.0	82.8	100.8	112.8	111.2	102 4	74.12
Daily irrigation + 5000 nematodes/plant	21.2	30.0	35.6	46.8	54.8	64.0	80.4	79.2	80.8	69.6	56.24
Irrigation once in 4 days + 0 nematodes/ plant	16.8	27.6	32.4	39 8	53.2	60.6	70.4	77.4	76.6	66.4	52.12
Irrigation once in 4 days + 5000 nematodes/plant	16.2	24.0	27 8	31 6	37.4	53.0	59.4	66.8	66.8	57.0	44 00
CD					5.79						1.83
					Shoot weight (g)						
Daily irrigation + 0 nematodes/plant	12.0	44.4	70 6	105.6	115.0	148 4	167.8	179 6	160 4	165 2	116.9
Daily irrigation + 5000 nematodes/plant	10.8	42.2	62.4	85 4	90.8	105.2	111.8	115 4	77 6	67.2	77.49
Irrigation once in 4 days + 0 nematodes/ plant	9.8	44.8	60.8	79.8	85.2	91.2	110.8	111 8	112 8	124 4	83.14
Irrigation once in 4 days + 5000 nematodes/plant	10.4	38.0	50 6	69.8	64.6	73.6	90.2	72.8	64.4	53.8	59.80
CD					4 69						1 48
					Root weight (g)						
Daily irrigation + 0 nematodes/plant	8.1	10.4	18.3	24 9	25.8	28.2	30.2	29 9	29 8	30 3	23 59
Daily irrigation + 5000 nematodes/plant	8.8	9.6	22.4	28.4	32 6	38 7	34.5	30 9	25 7	17.6	24 93
Irrigation once in 4 days + 0 nematodes/ plant	8.4	8.9	16.3	18 8	22 6	24.7	25.6	26.4	26 8	27.1	20 57
Irrigation once in 4 days + 5000 nematodes/plant	8.0	9.3	20.1	23 1	28.2	31.9	29.3	28 6	24 0	16 7	21 92
CD					0 81						0 72

frequency of irrigation than in the other treatment and the reduction in lower level was found to be 23.11 per cent.

3.2.3. The effect of water stress on the attack of *M. incognita* on *C. parviflorus*

In this study different parameters like number of leaves, number of branches, shoot length, shoot weight, root weight, population of *M. incognita* in soil and roots, number of root knots per 10 cm root and percentage (weight) of galls on roots were observed periodically at fortnightly intervals after inoculation with nematodes. Tuber formation was meagre and data on that respect could not be collected. Data related to the experiment are presented in Tables 13 and 14.

3.2.3.a. Number of leaves

The mean number of leaves of coleus inoculated with 5000 nematode larvae per plant and irrigated daily (349.84) was significantly lower than the number of leaves in corresponding control (433.32) the reduction being 19.27 per cent. At the lower level of irrigation (once in 4 days) also the number of leaves in the inoculated treatment (234.70) was significantly lower than that of control (290.78) the reduction occurred being 19.36 per cent.

Table 14. Effect of water stress on the root galls and population of *M. incognita* on *C. parviflorus*

Treatments	Observations recorded at different intervals after inoculation (fortnight)										Mean
	1	2	3	4	5	6	7	8	9	10	
Population of nematodes in soil (100 ml)*											
Daily irrigation + 0 nematodes/plant	.	. .	. . .	.		.	.	.	. . . . .	.	
Daily irrigation + 500 nematodes/plant	16 0 (4.12)	23 8 (4 99)	83 6 (9 20)	211 4 (14.56)	333 0 (18 29)	324 8 (18 05)	782 5 (27 99)	1040 6 (32 37)	843.8 (29.07)	986 6 (31 14)	463.45 (18 98)
Irrigation once in 4 days + 0 nematodes/plant	. .	. . .	. . .	. .			. . .	.	. .	. .	. .
Irrigation once in 4 days + 5000 nematodes/plant	9 9 (3.30)	22 0 (4.80)	40 9 (6.48)	147 5 (12 19)	195 8 (14 03)	216 4 (14 74)	587.9 (24.27)	553 6 (23 56)	454 8 (21.35)	657 6 (25 67)	288 67 (15 04)
CD					2 06						0 65
Population of nematodes in roots (5 g)*											
Daily irrigation + 0 nematodes/plant	. .	. . . .	. .	.				.	. . . .	. .	
Daily irrigation + 500 nematodes/plant	18.3 (4 40)	29.5 (5 52)	59.2 (7 76)	243.0 (15 62)	604 7 (24 61)	723.3 (26 91)	861.1 (29 36)	865.3 (29 43)	857.0 (29.24)	805 4 (28 48)	506 71 (20 13)
Irrigation once in 4 days + 0 nematodes/plant	. . . .	. . .	. . .	. .	. . .		. . .	. . .	. . . . .	. . .	.
Irrigation once in 4 days + 5000 nematodes/plant	13 79 (3.85)	21 52 (4 75)	42 70 (6 61)	178 8 (13 41)	438 7 (20 97)	497.1 (22 32)	596.1 (24 45)	521 3 (22 85)	518 7 (22 80)	518 6 (22.80)	334 81 (16 48)
CD					2 63						0 83
Number of root knots/10 cm root*											
Daily irrigation + 0 nematodes/plant	. . .	. . .	. .	.		.	. .	. .	. . .	. . . .	.
Daily irrigation + 5000 nematodes/plant	-	2 1 (1 93)	9 9 (3.30)	15 4 (4 06)	16 5 (4 22)	22.3 (4 82)	36.9 (6.16)	58.1 (6 26)	30.8 (5.64)	25 91 (5 56)	22.12 (4 66)
Irrigation once in 4 days + 0 nematodes/plant	. . . .	. . .	. . .	.	.	. . .	. .	. .	. . . .	. .	.
Irrigation once in 4 days + 5000 nematodes/plant	-	2 1 (1 94)	8 2 (3 05)	10 8 (3 44)	13 5 (3 61)	18 6 (4 43)	27 8 (5 37)	28 5 (5 44)	28 3 (5 42)	23.4 (4.95)	17 50 (4 21)
CD					0 84						0 28
Percentage (weight) of galls on roots**											
Daily irrigation + 0 nematodes/plant	. . .	. .	. . . . .	. .		. .	. . . . . .	.	. . . .	.	
Daily irrigation + 5000 nematodes/plant	-	11.2 (19 44)	14 7 (25 44)	22 0 (27 26)	35 8 (35 77)	41 1 (39 85)	45.7 (42 54)	72 3 (58 24)	85.6 (67.63)	93.4 (75.12)	46 80 (48 68)
Irrigation once in 4 days + 0 nematodes/plant	.	. . . . .	.				. . .	. .	.	. . . .	.
Irrigation once in 4 days + 5000 nematodes/plant	-	10.2 (18.56)	14 7 (22 57)	18 4 (25 37)	27 4 (31 53)	31 1 (35 19)	33 5 (35 34)	58 8 (49 5)	73 7 (39.17)	80.6 (63.89)	38 44 (37 89)
CD					6 57						2.19

* Figures in parenthesis are $\sqrt{x+1}$ transformed values

** Figures in parenthesis are angular transformed values

At the higher frequency of irrigation the data on number of leaves in treatments and control were on par during first, second and third fortnights while at lower frequency of irrigation they remained on par upto the sixth observation.

3.2.3.b. Number of branches

The mean number of branches in the treatment given higher frequency of irrigation (14.58) was significantly lower than the number in control (17.20) while in the treatment given lower frequency of irrigation number of branches in treatment were on par with corresponding control. The reduction observed in treatments compared to corresponding control given higher and lower frequencies of irrigation were 15.24 and 5.28 per cent respectively.

At the higher level of irrigation the data on the number of branches in treatment and control remained on par till sixth observation while in the treatment in the lower level of irrigation they remained on par in all fortnights except in the ninth and here the number of branches in the treatment was found higher than those in corresponding control (19.1 and 13.4 respectively).

3.2.3.c. Shoot length

The mean shoot length in the inoculated treatments and corresponding controls given higher and lower frequencies of irrigation differed significantly (74.12 and 56.24, 52.12 and 44.0 cm respectively). The reduction observed in the treatments compared to controls were 24.13 and 15.58 per cent in higher and lower frequencies of irrigation respectively.

At the higher frequency of irrigation the data on the shoot length in treatments and control were on par during first and second fortnights of observation while at lower frequency of irrigation they remained on par upto third fortnight of observation.

3.2.3.d. Shoot weight

The mean shoot weights in the inoculated treatments and corresponding controls given higher and lower frequencies of irrigation varied significantly (116.9 and 77.49, 83.14 and 59.80 g respectively) and the reduction occurred in treatments compared to control were 33.72 and 28.08 per cent respectively.

At the higher frequency of irrigation the data on the shoot weight in treatment and control were on par during first and second fortnights of observation while at a lower frequency of irrigation they remained on par only in the first fortnight of observation.

3.2.3.e. Root weight

The mean root weights in the inoculated treatment and given daily irrigation (24.93 g) was on par with the mean root weight in corresponding control (23.59 g). But at a lower level of irrigation (once in four days) the mean root weight in control (20.57) was significantly lower than that of the nematode infested crop (21.92 g). A slight increase in mean root weight was observed in the treatments than in corresponding control and in higher and lower irrigation frequencies the increase were 5.68 and 6.56 per cent respectively.

At the higher and lower frequency of irrigation the data on the vine lengths in treatments and control were on par during first and second fortnight of observation. An increase in root weight could be noticed in the treatments than in the corresponding controls both in higher and lower frequencies of irrigation from third to eighth fortnight of observation while the condition was just opposite during the remaining two fortnights of observation.

3.2.3.f. Population of nematodes in soil

The mean population of nematodes in soil was 463.45 and 288.67/100 ml when inoculated plants were irrigated daily and once in four days respectively and they were significantly different. Reduction in mean population of nematodes in the soil due to low frequency of irrigation was 37.72 per cent.

From the third fortnight of observation onwards the soil population of nematodes was significantly higher in daily irrigated plants than plants irrigated once in four days.

3.2.3.g. Population of nematodes in roots

The mean population of nematodes in 5 g root samples of the nematode inoculated plants were 506.71 and 334.81 when the frequency of irrigation was higher and lower respectively. The reduction due to low frequency of irrigation was 33.93 per cent.

Root population of nematodes was significantly higher in more frequently irrigated plants from the fifth fortnight of observation onwards.

3.2.3.h. Number of root knots per 10 cm root

Mean number of root knots was significantly higher in daily irrigated plants (22.12) than in plants irrigated once in four days (17.50). The reduction due to lower frequency of irrigation was 20.89 per cent.

But there was no significant difference in the number of root knots when the two sets of inoculated

Table 15. Effect of water stress on the attack of *M. incognita* on *Dioscorea* sp

Treatments	Observations taken at different intervals after inoculation (1½ month interval)						Mean	Observations taken at different intervals after inoculation (1½ month interval)						Mean
	1	2	3	4	5	6		1	2	3	4	5	6	
	Vine length (cm)							Weight of tubers						
Irrigation once in 2 days + 0 nematodes/plant	147.6	250.8	634.0	702.8	714.0	697.0	524.50	-	-	37.8	90.2	189.2	321.6	159.75
Irrigation once in 2 days + 5000 nematodes/plant	157.8	231.0	576.0	674.8	675.0	662.0	496.10	-	-	37.2	85.4	173.0	321.8	154.35
Irrigation once in 10 days + 0 nematodes/plant	145.6	202.2	497.2	528.0	506.0	460.0	389.83	-	-	29.0	67.0	112.2	188.0	99.05
Irrigation once in 10 days + 5000 nematodes/plant	137.2	188.0	470.0	500.6	458.6	436.0	365.13	-	-	31.2	60.4	108.4	172.4	93.10
CD	53.15						21.70	39.86						19.93
	Number of leaves							Population of nematodes in soil (100 ml)*						
Irrigation once in 2 days + 0 nematodes/plant	61.6	134.8	232.8	266.0	248.8	186.6	188.40	...						
Irrigation once in 2 days + 5000 nematodes/plant	55.6	134.4	229.2	247.2	218.0	165.0	174.46	33.6 (5.89)	38.6 (6.29)	41.9 (6.55)	39.6 (6.37)	43.3 (6.65)	53.7 (7.40)	41.81 (6.53)
Irrigation once in 10 days + 0 nematodes/plant	40.4	100.2	168.4	201.0	189.8	100.6	133.40	...						
Irrigation once in 10 days + 5000 nematodes/plant	38.6	90.8	163.6	178.6	166.8	85.4	121.53	26.7 (5.27)	26.8 (5.28)	29.4 (5.52)	33.6 (5.89)	31.4 (5.66)	38.4 (6.12)	30.71 (5.62)
CD	28.78						11.75	1.56						0.65
	Shoot weight (g)							Population of nematodes in roots (5 g)						
Irrigation once in 2 days + 0 nematodes/plant	237.0	336.2	698.0	795.0	837.2	785.0	614.73	...						
Irrigation once in 2 days + 5000 nematodes/plant	230.0	276.2	695.0	770.0	784.4	766.0	586.40	16.4 (4.17)	18.1 (4.37)	20.8 (4.67)	18.8 (4.45)	18.8 (4.45)	26.1 (5.21)	19.87 (4.56)
Irrigation once in 10 days + 0 nematodes/plant	172.0	204.2	523.4	653.8	646.8	653.8	475.47	...						
Irrigation once in 2 days + 5000 nematodes/plant	173.0	182.4	503.6	595.2	635.8	598.0	448.00	12.7 (3.70)	12.6 (3.70)	14.6 (3.96)	15.9 (4.12)	16.1 (4.14)	15.7 (4.09)	14.64 (3.95)
CD	61.74						25.20	1.08						0.44
	Root weight (g)							Population of nematodes in tubers (5 g)						
Irrigation once in 2 days + 0 nematodes/plant	77.6	92.2	118.2	141.6	156.2	143.0	121.45	...						
Irrigation once in 2 days + 5000 nematodes/plant	76.8	89.8	110.8	133.6	149.4	126.6	114.40	...	...	5.95 (2.64)	7.43 (2.95)	4.39 (2.32)	6.58 (2.75)	6.16 (2.67)
Irrigation once in 10 days + 0 nematodes/plant	54.6	77.6	86.6	121.8	128.2	127.2	99.43	...						
Irrigation once in 10 days + 5000 nematodes/plant	50.4	76.2	80.8	113.0	123.2	123.0	94.43	...	...	6.53 (2.74)	5.24 (2.50)	4.55 (2.36)	4.71 (2.39)	5.28 (2.50)
CD	15.16						6.19	1.08						0.54

* Figures in parenthesis are $\sqrt{x+1}$ transformed values

plants were observed at fortnightly intervals.

3.2.3.i. Percentage (weight) of galls

Mean percentage (weight) of galls on roots was significantly higher when the inoculated plants were irrigated daily (46.80) than given irrigation once in four days (38.44). The reduction due to lower frequency of irrigation was 17.87 per cent.

From the seventh fortnight onwards the percentage (weight) of galls was significantly higher in daily irrigated plants than that in plants irrigated at an interval of four days.

3.2.4. Effect of water stress on the attack of *M. incognita* in *Dioscorea sp.*

In this study various parameters like vine length, number of leaves, shoot weight, root weight, weight of tubers, population of nematodes in soil, roots and tubers were observed at one and a half month intervals. Data relating to the experiment are given Table 15.

3.2.4.a. Vine length

A significant reduction of 5.35 per cent was observed in the mean vine lengths of plants inoculated with 5000 nematodes per plant and irrigated once in two days

(496.10 cm) compared to the control plants irrigated at the same frequency (524.50 cm). In the case of plants subjected to a higher water stress by reducing the frequency of irrigation to 10 days, the result was similar. A reduction of 6.34 per cent was observed in the vine length of the nematode inoculated plants (365.13 cm) compared to that of control (389.83 cm).

At the lower frequency of irrigation, no significant difference was observed in the vine lengths at intervals of 1½ months while in the case of plants given higher frequency of irrigation vine length of nematodes inoculated plants was significantly lower at the third observation compared to control.

3.2.4.b. Number of leaves

Mean number of leaves was also found to be significantly lower in nematode inoculated plants at the two levels of irrigation compared to the corresponding controls. At the higher frequency of irrigation the mean number in nematode inoculated plants was (174.46) compared to control (188.40) showing a reduction of 7.6 per cent. At the lower frequency of irrigation the mean number of leaves were 123.53 and 133.40 in inoculated and control plants respectively with a reduction of 8.9 per cent.

No significant difference was observed between the number of leaves of inoculated and control plants at the lower frequency of irrigation when observed at different intervals of 1½ months. In the case of plants irrigated once in two days number of leaves was significantly lower in inoculated plants only at the fifth observation.

3.2.4.c. Shoot weight

At the high frequency of irrigation of two days, the mean shoot weight of plants inoculated with nematodes (586.4 g) was significantly lower than that of control (614.73 g), the reduction being 4.6 per cent. Mean shoot weight of plants irrigated at a lower frequency was also significantly lower in the case of treatment (448.0 g) than control (475.47 g), the reduction being 5.78 per cent.

There was no significant difference in treatments and control at both the levels of irrigation when observed at intervals of 1½ months.

3.2.4.d. Root weight

The difference in mean root weight of plants was significant at the higher frequency of irrigation only. The mean root weight of nematode inoculated plants irrigated once in two days was 114.40 g as against 121.45 g in the control, the reduction being 5.81 per cent.

The root weight was found on par with that of the respective control at both levels of irrigation at all the intervals, except at the sixth in the higher frequency of irrigation in which the root weight was significantly lower in the treatment.

3.2.4.e. Weight of tubers

The mean weight of tubers observed at different intervals in treatments were on par with the respective controls when the plants were subjected to irrigation at different frequencies.

3.2.4.f. Population of nematodes in soil

The mean population of nematodes in soil was significantly higher in inoculated plants irrigated at intervals of two days (41.81 per 100 ml) than those in lower frequency of irrigation (30.71 per 100 ml), the reduction being 26.55 per cent.

There was no significant difference between the two treatments when observed at intervals of 1½ months.

3.4.2.g. Population of nematodes in roots

Mean population of nematodes in roots was also significantly higher at the higher frequency of irrigation (19.87 per 5 g) compared to that in lower frequency (14.64 per 5 g).

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When observed at intervals of 1½ months, the root population of nematodes was significantly higher under the higher frequency of irrigation than that of the lower frequency at the sixth observation only.

3.2.4.h. Population of nematodes in tubers

The mean population of nematodes in plants given irrigation at two levels (2 and 10 days) did not show significant difference. Different observations made at 1½ month intervals also were on par in the two treatments.

Discussion

4. DISCUSSION

Distribution of nematodes associated with important tuber crops of Kerala

The detailed survey on the distribution of plant parasitic nematodes associated with the major tuber crops was attempted for the first time in Kerala. It was carried out with a view to ascertaining the extent and intensity of the infestation of different tuber crops by the different genera of nematodes. Result shows that a number of endo and ecto parasitic nematodes are associated with the tubers cassava, sweet potato, coleus, dioscorea and colocasia/ xanthosoma.

Nematodes associated with cassava: Result presented in para 3.1.1 showed that cassava is most widely attacked by *Rotylenchulus* *sp*. and it is followed by *Meloidogyne* *sp*., the frequency of occurrence in root samples being 76 and 40 per cent respectively. Juveniles of *Meloidogyne* *sp*. was present in all the soil samples. Data did not show significant variations in intensity of occurrence of the nematodes among the different panchayats or among the different agroclimatic zones covered in the survey though the mean population in the samples ranged from 1 to 23.95 larvae per 100 ml soil.

The soil population in some panchayats in which the root infestations was lacking (Ambalavayal and Thirunelly) also was low while in some (Shertallai South, Kulakada etc.) the soil population of the nematode was high while the root population was low or absent. This indicated that the absence of the nematode in the root samples might be due to the resistance of the varieties grown in the localities. Varietal resistance to Meloidogyne infestation in cassava has been reported by a number of earlier workers. No systematic survey on the occurrence of plant parasitic nematodes associated with cassava has been done earlier in Kerala or in any part of India though it had already been recorded as a pest of tapioca in India (Nirula and Kumar, 1963; Hoggen, 1971). Meloidogyne sp. has been reported as a serious pest on cassava in different parts of the world.

The possible injury from the levels of the pest population observed in the survey cannot be reliably inferred since information on the economic threshold levels of the pest on cassava are not available. There are reports that two populations levels of 500 larvae per plant (which when estimated at 100 ml volume basis will remain below 10) had affected the growth of the plant and at higher levels the significant yield reduction was observed in field

(Cavensis, 1982; McSorley *et al*., 1983; McSorley and Parrado, 1985). The population levels of the pest observed in the survey indicated that *Meloidogyne* can be considered as a potent limiting factor to cassava production in many tapioca growing tracts in the State.

Rotylenchulus sp. found in slightly higher population in all the panchayats in the different agroclimatic zones of Kerala has not so far been reported as a pest of crop from the State or from any part of India. But it has been recognised as a serious pest of the crop in Philippines (Gapasin, 1979) and Thailand (Thongjiem, 1983). Mc Sorley (1983) has included *R. reniformis* among the nematode pests of cassava occurring throughout the world. As in the case of *Meloidogyne* this nematode also were absent in root samples collected from some locations, though they were present in all soil samples collected. But such instances were less when compared to the data relating to *Meloidogyne sp*. The possible reason for this apparent anomaly may be the varietal resistance - a host reaction that may be less towards *Rotylenchulus sp*. than towards *Meloidogyne sp*. The population levels of *Rotylenchulus* in soil and roots were also slightly higher than those of *Meloidogyne sp*. No information is yet available on the pathogenecity of *Rotylenchulus sp*. on tapioca and hence no factual inference can be made on the potent menace from this pest to cassava cultivation in the State. But since *Rotylenchulus sp*. has been reported as a serious pest of a similar tuber crop sweet potato, in several parts of the world (Clark and Meyer, 1988) it has to be considered as a potent menace to cassava also.

The nematodes recorded in the soil, in root zone of the crop, but not in the roots, were *Helicotylenchus sp*., *Tylenchorynchus sp*., *Radopholus sp*., *Pratylenchus sp*. and *Tylenchus sp*. Among these *Helicotylenchus sp*. was more widely distributed (in 18/25 samples) and it was followed by *Tylenchorynchus sp*. (12/25 samples). The frequency of occurrence of *Radopholus sp*. and *Pratylenchus sp*. were on par. *Tylenchus sp*. was observed in only one sample. The above nematodes have been reported from soil and/or root samples associated with cassava by earlier works in Thailand (Thongjiem, 1983) and Trinidad (Bala, 1984). McSorley *et al*. (1983) had identified *Pratylenchus sp*. among the economically important nematodes associated with cassava. The pathogenecity of the other nematodes are not seen reported earlier. Since they are not seen in the root samples from any of the locations covered in the survey it may be inferred that they are not likely to be pathogenic to the varieties of cassava commonly grown in Kerala.

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Nematodes associated with sweet potato: The results presented in para 3.1.2 shows that *Meloidogyne sp.* and *Rotylenchulus sp.* were seen in all soil samples and in most of the root samples collected from different locations in the survey. Significant variations were lacking in the intensity of this pest among the different panchayats covered in the survey or among the different zones in the State. The absence of the nematodes in root samples, while they are present in soil, may be attributed to the differences in the susceptibility of the varieties grown or the stage of the crop in the field at the time of sampling. Resistance of some of the varieties to the attack of *Meloidogyne sp.* (Clark and Meyer, 1989; Lawrence *et al.*, 1986; Mohandas *et al.*, 1988) and *R. reniformis* (Thomas and Clark, 1983) has been reported earlier. Earlier studies have also shown the high pest potential of these nematodes on sweet potato either by damaging the fibrous roots and limiting production or by entering the tuberous roots and affecting the yield or reducing the quality of tubers (Clark and Meyer, 1988).

The pathogenecity studies have shown that the high population of *Meloidogyne sp.* reduces the yield of sweet potato (Gapasin and Valdez, 1979; Lawrence *et al.*, 1986) significantly. Reduction in root, tuber and top weights caused by the inoculation of R. reniformis has also been reported (Gapasin and Valdez, 1979; Gapasin, 1987). But the threshold levels of these nematodes have not been worked so far. In this context a projection of the potential crop loss from the observed population levels of the nematodes in the State may not be reliable. However being very widespread in occurrence the nematode has to be identified as a potential limiting factor in the cultivation of sweet potato in Kerala.

Helicotylenchus sp. was observed in most of soil samples collected from the different zones. Radopholus sp. was more frequent in high ranges and problem zones than in northern zone and were present in one and two samples from central and southern zones respectively. Both the nematodes were totally absent in root samples. Helicotylenchus sp. was observed to grow in the root tissues of sweet potato but it was not causing any reduction in yield (Lopez et al., 1981). In the absence of the nematodes in root samples and in the light of earlier studies it may be considered as less important as pests of sweet potato. The above pests and the species of Tylenchorynchus, Tylenchus and Heterodera observed in stray samples of soil and roots collected in the survey may be primary pests of other crops usually grown in rotation with sweet potato in field. Pratylenchus sp.

is known to cause a disease nematic root rot in sweet potato (Clark and Meyer, 1988) but the nematodes was found in very low population and in five locations only. Hence they may not emerge as serious menace to the crop in the near future.

Nematodes associated with dioscorea: The results shown in para 3.1.3 reveals that dioscorea is most widely attacked by Rotylenchulus sp. followed by Meloidogyne sp., the frequency of occurrence in roots being 58 and 60 per cent respectively among the samples collected. Soil population of the juveniles of Rotylenchulus sp. and Meloidogyne sp. were present in all the panchayats surveyed and the population did not show significant variations in intensity among different panchayats or among the different agroclimatic zones though the population of Rotylenchulus sp. and Meloidogyne sp. ranged from 1.32 to 11.16 and 1.43 to 16.72 larvae per 100 ml soil respectively.

Root population of Rotylenchulus sp. was seen higher compared to that of Meloidogyne sp. in samples. Root population of Meloidogyne sp. found very low in different panchayats surveyed.

Meloidogyne sp. has been reported as a serious pest of yams (Acosta, 1974) in different parts of the world and it has been found causing significant yield reduction in

D. alata at an inoculum level of 5000 nematodes per plant (Adesiyan and Odihiran, 1975b). Based on the damage of M. incognita on D. rotundata Atu et al., 1983 fixed the economic injury level as 1250 nematodes per plant. The very wide distribution of the pest and in view of its importance as a serious pest of yam it may be treated as a potent menace to the diascorea cultivation in Kerala. The reason for the absence of the nematode in root samples from some locations may be the resistance of the varieties grown their as observed, by Atu et al. (1984) in Southern Nigeria.

Though Rotylenchulus sp. is seen associated with the crop in Kerala information are lacking about the pathogenecity and the possible injury from the levels of the nematode to this crop cannot be inferred. The nematode had been reported on yams earlier also (Ayala and Acosta, 1975; Kasasiyan et al., 1978).

Pratylenchus sp. were seen associated with the crops in the high ranges. The nematode was observed in three panchayats in the high ranges from soil and roots, and their population varied from 5.75 to 18.25 and 3.5 to 8.0 per 100 ml soil and 5 g root respectively. The nematode was not obtained from other zones. Reason for the occurrence of the nematodes in high ranges alone may be the presence of some primary hosts of *Pratylenchus* *sp*. in the zone. *Pratylenchus* *sp*. has been identified as a limiting factor of yam cultivation (Adesiyan, 1975). The pest has also been recorded causing damage in different parts of world. *Pratylenchus* *sp*. was recorded in Kerala earlier in association with dioscorea (Mohandas *et* *al*., 1988). The pest is reported to cause dry rot at a level of 600 larvae per plant (Acosta and Ayala, 1975). The pest may become a potent limiting factor of dioscorea in high ranges in due course.

Other genera of nematodes observed from the soil from the root zone of crop, but not in the root samples were *Helicotylenchus* *sp*., *Hoplolaimus* *sp*. and *Radopholus* *sp*. The two ecto parasites *Hoplolaimus* *sp*. and *Helicotylenchus* *sp*. were seen in 22 and 15 panchayats in the different zones. *Hoplolaimus* *sp*. (Mohandas *et* *al*., 1988 in Kerala) and *Helicotylenchus* *sp*. (Ayala and Acosta, 1971; Brathwaite, 1972) have been recorded earlier at the crop. *Radopholus* *sp*. could be collected from 18 panchayats from soil samples but not from roots. Being an endoparasite the absence in root tissues eliminate the possibility of its association as a pest of the crop. Though *Helicotylenchus* *sp*. has been reported earlier on the crop the nature and extent of damage being unknown its potential as a pest on the crop cannot be inferred reliably. *Hoplolaimus* *sp*. was found only on dioscorea among the five crops covered in the survey. Here also knowledge on extent of damage caused by the nematode is limited. However the very widespread occurrence shows the signs of constant association of the two.

Nematodes associated with colocasia/xanthosoma: The results presented in para 3.1.4 shows that Meloidogyne sp. was seen in all soil samples and in most of the root samples collected from different locations in the State. The population varied from 1.61 to 30.08 per 100 ml soil while in root samples the range was from 0.71 to 17.31 per 5 g. Two of the panchayats in problem zone (Pandalam and Ochira) showed high population of the genus in soil and roots. Rotylenchulus sp. also has a wide distribution in Kerala and were recorded from 22 and 20 panchayats in soil and root samples respectively. Some of the panchayats (Madakkathara, Kizhakkanchery etc.) in central zone showed relatively high population of the nematode. One each panchayat from high ranges, problem zone and southern zone did not show population in soil and roots.

Meloidogyne sp. has been identified as a pest of C. esculenta in India (Srivastava et al., 1969) and it has been reported from Kerala (Nadakal and Thomas, 1964). It has also been recorded in xanthosoma (Roman, 1978; Acosta, 1979). The pest is found causing severe galling on taro

(Williams, 1980) and even crop failure was recorded in Hawaii (Jackson, 1980). Preplant population of 500 *M. incognita* per 100 cm^3 soil was found to cause significant reduction in corm weight in xanthosoma (Caveness *et al*., 1981). The result in the survey showed that *Meloidogyne sp*. can be a potent limiting factor in the productivity of aroids in Kerala.

Widespread association of *Rotylenchulus sp*. is also pausing a threat to aroids in Kerala. *Rotylenchulus sp*. had been recorded in greater numbers in the previous surveys also (Brathwaite, 1972; Orton Williams, 1980). Small root leisions due to heavy infestation of *R. reniformis* on taro (Brathwaite, 1972) and a 26 per cent reduction of dry corm weight was observed due to a preplant population of 56 *R. reniformis* and a final population of 400 per cm^3 of soil (Mc Sorley *et al*., 1983). The very widespread occurrence of the nematodes pause a threat to the cultivation of aroids in the State.

Pratylenchus sp. an endoparasite was recorded from soil samples and root samples of seven and three panchayats respectively. *Pratylenchus sp*. has been identified as a pest of aroids causing significant damage on colocasia. Kumar and D'Souza (1969) reported *Pratylenchus mutabilis* from the roots of colocasia in India. Being a susceptible host this nematode is a possible threat to taro in Kerala rather than xanthosoma. Heterodera sp. was obtained from the root and soil samples from one panchayat.

Other nematodes obtained from soil of the root zone of the crop and not from roots were Helicotylenchus sp., Tylenchorynchus sp., Radopholus sp., Helicotylenchus sp. were frequently observed in survey conducted by Orton Williams (1980) in Western Samoa, Fiji and Tonga. Radopholus similis also recorded in Western Samoa in a survey on taro (Orton Williams, 1980) with the limited knowledge of pathogenecity of these three genera of nematodes no inference can be drawn from the survey regarding the importance of the pest.

Nematodes associated with C. parviflorus: Results presented in para 3.1.5 shows the presence of Meloidogyne sp. in all the samples of soil and roots. Central zone presents the highest infestation followed by Southern Zone. The population of nematodes ranged from 10.75 to 57.06 per 100 ml of soil samples except in one panchayat (4.53) whereas in roots population ranged from 1.37 to 22.22 per 5 g in different panchayats. Meloidogyne incognita has already been recorded as a pest of C. parviflorus from Kerala (Satyarajan et al., 1966) and from other parts of India (Pushkarnath and Roy Chowdhary, 1958) causing high threat to cultivation of coleus. It is found to cause 29 per cent reduction in root length after 60 days with an inoculum of 10 juveniles per pot (Patnaik and Das, 1986). The widespread distribution of Meloidogyne sp. in association with coleus pauses a serious threat to cultivation of the crop in the State.

Rotylenchulus sp. is also seen associated with the crop extensively in Kerala. It could be observed from 24 panchayats in soil samples and 15 panchayats in root samples. Previous reports are lacking in the case of Rotylenchulus sp. while the widespread occurrence and reports of pathogenecity in similar tuber crops like sweet potato the pest may pause a serious threat to the cultivation of coleus in due course.

Helicotylenchus sp., Radopholus sp. and Pratylenchus sp. could be observed from all zones in soil around the root zones but not from the root samples. Tylenchorynchus sp. recovered from some of the panchayats in high ranges, central zone and one panchayat from southern zone while Heterodera sp. was recorded from two panchayats in southern zone, in the soil samples only. Previous reports on the occurrence of these nematodes in association with coleus are lacking. Potential damage to the crop cannot be inferred from the results of the survey in the absence of pathogenecity studies.

Crop loss caused by *M. incognita* with reference to *C. esculenta*

The effect of varying levels of *M. incognita* on the growth parameters and yield of *C. esculenta* was assessed in a pot culture experiment and the results are presented in para 3.2.1.

Even with the first level of nematode population ie. 500 larvae/plant there was significant reduction in the tuber yield. The reduction was about 12 per cent over control. The plant girth and number of leaves in the treatment also were significantly lower than those of control while the plant height, shoot weight and the root weights in the treatments and control came on par. The objective of the study was to ascertain the level of nematode population that can cause significant loss to *C. esculenta*. It can obviously be fixed around 500 larvae/plant. With reference to the quantity of soil used in the pot it could be worked out as seven larvae/100 ml soil. Caveness in 1981 reported that 500 *M. incognita* (race-2) larvae/100 ml soil caused significant reduction in corm weight in colocasia. The critical level arrived in the present experiment is much lower. These variations may be due to the variations in the varieties of the crops used in the experiments.

No linear relationship could be noticed with reference to the different levels of initial population and their effect on different criteria adopted for the assessment of the pathogenecity. But with an increase in the initial population of the pest a progressive suppression in plant height, number of leaves, shoot weight, root weight, weight of tubers and an increasing trend in pest population, root knot and percentage of galls (weight basis) were observed. This may be the result of a significant suppression in pots inoculated with a high level of nematode larvae caused by the over crowding and non-availability of adequate number of healthy roots for the entry and survival of the nematodes. The effect of the infestation got manifested from the second month after inoculation and generally continued upto the last observation. Low population of nematodes have been reported (200 larvae) to stimulate the tops, roots and tubers in yams (Ayala and Acosta, 1975) and cassava (Caveness, 1977, 1988). The suppression of yield with high population levels ranging from 500 to 1000 larvae have been reported on cassava (Caveness, 1977 & 1982; McSorley et al., 1983; McSorley and Parrado, 1985) on yam (Ayala and Acosta, 1975; Atu et al., 1983 and 1984) and on coleus (Patnaik and Das, 1986; Sosamma, 1988). The effect of graded levels of *M. incognita* on *C. esculenta* was studied for the first time.

Keeping quality of tubers harvested from different treatments in pathogenecity trial

The tubers of *C. esculenta* obtained from treatments for pathogenecity studies were infested to varying levels though they apparently appeared normal at the time of harvest. Such tubers of coleus have been reported to deteriorate in storage (Sosamma, 1988). The produce from *C. esculenta* is usually sold in the market after prolonged storage and hence the potential loss from the spoilage of tubers in storage/transit was also studied. The results are presented in para 3.2.2.1. It was observed that even when the population of larvae inoculated in pots was as low as 500/pot, the harvested tubers suffered a loss of 19.63 per cent in store in three weeks time while at higher levels of 1000 to 8000 larvae per pot the damage ranged from 20-88.42 per cent during the period. Hence in assessing the crop loss caused by root knot nematode the qualitative deterioration of the tubers obtained also has to be computed.

Histopathology of colocasia roots infested with *M. incognita*

The histopathology of roots of sweet potato (Krusberg and Nielson, 1958) and coleus (Sosamma, 1988) infested by *M. incognita* has been studied earlier. Colocasia being an important tuber crop grown in Kerala the nature of damage caused by the nematode was included in this studies. This is being done for the first time. Results presented in paragraph 3.2.1.2 showed that as in the other tubers juveniles migrate into the root tissue and feed at the stele pericycle or cortical region of the root. In all these hosts giant cells developed at the head end of the female nematode. Eggs are laid within the plant tissues in coleus and colocasia while they are seen protruding out in the roots of sweet potato. At the feeding site extensive necrosis and rotting of the tissues was seen in colocasia and coleus while in sweet potato the rotting was not that extensive. Mild galling and very small galls were seen in the roots of sweet potato while the galling was reported to be very extensive in coleus, the galls being very large and prominent. In colocasia slight thickening of the roots could be observed and the galls were also prominent.

The effect of water stress on the attack of *M. incognita* on different tuber crops

The favourable influence of irrigation on the population build up of different nematodes and consequent variations in damage caused by varying levels of irrigation

Table 16. Effect of varying levels of irrigation on the growth parameters of different tuber crops

Growth characters	Percentage reduction/increase over control in plant characters in					
	Sweet potato		Coleus		Dioscorea	
	HFI	LFI	HFI	LFI	HFI	LFI
Vine length/shoot length	11.86	9.18	24.13	15.58	5.35	6.34
Number of leaves	14.47	17.14	19.27	19.36	7.60	8.90
Shoot weight	14.05	11.02	33.72	28.08	4.61	5.78
Root weight	10.91	12.13	+5.68	+6.56	5.81	5.03
Weight of tubers/ tuberous roots	17.63	8.15	-	-	3.39	6.01
Number of branches	-	-	15.24	5.28	-	-

HFI - Higher frequency of irrigation

LFI - Lower frequency of irrigation

have been reported by earlier workers (Rodriguez and Caraballo Llosus, 1981; Onyoenobs, 1985; Kretsch, 1987). Some observations on this aspect relating to sweet potato also have been made (Rodriguez and Caraballo Llosus, 1981). Detailed studies on this aspect was just necessary since the information gathered might be useful for the development of cultural techniques for controlling the nematodes in field situations. The results of the pot culture experiment on this aspect are presented in paragraph 3.2.2 to 3.2.4. The water stress was generated by limiting the frequency of irrigation to the minimum possible level at which each crop just escaped wilting. This was ascertained by conducting observational trials. The extent of reduction in the vine length, number of leaves, shoot weight, root weight, tuber weight and number of branches have been summarised in Table 16. The results showed that the extent of adverse effect on the crop growth did not show wide variation at the two levels of irrigation. The loss in tuber yield was higher with more frequent irrigation (17.63 per cent) than with less irrigation (8.15 per cent) in sweet potato while in dioscorea the result was the reverse (3.39 and 6.01 per cent). Since proper tuber setting could not be observed in coleus during the period of the experiment (it is a seasonal crop) the effect of

Table 17. Effect of varying levels of irrigation on the population of *M. incognita* and on the damage of crops

Parameters	Percentage reduction in population of nematodes and damage indices in		
	Sweet potato	Coleus	Dioscorea
Population of nematodes in soil (100 ml)	34.05	37.12	26.55
Population of nematodes in roots (5 g)	39.94	33.93	26.33
Population of nematodes in tubers (5 g)	28.49	-	14.29
Number of root knots per 10 cm root	21.14	20.89	-
Percentage (weight) of galls on roots	23.11	17.87	-

irrigation on the yield of the crop could not be assessed. In coleus the adverse effect on the growth of the plant by nematodes appears to be maximum with higher levels of irrigation than under water stress. The population of nematodes in soil, roots, tubers as well as the number of root knots and percentage of root gall (weight basis) are presented in Table 17. The results showed that the less frequent irrigation in sweet potato and coleus caused higher reduction in the population of the pests compared to the population in dioscorea. Thus in dioscorea the reduction of pest population due to water stress appeared to be comparatively less than those of sweet potato while the reduction in tuber weight was more when compared to that of sweet potato. The results indicate that even with a lesser population more damage can occur in a crop under water stress and the response varies with the crop. The results also indicate the possibilities of regulating the nematode population and the consequent damage in crops through the adjustments in irrigation provided the technology is evolved independently for each crop and for each cropping situations.

Summary

SUMMARY

A detailed survey on the distribution of plant parasitic nematodes associated with the major tuber crops was conducted for the first time in Kerala during the period December 1988. The survey was carried out with a view to ascertaining the extent and intensity of the infestation of different tuber crops by the different genera of nematodes. Stratified multistage random sampling technique was adopted for the survey. Five panchayats were selected from one each of the five agroclimatic zones of Kerala. Samples of soil from around root zone and of the root of the crops were collected from four holdings in each panchayat.

Survey revealed that two genera of nematodes Meloidogyne sp. and Rotylenchulus sp. were frequently associated with the five tuber crops included in the study. The two genera could be extracted from soil and root samples of all the five tuber crops. Among the two genera Rotylenchulus sp. was more frequently seen and in high numbers in tapioca, sweet potato and dioscorea while Meloidogyne sp. dominated in crops colocasia/xanthosoma and C. parviflorus. Meloidogyne sp. was found in very high level in C. parviflorus.

Other nematodes obtained from all the five tuber crops in soil from root zone of plants but not from roots were Helicotylenchus sp. and Radopholus sp. Tylenchorynchus sp could be seen in the soil samples associated with all the crops except dioscorea. Hoplolaimus sp. was seen in soil sample associated with dioscorea in most of the panchayats surveyed. Pratylenchus sp. was observed in soil samples associated with all the tuber crops while it was recovered from root samples of dioscorea and colocasia/xanthosoma only. Heterodera sp. observed in soil and root samples associated with colocasia/xanthosoma from one panchayat while it was recovered from soil samples associated with sweet potato from two panchayats. Tylenchus sp. was seen in soil samples associated with tapioca and sweet potato from one panchayat each.

The effect of varying levels of M. incognita on the growth parameters and yield of C. esculenta was assessed in a pot culture experiment. A population of 500 larvae per plant significantly reduced tuber yield by 12 per cent over control. Plant girth and number of leaves were also significantly reduced but the plant height, shoot weight and root weight were on par with control. With an increase in the initial population of the pest a progressive suppression in plant height, number of leaves, shoot weight, root weight, weight of tubers and an increasing trend in pest population, root knot and percentage of galls (weight basis) were observed. But the increase was not linear.

The observation on the spoilage of tubers harvested from different treatments in the pot experiments and stored revealed that even when the population of larvae inoculated in pots was as low as 500 per pot harvested tubers suffered a loss of 19.63 per cent. At higher levels of 1000 to 8000 larvae per pot the damage ranged from 20 to 88.42 per cent. Hence in assessing the crop loss potential damage in storage also should be computed.

Histopathological study of the colocasia roots infested by *M. incognita* showed that the juveniles migrate into the root tissues and feed at the stele, pericycle or cortical regions of the root. Giant cells developed around the head of the nematode. Eggs were laid in the tissues. In the advanced stages necrosis and rotting were seen at the feeding sites. Cavities were formed by the disintegration of giant cells and nematodes. In general the damage was similar to those reported on coleus and sweet potato earlier.

Pot experiments were conducted to gather informations on the effect of water stress on the attack of nematode (*M. incognita*) on sweet potato, *C. parviflorus* and dioscorea.

Water stress was generated by limiting the frequency of irrigation to the minimum possible level at which the crop just escaped wilting. The experiment showed that the extent of adverse effect on the crops did not show wide variation at the normal and water stress conditions. The loss in tuber yield was higher with more frequent irrigation than with less irrigation in sweet potato while in dioscorea the result was reverse. In coleus the adverse effect on the growth of the plant by nematodes was found more with higher level of irrigation. Less frequent irrigation in sweet potato and coleus caused higher reduction in the population of the pest compared to that in dioscorea. Even with lesser population of nematodes more damage can occur in a crop under water stress and the response vary with crops.

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* Original not seen

Appendices

Appendix I

Summary analysis of variance related to Tables 6, 7 and 8.

Source	df	Mean squares		
		Plant height	Plant girth	Number of leaves
Treatment (A)	5	1623.50**	27.21**	16.32**
Error 1	24	57.47	0.58	0.39
Months after inoculation (B)	4	25017.37**	216.28**	14.49**
A x B	20	199.93**	3.02**	1.81**
Error 2	96	28.85	0.41	0.29

** Significant at 1% level

Appendix II

Summary analysis of variance related to Table 9.

Parameters	Source	df	Mean squares
Shoot weight	Treatments	5	82189.00**
	Error	24	3607.75
Root weight	Treatments	5	4919.97**
	Error	24	106.82
Weight of tubers	Treatments	5	7217.04**
	Error	24	444.29

** Significant at 1% level

Appendix III

Summary of analysis of variance related to Table 10.

Parameters	Source	df	Mean squares
Population of nematodes in soil (100 ml)	Treatment	5	32.16**
	Error	24	0.75
Population of nematodes in soil (5 g)	Treatment	5	73.38**
	Error	24	2.72
Population of nematodes in tubers (5 g)	Treatment	5	18.99**
	Error	24	1.87
Root knots per 10 cm root	Treatment	5	8.28**
	Error	24	0.27
Percentage (weight) of galls in roots	Treatment	5	3237.60**
	Error	24	25.52

** Significant at 1% level

APPENDIX IV

Summary of analysis of variance related in Table 12

Source	df	Mean squares: Vine length	Mean squares: Number of leaves	Mean squares: Shoot weight	Mean squares: Root weight	df	Mean squares: Weight of tuberous roots
Treatments	23	4531.52**	27140.74**	2939.74**	82.63**	19	158363.10**
A	5	12957.48**	82500.70**	81646.90**	236.51**	4	672707.30**
B	3	10495.33**	60527.00**	74624.00**	208.39**	3	46672.75**
AB	15	530.10**	2010.17**	2788.90**	6.18**	12	15787.61**
Error	96	101.36	497.08	507.15	1.84	80	1330.73

Source	df	Mean squares: Population of nematodes in soil	Mean squares: Population of nematodes in roots	df	Mean squares: Population of nematodes in tuberous roots	Mean squares: Number of root knots/ 10 cm root	Mean squares: Percentage (weight of galls on roots)
Treatments	11	31.87**	8.53**	9	2.23*	3.29**	157.92**
A	5	60.17**	11.24**	4	3.83**	6.90**	292.86**
B	1	40.88**	27.41**	1	3.24*	1.22 NS	101.16*
AB	5	1.77 NS	1.67 NS	4	0.37 NS	0.21 NS	37.26
Error	48	1.38	1.16	40	0.79	0.33	10.09

** Significant at 1% level

* Significant at 5% level

NS Not significant

APPENDIX V

Summary of analysis of variance related in Tables 13 and 14

Source	df	Mean squares				
		Number of leaves	Number of branches	Shoot length	Shoot weight	Root weight
Treatments	39	139271.20**	205.99**	3883.83**	9473.14**	356.96**
A	9	442970.20**	737.25**	11296.79**	26011.59**	1302.88**
B	3	360944.40**	16.59**	8098.48**	28498.09**	181.83**
AB	17	13407.85**	7.38**	222.33**	1846.49**	61.14**
Error	160	1841.26	3.42	21.78	109.77	3.26

Source	df	Mean squares		df	Mean squares	
		Population of nematodes in soil	Population of nematodes in roots		Number of root knots per 10 cm root	Percentage (weight) of galls in root
Treatments	19	462.17**	451.17**	17	8.69**	1539.69**
A	9	913.49**	912.31**	8	17.69**	3149.33**
B	1	388.15**	333.27**	1	4.67**	752.41**
AB	9	19.07**	13.67**	8	0.13 NS	28.46 NS
Error	80	2.67	4.32	72	0.44	26.99

** Significant at 1% level

* Significant at 5% level

NS Not significant

APPENDIX VI

Summary of analysis of variance related to Table 15

Source	df	Mean squares			
		Vine length	Number of leaves	Shoot weight	Root weight
Treatments	23	215095.10**	24005.87**	279734.50**	4504.81**
A	5	837295.20**	88992.05**	1153377.70**	17434.45**
B	3	183480.00**	31000.67**	200532.00**	4800.75**
AB	15	17016.80**	1082.75*	4360.53*	135.58 NS
Error	96	1783.32	522.71	2406.17	145.03

Source	df	Mean squares Weight of tubers	df	Mean squares Population of nematodes in soil	Mean squares Population of nematode in roots	df	Mean squares Population of nematodes in tuber
Treatments	15	44684.38**	11	1.95 NS	0.88 NS	7	0.25 NS
A	3	180134.10**	5	1.62 NS	0.62 NS	3	0.30 NS
B	3	25001.59**	1	12.27**	5.50**	1	0.28 NS
AB	9	6059.21**	5	0.21 NS	0.23 NS	3	0.19 NS
Error	64	993.13	48	1.54	0.72	32	0.70

** Significant at 1% level

* Significant at 5% level

NS Not significant

NEMATODES ASSOCIATED WITH THE TUBER CROPS IN KERALA

By

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ABSTRACT OF A THESIS

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A survey of plant parasitic nematodes of tuber crops, cassava, sweet potato, coleus, colocasia/xanthosoma and diascorea in twenty five panchayats representing five agroclimatic zones of Kerala was conducted during December, 1988. This was the first attempt in this line of investigation. Meloidogyne sp. and Rotylenchulus sp. were more widespread with all the five tuber crops in the five agroclimatic zones of Kerala. These two genera were seen in soil and root samples. Rotylenchulus sp. was more predominant than Meloidogyne sp. in tapioca, sweet potato and diascorea than in colocasia/xanthosoma and coleus. The two genera of nematodes are potential threat to cultivation of all the five tuber crops in Kerala. Pratylenchus sp. was also observed in soil samples associated with all crops but it could be collected from the root samples of diascorea and colocasia/xanthosoma only. In high population the genera may become a potent menace to both the crops since its pathogenecity on these crops have already been established. Helicotylenchus sp. and Radopholus sp. could be seen in soil samples associated with all the crops, Helicotylenchus sp. was more predominant in distribution and intensity in the tuber crops in all the agroclimatic zones. Hoplolaimus sp. was seen associated with diascorea alone in soil samples among the five crops in most cases. *Tylenchorynchus sp.* could be obtained from soil samples associated with all crops except diascorea. *Heterodera sp.* and *Tylenchus sp.* were recorded from colocasia/xanthosoma and sweet potato very sparsely.

The effect of varying levels of *M. incognita* on the growth parameters and yield of *C. esculenta* was assessed in a pot culture experiment. A population of 500 larvae per plant found causing 12 per cent yield reduction over control. With an increase in the initial population of the pest a progressive suppression in plant height, number of leaves, shoot weight, root weight and weight of tubers and an increase in trend in pest population, root knot and percentage of galls (weight basis) were observed. But these were not linear. Apparently healthy tubers harvested from the nematode inoculated treatments suffered spoilage in storage. Histopathological observation of *M. incognita* infested colocasia roots showed that the damage was similar to those reported in coleus and sweet potato.

A pot culture experiment revealed that the extent of adverse effect on the tuber crops did not show wide variations at the normal and water stress conditions. In coleus the adverse effect on the growth of the plant by nematodes was more with higher levels of irrigation. Less frequent irrigation in sweet potato and coleus caused higher reduction in the population of the pests compared to that in dioscorea. Even with lesser population of nematodes more damage can occur in a crop under water stress and the response was found to vary with crops.