STUDIES ON THE ROOT - KNOT NEMATODE OF PEPPER (Piper nigrum L.)

BY

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THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE

REQUIREMENT FOR THE DEGREE

MASTER OF SCIENCE IN AGRICULTURE

FACULTY OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI - TRIVANDRUM

1977

DECLARATION

I hereby declare that this thesis entitled "Studies on the root-knot nematode of pepper (*Piper nigrum* L.)" 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.

(J. ARTHUR JACOB)

Vellayani,

August, 1977.

CERTIFICATE

Certified that this thesis, entitled "Studies on the root-knot nematode of pepper (Piper nigrum L.)" is a record of research work done independently by Shri.J.Arthur Jacob, 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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A C K N O W L E D G E M E N T S

The author wishes to place on record his deep sense of gratitude and indebtedness to:

Dr.K.John Kuriyan, Associate Professor of Nematology for his sincere guidance, critical suggestions and constant encouragement during the course of this investigation,

Dr. M.R.G.K. Nair, Professor of Agricultural Entomology, for his inspiring suggestions and valuable advices during the course of this investigation,

Shri. J.Johnson, Associate Professor of Agricultural Entomology, Shri. P.V. Pally, Associate Professor of Plant Pathology, Dr. Abraham Jacob, Assistant Professor of Agricultural Entomology for their suggestions and criticisms,

all other members of the Division of Agricultural Entomology for their help during the course of this investigations,

The Kerala Agricultural University for awarding me the merit scholarship.

(J. ARTHUR JACOB)

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INTRODUCTION

INTRODUCTION

Pepper, Piper nigrum L., king of spices, is one of the most remunerative cash crops, grown in different parts of South and South East Asia. Pepper contributes about 50 per cent of the gross value of all spices produced in India. The production of pepper during 1975-76 was 27728 tonnes, from an area of 120956 hectares. This is 25 per cent of the total world production (Shanmugavelu and Madhava Rao, 1977). The export of Black pepper earned a foreign exchange of Rs.34.48 crores during 1974-75 (George, 1976).

Kerala is the leading state in India for pepper cultivation producing 90 per cent of the total production. The area under pepper during 1975-76 was 117516 hectares and the production was 27564 tonnes with an average yield of 235 kg black pepper per hectare (Anon, 1977).

The yield of pepper had been declining in Kerala during the past two decades. There was a decrease of 1.3 per cent per hectare during 1974-75 over 1973-74 (Anon, 1976).

It is recognised that diseases and pests contribute substantially in limiting production of pepper in Kerala.

Among pests, nematodes have recently been observed to constitute a major threat to the pepper production in the State (D'souza, et al., 1970; Venkitesan, 1972). The slow wilt disease prevalent in many pepper growing tracts is suspected to be a complex of nematode and fungus infection, coupled with nutritional deficiency (Radha and Rawther, 1976). Among other diseases of pepper, root-knots caused by the nematodes of the genus Meloidogyne is one of the most important (Venkitesan, 1972). The nematodes often become a serious limiting factor for successful cultivation of this crop resulting in heavy loss of yield (Minto, 1972 and Ting, 1975).

Though the occurrence of root-knot nematode was reported in 1972 (Venkitesan), investigation of this nematode on pepper was not done in this State.

Therefore, to gather some information on the extent of damage done by this nematode on pepper and to evolve suitable control measures, the present investigation was carried out.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The occurrence of root-knot nematodes, Meloidogyne spp. attacking almost all the economically important crops in different parts of India had been reported by many workers (Sitaramaiah, et al., 1971).

Reports from Kerala include those of Nadakal (1963, 1964, 1965), Mammen 1973 (a), 1973 (b), Venkitesan (1972) and Raveendran and Nadakal (1975). Venkitesan (1972) reported the occurrence of root-knot nematode, M. incognita on Black pepper. Mammen (1973 b) reported the infestation of root-knot nematode M. incognita on Ginger.

Sharma and Loof (1974) recorded M. incognita among other nematodes infesting pepper in Brazil. Ting (1975) reported Meloidogyne spp. as the most important group of nematodes in Malaysia causing gradual decline of Black pepper characterised by unthrifty growth and yellowing of leaves. Ichinohe (1976) recorded the infestation of Black pepper by the root-knot nematode in Brazil.

Radha and Rawther (1976) suspected the slow wilt of pepper to be a complex of fungal and nematode infection coupled with nutrient deficiency.

Economic importance.

Olthof, et al., (1970) recorded the plant parasitic

nematodes of economic importance in Ontario and found that the most destructive ones include Meloidogyne sp.

A severe infestation by root-knot nematodes M. javanica was observed in Curu Valley (De Ponte, et al., 1971). Dement'eva (1971) found M. hapla and M. incognita were infesting Tomato, Pepper and Egg plant in 10 of 15 regions of Moldavia. Attack varied greatly in intensity from region to region. A severe occurrence of M. hapla on sugar beet resulted in crop losses of 20 per cent and none of the cultivars exhibited resistance (Grujicic, et al., 1971).

Bhardwaj, et al., (1972) recorded the root-knot nematode Meloidogyne spp. infestation on Tomato in Solan area of Himachal Pradesh. Studies indicated that M. incognita and M. javanica were serious pests of tomato in the Solan area of Himachal Pradesh. The nematode infestation range between 5 and 100 per cent in the various localities surveyed. Rao and Biswas (1973) evaluated the yield losses in rice due to the root-knot nematode M. incognita. The grain weight was less in the case of infected plants.

Host range of Root-knot nematode.

David (1959) reported the occurrence of Meloidogyne spp.

on sugarcane roots in Nellikkuppam and surrounding areas in Madras State. Dutt (1960) recorded the incidence of M. incognita on bitter jute Corchorus capsularis and C. olitorius. Dhande and Sulaiman (1961) found the occurrence of root-knot nematodes on betelvine in Maharashtra. M. incognita was reported as parasite on 5 species of Banana in Philippines which was a new host record for this nematode (Claudio and Davide, 1968).

Krishnamurthy and Elias (1968) reported M. incognita causing root-knot on tobacco in Mysore State. Mathus, et al., (1970) recorded stem galls caused by M. javanica in Rajasthan in Cucurbita maxima and Lagenaria siceraria. M. incognita caused prominent stem galls in Luffa acutangula. Saxena and Chhabra (1970) found the infection of M. javanica and M. incognita in peaches (Prunus persica), a new record from India. Singh and Misra (1970) reported the root-knot nematodes M. incognita and M. javanica on sugar beet in India. Kumar, et. al., (1971) found that M. incognita multiplied on Elettaria cardamomum, Musa sp., Piper nigrum, Ananas sativum and Theobroma cacao. Nigam and Reddy (1972) reported Trianthema govindea as a new host of M. incognita and M. javanica. Chandramathi (1973) reported the occurrence

of root-knot nematode in Weeta (Hibiscus cannabinus).

Hannen (1973 a) found M. incognita infesting the cover crops in rubber plantations of Kerala. The leguminous cover crops Calopogonium mucunoides and Pueraria phaseoloides widely grown in rubber plantations in Kerala were attacked by M. incognita. Mukherji and Sharma (1973) identified M. incognita in galled roots of Trichosanthes dioica. The plants were stunted and yield of fruits reduced. Bano (1974) recorded the weed hosts of root-knot nematodes in Tea estates around Assam. Amaranthus graecilis and Chenopodium amaranticolor were also found to be attacked by M. incognita (Haqui and Alam, 1974). Sharma and Loof (1974) studied the nematodes of cocoa and nematodes in the rhizosphere of pepper (Piper nigrum) and clove (Eugenia caryophyllata). Examination of soil and root samples from around Piper nigrum revealed the presence of M. incognita.

Alam (1975) recorded the Cassia tora, Cucumis melo, Gomphrena globosa as the new hosts of M. incognita from India. Jayaraman, et. al., (1975) reported the occurrence of root-knot nematodes M. javanica and M. incognita in Polianthes tuberosa for the first time. Raveendran and Hadakal (1975) reported M. incognita to attack 11 plants of commercial importance. A survey in Aligarh revealed

the presence of M. incognita on Hibiscus rosasinensis and Cassia occidentalis (Alam, et al., 1976). Rao and Singh (1976) observed root-knot nematode M. incognita on commercial plantings of tuberose in India.

Symptoms and damage to crops by Root-knot nematodes.

Claudio and Davide (1968) studied the pathogenicity of M. incognita and found to cause stunted growth, bunching of petioles and narrow and pale yellow leaves. Wong and Willetts (1969) reported the gall formation in aerial parts of plants inoculated with M. javanica of tomato and beans. Birat (1970) found no galls on roots of chillies and wheat attacked by M. javanica.

Clemons and Krusberg (1971) observed that the root-knot nematodes Meloidogyne spp. feeding on trees may cause severe scorching by interfering with water transport in trees especially during dry periods. Root-knot nematodes artificially inoculated on potato and coleus stems induced galls on the latter (Huang and Lin, 1971). Development of the stem galls involves giant cell formation, hyper-plasia, abnormal tracheal differentiation and disappearance of starch reserves from the infected tissues. Only those nematodes having their heads associated with vascular parenchyma developed to maturity.

Kinloch and Allen (1972) showed M. hapla to produce a greater incidence of terminal galls and lateral roots on tomato. Winto (1972) studied the effect of Meloidogyne spp. on the growth of Piper nigrum. Seedlings of Piper nigrum were inoculated with M. incognita or M. javanica and observed for 10 months. It was found that growth of the main and lateral shoots was greatly reduced in infected plants and leaves were yellow.

The effect of M. incognita on the growth characteristic of brinjal with reference to shoot length was studied by Prasad and Gaur (1974) and found them to reduce the plant growth. Reduction in root weight and in root surface was also reported by Waseem Ismail and Mashkoor Alam (1975).

Screening and surveying.

Kurian (1970) screened 323 varieties of tobacco and found 319 highly susceptible, 3 moderately resistant and one resistant against M. incognita and M. javanica. Yadav , et al., (1970) reported 30 different plant species as hosts of M. incognita in Rajasthan.

Bhardwaj, et al., (1972) found the root-knot nematode Meloidogyne spp. infestation ranged between 91 and 100 per cent on tomato in Solan area of Himachal Pradesh.

Ichinohe (1975) surveyed the fields of Black Pepper (Piper nigrum) in Brazil. Only one field out of 74 was free of infection by M. incognita. Out of 85 hybrids of tomato and 18 parents tested by Mahajan, et al., (1975), a high degree of resistance was shown by crosses having Nematex as a parent. Nematex was completely resistant and the most susceptible varieties were PI 32782 and Fire cracker. Sasser (1975), suggested that a probability index can be developed to predict the likelihood of a given nematode species being transported, established and becoming economically important in regions of the world where it does not already occur.

Histopathology.

Baldwin and Barker (1970), recorded the development of giant cells, hyper-plasia and root necrosis , on corn hybrids infected with M. incognita. Webber, et al., (1970), recorded the effect of M. incognita on transpiration of tomato. Under stress conditions transpiration rates from infected plants were greater than from controls and were disproportionately higher than expected in relation to the quantity of leaf tissue.

Ernie and Bergeson (1974) observed the biochemical changes in root exudate and xylem sap of tomato plants

infected with M. incognita. Aminoacids were moderately reduced to 52 to 56 percentage. Galled root exudate contains 3 sugars, 12 Aminoacids, 3 organic acids. Healthy root exudate contained 4 sugars, 15 Aminoacids and 4 organic acids. Michael, et al., (1974) found that development of M. incognita in the resistant cotton roots was greatly retarded.

Sharma and Sethi (1975) reported that the nematodes interfered with leghaemoglobin content of cow pea root nodules, with M. incognita causing more reduction, than Heterodera cajani. Siddiqui and Ghouse (1975) indicated the formation of phloem at all levels of infection of L. leucantha by M. incognita.

M. incognita was generally found inside vascular bundles in soybean nodules by Barker and Mussey, 1975. This parasite did not alter the structural integrity of soybean nodules. Ogboji (1976) found that in corn the giant cell developed mainly in the stele and there was the rare case of giant cell formation in the cortex. Giant cells contained several nucleii either scattered or in clusters. Cytoplasm of the giant cells was dense and cell walls thickened.

The seedlings of Hibiscus sabdariffa growing in infected soil contained larvae of M. incognita or M. javanica in hypocotyl tissue before emergence from the soil. During

growth, galls developed on the stems below the cotyledons and giant cells formed after 40 days (Taylor, 1976)

Resistance of crops to Root-knot nematodes

Barrons (1939) found that mean number of larvae observed in ten rootlets each of ten plants of resistant and susceptible varieties of Lenia beans was 3.84 to 4.70 in the resistant and 3.95 to 5.40 in the susceptible variety.

Work of Christie (1949) showed that production of giant cells is necessary for development of root-knot nematode females and that host plants may react differently with regard to resistance against individual species of Meloidogyne.

Drolsom and Moore (1958) found that in flue cured tobacco lines of root-knot resistant parentage, the breeding lines differed in respect of the amount of egg production by the various root-knot nematode species.

Powell (1962) studied the histological basis of resistance to root-knot nematodes in the cured tobacco and the comparative studies made of M. incognita acrita in both susceptible and resistant tobacco lines showed that there were no apparent differences in reaction between resistant and susceptible plants after three days and after giant cell initiation had begun in each.

Graham (1965) observed that NC 95 tobacco was resistant to M. incognita acrita but susceptible to M. javanica.

Kurian (1970) found three varieties of Nicotiana rustica to be moderately resistant to M. incognita and M. javanica.

Curi, et al., (1971) studied the new sources of genetic resistance of coffee in the control of the coffee nematode M. exigua. They found all varieties of C. canephora, C. congenis and C. eugenioides resisted the infestation.

Except the wild species of tomato which is resistant all species of tomato were susceptible to attack by M. incognita. Of the 20 varieties of cucurbits tested, only Cucumis sp. (var. Bikaner) and Cucurbita moschata (var. Jaipuri) proved tolerant to infection by M. incognita (Khan, et al., 1971).

Fassuliotis and George (1972) screened cucurbits against M. incognita and found a total of 542 plants of Cucurbita spp. were susceptible and exhibited the galling response. Resistance to root-knot nematode was difficult to find in these species. Jatala, et al., (1972) reported the sweet potato varieties, Allgold as susceptible and Nemagold as resistant variety against M. incognita. Infestation of the root-knot nematode resistant tobacco variety NC 95 by M. incognita was reported by Reddy, et al.,(1972). This confirms the presence of

pathotypes in this nematode species.

Singh and Chaudhury (1973) concluded that tomato varieties S1 120 and Nematex can be used commercially and that VFN-8 65 N 215-1 and 65 N 255-1 can be used as a source of resistance to be transferred to commercial cultivars.

All the 14 varieties of pepper, 7 okra and all except the 3 varieties of 14 egg plant tested were highly susceptible to the nematode attack(Alam, et al., 1974).

Dhillon and Nandpuri (1975) recorded the root-knot nematode resistance in tomato varieties 7540 and Heeleni showed a high degree of tolerance and was followed by Kalohi. Jonnee, et al., (1975) found sweet potato variety W 13 was resistant to M. incognita. It is high yielding with well shaped, copper skinned orange fleshed tubers.

Control.

Winchester and Ozaki (1964) found Guano and calcium nitrate fertilized with sodium nitrate and ammonium nitrate to be more effective against M. incognita.

Ditrapex,Nefis, Nemaphos, Neosar and Temik were tested against nematodes, mainly M. incognita on tobacco in Italy by Dimuro (1970). High nematicidal effect was obtained with Temik and with Nemaphos.

Mukhopadhyaya (1970) studied the efficacy of DD, EDB, DBCP and VC-13 in controlling plant parasitic nematodes. In a potato field in Himachal Pradesh infested with M. incognita numbers of larvae were reduced by 90 per cent with DD (400 lit/ha) and EDB (150 kg/ha) and by 70 per cent with DBCP (45 lit/ha) as compared with an increase of 65 per cent in the control plots.

The control of M. incognita on potato by various nematicides was assessed in 3 year trials at Simla by Raj and Nirula (1970). Build up of nematode numbers and root infection was significantly lower in plots treated with Temik, Phorate, Disulfoton, Zinophos, Nellite, Nemacide and Vapam than in control plots but no treatment completely erradicated the nematode. Temik prevented the attack of tubers and Zinophos, Phorate, Disulfoton, Nellite and Nemacide reduced tuber infection.

Yadav (1970) tested the nematocidal properties of some weed plants on M. incognita. Root exudate of Euphorbia hirta inhibited the hatching of M. incognita eggs. E. microphylla, Trienthema protulacastrum were also found effective.

Root dip treatments of Tomato seedlings with Parathion, Dimethoate and Diazinon, Fenitrothion, Gardona, Formothion,

Disulfoton and Carbofuran were found effective by Bindra and Kaushal (1971).

Temik, Phorate, Disulfoton, Dinophos and Nellite at the rate of 5 kg/ha, Nemacide at 25/ha and Vapam at 200/ha were tested for the control of M. incognita on potato. No tuber infestation was found in the plots treated (Raj and Mirula 1971 a).

Raj and Mirula (1971 b) tried DD against root-knot nematode and found DD at 600 lit/ha was significantly more effective in reducing the population of Meloidgyne larvae than at 200 lit/ha.

Field experiments conducted by Singh and Sitaramaiah (1971) have shown that effective control of M. javanica can be achieved if the soil is amended with 2200 lb/acre sawdust, 3 weeks before planting followed by inorganic nitrogenous fertilizers along with P and K applied at the time of planting. Not only was the intensity of root galls reduced but several fold increase in yield had also been obtained by this treatment.

Goswami and Swarup (1972) recorded the effect of oil cake amended soil on the growth of tomato and root-knot nematode population. The soil amended with Karanj and

groundnut cakes, showed considerable decrease in populations of the nematodes and improved the growth of plant.

Reddy and Seshadri (1972) found that tomato plants treated with Thionazin or Aldicarb were not invaded by larvae of M. incognita.

Meloidogyne sp. control and tobacco yields in plots infected with M. incognita and treated with non volatile nematicides, Aldicarb, Nemacp were greater than those on similar plots treated with volatile nematicides such as DD, DD + MIMCS, Tetrachloro thiophene. Root-knot control and tobacco yields in plots treated with Carbofuran or Dasanit were equal to that obtained with DD + MIMCS, but less than that obtained with the other volatile soil nematicides (Broodie and Good 1973).

Temik 10 G, Nemacp 10 G and Nemagon 20 G applied at 1 gm/gallon of water as 15 minutes dip treatment to Banana suckers, resulted in slight to moderate galling from M. incognita in pot experiments and gave greater increase in growth (Davide 1973).

Di Sanzo (1973) studied nematode response to Carbofuran and concluded that Carbofuran may act by affecting orientation and feeding mechanism of nematodes. Khan, et al., (1973) tried organic amendment in the form of oilcakes of Neem,

Castor, Groundnut on Tomato plants affected by M. incognita.

Bindra and Goodan (1974) conducted experiments on the chemical control of root-knot nematode. In pot experiments Brinjal plants in soil infected with M. incognita were treated with DD as a preplant soil infection at 5 doses from 112.33 to 336.99 litres ai/ha or with a broadcast application of Phorate at planting time at 5 doses from 1.24 to 7.41 kg ai/ha. All treatments resulted in significantly lower nematode population than untreated.

Temik 10 G, Dasanit 5 G, Thimet 10 C broadcast at 10 kg ai/ha before transplanting of tomato to a field infested with M. incognita and Tylenchorhynchus brassicae, each effectively reduced the population of both nematode species. However only Aldicarb gave significantly increased yields (Chhabra and Mahajan 1974).

Desai, et al.,(1974) worked on the nematicidal property of some plant extracts against a mixed population of larvae of M. javanica and M. incognita acrita. Out of 26 extracts,13 were found effective. However, the active chemical principles in these plants have yet to be determined.

Khan, et al., (1974) worked on the effect of water soluble fraction of oil cakes and bitter principles of

neem on some fungi and nematodes. Water soluble fractions of the oilcakes, neem, groundnut and castor inhibited larval hatch of M. incognita. The bitter principles of neem namely nimbidin and thionimone also effectively suppressed the growth of fungi in culture media and were highly effective in killing the nematodes and inhibiting the larval hatch of M. incognita.

The reduction of Tylenchulus semipenetrans and root-knot nematode M. incognita populations in soil by chitin and cellulose amendments was demonstrated by Mankau and Sitanathdas (1974).

DD, DBCP, Fensulphothion, Aldicarb and Methomyl were tried against Meloidogyne spp. on chick pea and found to be giving good control and 15 to 37 per cent increased yield (Reddy 1975 a).

Spot application and row application of Aldicarb 10 G Fensulfothion 5 G or Carbofuran 3 G to tobacco seedlings planted in soil infested with M. incognita and M. javanica increased cured yields and decreased root galling. (Reddy 1975 b).

Application of 20 to 30 gm Dasanit 5 G in the basins of the vines followed by a drench of cerasan solution as a fungicide was recommended by Radha and Rawther (1976).

MATERIALS AND METHODS

MATERIALS AND METHODS

I. Survey

(a) Collection of soil and root samples.

Soil and root samples were collected from the base of healthy and diseased pepper plants. About 500 gm of the soil and 50 gm of the roots, each were collected at depths of 10 to 15 cm. Both soil and root samples were put in polythene bags with proper labels for further studies.

(b) Processing of soil samples.

Each soil sample was processed by Cobb's sieving and sifting technique (Cobb, 1918). The fine debris in the nematode suspension was cleared through a modified Baermann funnel technique (Staniland, 1954). The nematode suspension was drawn out after 48 hrs and used for further studies.

(c) Processing of root sample.

Ten grams of the root was weighed out from each sample and taken in a plastic container and the roots were gently cleaned of any soil adhering to them by holding them in a stream of water under a tap. The cleaned roots were then sliced into small bits of less than 1 cm in length. They were then put over a layer of tissue paper kept on the flat bottomed circular wire

gauze in a petry dish. The petry dish was filled with water just touching the base of the wire gauze. The setting was left undisturbed and at the end of 24 hours 30 cc of water was drawn out from the petry dish. This was continued till no more nematodes were obtained. The extracts were pooled together and used for further studies.

(d) Estimation of nematode population in soil and root extracts.

The nematode suspensions drawn from the Baermann funnel and the petry dish were taken in a clean 250 ml beaker, allowed to settle for 3 hours and concentrated to 5 ml by using a filter. The total population of Meloidogyne incognita and other genera of plant parasitic forms were counted and estimated from this 5 ml suspension. The nematode suspension was preserved by adding equal quantity of boiling 5 per cent formalin, whenever necessary, for further observation. The root-knot index was calculated as below:

$$\text{Root-knot index} = \frac{\text{No. of roots with root-knots}}{\text{Total No. of roots}} \times 100.$$

II. Screening of pepper varieties for resistance against M. incognita

(a) Collection of pepper varieties.

The following varieties were collected from

different localities for screening against M. incognita.

Name of variety	Locality
1. Pannlyur 1	Pannlyur, Neriamangalam, Kozha, Mavelikara, Peringamala.
2. Cheriakaniakadan	Pannlyur.
3. Kalluvally	Pannlyur.
4. Kottanadan	Pannlyur.
5. Balancotta	Pannlyur, Kozha.
6. Karimunda	Pannlyur, Neriamangalam.
7. Narayakodi	Palode.
8. Padappan	Palode.

(b) Preparation and sterilization of soil.

Pot mixture was prepared by mixing sieved field soil, sand and sieved, well decomposed farm yard manure in the ratio of 3 : 1 : 1. This soil-sand-compost mixture was sterilized (denematized) by applying Nemagon at the rate of 5 ml per 100 cft of pot mixture and stored away from contaminations, for use, as and when necessary. Whenever this soil mixture was used for experimental purposes, it was examined and confirmed that no nematodes were present.

(c) Raising and maintenance of rooted cuttings of pepper vine.

Stem cuttings of matured vines of pepper varieties were obtained and cuttings with 2 nodes were planted in 30 x 30 cm pots containing the sterilized soil mixture mentioned earlier. Each pot contained 5 kg of sterilized soil mixture. They were regularly watered and allowed to grow. Large numbers of such pepper seedlings were raised and maintained for experimental purposes.

(d) Pure culture of M. incognita.

Pure cultures of M. incognita were raised from single egg masses collected from pepper roots, after identifying the species by observing perineal pattern, and maintained on pepper plants in sterile soil. Further multiplication was done on pepper vines by collecting egg masses from the above culture maintained separately. Sub-culturing was done periodically to ensure availability of sufficient larval population for inoculation purposes. The culture so obtained was used in all the experiments.

(e) Screening of pepper varieties for resistance against M. incognita.

Eight cultivated varieties of pepper listed above were selected for screening. Sterilized pot mixture as described already was used for raising pepper plants.

The vines used were of same age, same height and were having same number of nodes. Eight rooted cuttings of each variety were inoculated with 500, one day old larvae of M. incognita. One plant of each variety was also maintained as control.

For obtaining one day old larvae of the nematode, a large number of egg masses from the culture plants maintained was hand picked and kept in a cavity block containing sterile water. Care was taken to see that the egg masses were in contact with water. Every 24 hours, the suspension in the cavity block was collected into a measuring cylinder. The number of larvae per ml of suspension was determined with the help of Peters one ml eelworm counting slide (Peters,1952). An average of three counts was taken as the number of larvae per ml of the suspension. The larval concentration was adjusted to 500 larvae per ml of suspension by dilution with a suitable quantity of sterile water. One ml of this suspension was used for inoculating each of the potted plant. Actual inoculation was done by boring 5 holes in the soil about 4 cm deep with a glass rod, 1.5 cm away from the base of the stem. One ml of the above

suspension was pipetted out equally into 5 holes which were closed immediately. The inoculation of all the eight replicates in each variety was completed on the same day. Pots were irrigated to keep the soil just moist. Six weeks after inoculation the following observations were taken on each plant.

1. Total number of roots.
2. Total number of roots with root-knots.
3. Total number of root-knots.
4. Weight of roots (wet).
5. Number of nematodes observed in 250 gm of soil and 10 gm of root.

The root-knot indices and the number of root-knots per gm of root were calculated. The root-knot index was calculated as described earlier.

III. Extent of damage caused by M. incognita infestation on pepper

Four varieties namely Panniyur I, Cheriakanlakadan, Kalluvally and Kottenadan were selected for this. The following observations were taken on the 9 experimental plants of each of the above varieties used for the screening, six weeks after inoculation.

1. Length of shoot from 1st node to tip.
2. Number of leaves.

3. Girth at first node.

4. Shoot weight.

5. Number of roots.

6. Weight of roots.

The inoculated and uninoculated plants were compared to study the extent of damage.

IV. Histopathology

Uniform seedlings of Panniyur 1 were selected from the sterile seedlings raised and maintained as described earlier, and inoculated with 100 one day old larvae of M. incognita. The inoculation was done by boring 5 holes in the soil about 4 cm deep with a glass rod and 1.5 cm from the base of the stem. After one month, one pepper plant was removed carefully and the roots washed free off all adhering soils. The roots were cut with the help of a sharp blade and fixed in F.A.A. The fixed roots were then processed for microtomy using safranin and fast green stain as described by Johansen (1940).

V. Control

Three months old rooted cuttings of Panniyur 1, infected artificially with M. incognita were used for this experiment. The experiment was laid out in a

completely randomised design (C.R.D.) with 6 different nematicides and six replications. The nematicides used and the dosages used were:

1. Nemagon 60 EC - 40 litai/ha (0.06 ml/3 kg of soil)
2. Dasanit 5 G - 60 kg ai/ha (1.8 gm/3 kg of soil)
3. Nocap 10 G - 10 kg ai/ha (0.15 gm/3 kg of soil)
4. Neemcake - 2000 kg/ha (3 gm/3 kg of soil)
5. Temik 10 G - 10 kg ai/ha (0.15 gm/3 kg of soil)

The observations, namely, height of the plant, number of leaves, girth of stem at the first node from the ground level, nematode population in soil in each pot, total number of roots and number of roots with root-knots were taken before applying nematicides. After 3 months, the above observations were again taken. The root-knot indices were calculated as in the screening experiment. The effect of nematicides was compared using the above data.

RESULTS

RESULTS

I. Survey

(a) Survey of nematodes associated with pepper in Kerala.

A survey of nematodes associated with pepper was made from different parts of Kerala. A total of 93 samples from different places spread out in 5 districts were collected. The soil and root samples were processed and examined as described earlier. The results are presented in Table 1.

A total of 44 samples were collected from Panniyur pepper tract, 16 samples from Neriamangalam tract, 9 samples from Kozha tract, 8 samples from Mavelikara tract and 16 samples from Peringamala tract. From table 1 it may be seen that all the areas covered were infested with root-knot nematode Meloidogyne incognita, Radopholus similis and Hellcotylenchus sp.

Species of root-knot nematode observed in all the samples were identified as M. incognita based on perenial pattern.

(b) Relative susceptibility of different varieties of pepper to infestation by nematodes in Kerala.

The population of different species of nematodes observed in 250 gm of soil and 10 gm of root is presented

Table-1. Survey of nematodes associated with pepper in different parts of Kerala

Locality	Pepper varieties examined	Nematode species noted		
		M. incognita	R. similis	Helicoty-lenchus sp.
Panniyur	Panniyur I, Karimunda, Balancotta, Kalluvally, Kottanadan, Chariakanlekadan.	+	+	+
Neriamangalam	Panniyur I, Karimunda.	+	+	+
Kozha	Panniyur I, Balancotta.	+	+	+
Mavelikara	Panniyur I.	+	+	+
Peringamala	Panniyur I, Local.	+	+	+

in Table No. 2.

In Ponniyur 1 variety, 250 gm of soil contained 27 to 467, with an average of 231 M. incognita, 0 to 140 with an average of 37 R. similis and 0 to 127 with an average of 34 Helicotylenchus sp. and in 10 gm of root, 0 to 98 with an average of 24 M. incognita, 0 to 33 with an average of 11 R. similis and 0 to 8 with an average of 1 Helicotylenchus sp.

In Karimunda variety, 250 gm soil contained 10 to 312 with an average of 151 M. incognita, 4 to 100 with an average of 45 R. similis and 2 to 95 with an average of 53 Helicotylenchus sp. and in 10 gm root, 0 to 41 with an average of 18 M. incognita and 0 to 17 with an average of 8 R. similis.

In Balancotta variety, 250 gm soil contained 26 to 533 with an average of 274 M. incognita, 0 to 91 with an average of 25 R. similis and 0 to 52 with an average of 28 Helicotylenchus sp. and in 10 gm root, 2 to 54 with an average of 25 M. incognita and 0 to 26 with an average of 11 R. similis.

In Kalluvally variety, 250 gm soil contained 30 to 396 with an average of 240 M. incognita, 0 to 63 with an average of 33 R. similis and 0 to 35 with an average of 16 Helicotylenchus sp. and in 10 gm root,

Table-2. Relative susceptibility of pepper varieties to infestation by different nematodes

Pepper variety	Population of nematodes in soil (250 g) and roots (10 g)											
	M. incognita				*R. similis*				*Helicotylenchus* sp.			
	Soil		Roots		Soil		Roots		Soil		Roots	
	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range	Average
Panniyur I	27-467	231	0-98	24	0-140	37	0-33	11	0-127	34	0-8	1
Karimunda	18-312	131	0-41	18	4-108	43	0-14	8	2-85	53	--	--
Balancotta	26-533	274	2-54	23	0-51	25	0-26	11	0-52	28	--	--
Kalluvelly	38-396	240	12-73	32	0-63	33	0-21	8	0-35	16	0-8	2
Kottanadan	32-513	281	0-54	25	0-22	9	0-23	10	9-18	14	--	--
Cheriakaniakadan	47-479	298	8-69	41	9-64	47	0-23	12	2-45	26	--	--
Peringamala local	12-93	56	0-16	6	6-21	13	--	--	0-21	12	--	--

12 to 73 with an average of 32 M. incognita, 0 to 21 with an average of 8 R. similis and 0 to 8 with an average of 2 Helicotylenchus sp.

In Kottamadan variety, 250 gm soil contained 32 to 513 with an average of 281 M. incognita, 0 to 22 with an average of 9 R. similis and 9 to 18 with an average of 14 Helicotylenchus sp. and in 10 gm root, 0 to 94 with an average of 25 M. incognita and 0 to 23 with an average of 10 R. similis.

In Cheriakamiakadan variety, 250 gm soil contained 47 to 479 with an average of 293 M. incognita, 9 to 64 with an average of 47 R. similis and 2 to 45 with an average of 26 Helicotylenchus sp. and in 10 gm root, 8 to 69 with an average of 41 M. incognita and 0 to 23 with an average of 12 R. similis.

In Peringamala local variety, 250 gm of soil contained 12 to 93 with an average of 56 M. incognita, 6 to 21 with an average of 13 R. similis, 0 to 21 with an average of 12 Helicotylenchus sp. and in 10 gm of root, 0 to 16 with an average of 6 M. incognita.

(c) Nematode population in relation to the wilt disease of pepper.

The population of nematodes present in soil and

roots of healthy and wilted plants of Panaiyur 1 variety is presented in Table 3. Two hundred and fifty gm soil of healthy Panaiyur 1 variety contained 27 to 467 with an average of 231 M. incognita, 0 to 140 R. similis with an average of 27 and 0 to 127 with an average of 22 Helicotylenchus sp. and 10 gm of root contained 0 to 98 with an average of 24 M. incognita, 0 to 30 with an average of 6 R. similis and 0 to 8 with an average of 1 Helicotylenchus sp. 250 gm soil of a wilted Panniyur 1 variety plant contained 149 to 2006 with an average of 925 M. incognita, 0 to 420 with an average of 91 R. similis and 0 to 581 with an average of 80 Helicotylenchus sp. and in 10 gm of root, 12 to 184 with an average of 81 M. incognita, 0 to 184 with an average of 8 R. similis and 0 to 57 with an average of 2 Helicotylenchus sp.

11. Screening of pepper varieties for resistance against Meloidogyne incognita.

Eight cultivars of Piper nigrum were screened against M. incognita as already described. The total number of nematodes observed in the soil and roots 6 weeks after inoculation of the nematode larvae, the root-knot index and the number of root-knots per gm of root are presented in Table 4 and Figure 1.

Table-3. Relative nematode population on healthy and wilted pepper plants: Variety - Pannlyur I

Nematode species	No. of nematodes in 250 gm soil & 10 gm root							
	Healthy				Wilted			
	Soil		Roots		Soil		Roots	
	Range	Average	Range	Average	Range	Average	Range	Average
M. incognita	27-467	231	0-98	24	149-2006	925	12-184	81
R. similis	0-140	27	0-33	6	0-420	91	0-184	8
Helicotylenchus sp.	0-127	22	0-8	1	0-381	80	0-37	2

Table-4. Population of M. incognita and root-knot index in different varieties of pepper, 6 weeks after inoculation

Name of pepper variety	Nematode population in		Root-knot index	No. of Root-knot/gm of root
	250 gm soil	10 gm root		
Panniyur I	1436	43	100	24
Cheriakaniakadan	1276	38	100	28
Kalluvally	1085	36	87	19
Kottanadan	947	35	83	23
Balancotta	860	28	71	19
Karimunda	851	29	68	17
Narayakodi	794	12	56	15
Padappan	720	14	53	13

From the table it can be seen that all the varieties tried are susceptible to the attack of M. incognita. Of these, Pannivur I and Cheriakanlakadan showed a root-knot index of 100 per cent indicating high susceptibility to M. incognita. The varieties Kalluvally, Kottanadan, Balancotta and Karimunda showed a root-knot index of 87, 83, 71 and 68 respectively against M. incognita. Narayakodi and Padappan varieties showed a root-knot index of 56 and 53 respectively against M. incognita indicating them to be less susceptible to these nematodes. The number of root-knots per gm of root in the highly susceptible varieties varied between 24 and 28, whereas in Kalluvally, Kottanadan, Balancotta and Karimunda varieties it was 19, 23, 19 and 17 and in the less susceptible Narayakodi and Padappan varieties it was only 1> and 13. The final population of nematodes after 6 weeks of inoculation with 500 larvae of M. incognita also showed a similar trend. The highly susceptible varieties showed the maximum number of 1436 and 1276 in 250 gm soil and 43 and 38 in 10 gm roots. The other four varieties showed a medium position with 1085, 947, 860 and 851 in 250 gm soil and in 10 gm root 36, 35, 28 and 29 respectively. The least population was seen in

Narayakodi and Padeppan with 794 and 720 in 250 gm soil and 12 and 14 in 10 gm root respectively.

III. Extent of damage caused by M. incognita on pepper

Evidently the most conspicuous effect of this nematode on the host plant is the formation of galls or root-knots on the roots. In one single plant, infection by these nematodes can produce 13 to 28 galls per gm of root. (Table 4).

Observations on the extent of damage by M. incognita on 4 selected varieties namely Panniyur I, Cheriakanichadan, Kalluvally and Kottanadan are presented in Table 5. From the results presented the following conclusions can be drawn.

Both the shoot growth and root growth in all the four varieties were affected by the infestation of M. incognita. Characters like shoot length, number of leaves, girth at first node, weight of the shoot, number of roots and weight of roots of inoculated and uninoculated plants of the same variety were compared. There was a reduction of 29, 34.4, 26 and 22.7 per cent in shoot length; 18.4, 16.5, 12.7 and 11 per cent in the number of leaves; 10, 17.6, 11.1 and 9.5 per cent in girth;

6.2, 4.4, 4.04 and 3.4 per cent in shoot weight; 41, 30.4, 12 and 12.5 per cent in number of roots and 16.6, 16.6, 12.3 and 10.5 per cent in weight of the root in the four varieties. Thus there was an appreciable decrease in the top growth and root growth of all the varieties due to the nematode attack.

IV. Histopathology

As mentioned under materials and methods, sections of the healthy and infected roots of pepper were prepared and examined under the microscope. Photomicrograph of the microtome sections in Figure 3 shows that the stelar portion of the roots are mostly affected by the nematodes. The nematodes mainly attack the xylem vessels. Thus the flow of food materials to the various parts of the plant is suppressed, which affect the normal growth of the plant.

The phloem vessels are not affected by the nematodes. There is no difference between the phloem vessels in healthy and affected roots.

The protoplasm in the infected cells become granular. Each larva is associated with 4 to 6 giant cells. The giant cells are caused by the disintegration of the cell walls of the parenchymatous cells around the head of the larva. Simultaneous multiplication of surrounding cells

cause the roots to swell, forming root-knots.

The parenchymatous cells of the nematode infected roots are slighly enlarged than the cells in the uninfected roots. The starch grains per cent also, are more or less depleted in the case of infected cells.

V. Control of M. incognita on pepper variety Panniyur 1 using nematicides

An experiment was laid out in completely randomised design (CRD) with 6 treatments and six replications as described in materials and methods, to study the effect of four nematicides namely Dasanit, Nemagon and Temik and one organic cake namely Neemcake in controlling M. incognita on pepper. Panniyur 1 variety was selected for the study. Growth characters like height of plant, number of leaves, girth at first node and root-knot index (calculated as described earlier) and the final nematode population in the soil were used to compare the effect of each of them. Observations are presented in Table 6, 7, 8, 9, 10, 11, 12 and 13.

The results were statistically analysed and presented in Appendices I, II and III.

The pre-treatment data was analysed in CRD and it was found that the treatments did not differ significantly for the characters studied. Hence the post treatment

data was analysed for purposes of comparison of the effect of the materials used.

Effect of nematicides on height of the plant.

The height of the plants under various treatments after 90 days of application of nematicides under study, and the analysis data are presented in Table 6 and 7 and Appendix I. Statistical analysis revealed significant differences in plant height between control and treatments with Tenik, Nemagon, Nemap and Basamit. The effect on plant height by the use of nemeake Mi not differ significantly over control. The increase in height of control plants was only 5.16 cm compared to 20.65 cm in plants under Tenik, 18.16 cm under Basamit, 13.83 cm under Nemap, 12.16 cm under Nemagon and 11.13 cm under Neemeake. Though there is an increase of 11.13 cm under neemeake it is not statistically significant at 5 per cent level.

Effect of nematicides on number of leaves.

The number of leaves produced by plants under various treatments after 90 days of application of nematicides under study and the analysis data are presented in Tables 8 and 9 and Appendix II. The

Table-6. Mean height of pepper plants under different nematicidal treatments before and after their application

Nematicide	Mean height (cm)		Increase in height due to treatments
	Before application	After application	
T_1 Dazomet	62	80.16	18.16
T_2 Nemap	66.5	80.33	13.83
T_3 Nemagon	70	82.16	12.16
T_4 Nemacake	65.7	76.83	11.13
T_5 Tenik	67	87.83	20.83
T_6 Control	68.50	71.66	3.16

Table-7. Mean table for the height of the plants

Treatments	T_1	T_2	T_3	T_4	T_5	T_6
Mean	80.16	80.33	82.16	76.83	87.83	71.66

CD = 6.26

Table-8. No. of leaves of pepper plants under different nematicidal treatments before and after their application

Nematicide	Mean No. of leaves		Increase in No. of leaves due to treatments
	Before application	After application	
T_1 Dasanit	22.6	43.00	20.4
T_2 Nocap	24.3	58.16	33.86
T_3 Nemagon	25.7	44.33	18.6
T_4 Neemcake	27.1	49.83	22.73
T_5 Temik	28.5	41.66	13.16
T_6 Control	25.7	33.50	7.80

Table-9. Mean table for the number of leaves

Treatments	T_1	T_2	T_3	T_4	T_5	T_6
Mean	43.00	58.16	44.33	49.83	41.66	33.50

CD = 10.11

statistical analysis revealed significant differences in number of leaves produced between control and treatments with Mocap, Neemcake and Nemagon. The effect on leaf production by the use of Dasanit and Temik did not differ significantly over control. The increase in number of leaves in Mocap was 33.86, Neemcake 22.73 and in Nemagon 18.6. The increase in the case of Dasanit and Temik was 20.4 and 15.16 respectively whereas the increase in number of leaves in the control plant was only 7.8. Though there is an increase of leaves under Dasanit and Mocap over control it is not significant at 5 per cent level.

Effect of nematicides on girth of plant at first node.

The girth of the plants under various treatments after 90 days of application of nematicides under study and the analysis data are presented in Table 10 and 11 and Appendix III. Statistical analysis revealed significant difference between control and the treatments with Dasanit, Nemagon, Neemcake and Temik. The effect on girth by the use of Mocap did not differ significantly over control. The girth of the control plant was reduced to 14.33 mm from 16.0 mm. But the increased girth of the plants treated with Dasanit was 3.23,

Table-10. Girth of pepper plants under different nematicidal treatments before and after their application

Nematicide	Mean girth of plant (mm)		Increase/ decrease in girth of plant due to treatment
	Before application	After application	
T_1 Dasanit	15.6	18.83	+ 3.23
T_2 Mocap	14.3	16.66	+ 2.36
T_3 Nemagon	19.6	21.66	+ 2.06
T_4 Neemcake	13.6	20.66	+ 7.06
T_5 Temik	16.0	20.33	+ 4.33
T_6 Control	16.0	14.33	- 1.67

Table-11. Mean table for girth of plant

Treatments	T_1	T_2	T_3	T_4	T_5	T_6
Mean	18.83	16.66	21.66	20.66	20.33	14.33

CD = 3.53

Nemagon 2.06, Neemeake 7.06 and Temik 4.33. Though there is an increase of 2.36 mm under Nocap it is not significant at 5 per cent level.

Effect of nematicides on the root-knot index.

The number of root-knot index in plants under various treatments after 90 days of application of nematicides are presented in Table 12. The control plants gave an increase of 24.5 root-knot index whereas the reduction of root-knot index in the treated plants are as follows. Temik gave a reduction of 93.45, Dasanit 50.16, Nemagon 43, Neemeake 42.50 and Nocap 35.50.

Effect of nematicides on Nematode population in soil.

The number of nematodes present in soil under various treatments after 90 days of application of nematicides are presented in Table 13. There was an increase of nematodes in the case of control plants and a decrease of nematodes in the treated plants. Increase in control plants was 247 whereas the reduction was 956 in the case of Nocap, 898 in Dasanit, 779 in Neemeake, 759 in Nemagon and 691 in Temik.

Table-12. Decrease/increase in root-knot index by applying nematicides

Nematicide	Root-knot index ( )		Decrease/ increase in root-knot index due to treat-ment
	Before application	After application	
T_1 Dasanit	69.66	19.50	- 50.16
T_2 Nocap	60.66	25.16	- 35.50
T_3 Nemagon	68.33	25.33	- 43.00
T_4 Nemacide	70.33	27.83	- 42.50
T_5 Temik	66.16	12.71	- 53.45
T_6 Control	62.00	86.50	+ 24.50

Table-13. Decrease/increase in the nematode population by the application of nematicide

Nematicide	Population of Nematodes		Decrease/ increase in the nematode population due to treatment
	Before application	After application	
T_1 Basamit	1131	233	- 898
T_2 Nemap	1044	188	- 856
T_3 Nemagon	1028	269	- 759
T_4 Heemeke	986	207	- 779
T_5 Tenik	839	148	- 691
T_6 Control	944	1193	+ 247

DISCUSSION

DISCUSSION

The main contributions resulting from the present investigations are that:

1. Survey of the commonly cultivated varieties of pepper from 5 districts of Kerala for occurrence of nematodes has been done. All the varieties, in all the areas surveyed is infested with rootknot nematodes Meloidogyne incognita, Radopholus similis and Helicotylenchus sp.

2. Eight cultivars of pepper have been screened against root-knot nematode M. incognita and all of them are found to be susceptible to their attack.

3. Extent of damage done by M. incognita on 4 cultivars of pepper has been worked out.

4. Histopathology of the M. incognita infection on roots of Panniyur 1 variety has been studied.

5. Four nematicides and one organic cake have been evaluated for controlling M. incognita on pepper.

M. incognita has been reported to attack pepper in Kerala by Venkitesan (1972). The slow wilt of pepper which is now prevalent in pepper growing tracts has been suspected to be a complex of nematode and fungal infection coupled with nutrient difficiency(Radha and Nawther 1976).

Nematode injury to crops is most commonly evaluated by measuring changes in yield under varying degrees of infection and by actual root examination. The nematode usually causes a distinct reduction in vitality and growth of host plant without being lethal. The effect of infection on top growth is such that the visible symptoms have often been diagnosed as due to various nutrient deficiencies.

Pepper has been grown in our country for a very long time, but organised research on cultivation and maintenance of pepper for better and higher yield has been started only very recently. None of the workers has paid much attention to the nematode problem or its control. It was, therefore, hoped that useful results may emerge from these investigations.

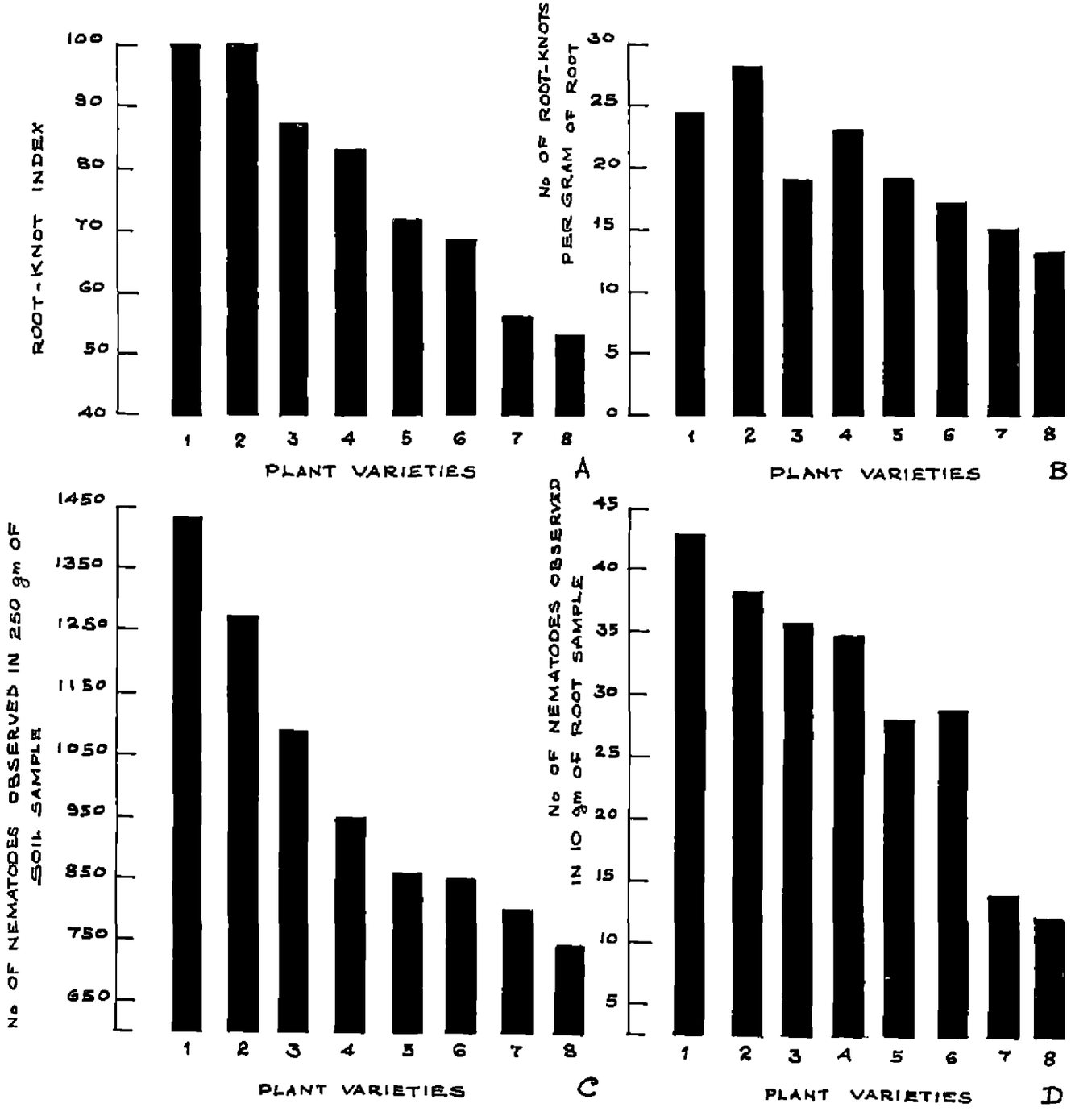
In the present study a survey of nematodes associated with pepper was done from different places spread out in five districts of Kerala. The survey have shown that all the pepper growing areas covered (Table 1) and all the varieties grown in these areas (Table 2) are infested with M. incognita, Radopholus similis and Helicotylenchus sp. This is the first time

such a survey was conducted in Kerala. Venkitesan (1976) also has recorded the occurrence of Meloidogyne spp. in Cannanore and Calicut districts of Kerala. Root-knot nematode M. incognita form the major group of nematode with a very large population present in both soil and root. M. incognita was associated with several cultivars of pepper. Similar observations have been made by several workers. Claudio and Davide (1968) reported M. incognita on 5 species of Banana and Kurian (1970) reported them to attack all the 323 varieties of tobacco screened. The population of M. incognita, R. similis and Heliocotylenchus sp. were higher in soil and roots of wilted pepper plants than in healthy plants. (Table 3) The number of nematodes observed in the apparently healthy plant might not be sufficient to produce any disease symptoms on the plant or some inherent character of the variety involved might have resisted the development of any visible symptoms. Venkitesan (1976) found that an inoculum level of 10 or 100 R. similis per 1500 ml of soil did not produce any visual symptoms on pepper. An inoculum of 1000 R. similis was needed to induce any visual symptoms. Like-wise Vander Vecht (1950) could not reproduce the yellowing of

leaves in inoculated plants.

The eight cultivars of pepper screened did not reveal any immunity or resistance to M. incognita (Table 4 and figure 1). However, they can be grouped into three categories. Variety Panniyur 1 and Cheriakanlakadan have the highest root-knot index of 100 each, largest number of root-knots per gm of root (24 and 28 respectively) and the largest population build up of nematodes in soil and root (1436 and 1276 in soil and 43 and 39 in root). These two varieties may be grouped as highly susceptible. The varieties Kalluvally, Kottanadan, Balamcotta and Karimunda are median in reaction in all the characters studied and can be grouped as susceptible. The varieties Narayakodi and Padappan have the least root-knot index (56 and 53 respectively), least number of root-knot per gm of root (15 and 13 respectively) and least build up of nematodes in soil and root (794 and 720 in soil and 14 and 12 in root respectively). They can be grouped as less susceptible. Thus three groups namely highly susceptible, susceptible and less susceptible may be identified among the cultivars screened. According to Rohde (1965) the nature of resistance in plants to nematode is to be measured in terms of ability of the parasite to survive and multiply and not always directly

ROOT-KNOT INDEX, No OF ROOT-KNOTS PER GRAM OF ROOTS, AND No OF NEMATODES IN THE SOIL AND ROOT, AGAINST M INCOGNITA ON PEPPER VARIETIES



-VARIETIES-

1	PANNIYOOR-I	5	BALANKOTTA
2	CHERIAKANIAKADAN	6	KARIMUNDA
3	KALLUVALLY	7	NARAYAKODI
4	KOTTANADAN	8	PADAPPAN

FIGURE 1

related to plant growth. The root-knot index and number of root-knots per gm of root are indicators of survival of nematodes in the host.

An assessment of the nature and extent of the loss caused to the four selected varieties by M. incognita was also done as part of the present investigation. In all the four varieties namely Ponniyur 1, Cheriakaniakadan, Kalluvally and Kottanadan reduction in top growth and root growth was found to be substantial (Table 5 and Figure 2). Besides, in one single plant, these nematodes can produce 15 to 28 galls per gm of root within 6 weeks of inoculation (Table 4). The number of galls per gm of root in one single tobacco plant by M. incognita is 20-100 (Kurian 1973). Pinto (1972) also found pepper seedlings heavily galled by Meloidogyne spp. and lacking in young feeder roots. Birat (1970) could not find any galls on roots of chillies and wheat by M. javanica. Wong and Willetts (1969) and Huang and Lin (1971) could induce galls on the aerial parts of tomato, beans, potato and coleus.

The shoot length, number of leaves, girth at first node, weight of the shoot, number of roots, and weight of roots were all reduced considerably due to the

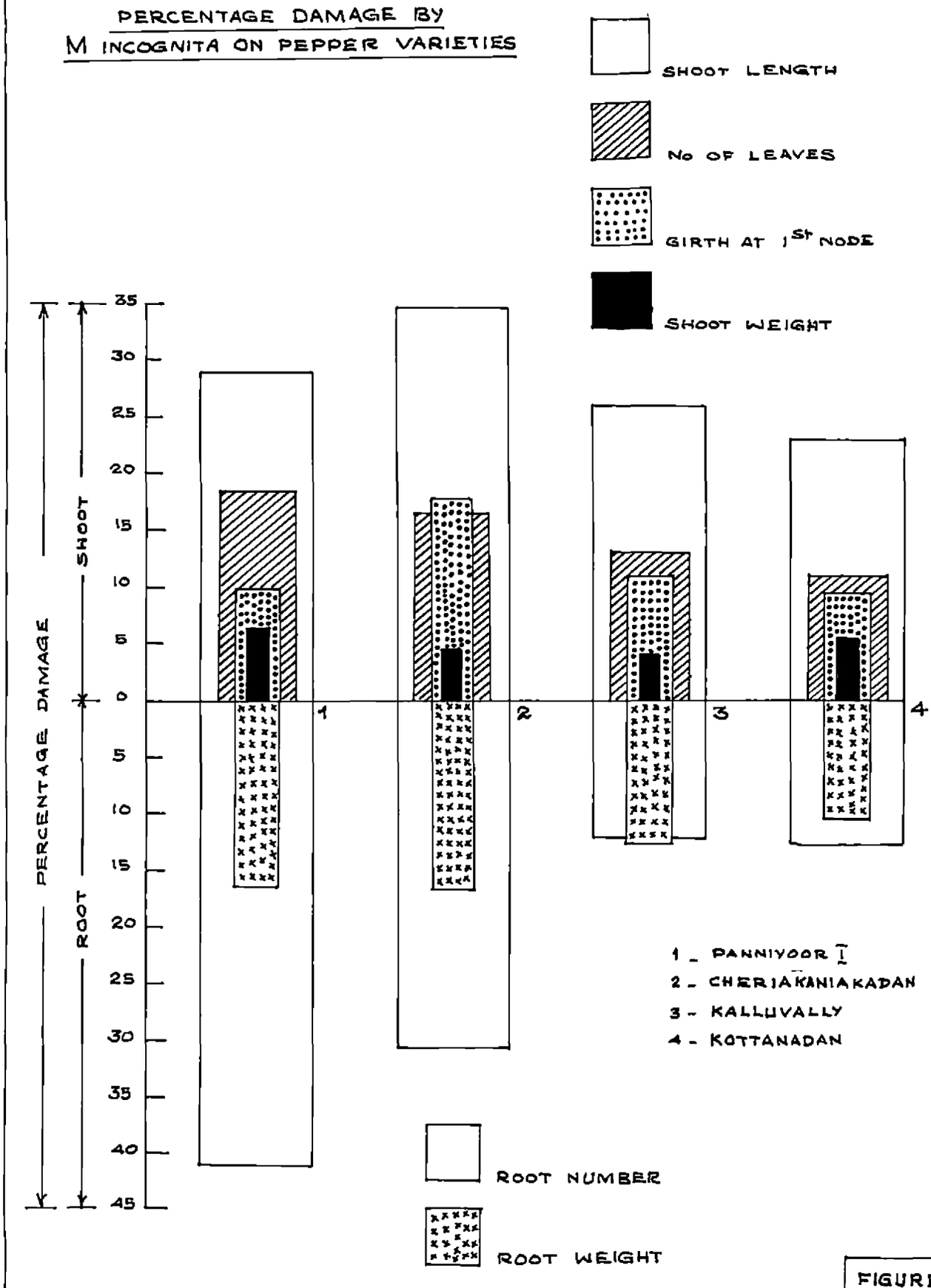

PERCENTAGE DAMAGE BY
M INCOGNITA ON PEPPER VARIETIES
SHOOT LENGTH
No OF LEAVES
GIRTH AT 1st NODE
SHOOT WEIGHT
PERCENTAGE DAMAGE
SHOOT
ROOT
35
30
25
20
15
10
5
0
5
10
15
20
25
30
35
40
45
1
2
3
4
1 - PANNIYOOR I
2 - CHERIAKANIAKADAN
3 - KALLUVALLY
4 - KOTTANADAN
ROOT NUMBER
ROOT WEIGHT

FIGURE 2

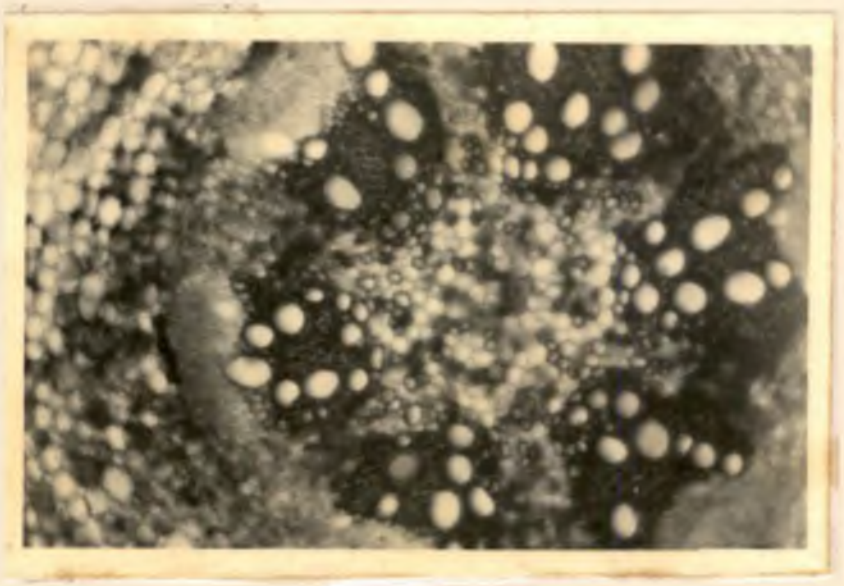
infection of M. incognita. Within a period of 6 weeks there was a reduction of 22.7 to 34.4 per cent in shoot length, 11.0 to 18.4 per cent in number of leaves, 9.5 to 17.6 per cent in girth, 4.0 to 6.2 per cent in shoot weight, 12.0 to 41.0 per cent in number of roots and 10.5 to 16.6 per cent in weight of the root, in the four varieties tried, compared to uninoculated plants. Similar effects on top growth and root growth on plants by M. incognita have been reported by several workers. Vinte (1972) reported a reduction in plant weight of pepper seedlings by 37.4 and 10.2 per cent due to M. incognita and M. javanica over control after 10 months of inoculation. Stunted growth and yellowing of leaves were reported by Claudio and Davide (1968). Prasad and Gaur (1974) also recorded reduced plant growth due to the effect of M. incognita on brinjal. Reduction in root weight and root surface was also reported by Waseem Ismail and Mashoor Alam (1975). Many workers have shown that an upset in the normal balance between various plant constituents results from nematode parasitism. Reports of van Gundy and Martin 1961, Shaflee and Jenkins (1963) and Heald and Jenkins, (1964) indicate that nematodes do have a profound influence in the uptake and accumulation of various nutrients in the host.

Multinucleate structures or giant cells in plants infected by root-knot nematodes are believed to arise in response to substances emanating from the parasite (Dropkin and Nelson, (1960) Ducharme (1959) stated that the resulting tumours and galls were due to reactions of the host plant and might be considered as a kind of defence mechanism. Observations on the histopathology of the infected roots of pepper show that the first reaction of the plant root cells to nematode feeding was giant cell formation and swellings on the roots. Similar observations have been made by earlier workers (Dropkin and Boone 1966; Dropkin and Webb 1967) who found that galls appeared from the first to fourth day on tomato roots. In the present studies it was seen that each larva was associated with about 4 to 6 giant cells which are multinucleate (Figure 3). In tobacco varieties each larvae of M. incognita was associated with 4 to 9 giant cells which were multinucleate (Kurian, 1970).

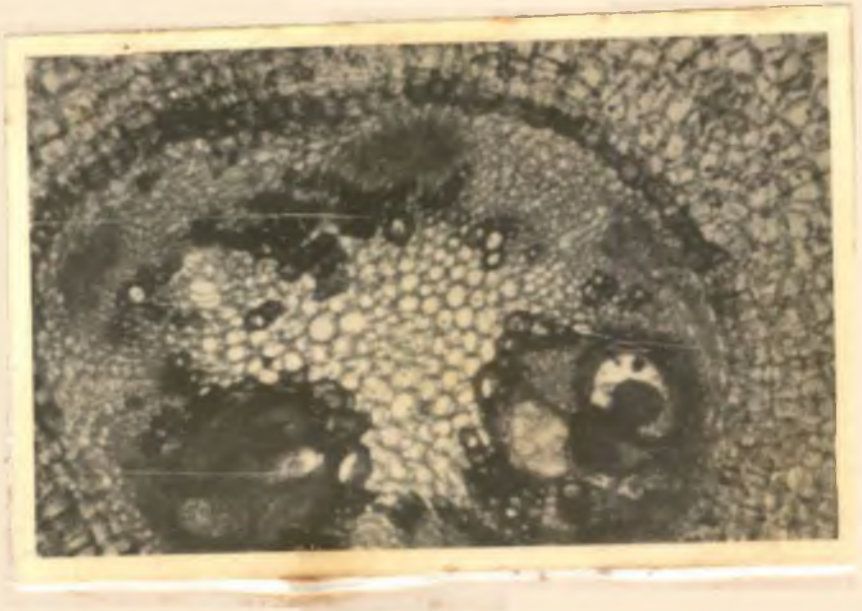
From Figure 3, it can be seen that the stelar portion of the roots are attacked by the larvae. Within the stele, the xylem vessels are preferred more and the phloem vessels are more or less intact. Due to the damage of xylem vessels, flow of food materials to the various parts of the plant is suppressed. The normal growth of

TRANSVERSE SECTIONS OF HEALTHY AND
M. incognita INFECTED PEPPER ROOTS

Fig. 3.



(HEALTHY)



(INFECTED)

the plant will be thus impossible. The phloem vessels of healthy and affected roots does not show any difference. Hence it may be presumed that the phloem vessels are not affected by these nematodes. Ogboji (1976) found that the giant cells developed mainly in the cells in corn roots by M. hapla. Xylem element interruption caused by the giant cells due to M. incognita attack was also reported by Murlan (1970) in tobacco roots. Destruction of primary phloem at the site of infection by M. incognita in roots of Lagenaria leucantha was reported by Siddiqui and Ghouse (1975).

The protoplasm in the infected cells become granular and the starch grains in them are more or less depleted. Such cellular changes are also reported by other workers. Disappearance of starch reserves from infected tissues was noticed by Huang and Lin (1971). Ichde (1965) found that giant cell nucleii increased in size. Cytoplasm of the giant cells was found to be dense in corn roots by Ogboji (1976). Christie (1949) showed that production of giant cells is necessary for development of root-knot nematode females. Thus there is considerable evidences to show that favourable host plants should react in a manner advantageous for the proper development of the nematode.

The experimental studies on the control of M. incognita indicated that Nemagon at 40 lit ai/ha was the most promising over the other materials as evidenced by the improvement of plant growth and reduction in root-knot index (Tables 6, 7, 8, 9, 10, 11, 12 and 13 and Appendices I, II and III). None of the materials used namely Nemagon, Dasanit, Mocap, Neemcake and Temik were phytotoxic at the doses tried to the pepper seedlings.

Increase in height of the plant produced by the use of Temik, Nemagon, Mocap and Dasanit were statistically significant over the control. There is an increase of 20.83 cm in Temik, 18.16 cm in Nemagon, 13.83 cm in Mocap and 12.16 cm in Dasanit. Though the increase of 11.13 cm in plant height by the use of Neemcake is not statistically significant, it may be seen that there is a definite improvement in the plant height compared to the control, where the increase in height was only 3.16 cm.

Mocap, Neemcake and Nemagon gave significant increase in number of leaves over the control. The number of leaves increased by 33.86 in Mocap, 22.73 in Neemcake and 18.6 in Nemagon. The other two materials Dasanit and Temik produced more leaves (20.4 and 13.16 respectively) compared to control but the difference was not statistically significant.

Dasanit, Nemagon, Neemcake and Temik gave significant increase in the girth of the plant over the control. The girth of the control plant was reduced to 14.33 mm from 16.0 mm, showing a reduction of 1.67 mm during 90 days of infection. Dasanit increased the girth by 3.23 mm, Nemagon by 2.06 mm, Neemcake by 7.06 mm and Temik by 4.33 mm. Nocap produced an increase in girth of 2.36 mm but was not statistically significant.

There was a defenite decrease of nematode population in soil and consequent reduction in root-knot index as seen in Table 12 and 13. The root-knot index (Table 12) was increased by 24.5 in control plants. But the application of Temik, Dasanit, Nemagon, Neemcake and Nocap reduced the root-knot index by 53.45, 50.16, 45.0, 42.50 and 35.50 respectively. The nematode population (Table 13) increased by 247 in control plants within 90 days whereas the application of Nocap, Dasanit, Neemcake, Nemagon and Temik reduced the population by 956, 898, 779, 759 and 691 respectively.

Thus it has been found that Nemagon at 40 lit ai/ha gave consistant and significant control of M. incognita based on all the characters studied. Dasanit at 60 kg ai/ha, Nocap at 10 kg ai/ha, Temik at 10 kg ai/ha and Neemcake at 2000 kg/ha gave the next best control, though each of

them did not give statistically significant control for either one or other of the characters studied.

DBCP at 45 lit/ha gave good control of M. incognita on potato (Mukhopadhyaya,1970). Temik at 5 kg/ha was effective in producing potato tubers free of infection (Raj and Mirula,1971 a). Soil amended with groundnut cake showed considerable decrease in population of root-knot nematodes and improved the growth of the tomato plant (Goswami and Swarup, 1972 and Khan, et al., 1973).

Reddy and Seshadri (1972) found tomato plants treated with Aldicarb were not invaded by larvae of M. incognita. Similar results by Aldicarb was obtained by Broodie and Good (1973). Davide (1973) could reduce the galling in roots of banana and get increased growth by using Temik, Nemagon and Nemagon applied at the rate of 1 gm/gallon of water as 15 minute dip treatment. Temik, Counait and Thimet reduced the population of M. incognita in tomato but increased yield was obtained only for Temik (Chhabra and Mahajan, 1974). The bitter principles of neem namely nimbidin and thionimone were effective in killing nematode and larval hatch of M. incognita (Khan, et al., 1974). Spot application of Aldicarb at 1.4 kg/ha and Fenusulphothion

at 1.0 kg/ha was found to be economical methods of control of M. incognita on tobacco by Reddy (1975 b). Thus the results obtained in the present control trials agree with the results of similar trials already reported.

The investigations carried out here revealed that M. incognita had wide spread occurrence in the five pepper growing districts studied. Cultivars of pepper screened against M. incognita showed that a few had less susceptibility. Kerala and Karnataka being the original home of pepper (Abraham,1959), screening of all the available germplasm, is, therefore, necessary to detect a more suitable source of resistance.

SUMMARY

SUMMARY

A survey was conducted in the pepper growing areas of five districts in Kerala. All the 93 areas and all the varieties grown were found to be infested with root-knot nematodes, Meloidogyne incognita. The number of root-knot nematode in 250 gm soil of healthy Panniyur 1 variety ranged from 27 to 467 with an average of 231 and in wilted plants from 149 to 2006 with an average of 925. The population in 10 gm root of healthy plant of the same variety ranged from 0 to 98 with an average of 24 and in wilted plant from 12 to 134 with an average of 81. The species of root-knot nematode observed in all the samples of all the varieties were identified as M. incognita. Other plant parasitic nematodes namely Radopholus similis and Helicotylenchus sp. were observed in all the samples studied.

Eight cultivars of Piper nigrum were screened against M. incognita. Panniyur 1 and Cheriakaniakadan varieties were highly susceptible. Kalluvally, Kottanadan, Balancotta and Karimunda were susceptible and Narayakodi and Padappan varieties were less susceptible to the attack of M. incognita.

The extent of damage done by this nematode to four selected varieties of pepper was estimated and it was

found that there was an appreciable decrease in the top as well as root growth in all the varieties.

Histopathological studies showed that 4 to 6 giant cells were formed around a single female and the nematodes disrupted the xylem vessels affecting the translocation of food materials.

Among the four nematicides namely Nemagon, Dasanit, Nocap, Temik and one organic amendment namely Neemcake tested for control of M. incognita on pepper, Nemagon at 40 lit ai/ha was found to give significant control of M. incognita.

REFERENCES

REFERENCES

Abraham, P. (1959). Pepper cultivation in India. Farm bull.No.55, Farm Information unit, Directorate of Extension, Ministry of Food and Agric. New Delhi. 80 pp.

Alam, M.M. (1975). New host records of the root-knot nematode, Meloidogyne incognita. Curr. Sci. 44: 445.

Alam, M.M., Khan, A.M., and Saxena, S.K. (1971). Reaction of some cultivated varieties of egg plant, pepper and okra to the root-knot nematodes. Indian J. Nematol. 4: 64-68.

Alam, M.M., Khan, A.M., and Saxena, S.K. (1976). Additional host records of the root-knot nematode M. incognita in North India. Curr. Sci. 45: 350.

Anon, (1976). Economic review of Kerala 1975. The State Planning Board, Trivandrum.

Anon, (1977). Farm Information Bureau, Government of Kerala.

Baldwin, J.G., and Barker, K.R. (1970). Histopathology of corn hybrids infected with root-knot nematode M. incognita. Phytopathology. 60: 1193-1198.

Barker, K.R., and Hussey, R.S. (1970). Histopathology of nodular tissues of legumes infected with certain nematodes. Phytopathology. 66: 851-855.

*Barrons, K.C. (1959). Studies on the nature of root-knot resistance. J. Agric. Res. 98: 265-272.

*Basu, S.D. (1974). Weed hosts of root-knot nematodes in Tea Estates around Jorhat. Two and a Bud. 21: 50.

Bhardwaj, A.K., Sharma, P.L., and Phunchog, S. (1972). Root-knot nematode (Meloidogyne spp.) infestation on tomato in Solan area of Himachal Pradesh. Indian J. Nematol. 2: 197-198.

Bindra, O.S., and Kaushal, K.K. (1971). Chemical root dips for control of root-knot nematode attacking tomato. J. Res. 17: 453-457.

Bindra, O.S., Soodan, I.S. (1974). Studies on the chemical control of root-knot nematode. (M. incognita) Indian J. Hort. 31: 286-290.

Birat, R.B.S. (1970). Influence of cropping pattern on the population of Meloidogyne javanica. Indian Phytopath. 22: 391-395.

Brodie, B.B., and Good, J.M. (1973). Relative efficacy of selected volatile and non-volatile nematicides for control of M. incognita on tobacco. J. Nematol. 5: 14-18.

Chandramathi, P.S. (1973). Occurrence of a root-knot nematode in mesta. (Hibiscus cannabinus). Madras Agric. J. 60: 600.

*Chhabra, H.K., and Mahajan R. (1974). Effect of 3 granular nematicide in the control of root-knot and stunt nematode infesting tomato. Nematologia Mediterranea 2: 113-115.

Christie, J.R. (1949). Host-parasite relationships of the root-knot nematode Meloidogyne spp. III. The nature of resistance in plants to root-knot. Proc. helminth. Soc. Wash. 16: 104-108.

*Claudio, M.E., and Davide, R.G. (1968). Pathogenicity and identity of root-knot nematodes on five varieties of banana. Philipp. Agric. 51: 241-251.

Clemons, G.P., and Krusberg, L.R. (1971). Root-knot nematode found on London plane trees. Pl.Dis.Reptr. 55: 280.

*Cobb, N.A. (1918). Estimating the nema population of the soil. Agric. tech. Circ. 1, Bur. Plant Industr., U.S. Dept. Agric. 48 pp.

*Curi, S.M., Carvalho, A., Moraes, F.P., Monaco, L.C., and De Arruda, M.V. (1971). New sources of genetic resistance of coffee in the control of the coffee nematode, M. exigua Biologico (Sao paulo) 36: 293-295.

*Da Ponte, Jolio, J., and Maria Do Socorro Sena Silva. (1971). A nematode harmful to the cultivation of alfalfa Medicago sativa in Brazil. Turrialba 21: 253.

David, H. (1959). Root-knot nematode in sugarcane. Indian J. Sug. Res. and Dev. 3: 234-236.

*Davide, A.G. (1973). Evaluation of 3 nematicide for the control of M. incognita affecting banana. Philipp. Agric. 57: 187-197.

*Dement'eva, S.P. (1971). Parasitic species of nematodes on solanaceous crops in Moldavia. Shtiintsa. 7: 139-142.

Desai, M.V., Shah, M.M., and Pillai, S.N. (1974). Nematicidal property of some plant species. Indian J. Nematol. 3: 77-78.

Dhande, G.V., and Sulaiman, M. (1961). Occurrence of root-knot nematode on betelvine in Maharastra. Curr. Sci. 30: 351-352.

Dhillon, G.S., and Mandpuri, K.S. (1972). Root-knot resistance in tomato (Lycopersicon esculentum. J. Res. Punjab Agric. Univ. 12: 373-377.

Dimuro, A. (1970). Efficiency of row injecting treatment for control of nematodes of the genus Meloidogyne. Tobacco, 74: 55-61.

Di Sanzo, G.P. (1973). Nematode response to carbofuran. J. Nematol. 5: 22-27.

Droleom, P.N., and Moore, E.L. (1958). Reproduction of Meloidogyne species in flue-cured tobacco lines of root-knot resistant parentage. Pl. Dis. Reptr. 42: 596-598.

Dropkin, V.H., and Boone, W.R. (1966). Analysis of host-parasite relationships of root-knot nematodes by single larva inoculations of excised tomato roots. Nematologica. 12: 225-236.

Dropkin, V.H., and Nelson, P.E. (1969). The histopathology of root-knot nematode infections in soy beans. Phytopathology. 59: 442-447.

Dropkin, V.H., and Webb, R.E. (1967). Resistance of axenic tomato seedlings to Meloidogyne incognita var. acrita and to M. hapla. Phytopathology. 57: 584-587.

D'Souza, D.I., Kumar, A.C., Kasiviswanathan, P.R. and Shamanna, H.V., (1970). Relative distribution and prevalence of plant parasitic nematodes in the coffee tracts of South Western India. Indian Coff. 34: 329-342.

Ducharme, E.P. (1959). Morphogenesis and histopathology of lesions induced on citrus roots by Radopholus similis. Phytopathology. 49: 388-396.

Dutt, N. (1969). Incidence of nematodes in jute and allied fibre crops. Proc. 47th Indian Sci. Congr. 37: 42.

Ernie L.G. Wang and Bergeson, G.B. (1974). Biochemical changes in root exudate and xylem sap of tomato plants infected with M. incognita. J. Nematol. 6: 194-202.

Fasseliotis and George (1972). Susceptibility of Cucurbita spp. to the root-knot nematode Meloidogyne incognita. Pl.Dis.Reptr. 55: 666.

George, C.K., (1976). Pepper production programmes in five year plans. Paper presented at the Intern. Seminar on pepper, Cochin, India, 7-10 pp.

Goswami, B.K., and Swarup, G., (1972). Effect of oilcake amended soil on the growth of tomato and root-knot nematode population. Indian Phytopath. 24: 491-494.

Graham, T.W. (1965). Tobacco varieties used to show differential response to root-lesion and root-knot nematodes. Pl. Dis.Reptr. 49: 822-826.

*Grujicic, Gavrilo and Milos Daunovic, (1971). A contribution to the study of the root-knot nematode (Meloidogyne hapla. Chitwood). Zastit Bilja. 22: 147-152.

Heald, C.M., and Jenkins, W.R. (1964). Aspects of the host-parasite relationship of nematodes associated with woody ornamentals. Phytopathology. 54: 718-722.

*Huang, C.S., and Lin, L.H. (1971). Pathological responses of stems to root-knot nematode infection. Bot. Bull.Acad. Sinica. (Taiwan). 11: 79-87.

*Ichinohe, M. (1975). Infestation of black pepper vines by the root-knot Meloidogyne incognita at Brazil. Japanese J. Nematol. 5: 36-40.

*Ichinohe, M. (1976). Infestation of Black pepper by the root-knot nematode in Brazil. Jarq. 10: 17-20.

Jatala, Parvis and Russell, C.C. (1972). Nature of sweet potato resistance to Meloidogyne incognita and the effects of temperature on parasitism. J. Nematol. 4: 1-7.

Jayaraman, V., Rajendran, G., and Muthukrishnan, T.S. (1975). Occurrence of root-knot nematodes in Polianthes tuberosa in Tamil Nadu. Indian J. Nematol. 5: 101-102.

Johansen, D.A. (1940). Plant Microtechnique. McGraw-Hill, New York. 523 pp.

Jones, A., Dukes, P.D., and Cuthbert, D.P.J. (1975). Resistance in sweet potato. Hort. Sci. 10: 533.

Khan, M.W., Alam, M.M., and Khan, A.M. (1974). Effect of water soluble fraction of oil cakes and bitter principles of neem on some fungi and nematodes. Acta Botanica Indica. 2: 120-128.

Khan, M.W., Khan, A.M., and Saxena, S.K. (1973). Influence of certain oil cake amendments on nematodes and fingi in tomato field. Acta Botanica Indica. 1: 49-54.

Khan, A.M., Saxena, S.K., and Siddiqi, Z.A. (1971). Reaction of some cultivated and wild species of Lycopersicon and cucurbits to Meloidogyne incognita. Indian Phytopath. 24: 24: 197-199.

Kinloch, R.A., and Allen, M.W. (1972). Interaction of Meloidogyne kanla and M. javanica infecting tomato. J. Nematol. 4: 7-16.

Krishnamurthy, G.V.G., and Elias, M.A. (1968). Additions to host range of Meloidogyne incognita causing root-knot on tobacco in Hunsur, Mysore State. Indian Phytopath. 21: 351-352.

Kumar, A.C., Viswanathan, P.R.K., and D'Souza, G.I. (1971). A study on plant parasitic nematodes of certain commercial crops in coffee tracts of South India. Indian Coffee. 35: 222-224.

Kuriyan K. John, (1970). Studies on the resistance in tobacco to root-knot nematodes. Ph.D. Thesis, P.G. School, Indian Agricultural Research Institute, New Delhi.

Mahajan, R., Kanwar, T.S., and Hamdduri, K.R. (1975). Field screening of some tomato varieties and hybrids against the root-knot nematode Meloidogyne incognita. J.Res. Punjab. Agric. Univ. 12: 40-42.

Mammen, K.V. (1973 a). Meloidogyne incognita infesting the cover crops of rubber in Kerala. Curr. Sci. 42: 659.

Mammen, K.V. (1973 b). Root-gall nematodes as a serious pest of ginger in Kerala. Curr. Sci. 42: 549.

Mankau, R., and Sitanathdas. (1974). Effect of organic material on nematode Bionomics in citrus and root-knot nematode infested soil. Indian J. Nematol. 4: 138-151.

*Mathur, B.N., Handa, D.K., and Bhargava, L.P. (1970). Out breaks and new records, India, Stem galls in cucurbits. Pl. Prot. Bull. F.A.C. 18: 115.

Michael, A.McClure., Ellis, K.G., and Edward, L.High. (1974). Post infection Development and histopathology of Meloidogyne incognita in resistant cotton. J. Nematol. 6: 21-26.

Mukherji, S.K., and Sharma, B.D. (1973). Root-knot disease of Trichosanthes dioica. Indian Phytopath. 26: 348-349.

Mukhopadhyaya, M.C. (1970). Efficacy of D.D. -D.B., D.B.C.P. and V.C. 13 in controlling plant parasitic nematodes. J. Res. Punjab Agri. Univ. 7: 659-662.

Nadakal, A.M. (1963). Meloidogyne spp. infecting certain plants in Kerala. Curr. Sci. 32: 560-561.

Nadakal, A.M. (1964). Studies on plant parasitic nematodes of Kerala. J. Bombay Nat. Hist. Soc. 61: 467-469.

Nadakal, A.M. (1965). Studies on plant parasitic nematodes of Kerala. Indian J. Exp. Biol. 4: 37-39.

Naqvi, S.Q.A., and Alam, M.M. (1974). Addition to the host records of the root-knot nematode, M. incognita (Kofoid and White) Chitwood. Curr. Sci. 43: 564.

Nigam, B.C., and Reddy, A.S. (1972). Occurrence of the root-knot nematode on Trianthema govindia a new host from Rajasthan. Indian Phytopath. 25: 315-316.

Ogboji, R.O. (1976). Giant cell formation in corn roots caused by Meloidogyne hapla infection. Nematologica. 22: 62-64.

*Olthof, T.H.A., Townshend, J.L., Potter, J.W., and Marks, C.F. (1970). Plant parasitic nematodes of economic importance in Ontario". Proc. Entomol. Soc. Ont. 100: 8-9.

*Peters, B.G., (1952). Toxicity tests with vinegar eelworm. 1. Counting and culturing. J. Helminth. 26: 97-110.

Powell, N.T. (1962). Histological basis of resistance to root-knot nematodes. Phytopathology. 52: 25.

Prasad, S.K., and Gaur, H. (1974). Effect of Meloidogyne incognita on the growth characteristics of Brinjal with reference to shoot length. Indian J. Nematol. 4: 225-226.

Radha, K., and Rawther, T.S.S. (1976). Pests and diseases of garden land crops. Indian Farming 25: 31, 33-35.

Raj, B.T., and Nirula, K.K. (1970). Soil treatment for the control of root-knot nematode on potato (Solanum tuberosum L). Indian J. Agric. Sci. 40: 875-882.

Raj, B.T., and Nirula, K.K. (1971 a). Soil treatment for the control of root-knot nematode on potato. Indian J. Agric. Sci. 40: 878-882.

Raj, B.T., and Nirula, K.K. (1971). Eradication of root-knot nematode with D.D. in potato fields. Indian Phytopath. 24: 155-158.

Rao, Y.S., and Biswas, H. (1973). Evaluation of yield losses in rice due to the root-knot nematode Meloidogyne incognita. Indian J. Nematol. 1973-74.

Rao, V.R., and Singh, D.B. (1976). The root-knot nematode on commercial plantings of tuberose in India. Curr. Sci. 45: 348.

Raveendran, V., and Nadakal, A.M. (1975). An additional list of plants infected by the root-knot nematode, Meloidogyne incognita. (Kofoid and White 1919). Chitwood, 1949 in Kerala. Indian J. Nematol. 5: 101-135.

Reddy, D.D.R. (1975 a). Pathogenicity and control of root-knot nematodes (Meloidogyne spp.) infecting chick pea. Mysore J. Agric. Sci. 9: 434-439.

Reddy, D.D.R. (1975 b). Comparison of method of application and rate of granular nematicide for the control of Meloidogyne spp. on tobacco. Pl. Dis. Reptr. 59: 83-85.

Reddy, D.D.R., and Seshadri, A.R. (1972). Studies on some systemic nematicides. Further studies on the action of thionazin and aldicarb on M. incognita and Rotylenchulus reniformis. Indian J. Nematol. 2: 182-190.

Reddy, P.P., Setty, K.G.H., and Govindu, H.C. (1972). Susceptibility of flue-cured tobacco variety N.C 95 to Southern root-knot nematode. Mysore J. Agric. Sci. 6: 192-193.

Rohde, R.A., (1965). The nature of resistance in plants to nematodes. Phytopathology. 55: 1159-1162.

Sasser, J.N. (1975). World wide dissemination and importance of the root-knot nematodes Meloidogyne spp. J. Nematol. 9: Jan. 1977.

*Saxena, P.K., and Chhabra, H.K. (1970). Infection of root-knot in peaches (Prunus persica) a new record from India. Labdev. J. Sci. Technol. 8(3): 115.

Shafiee, M.T., and Jenkins, W.R. (1963). Host-parasite relationships of Capsicum frutescens and Pratylenchus penetrans, Meloidogyne incognita acrita and M. hapla. Phytopathology. 53: 325-326.

Shanmugavelu, K.G. and Madhava Rao, V.N. (1977). Spices and plantations crops. Popular Book Depot. Madras. 1st Ed.

*Sharma, R.D., and Loof, P.A.A. (1974). Nematodes of the cocoa region of Bahia, Brazil IV. Nematodes in the rhizospheres of pepper (Piper nigrum L.) and clove (Eugenia caryophyllata Thunb). Revista Theobroma. 4: 26-32.

Sharma, N.K., and Sethi, C.L. (1975). Leghaemoglobin content of cowpea nodules as influenced by M. incognita and Heterodera cajani. Indian J. Nematol. 5: 113-114.

Siddiqui, Z.A., and Ghouse, A.K.M. (1975). Formation of phloem in the roots of Lagenaria leucantha infected with Meloidogyne incognita. Indian J. Nematol 5: 102-104.

*Singh, B., Chaudhury, B. (1973). Yield and quality of fruits of tomato cultivars resistant and susceptible to root-knot nematodes. Haryana J. Hort. Sci. 2: 88-93.

Singh, K., and Misra, S.R. (1970). Root-knot nematodes on sugar beet in India. Plant Science. 2: 186.

Singh, R.S., and Sitaramaiah, K. (1971). Control of root-knot through organic and inorganic amendments of soil. Indian J. Nematol., :80-84.

Sitaramaiah, K., Singh, R.S., Singh, K.P., and Sikora, R.A. (1971). Plant parasitic and soil nematodes of India. U.P. Agric. Univ. Pantnagar. Exn.St. Bull. (3): 70 pp.

*Staniland, L.N. (1954). A modification of Baermann funnel for the collection of nematodes from plant material. J. Helminth. 28: 115-117.

Taylor, D.P. (1976). Histopathology of Meloidogyne, induced galls on the stems of roselle, Hibiscus sabdariffa. Nematologica. 22: 219-221.

Ting, W.P. (1975). Plant Pathology in peninsular Malaysia. Rev. Pl.Path. 54: 297-305.

*Vecht, J.van der, (1950). On planten parasiterende aaltjes. In L.G.Kalshoven (ed) 'De plagen van de cultuurgewassen in Indonesie'. S-Gravenhage: W.van Hoeve, 16-41 pp.

Van Gundy, S.D., and Martin, J.P. (1961). Influence of Tylenchulus semipenetrans on the growth and chemical composition of sweet orange seedlings in soils of various exchangeable cation ratios. Phytopathology. 51: 146-151.

Venkitesan, T.S. (1972). On the occurrence of plant parasitic nematodes associated with different crops in Cannanore District, Kerala. Agric.Res.J. Kerala.10: 179-180.

Venkitesan, T.S. (1976). Studies on the Burrowing nematode Radopholus similis (Cobb, 1893) Thorne 1949 on pepper (Piper nigrum L.) and its role in slow wilt disease. Ph.D. Thesis. Univ. Agric. Sci.Bangalore.

Waseem Ismail and Mashkoor Alam, M.I. (1975). Influence of Meloidogyne incognita on the penetration of subsequent population of the same species. Indian J. Nematol. 5: 109-110.

Webber, A.J., Fox, J.A., and Hale, M.G. (1970). Effect of Meloidogyne incognita on transpiration of tomato. Phytopathology. 60: 1019.

*Winchester, T.A., and Ogaki, H.Y. (1964). Some effects of nitrogen source on beans and peppers growing in root-knot infested soil. Proc. Fla.St.Hort.Soc., 76: 163-168.

* Winto, L.S. (1972). Effect of Meloidogyne spp. on the growth of Piper nigrum. Malaysian agric. Res. 1: 86-90.

Wong, C.L., and Willette, H.J. (1969). Gall formation in aerial parts of plants inoculated with Meloidogyne javanica. Nematologica. 15: 425-428.

Yadav, B.S. (1970). Tests for the nematocidal properties of some weed plants on M. incognita. Proceedings of the Indian Science Congress Association. 57: 551.

Yadav, B.S., Varma, L.K., and Naik, S.N. (1970). A note on the prevalence of M.incognita (Kofoid and White, 1919) Chitwood 1949, in various plants of Rajasthan. Curr. Sci. 39: 470-471.

* Original not seen.

APPENDICES

APPENDIX I

Analysis of variance table for height of the plant

Source	S.S.	df	M.S.	F
Total	1725	35		
Treatment	873	5	174.6	6.169*
Error	850	30	28.3	

CD Significant at 5 level

APPENDIX II

Analysis of variance table for number of leaves

Source	S.S.	df	M.S.	F
Total	4272.5	35		
Treatment	2066.92	5	413.38	5.61*
Error	2205.83	30	73.5	

CD Significant at 5% level

APPENDIX III

Analysis of variance table for girth of the plant

Source	S.S.	df	M.S.	F
Total	498.75	35		
Treatment	231.25	5	46.25	5.187*
Error	267.50	30	8.916	

CD Significant at 5% level

STUDIES ON THE ROOT - KNOT NEMATODE OF PEPPER (*Piper nigrum* L.)

BY

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ABSTRACT OF THE THESIS

SUBMITTED IN PARTIAL FULFILMENT OF THE

REQUIREMENT FOR THE DEGREE

MASTER OF SCIENCE IN AGRICULTURE

FACULTY OF AGRICULTURE

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF AGRICULTURAL ENTOMOLOGY

COLLEGE OF AGRICULTURE

VELLAYANI - TRIVANDRUM

1977

ABSTRACT

Nematodes have recently been observed to constitute a major threat and limiting factor to the pepper production in Kerala State. Among the nematodes, Meloidogyne spp. causing root-knots on pepper is one of the most important. Investigation on this nematode in pepper was not done in this State. Therefore, to gather some information on the extent of damage done by this nematode on pepper and to evolve control measures the present work was carried out.

A survey of nematodes associated with pepper was conducted in the pepper growing areas of five districts in Kerala. The nematode population was estimated from the soil and root samples of healthy and diseased pepper plants. M. incognita, Radopholus similis and Helicotylenchus sp. were found to infest all the pepper varieties in all the areas studied.

Eight cultivars of pepper were screened against M. incognita and found that Panniyur 1 and Cheriakaniakadan were highly susceptible having a root-knot index of 100. Kalluvally, Kottanadan, Balancotta and Karimunda were susceptible and the varieties Narayakodi and Padappan were less susceptible.

The extent of damage caused by M. incognita on four

selected varieties were studied and found that the nematodes were causing considerable damage to the crop by decreasing the height of the plant, number of leaves, girth of the plant and also the root growth.

Histopathological studies showed that the starch grains are more or less depleted in the case of affected plant roots. Each female is associated with 4 to 6 giant cells. The nematodes disrupted the xylem vessels affecting the translocation of materials.

Four nematicides and one organic amendment were tried against M. incognita on pepper. Furadan 5 G - 60 kg ai/ha, Nemcap 10 G - 10 kg ai/ha, Nemagon 60 EC - 40 lit ai/ha, Temik 10 G - 10 kg ai/ha and Neemcake 2000 kg/ha, gave good control of this nematode, with Nemagon giving the best result.