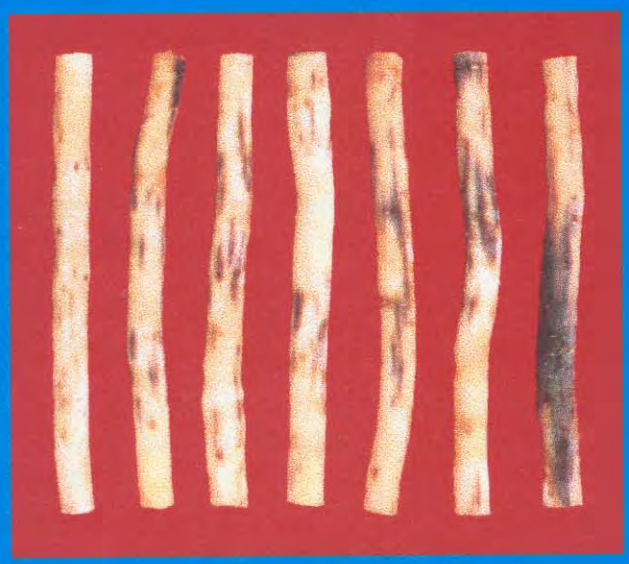
PROCEEDINGS OF THE GROUP MEETING OF NEMATOLOGISTS WORKING ON HORTICULTURAL CROPS

16th to 18th January 1998



CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
(INDIAN COUNCIL OF AGRICULTURAL RESEARCH)
REGIONAL STATION, KAYANGULAM,
KRISHNAPURAM - 690 533, KERALA, INDIA

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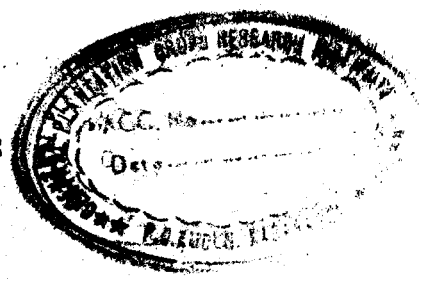
HORTINEMA '98

INTRODUCTION

The group meeting of Nematologists working on Horticultural Crops was conducted at the Central Plantation Crops Research Institute, Regional Station, Kayangulam, Kerala-690 533 from 16th to 18th January 1998 with the following objectives:

1. To take stock of the nematological investigations that have been carried out on important nematode problems occurring on horticultural crops in India.
2. To identify the important nematode problems on various horticultural crops in India.
3. To assess the effectiveness and practical feasibility of methods already suggested to control nematode diseases on horticultural crops.
4. To identify the gaps existing in nematological research pertaining to horticultural crops.
5. To develop integrated nematode management strategies by giving emphasis to bioagents, resistant varieties and cultural practices and minimising/avoiding the use of chemicals.
6. To make uniform the methods of control for the same nematode disease on the same crop, as far as possible, by various agencies like Department of Agriculture/ Horticulture of different States, Agricultural Universities and ICAR Institutes by general consensus of the agencies involved.



PRESIDENTIAL ADDRESS

Dr. KUK Nampoothiri
Director
CPCRI., Kasaragod

Dr.RN Pal, Asst. Director General (PC),Dr.Gopal Swaroop, Retired Professor and Head, Division and Nematology, IARI, Dr.P.K.Koshy, Head, CPCRI Regional Station, Kayangulam, Dr.(Mrs)Sosamma Varghese, Senior Scientist, Distinguished delegates from various parts of India and Ladies and Gentlemen,

I would like to add my own words of welcome to all of you to CPCRI on this occasion of the inaugural session of Nematology Group meeting on Horticultural Crops.

As you are aware, I am not a Nematologist, myself but I am happy to be associated with this function in view of our concern on the serious problems these tiny animals can cause to plantation crops. It is very interesting to note that the Science of Plant Nematology had its birth in Kerala with the first two reports of root-knot nematode on tea from Munnar followed by the same Nematode on Black pepper from Wayanad.

Important nematode problems on plantation crops are:-

1. The burrowing nematode infesting coconut, arecanut, oil palm, black pepper, ginger, turmeric and the intercrops in coconut and arecanut based farming systems such as banana, betel vine etc.

2. The root lesion nematode, *Pratylenchus coffeae* and other species infesting coffee, cardamom, banana and oil palm.

3. The root-knot nematode, *Meloidogyne incognita* on black pepper, cardamom, ginger, turmeric, betel vine, banana, vegetables, tuber crops and many other crops.

Research on plant nematology in this Institute was initiated with the establishment of the Division of Nematology at CPCRI RS Kayangulam, Kerala in October, 1972. The major objective of the Division is to conduct fundamental as well as problem oriented applied research on plant parasitic nematodes associated with plantation crops especially the occurrence and distribution of important species, their host range, bionomics, pathogenicity,

disease complex involving nematode sand other pathogens and developing integrated management against them.

The major research accomplishments are:-

1. Extensive surveys conducted on coconut and other crops revealed the presence of 54 species of nematodes belonging to 40 genera from the root zone of coconut. Recorded the wide spread occurrence and pathogenicity of burrowing nematode *Radopholus similis* on coconut and arecanut.

2. Axenic culturing of *R. similis* on carrot disc and within the mesocarp of coconut was reported for the first time in India.

3. Pathogenicity experiment of *R. similis* under field condition for 11 years which is first of its kind in plantation crops . This proved the pathogenicity and indicated the loss in yield of coconut caused by *R. similis*

4. Standardisation and recommendation of the method and rate of application of oil cakes for the management of *R. similis*.

5. Chemical control measures by using nematicides for the control of *R. similis* in the nursery as well as in field. We also have a nematology unit at CPCRI Kasaragod working on nematode management on arecanut based farming system.

6. At the moment, we are concentrating on management of *R. similis* using biocontrol agents, viz. *Paecilomyces lilacinus, Pasteuria penetrans* and VAM.

From early eighties Scientists from various ICAR institutes, State Agricultural Universities, plant protection officers of Agricultural Departments and research scholars from different parts of the country as well as from abroad (Netherlands and Sri Lanka) came to this lab for training on different aspects of Nematology, identification and culturing of *R. similis* mainly because of the expertise available here.

We were also fortunate to be the hosts of eminent Nematologists like Drs. DJ Raski, R. Mankau, Saroj Mankau, Abrar M. Khan, A.R. Seshadri, KC Sanwal, CL Sethi and to have their valuable suggestions in improving the Nematology work.

Further we were also invited to run a training course on "Identification of Burrowing Nematode, *Radopholus similis* and *Heterodera oryzicola* by the ICAR. Nematology lab at CPCRI RS Kayangulam thus provided a pivotal role in the development of science of Nematology. It was therefore in fitness of things that ICAR proposed to organise this Nematology Group Meeting on Horticultural crops at this Station.

It is a matter of great satisfaction to me that we have published well over 100 research papers in journals of repute. Five students have obtained their Ph.D's so far. We have also not lagged behind in acquiring the latest sophisticated equipments without which so much progress not have been possible.

We have already handled successfully over 3 research schemes funded by ICAR. At the moment there is one ICAR and one US aided PL 480 scheme running successfully in this laboratory. We have also started working on Entomopathogenic Nematodes for the control of insect pests of coconut which is now gaining importance world wide and this is important to us since coconut is attacked by a wide range of insects.

It is a matter of great pleasure for me to point out that the lab here is recognised as a leading centre on *R. similis* on plantation crops not only in India but also abroad. At this juncture I congratulate Dr.PK Koshy and his colleagues for the outstanding work that have been done here and also for the promise it holds for future. I am sure that the nematologists gathered here will help them to reach further heights. We shall be only glad to be at the service of any organisations in solving problems related to nematodes by providing the facilities - equipments as well as manpower at our disposal.

With these few words, I once again welcome you all to this function.

INAUGURAL ADDRESS

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Dr.KUK Nampoothiri, Director, CPCRI, Dr.Gopal Swaroop, Retired Professor and Head, Division and Nematology, IARI, Dr.P.K.Koshy, Head, CPCRI Regional Station, Kayangulam, Dr.(Mrs)Sosamma Varghese, Senior Scientist, Distinguished delegates from various parts of India and Ladies and Gentlemen,

I consider it a unique privilege for me to be here with you this morning on the occasion of inaugural ceremony of Nematology Group Meeting on Horticultural Crops. I am glad, this meeting is organised at Central Plantation Crops Research Institute, Regional Station, Kayangulam, Kerala. I congratulate Dr.Nampoothiri, Director, CPCRI and Dr.Koshy, Head, CPCRI RS Kayangulam for taking timely initiative in organising this group meeting.

Needless to mention nematodes are very tiny animals affecting our life both as friends and foes in many ways. Due to their hidden nature the majority of us are either ignorant about their presence or prefer to ignore them. They are found everywhere in all kinds of habitat. In numbers they surpass all groups of metazoic animals and in species are perhaps second only to the insects.

Prior to 1950 only a few species of plant parasitic nematodes of high economic value were identified. When the world awakened to face the challenges of economic rehabilitation after the second world war, increasing agricultural productivity was one of the main considerations.

The monoculturing of many crops had already depleted yields considerably due to substantial rise in the population levels of pests. At this Stage, perhaps for the first time the realisation dawned upon mankind that nematodes are serious pests of crops.

With the growing awareness about the importance of nematodes, the discipline of Nematology made rapid progress during 1960's and is still continuing to do so, inspite of limited

resources and facilities that are available to the Nematologists. A considerable amount of literature on different aspects of nematological research in India has been published even though this discipline was recognised only three decades back. This clearly reflects the rapid progress made by this discipline in a short period of time. In addition to this, almost all the Crop Research Institutes and State Agricultural Universities today have nematology as an independent discipline.

History of Nematology in India

It is interesting to note that the science of plant nematology had its birth in India with the report of the root-knot nematode on tea by CA Barber in 1901 from Munnar, Kerala, followed by a report of the same nematode on black pepper by Butler in 1906 from Wayanad in Kerala itself. The discovery of Golden Nematode of Potato in 1961 and report on root-knot nematode on vegetables, fruits and ornamental crops are considered as events which laid foundation for the development of Nematological Research in India.

The land marks that led to the fast development of the science of Nematology in India are

- The pioneering work on nematode survey and taxonomy.
- Continuous report on nematode damage on variety of crops e.g. Root-knot Nematode on vegetables, pulses, banana, ornamentals etc. Cyst Nematode on potato in The Nilgiris, Cyst nematode on wheat, barley, reniforme nematode on vegetables, pulses, grapevine etc. Citrus nematode on citrus, burrowing nematode on Banana, Coconut, Arecanut, Black pepper etc.
- Establishment of full fledged Nematology department at IARI and in many Central Institutes increased the availability of trained man power for nematological investigation.
- Organisiation of series of training programmes and practical demonstrations of increased yields in many crops due to nematode control.
- Establishment of the Nematological Society of India in 1969.
- and publication of the Indian Journal of Nematology from 1971.

The progress of research is particularly impressive in the areas of nematode survey and taxonomy, identification of numerous nematode problems in the field, biology of several nematode species on variety of crops and soil conditions, assessment of

pathogenicity and estimation crop loss caused by different species, basic work on nematode physiology. Over the years, necessary facilities and expertise have also been built up for the post graduate teaching and research and for organising short course/training programme to take care of the manpower needs in the coming years.

During the past one decade the scope of nematology expanded rapidly with the emergence of new areas such as application of DNA based technique in nematode taxonomy, use of free living nematodes in environmental monitoring and exploiting entomopathogenic nematodes in insect pest control. On the other hand removal of potential nematicides from world market due to increased consciousness about environmental hazards of pesticides and consequent slow pace of development of newer nematicides is posing a serious challenge to phytonematode management.

I would like to place before the distinguished nematologists certain ideas and priorities for your deliberations.

1. Though large number of crops are known to suffer huge losses in the nursery and in main plantations, precise estimates on crop losses are not available on all crops.

2. In many cases application of nematicide was found to be very effective in controlling nematode populations and increasing the crop yield, but there have been only very little information on the residue left in the product of these treated crops. This is extremely important as most of the product of these plantation crops are export oriented crops. This is very important before the recommendations on nematode management are passed on to the extension agencies to rule out the likelihood of any residues in the export oriented products.

3. Integrated management of nematode diseases, especially by the use of biocontrol agents is an area that requires immediate attention in view of environmental pollution. Though large number of biocontrol agents have been identified and isolated most of the research are confined to lab and pot culture studies. Large scale use of this parasite which has many good attributes including specificity, survival in soil, virulence etc. has been limited because of the inability to culture these organisms *in vitro*. I hope that this limitation will be overcome soon and its exploitation becomes a reality in controlling nematodes at the field level.

Taking the overall view of progress, I feel very happy that Nematology in India has experienced steady growth during the past three decades. This has been possible due to well planned concerted efforts made by the nematologists engaged under the ICAR Institutes and Agricultural Universities.

The main objective of this group meeting is to be make uniform the methods of control for the same nematode disease on the same crop, as far as possible, by various agencies like Agricultural Universities and ICAR institutes by a general consensus of the agencies involved. At ICAR Headquarters we will be looking forward for the concrete suggestions and action plan regarding nematological research on horticultural crops.

With these words, I have great pleasure in inaugurating this NEMATOLOGY GROUP MEETING ON HORTICULTURAL CROPS and wish it a great success.

Technical Session - I

MANAGEMENT OF NEMATODES INFESTING VEGETABLE CROPS

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Vegetables constitute an important component of our daily diet in providing proteins, minerals, vitamins, fibres and fluid. The anticipated total area under vegetables during 1996-97 would be 51.2 lakh hectares yielding a production of about 808 lakh tonnes, an increase of 38% over the production recorded during 1991-92 (Table 1). The increasing and fast means of transportation coupled with modern processing techniques have made these often perishable commodities, which were previously available on a seasonal basis in local market or restricted to growing areas, readily available nationally and internationally around the year. The gradual rise in exports during 8th and 9th Five year plans have further provided incentives to the growers for cultivating vegetable crops (Table 2). However, despite the use of high yielding varieties of some of the vegetable crops and providing optimum inputs, the increase in their yield has not been the same in all the States. Also, we are still lacking behind in achieving the optimal productivity targets as have been recorded in other countries.

Table 1. Area and Production of Vegetables

Year	Area (Lakh ha)	Production (lakh tonnes)
1991-92	51.3	585.3
1993-94	48.2	650.9 (+11.2%)
1996-97 (anticipated)	51.2	808.0 (+ 38.0%)
Demand for 2002 (Projected)	69.61	1312.0
Target for 2002 (Projected)	57.32	1080.0

Table 2. Exports during VIII and IX Five Year Plans (Crore rupees).

Items	Years						
	92-93	93-94	94-95	95-96	96-97	2002-2 (anticipated)	2005-6 (projected)
Fresh fruit & vegetables	347	397	465	504	800	1106.2	1500
Processed Fruit & Veg.	206	246	310	350	400	1194.4	1750

Nematodes are among the various biotic stress factors contributing towards the lower productivity of vegetable crops. It is well recognised that in addition to debilitating value, the plant parasitic nematodes in combination with other soil microorganisms like fungi, bacteria and viruses greatly enhance the damage potential. A large number of plant parasitic nematodes and their species have been recorded from the rhizosphere and roots of vegetable crops but generally the nematode belonging to two important groups, the root-knot nematodes (*Meloidogyne* spp.), and the reniform nematode (*Rotylenchulus reniformis*) have been well documented as the serious pests of these crops in India. Since both root-knot and reniform nematodes are polyphagous in habit, they are widely distributed in our country.

A few other nematodes like *Tylenchorhynchus brassicae* in north-western plains and *M. hapla* in comparatively higher and cooler hills of India have also been recorded to be serious pests of vegetable crops. But their overall impact is yet to be properly appreciated. Likewise, Koshy and Sosamma (1975) have recorded the existence of *Radopholus similis* on beans, cabbage, beet, cantaloup,

carrot, cowpea, okra, pea, sweet potato, pumpkin, radish, squash and tomato but its limiting role with these crops under field conditions have yet not been observed. Therefore, there is need to monitor the association of some of these plant parasitic nematodes as they may not be significant pests today but might develop over the time, unless adequate and timely precautions are taken.

1. Root-knot nematodes (*Meloidogyne* spp.) :

Root-knot nematodes commonly refer to the species of genus *Meloidogyne*. These nematodes cause knots or galls on the roots of the host plants. The intensity of manifestation, like big/small galls on the plant generally depend upon initial nematode population in soil, nematode species, host plant, duration of crop and nutrition factors etc. World over, there are more than 60 species of this genus, whereas in India about 12 species have been reported to occur. But, of all these species, pre-dominating populations encountered are of *M. incognita, M. javanica, M. arenaria* and *M. hapla*. *M. incognita* and *M. javanica* are commonly found in the tropics while *M. arenaria* is most common in the subtropics. *M. hapla* occurs in the temperate regions or cooler upland tropics. These nematodes are major pests of vegetables belonging to solanaceous (tomato, brinjal, chilli), cucurbitaceous (bittergourd, cucumber, pumpkin, bottlegourd), leguminous (cowpea, bean, pea), cruciferous (cauliflower, cabbage, broccolli, brussels sprout), okra and several other root and bulb crops (onion, garlic, lettuce, celery, carrot, radish).

1.1 Economic Loss

Information on monetary losses due to nematode in vegetable crops under Indian conditions are still scanty. According to Taylor and Sasser (1978) the average yield loss in world is around 5% and much higher in developing countries in tropics and subtropics. However, this aspect has started receiving attention of nematologists from the past some time. Comparing the protected with unprotected crop, the magnitude of these yield losses range from 28.0 to 47.5% in tomato, 26.2-50.0% in brinjal, 19.7-33.3% in chillies, 6-90% in okra, 38-47.4% in bittergourd (AICRP, 1992). The yield loss is influenced by several biotic and abiotic factors and there is a need to have a comprehensive information database on the interaction of these factors for developing a forecasting model for usage in advisory services.

1.2 Life cycle

Root-knot nematodes have a very wide host range. Its life cycle remains similar on all these hosts with 2nd stage juvenile being the infective stage. Sasser and Carter (1985) have documented exhaustive information on the biology, taxonomy, methodology and control of this nematode. Dasgupta and Gaur (1986) have reviewed the same on the root-knot nematode spp. in India. Wyss *et al.* (1992) have captured the life cycle of the root-knot nematode in a video camera on *Arabidiopsis*. It is by far one of the best accounts of nematode establishment on the host.

The second stage juvenile (J2) on establishment in the host induces the formation of large multinucleate, metabolically active cells called the giant cells, which serve as a permanent source of nutrients for the endoparasite (Huang, 1985). Molecular and cellular details of giant cells have been reviewed by Bird and Wilson, 1994. They have isolated a suite of genes with apparently up regulated expression in *M. incognita* induced giant cells. These genes (e.g. a plasmalemma H+ATPase) appear to encode functions likely to be responsible for the biochemical make up of giant cells. Other genes (e.g., a putative transcript factor and an apparently vascular parenchyma/specific E2 enzyme) may also play regulatory roles in giant cell formation.

1.3 Races

The existence of physiological variation in the species of *Meloidogyne*, based on the host differential reactions for the four major species and their races was developed by Hartman and Sasser (1985). World over four races of *M. incognita* and two of *M. arenaria* have been identified. The taxonomy of the species even though is still broadly based on morphological characters, but in recent past, it has also been possible biochemically to segregate some of the most common prevalent nematode species using b-esterase (Ganguly and Dasgupta, 1989). This has an added advantage as the identification is possible by using a single female. All the four races of *M. incognita* have been recorded from this country (Bajaj *et al.*, 1986; Khan and Khan, 1991; Sharma and Gill,1992; Khan and Khan, 1992). Recently, Suresh (1997), using RAPD - PCR has differentiated all the four races of *M. incognita* using a 10-mer primer, OPA-08, thus suggesting race differentiation at genomic level. In case of *M. javanica*, Patel *et al.*, (1991) have reported the existence of two pathotypes based on

groundnut cultivar differentials. Only Race 2 of *M. arenaria* has been reported from India by Khan and Khan (1991).

1.4 Symptoms

The presence of galls is the primary symptom of root-knot nematode pathogenesis. Symptoms of root-knot on crops like onion and leek are very discrete, the main symptoms being the presence of protruding eggmasses. Galls on roots of brinjal are bigger as compared to tomato whereas galls in sweet and chilli pepper are usually small. Carrots infected with root-knot nematode often exhibit galling, forking, stubbing and fasciculation of roots. *M. hapla* produce only small, more or less spherical galls with profuse root branching originating from the gall tissue giving a"bearded root" symptom (Netscher and Sikora, 1990).

1.5 Disease Complexes

The pathogenic effects of these nematodes on host crops invariably undergo a change in the presence of other microorganisms like fungi, bacteria, virus, mycoplasma etc. and intensity of disease often gets aggravated. Amongst the most common fungi found to be associated largely with root-knot nematode and reniform nematode, are the species of *Fusarium* followed by *Rhizoctonia solani*. Other fungi encountered are *Sclerotium rolfsii*, *Macrophomina phaseoli*, *Pythium aphenadermatum*, *Colletotrichum atramentarium*, *Verticillium dahliai*, *Phomopsis vexans* and *Ozonium texanum*. Dhawan (1977) also reported interaction of Mycoplasma like organism with root-knot nematode on eggplant. The nematode-fungal complex may effect the host plant by breakdown of fungal resistance, additive or synergistic pathogenic effect, suppression of symptom or even earlier appearance of disease symptoms. Presence of *M. incognita* and *Pseudomonas solanacearum* together in tomato plants shows an additive adverse effect when compared to their individual effect. Further, the wilt symptom may appear early when nematode precedes the bacterial infestation i.e. 75% with bacterium alone in 49 days as against 100% with nematode + bacterium combination in 34 days (Sitaramaiah and Sinha, 1984; AICRP, 1992). *M. incognita* in association with *R. solani* reduced the germination of brinjal while in association with *F. lycopersici*, the plants showed reduced growth and wilting (Arya and Saxena, 1988). *M. incognita* along with *R. solani* also reduced the tomato seed germination and caused severe damping off in association than alone (Chahal and Chhabra, 1984). Above cited examples clearly show that all these organisms co-inhabit in soil and there is a need to identify their individual role in the etiology of disease with respect to yield loss.

2. Reniform Nematode

Reniform nematode, *Rotylenchulus reniformis*, with pre-adult female as the infective stage is the other important nematode pest of vegetable crops after the root-knot nematodes. Varaprasad (1986) has reviewed the available information on this nematode in India. World over about 10 species of *Rotylenchulus* are known (Gaur and Perry, 1991).

Not much information exists on the economic damage caused by the nematode. Usually, nematode population density of 1 larva/cc of soil can cause a significant reduction in plant growth. Hosts like tomato and brinjal show damage at even 0.1-0.5 infective females per cm-3 of soil. The tolerance level increases with increase in the age of the plant at the time of inoculation (Mahmood and Saxena, 1986). Tomato yield was reduced following the inoculation of 100 juveniles/plant (Singh and Khera, 1979).

2.2 Biological races

Difference in the parasitism of *R. reniformis* populations on sugarcane led Birchfield and Brister (1962) to conclude that races existed in the nematode. Dasgupta and Seshadri (1971) have established the existence of two races in *R. reniformis*, race A multiplying on cowpea, castor and cotton while race B only on cowpea. Recently, Prasada Rao and Ganguly (1996) have reported occurrence of 4 physiological races based on differential reproduction capabilities on pearl millet, cotton, cowpea, castor and mustard.

2.3 Symptoms

The above ground symptoms are typical of nematodes. The nematode at high population densities can induce or delay seedling germination and emergence of some vegetable crops (Nanjappa *et al.*, 1978; Patel *et al.*, 1986a). The appearance of partly protruding reniform female

covered with a gelatinous matrix and adhering soil particles on the poorly developed root, with fewer secondary roots is unmistakable evidence of infection by the reniform nematode.

2.4 Disease Complexes

Root injury by nematodes and perhaps, associated changes in root physiology appear to be responsible for the increase in severity of fungal diseases. Resistance of cowpea cvs. RC-8 and EC 4213-A to *Rhizoctonia solani* was broken in the presence of reniform or root-knot nematode (Khan and Husain, 1989 a).

The presence of *Pratylenchus sefaensis* on cowpea made it more vulnerable to *R. reniformis* invasion (Egunjobi *et al.*, 1986). Also, cowpea cultivar resistant to *R. reniformis* became susceptible to it in the presence of *M. incognita* (Khan and Husain, 1989 a,b).

3. Management

The most important consideration in the nematode management of vegetable crops is to follow the thumb rule that, prevention is better than cure. Several physical and cultural methods like destruction of infested roots after crop harvest, burning of paddy husk and saw dust on infested nursery (Chaudhary, 1981), rotation with non-host or antagonistic hosts like mustard, sesame, maize, wheat in cropping system (Haque and Gaur, 1985; Siddiqui and Saxena, 1987), flooding, summer ploughing, harrowing and solarization have been evaluated alone or in various combinations to check the multiplication of root-knot, reniform and lesion nematodes infesting wide range of vegetable crops. However, the adoption of these methods has been by and large limited and very often location-specific. Also the past three decade period has been generally the era of chemical evaluation, starting from the fumigants to organophosphates and carbamates for nematode management, as these bring down the nematode population quickly and provide spectacular crop growth giving enhanced yield. However, despite these positive gains, their application in the field have not taken off due to the increasing awareness of their adverse effects on the health hazards, pollution and toxicity, besides high cost and often non-remunerative situation except for few cash crops like grapes, tobacco and potato. Judicious use of chemicals like nursery bed treatment, bare root dip, seed dressing, seed soaking, foliar application alone or in combination with other ecofriendly and economically viable practices is recommended as it is not completely feasible to dispense with their use.

3.1 Chemical Control

3.1.1 Nursery-Bed Treatment

Among all available chemicals with known nematicidal properties, nursery bed treatment with metham sodium @ 25 ml/m^2, carbofuran and to lesser extent thimet each @ 0.3 g a.i./ m^2 have been recorded to give generally nematode free healthy nursery of transplanted vegetable crops (tomato, brinjal, chilli, etc.) showing vigorous growth, which on transplantation in the main field establish much better. Reduced gall index and enhanced yield ranging from 53.5 - 262.0% in tomato; 6.8 - 160.0% in brinjal and 5.6% in chillies have been recorded (AICRP, 1992). Phenamiphos, the only known nematicide, even though permitted for field use to control nematode infesting a few crops, is still to go on a large scale trials for its various effects especially in relation to vegetable crops.

3.1.2 Bare Root Dip Treatment

The bare root dip treatment of the seedlings at transplanting stage in EC formulation of systemic nematicides has shown to provide adequate protection against nematode by way of reducing nematode gall index and its soil population which have resulted in giving increased yield. Various combinations of chemical concentrations (500-2000 ppm) and time exposure (30 min to 12 hours or more) have been investigated by several workers. Dimethoate @ 500 ppm for 6 hours, phosphamidon and dichlofenthion each @ 1000 ppm for 8 hours against *M. javanica* and carbofuran @ 100 and 1000 ppm for 6 hours against *Meloidogyne incognita* have shown promising results (Tiagi *et al.*, 1986; Khan *et al.*, 1985).

3.1.3 Seed Dressing

In case of directly seeded vegetable crops like okra and cucurbits, seed dressing with chemicals is being viewed to be another measure of protecting tender seedlings from nematode damage. Among the few available chemicals, carbofuran (25% ST) applied @ 3% w/w alone or its combination with fungicide like thirum or carbendazin @ 0.2 g a.i./m2, the latter two being used to ward off pathogenic soil fungi, gave an increase in yield ranging from 30.6-96.9% in okra, 111 - 166.5% in

pointed gourd and 28.6% in bittergourd against *Meloidogyne* spp. (AICRP, 1992). Higher doses upto 6% w/w have been observed to further reduce the nematode damage.

3.1.4 Seed Soaking

The seed soaking in the EC formulation prior to sowing has been one of the methods to reduce the quantity of chemicals used in minimising the nematode damage. The soaking of okra seeds in 0.1% dimethoate, phosphamidon and UC 54229 have been observed in reducing the gall index ranging from 0.2 to 0.6 times over control (AICRP, 1992). Triazophos @ 0.1% has also proved equally effective in giving protection to okra plants against *M. incognita* (Jain and Gupta, 1986).

Some workers have also attempted to evaluate the effectiveness of chemicals like, dimethoate, methyl demeton, monocrotophos and phosphamidon as foliar application to minimise the damage to the standing crop by plant parasitic nematodes. Methyl demeton when sprayed @ 0.05% on brinjal plants prior to inoculation of *M. javanica* significantly reduced the infestation (Nandal and Bhatti, 1980). Further, intensive work in this area might open up the possibilities of treating the standing crops infested with nematodes which otherwise is not possible with the present generation of available nematicides.

3.1.5 Soil application

Some researchers have evaluated chemicals for application under field scale against vegetables. Application of carbofuran @ 3 kg/ha to the soil with carrot var. Early Nantes in Assam gave a significant reduction in plant height (10.53%) tap root length (27.52%) and yield (40.81%) in untreated plots compared to treated (Devi and Das, 1994). Application of phorate @ 6 and 3 kg/ha on tomato *cv.* Money maker in field trials in Himachal Pradesh gave maximum reduction to root gall index (52.6 and 42.1%) and maximum increase in yield (65.2% and 38.5%) respectively (Sharma and Khan, 1995).

3.2 Cultural Practices

Deep ploughing, fallowing and solarization are the best natural means to reduce the nematode population in our country where the temperature during summer ranges from 35-45^{0}C. Ploughing not only leads to disturbance and instability in nematode community but also causes their mortality by exposing them to solar heat and desiccation. Generally, two or three summer ploughings each at 10 days interval during June (40-46^{0}C) have been recorded to reduce 96% of *M. javanica* population while fallowing itself during the same period registered 45.5% reduction. The additional use of plastic sheet for covering soil either in nursery beds or in field further enhance nematode reduction. Maximum nematode reduction and significant increase of yield in okra and brinjal were observed in case of soil ploughing and covering with polythene sheets, followed by soil ploughing and exposure to sun in comparison to no ploughing and covering (Anon., 1989). Such an approach also helps in reducing the intensity of weeds, fungi and bacteria in the soil. This has become a viable technology in raising nematode free nursery for transplanted vegetable crops like brinjal, tomato, chilli etc.

3.3 Biological Control

The identification and exploitation of naturally occurring biological control agents in our country has become the research priority for nematologists in recent years. Being cost effective and ecofriendly these can well incorporate into any integrated nematode management package.

3.3.1 Fungi

Nematophagous fungi like *Dactylaria eudermata*, *Dactylella cynopaga*, species of *Arthrobotrys*, *Cytopage* and *Stylopage* etc. have been recorded in past showing promising results in nematode management. Of these, *Arthrobotrys robusta* and *A. irregularis* have been commercially released in France as Royal 300 for control of mushroom (*Agaricus bisporus*) nematodes and Royal 350 against root-knot nematode in tomato respectively. Field trials using Royal 350 (cultured on oat seed medium) applied @ 140 g/m2 a month before transplantation resulted in good protection of tomato crop against root-knot nematode. However, their application by and large were confined to experimental trial/microplot observation.

Among the large number of nematode endoparasitic fungi, the promising ones include egg parasites (*Verticillium chlamydosporium*, *Paecilomyces lilacinus*, *Dactylella oviparasitica* and *Cephalosporium* spp.), and parasites of sedentary females (*Nemaphthora gynophilla*, *Catenaria oxylaris*, *Glomus*spp., *Fusarium* spp. and *Aspergillus* spp. etc.). Among these the efficacy of *P.*

lilacinus has been documented to be comparatively higher in suppressing the population of *Meloidogyne* spp. and *R. reniformis* on vegetable crops. The adaptability of the fungus to a wide range of soil pH and temperature (Bansal *et al.*, 1988) make it rather competitive organism in agricultural soil around the world. It is also found to be equally compatible with most available fungicides and nematicides. Sasser (1991) reviewed the results regarding the efficacy of this fungus in 15 countries and observed it giving successful results in arid and semi-arid regions and less than 50% success in other regions (temperate, semi-tropical and tropical). These results encouraged its commercial production under the name B-CON in Philippines. Pandey and Trivedi (1992) reported that infestation of *M. incognita* on *Capsicum annum* was significantly reduced in the presence of *P. lilacinus*. However, indications of pathogenic/allergic effects to human beings of this fungus need in-depth clinical investigation prior to its commercial development.

3.3.2 Bacteria

Among the bacteria β-exotoxin produced by *Bacillus thuringiensis* (*Bt*) kills 95% larvae of *Meloidogyne* spp. (Rai and Rana, 1979). The two insecticidal strains, Deipel and SAN 415, suppress the eggmass formation and nematode population in soil, the latter being more effective than former. Another isolate of *Bt* (R-371) was found effective in reducing *Meloidogyne* galls on tomato (Zuckerman *et al.*, 1993). Sharma (1994) recorded 53 - 66% level of nematode control by using 2 strains of *Bt* var. *thuringiensis* (*Btt*) and *israelensis* (*Bti*). However, the subsequent reports identified *Pasteuria penetrans* as the most promising bioagent despite its limitation of mass production. In India, its two strains, one going to pigeon pea cyst nematode and the other on root-knot nematode have been reported. The galling of tomato roots and population of *M. javanica* in soil at harvest were significantly reduced when the root material containing *P. penetrans* spores (@ 212-600 mg powder/kg soil) was incorporated in the root-knot infested soil (Sayre, 1984). Somasekhar and Gill (1991) observed that application of *P. penetrans* in nursery bed in combination with carbofuran @ 1.5 kg a.i./ha was as good as carbofuran applied @ 3 kg a.i./ha in respect to plant growth parameters and nematode reduction. It has also been observed that *P. penetrans* (cyst strain) reduced the population of *Heterodera cajani* on cowpea by 87.2 % at the end of third planting which could further go to the stage of near extinction in proceeding generations (Singh and Dhawan, 1996). Further, it is far more easier to introduce this organism at field level through transplanted crops than directly seeded ones.

3.3.3 Vasicular-Arbuscular Mycorrhizae

Role of several species of vasicular-arbuscular mycorrhizae (VAM) especially *Glomus fasciculatum* against root-knot nematode and *G. mossae* against *R. reniformis* in tomato has been well documented (Sitaramaiah and Sikora, 1981; Suresh and Bagyaraj, 1984). More recently, it has been worked out that the efficacy of VAM gets enhanced when combined with other organic amendments and synthetic chemicals. An increase in plant growth parameters coupled with decrease in root-knot index and population of root-knot nematode were observed in treatments where mycorrhizal tomato seedlings were transplanted in neem cake amended soil. High colonisation of *G. mossae* in tomato roots indicated favourable effect of neem cake on its growth (Rao *et al.*, 1995). Inoculation of *G. fasciculatum* in *M. incognita* infested tomato nursery beds amended with *Calotropis procera* leaves indicated their synergistic effect (Rao *et al.*, 1996).

3.4 Organic amendments

Application of parts and products of several plants like neem, mahua, groundnut, mustard, cotton etc. alone or in combination with chemicals have shown an improvement in plant growth with corresponding decline in nematode population either through promotion of natural enemies or release of toxic (Gill and Jain, 1995)/ phenolic compounds especially hydroquinine (Mahmood and Siddiqi, 1993). Application of neem cake @ 15 g per spot or 100 g per m furrow, three weeks prior to transplanting of tomato or brinjal have been reported to give 36-450% enhanced yield (Gill and Jain, 1995) with corresponding reduction in gall index to 2.3 as against 4.3 in control. Application of neem leaves @ 6 g/kg soil on tomato *cv.* HS-101 gave high tomato growth and low number of galls whereas in case of brinjal *cv.* BR-112, there was approximately 81% reduction in gall formation and eggmass production in treatments receiving 10-15 g neem leaves/kg soil (Walia and Gupta, 1995). Nimin, a neem based product, and oil from castor, mustard, neem and rocket-lettuce (*Eruca sativa*) when applied as bare root dip treatment at concentration of S, S/2 and S/10 (where Standard S = 10 ml extract + 90 ml distilled water), reduced the incidence of root-knot nematode on chilli *cv.* Jwala (Akhtar and

Mahmood, 1994). Seed treatment of okra in latex extracts of *Calotropis procera* and *Euphorbia caducifolia* for 72 hr reduced the root-knot nematode development (Wani *et al.*, 1994).

Some secondary plant metabolites have also been tested as successful nematicides. Serpentine, an isolate from roots of *Catharanthus roseus* + citronellol, an oil from *Pelargorium graveolens* @ 0.02% as seed treatment significantly increased the growth of tomato and decreased *M. incognita* infestation (Rao *et al.*, 1996).

It has been observed from the literature that the above listed organic amendments with similar dosages are also found to be equally effective in suppressing the population of several other nematodes like *R. reniformis*, *Pratylenchus* etc.

3.4 Resistance

Host resistance exploited in breeding nematode resistant varieties is the most cheapest and viable approach in tackling nematode problems at field level. The sources of resistance in various vegetable crops have been identified by several workers against the root-knot and reniform nematode in India (Table 3 and 4). However, the success in breeding nematode resistant varieties has so far been with tomato (Hissar Lalit and PNR-7) and cowpea (GAU-1) against the root-knot nematode.

Table 3. List of resistant varieties against root-knot nematodes.

Crops	Resistant Varieties
Tomato	SL-120, PNR-7, Hissar Lalit, Cambell-25, VFN-Bush, Patriot, Ronita, Pierseol, Rossol, Kewalo, Motabo, Punuui, F-455-D-1, Mangala Hybrid, Karnataka Hybrid, Nematex, Y-220, Atkinson, 569 N-10
Brinjal	Pbr-91-2, Gulla, Gachha baigan, Vijaya hybrid, Ghatika white, Black beauty, T2, Banaras Giant, *Solanum sisymbrifolium*, Black round, Jaumpuri long, PBR 91-1
Cowpea	GAU-1, C-152, 82-1B, IC 9641, IHR 29-5
Okra	IC-52314
Pea	C-50, A-70, B-58, DDR-4, DMR-17, DMR-14, DMP-6
French bean	banat, Blue Lake, Stringless, Brown beauty, Cambridge, Countess, Bountiful flat,
Cabbage	Early express , Unali K 84.26, Market queen, Durhum early, Red cabbage
Cauliflower	Indian Snowball, early Patna, Late Patna
Chilli	Pusa Jwala, Malagachi yellow, Jalandhari, Laichi-2

Table 4. List of resistant varieties against reniform nematode.

Crop	Resistant Varieties
Beans	Jack bean, velvet bean (non hosts)
Cowpea	V-16, Pusa Phalguni, RC-48, C-152, S-488, EC-4213 A, RC-8
Onion	Evergreen
Tomato	Kalyanpur Selection I & III, LA 121, EC 118272, EC 118276, Peto 108, Peto 95, Nem 1400, Petopride.
Turnip	Purple Top, White Globe.
***Capsicum* spp**	Sweet Bell, California Wonder, *C. annum* var. *fasciculatum*, *C. frutescens* var. *microcaspum*.

Researchers while attempting to understand the mechanism of resistance in host crops against nematodes have observed change in the activity of several enzymes, like, peroxidase (PO), poly phenol oxidase (PPO), phenylalanine ammonia lyase (PAL) and tyrosine ammonia lyase. Observations on *M. incognita*-tomato combinations in which PPO was stimulated, led Ganguly and Dasgupta (1984) to a view that stimulation of PPO was due to the activation of latent enzyme by the nematode secretions. Recently, Ramesh *et al.* (1996) have used inherent PPO activity in tomato cultivars as a marker of resistance against *M. incognita*. Higher activity and *de novo* synthesis of PAL was observed in resistant cultivars of tomato and cowpea than in susceptible ones on nematode inoculation (Mote and Dasgupta, 1979; Sirohi and Dasgupta, 1993a and b). Symptom expression in the root-knot infected cowpea plant was triggered by *de novo* synthesis of new species of mRNA (Raja and Dasgupta, 1986). Increase in the production of more amino acids and o-dihydroxyphenols in the reniform nematode

resistant cultivars of tomato and brinjal has been observed (Mahmood, 1985; Mahmood and Saxena, 1986).

Resistance genes in some of the vegetable crops have yet to be identified or located whereas in some others they have been located in wild relatives from where their transfer to cultivable varieties is restricted because of sexual incompatibility. In eggplant, resistance has been reported in wild relatives like *Solanum sisymbrifolium* (Fassuliotis, 1979). In tomato 'Mi' gene on chromosome number six is found to impart resistance against root-knot nematode (Messeguer*et al.*, 1991; Ho *et al.*, 1992; Klein-Lenkhorst *et al.*, 1991; Yaghoobs *et al.*, 1995; Williamson *et al.*, 1994). A single recessive gene 'mj' for resistance to the root-knot nematode, *M. javanica*, has been identified in the cucumber (*Cucumis sativus* var. hardwickline LJ 90430) by Walters *et al.* (1997). Cowpea is one of the first crops in which resistance to root-knot nematode was identified (Webber and Orton, 1902). It is under a control of a dominant gene 'Rk' (Amosuand Franckowiak, 1974; Fery and Dukes, 1980). This gene was initially thought to provide resistance against most of the species of*Meloidogyne* but variation in virulence to resistance gene Rk has been found against *M. incognita* and *M. javanica* (Roberts *et al.*, 1995). New resistance has been identified and characterised as Rk2 in accession IT 845-2049 of cowpea. This dominant trait is another allele of Rk or a locus tightly linked to Rk, and it confers resistance to nematode populations able to attack plants with Rk (Roberts *et al.*, 1997).

Cai *et al.*, (1997) have been the first to clone a nematode resistance gene HS1Pro-1 from sugarbeet imparting resistance to *Heterodera schachtii*. Laboratory and field tests of transgenic tobacco with Tob RB7 promoter nematode responsive element have already been conducted by Opperman and Conkling (1995) wherein they found about 70% reduction in root galling. Newer and better techniques of molecular biology will help overcome the genetic barriers for gene transferring and future is not far when transgenic plants against nematodes will be commercially available.

3.5 Integrated Nematode Management

Integrated Nematode Management promises an environmentally safe and economical approach but unfortunately, the exploitation of various available methods of nematode control in an integrated fashion is still not practised under field conditions. Possible reason could be the lack of adequate research activity and its demonstration at the farmers level at a wider scale. AICRP (1992) proposed an integrated approach by combining cultural methods with organic amendments, chemicals and inorganic fertilisers to reduce the population of pathogenic nematodes and enhance the yield of vegetable crops. In case of transplanted crops like tomato, brinjal and chilli, fallowing integrated with nursery bed treatment of carbofuran/aldicarb each @ 0.3 g a.i./m^2 increased the yield in the range of 25.6 to 262.0% against root-knot nematode. Solarization of nursery beds prior to sowing of these crops further reduced the galls by 0.3 to 0.5 times over control. For direct sown crops like okra, bittergourd and bottlegourd, fallowing coupled with seed dressing with Carbosulfan @ 3% w/w reduced the galls by 0.2 to 0.7 times over control and showed an increase in yield in the range of 14.9 to 166.5%.

Application of urea @ 23.8 kg/ha and neem cake @ 200 kg/ha in combination with carbofuran @ 1 kg a.i./ha in root-knot infested field gave an enhanced yield of tomato (32.2-68%), brinjal (36.7%) and okra (75.8-106%) and reduced the galls by 0.2 to 0.9 times over untreated crop (AICRP, 1992). Jain and Bhatti (1985) have suggested the integration of deep ploughing (upto 20 cm) and nursery bed treatment with aldicarb @ 0.4 g/m^2 and main field treatment of aldicarb @ 1 kg a.i./ha against root-knot nematode on tomato which also registered maximum yield. Intercropping of brinjal with marigold in combination with carbofuran @ 1 kg a.i./ha reduced the infestation of*M. javanica* (Singh, 1991).

Rao and Parvatha Reddy (1992) suggested that incorporation of neem cake, neem leaf/ castor leaf/ pedilanthus leaf/ pongamia leaf each @ 500 g/m and application of spore suspension of *P. lilacinus* or *V. chlamydosporium* in nursery beds, reduced the incidence of root-knot and reniform nematodes even after transplantation of tomato plants in the main field. Similarly, nematode free, healthy brinjal seedlings were obtained from the nursery initially treated with *G. mossae/G. fasciculatum* and subsequently by 5% aqueous extract of neem cake/castor cake/ neem leaf/ calotropis leaf (Rao *et al.*, 1996).

4. Future Thrust

World-wide yearly economic loss of more than $ 78 billion to major food and fibre is caused by plant parasitic nematodes (Barker *et al.*, 1994). Thus, there is a considerable need to reduce these avoidable yield losses by developing new environment friendly, economically acceptable and ecologically based management strategies as the current options become ineffective or

unacceptable. Crop resistance offers to be of great importance in this direction. Utilisation of biotechnology for isolating and cloning resistance genes will facilitate direct gene transfers within and across crop species. In addition, an intensive search of plant germplasm collection for natural resistance to nematodes and their races is also required. An in-depth understanding is needed of the molecular basis of how and why plants are susceptible to nematodes. New progress is being made in studying changes in gene expression during the infection of plants in nematode-host interactions where feeding sites are formed.

The research on identifying the promising biocontrol agents, their mass production, application techniques and their behaviour in the soil under varying agro-climatic conditions need to be intensified.

Research on plant constituents which may alter nematode behaviour and development, serve as nematicides, or disrupt molting, hatching and other hormonally regulated processes needs to be expanded. There is also a need to develop environmentally safe and economical nematicides which can not only be put to use by commercial farmers but also by poor or subsistence farmers of our country.

The information on yield loss, which are greatly influenced due to the interaction of abiotic and biotic factors, need to be further augmented. More research is needed on *R. reniformis, Radopholus similis, Tylenchorhynchus, Pratylenchus* and other nematodes to identify their role in vegetable crop production.

Future nematode management must employ sustainable agricultural practices that take into account beneficial, detrimental and other nematode species in the rhizosphere and in soil. More data needs to be generated in identifying suitable cropping systems which are realistic to the needs as well as acceptable to the farmers including cover crops, antagonistic crops, green manure crops etc.

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MANAGEMENT OF POTATO NEMATODE PARASITES *

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1. INTRODUCTION

The cultivated potato *(Solanum tuberosum)* is a native of Andes Mountain of South America. It was introduced to India in the early 17th century and it's cultivation become wide spread by the end of 19th century. Basically this crop exists in the colder regions of the world and is more suited to the temperate climatic conditions. However the flexibility of growing the crop under varying situations of sub tropical conditions and its adaptability to warmer climatic conditions of the tropics has been well exploited to meet the increasing demand of food supply throughout the world. Now, it is expected that potato would serve as a major source of food in the 21st century particularly in the developing countries. Presently the crop is cultivated in about 130 countries throughout the world with an annual production of 312 million tons from an area of about 20 million hectares. The present area under potato in India is about one million hectares which is about 0.4 per cent of total cropped area. The crop is cultivated throughout the country under varying ecological situations all most throughout the year. The annual production is about 20 million tonnes (an estimated value of Rupees 40,000 million) which is nearly 3 per cent of the output value of agricultural sub sector in the country.

The estimated annual potato production in the world is about 450 million tonnes comparable to the actual achievement of 312 million tonnes. This is due to losses through diseases (12 per cent); pests (7 per cent); nematodes (11 per cent); weeds (3 per cent) and other causes (2%). The nematode parasites have been known to affect the potato crop for the past 110 years and presently about 156 species belonging to 52 genera are reported associated with the crop around the world. Our country which is placed Vth in potato production the world accounts for 93 species of nematodes belonging to about 40 genera. Among these the potato cyst nematodes and the root knot nematodes have been recognised as the major nematode parasites not only in our country but also in the world. The potato cyst nematodes are prevalent in the South Indian hills while the root knot nematodes on potato are distributed throughout the country. In addition the stunt, spiral, lesion and reniform nematodes have also been constantly encountered in the potato cultivation which may late become key pests of the crop.

2. POTATO CYST NEMATODE

The potato cyst nematode, popularly known as the Golden nematode of potato, has established as one of the major crop protection problems of the world. An average loss of about nine per cent of global potato is accounted to these nematodes amounting to build up to damageable levels in the short span of 5-6 years; substantial yield reductions in the crop, lack of inexpensive nematicides for soil treatment capable of providing adequase level of central under field conditions, the relative ease with which the cysts are dispersed with soil adhering to the seed tubers and the long persistence of eggs within the cysts in the absence of the host makes this nematode as probably the most important pest problem of all cultivated crops.

Distribution

Andes mountain of South America has been considered to be the original home for the cyst nematode which are thought to have organized along with their host potato. The cysts must have got

introduced into Europe with the breeding material brought for late blight disease resistance in 1850's and later spread throughout the world with the improved potatoes developed in Europe at that time. So, Europe has been considered as the secondary distribution centre and at present these nema-

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todes are prevalent in about 60 countries. The yellow cyst nematode *G. rostochiensis* is more wide spread being reported from 58 countries while *C. pallica* is prevalent in about 27 countries. The later species is able to adopt itself under subtropical climatic conditions and shows a wide genetic variability in it's original home Andes mountains.

In India, the nematode was detected by Dr.R.w Jones in 1961 from a field at Vijayanagaram State Farm in Ootacamund of Niligiri hills in Tamil nadu. The nematode was probably introduced from British Islands since these fields contained European weeds. Later their occurrence was noticed in Kodaikanal hills also. Detailed surveys conducted earlier in other major potato growing areas of Assam, Karnataka, Himachal Pradesh, Punjab and Uttar Pradesh had indicated that this nematode was absent in these states confirming it's prevalence only in Tamilnadu State. Realising the potential danger of this nematode to potato cultivation in the country, the Destructive Insect Pest Act 1919 was amended by the Tamil Nadu Government in 1971 to ensure strict checking of potato for marketing from infested fields.

A massive chemical control attempt was also made under the Indo-German Nilgiris Development Project during 1971-75. The treatment was made mandatory under the Tamil Nadu Pest Act 1971 and all the infested fields at that time in the Nilgiris were treated at the rate of 30 kg ai/ha of fensulfothion in the first year followed by 15 kg ai/ha in the next year. Inspite of 15 times more quantity of nematicide applied in comparison of present recommendation @2 kg ai/ha the potato cyst nematode is still a major constraint of potato production in Tamil nadu hills ie. Nilgiri hills and Kodaikanal hills. Of late, this nematode has been recorded from potato fields of neighbouring states of Karnataka and Kerala. Although the cysts observed at Karnataka were non viable, these pose as a major quarantine problem which calls for strict vigilance in enforcing domestic quarantine.

Species and Pathotypes

This nematode was first noticed by Julius Kuhn in 1881 at Rostoch in Germany which was thought to be a strain of sugarbeet cyst nematode, *Heterodera schactii.* Differences between these two nematodes were observed by Wollenweber in 1923 and he isolated them as *H. schactii* var. *rostochiensis* denoting the place where they were first noticed. Later, Franklin in 1940 recognised it as an independent species, *H. rostochiensis.* Further developments in breeding potato for resistance to these nemetodes, separation of round cyst nematodes as genus *Globodera* and detailed studies on chromogenesis and morphology of potato cyst nematode varients, made it clear that they are two species. The populations with white or cream coloured females were designated as *G.pallida* while those with golden yellow coloured females being retained as *G.rostochiensis.* Although the females of these two species could be differentiated initially by their colour at developing stage, it is difficult to separate them once they become brown cysts at which stage they cannot be easily distinguished by other *Globodera* species.

The identification of prevalent cyst nematode species from different localities in Nilgiris have indicated that both G. pallide and G. rostochiensis are prevalent at most of the localities surveyed in mixed populations. At Kodaikanal hills also both the species were encountered. Although, the cysts found at Karnataka in potato soil could not be characterised. *G. pallida* was found associated with potato at Kerala. Initial studies on pathotypes indicated that Ootacamund populations belonged to aggressive pathotype 'D' which was not having any source of resistance in *Solanum* species at that time. Detailed studies with several populations around major potato growing localities of Ootacamund town has revealed that 'Ro1 of *O. rostochiensis* and 'Pa2' of *G. pallida* are the most prevalent pathotypes. The other prevalent pathotypes were Ro2 and Ro5 of the former and Pa1 and pa3 of the later species.

Biology

The batching of larvae from cysts in initiated by root diffuses of members of family 'Solanaceae'. The 2nd stage larvae hatched out of the cyst move actively in the soil, invade the roots and lie parallel to the vascular system. This infection results in the formation of giant cells from which the nematodes extract nourishment. The larvae undergo successive molts increasing in size each time to reach a spherical shaped female. The adult female remain attached to the roots with its neck. These females are about 0.7 mm to 0.8 mm in diameter and are yellow or white in colour which gradually turn brown. At the time

of harvest, these brown cysts containing eggs are easily dislodged into the soil. The eggs may remain viable upto 15 years in the absence of potato root diffusstes. The male nematodes retain their thread like appearance and come out freely from the root system and helps the female in fertilizing the eggs.

The laboratory studies have indicated that the 2nd stage larvae took 37-39 days during summer crop (April-July) and 40-42 days during autumn crop (September - December) to become cyst at Oatacamund. Generally one generation is completed in one crop season but there are evidences of 2nd generation of *G. rostochiensis* being completed, because of its' shorter dormancy of 45 to 60 days and longer duration of the crop upto 120 days. However, *G. pallida* has a dormancy period ranging from 60 to 75 days. The multiplication rate for both the species was 7 to 13 times in summer crop and 6 to 11 times in autumn crop when the temperatures normally ranged between 15° to 21°C at Ootacamund. Recent studies have shown that *G. pallida* is able to develop and reproduce in the foot hills of Nilgiris situated at 300 to 350 meters above sea level during October to February where the temperatures ranged from (14° to 19°C minimum and 22 to 30°C (maximum). However *G. rostochiensis* could develop into females only below the maximum temperature of 25°C which were prevalent in altitude of 1400 meters and above. The cysts with eggs within them usually spread along with the soil adhering to farm implements, harvested tubers, gunny bags etc. Other major means of spread are compost, labourer's feet, and seed potatoes. The experimental evidence of cysts being carried through wind was also demonstration during monsoon months in Nilgiries and water running down the slopes transmitted cysts from infested fields to nematode free fields.

Interaction with micro organisms

The association of fungi like *Rhizoctonia solani* and *Verticillium dahliae* with *G. rostochiensis* and species of Phoma, *Collectotrichum* and *Pseudomonas* cyst *G. pallida* have been reported from other parts of the world indicating that cyst nematodes cause disease complexes. However, no such reports have come forth under Indian conditions, probably due to the limited occurrence of cyst nematodes mainly in hilly tracts of Tamilnadu. The nematode helping in increased brown rot disease at Nilgiri hills cannot be ruled out an certain localities are endemic to known rot pathogen wherein the nematode populations are generally encountered at high intensities.

Management

The potato cyst nematodes are the most successful plant parasitic nematodes exhibiting a highly specialised survival mechanism. They are restricted to a limited host range in family solanaceae and have got themselves distributed along with their host adjusting to the surrounding variations. The experience has shown that they cannot be completely eradicated once they establish in a given locality and thus they have to be managed by adopting several plant protection strategies.

Cultural practices : Growing non-host crops and following crop rotation atleast for one year with any non-solanaceous vegetables such as beetroots, cabbage, carrots, cauliflower, frenchbeans, garlic, radish, turnips etc. during autumn season brings down the cyst populations to a great extent, and thus the management of cyst nematode becomes more fensible. The four year rotational sequence using potato-franchbeans-peas had increased the cyst populations by 98 to 99% and increased yields in potato. Presently the Nilgiri farmers adopt Potato-Cabbage-Carrots for the best management of potato cyst nematodes which also helps in maximum utilisation of nutrients applied to the soil.

Breeding for resistance : Research work on breeding for cyst nematode resistance began at CPRS, Ootacamund in 1968 and the studies indicated high degree of resistance in *S. ajanhurri, S. bulbocastanum, S. gandarlassi* and *S. tuberosum* sub species *andigena, S. vernei* and *S. spegazzinii.* A large hybrid seedling population was produced using resistant *S. tuberosum* sub species andigena clones, *S. multidissectum* (selection No.3246) obtained from Scottish plant Breeding Station, Edinburgh, UK and some commercial varieties as parental material. Testing of these hybrids had indicated 3 hybrids possessing high degree of resistance to cyst nematodes. However, further studies and screening showed that genotypes reported resistant earlier proved to be susceptible since there existed two nematode species

and several pathotypes occurred within them. Subsequent screening of germplasm in later years showed that resistance was available in several clones of tuber bearing *Solanum* species.

High degree of resistance to several populations of cyst nematode was exhibited in *S. vernei* clone Vin² 62-33-3 obtained from Netherlands. This hybrid was highly susceptible to late blight disease. Hence, 'Kufri Jyoti' a late blight resistant commercial variety was used as female parent with this clone to obtain several genotypes. One selecting bearing no.110 possessed desirable yield characters in addition to reducing the cyst populations below the initial inoculum levels. This selection has been released as 'Kufri Swarns' in 1985 which presently occupies about 40 per cent of potato area in Nilgiris.

Observations recorded in our farms as well as in the farmer's field has shown that this variety perform well over under drought conditions that is seen specifically under Nilgiri conditions.

The pot experiments have shown that this variety allowed 57.6 per cent of larvae to enter into roots in comparison to 61.2 per cent entry in susceptible Kjyoti 5 days after inoculation. Although there is no much difference in larval penetration, nematode development in K. Swarna was only 1.07 per cent compared to 36.07 per cent is Kjyoti. Further the nematode life cycle was also delayed by 7 days is resistant variety K. swarna in comparison to K.jyoti.

Another advance hybrid D.79-56 has been consistently performing better than the two popular varieties viz., K. Swarna and K. jyoti in Nilgiri hills. It is tolerant to cyst nematodes and highly resistant to late blight disaes and is recommended for release as 'Kufri Thenmalai' other 13 hybrids viz., E-79-15, E/79-42, H/81-5, J-81-6, K-81-16, M-81-10, P/81-22, Q/81-14, Q/81-14, Q/81-15, R-81-67, R-81-143 and T-81-27 are under confirmatory yield trials.

The availability of combined resistance in several advance hybrids to the later blight disease and potato cyst nematodes indicates that there is a provision to manage these problems in Nilgiries. However, since major genes occuring in wild species are used for resistance to both the diseases the protective effect could be nullified since both the parasite and pathogen is able to adopt itself to the new environment as has happened in several cases. It is suggested that for country like ours where legal restrictions cannot be forced to check cyst nematode by resistant varieties, breeding tolerant varieties seems to offer better prospects than using major genes for resistance.

Biological management

The use of nematode antaginistic microorganism for control of potato cyst nematodes have been attempted throughout the world with less success. This has been mainly due to the non mobility of these organisms in search of target nematodes and their non adaptability to the existing environment. Further lack of basic information on these organisms and inadequate studies for field implementation on large scale have made this most prospective and promising management practice as the least effective one. Very limited work done at CPRS, Ootacamund has shown that thirteen fungi were able to infect the cysts and cyst contents from nearly 60 fungal colonies isolated from soils of Nilgiris. The frequency of occurrence was maximum with species of *Dachylaria* (31.6%) followed by *Aspergillus* sps (14%) *Humicola grisea* (10.5%) *Cladosporium* sp. (8.8%). Other fungal species recorded were *Trichoderma, Penicillium, fusarium* and three non sporulating fungi in the frequency range of 7.2 to 1.75%.

Invitro parasitization of eggs by these fungi indicated maximum mortality by *Dactylaria* sps (82.4%), *Penicillum* sps (80.6%), *Aspergillus* sps (68%) and *Humicola grisea* (60%). Other fungi excepting *Fusarium* species were able to parasitize the eggs to varying extents. The parasitization of eggs in *Dactylaria* species was evident from the third day onwards where 6% eggs were surrounded by the fungus and the hyphae growing through them which had increased to 32%, 43% and 82.4% on 5th, seventh and 9th day respectively. Inoculation with *Penicillium* species had shown that the contents of the eggs were distorted though the hyphae had not passed through them indicating a possible role of nematoxin. Though the fungus *Paecilomyce lilacinus* is used as a bioagent for nematode management in other countries but it was not found in Nilgiris soils.

Chemical Management

Initially halogenated hydrocarbons such as DD (1-3 Dichloropropane 1-2 dichloropropene), EDB Ethylene dibromide), MBr (Methyl bromide), DBCP (Dibromochloropropene), Dorlone (mixture of DD and EDB) were used for controlling potato cyst nematodes. Later, after standardisation of use of systemic pesticides, aldicarb or carbofuran at 2 kg ai/ha is effectively used for economical management of potato cyst nematodes under Nilgiri conditions.

Integrated Management

The experience has shown that potato cyst nematodes cannot be completely eradicated once they establish in a locality. They have to be managed by adopting several plant protection strategies. Now the problem is being managed in Nilgiris by chemical treatments, crop rotations and utilizing the available sources of resistance in tuber bearing *Solanum* species. Initially, several halogenated hydrocarbons were used as fumigents. Due to the hazardous nature and difficulties in application of these pesticides they were slowly replaced by systemic granular pesticides. The escalating costs of these pesticides, associated residual problems and slow build up of nematode populations to unmanagable levels have made chemical treatments as uneconomical at several places. However, the restriction of the parasites only to a selected host range has helped in the management of the problem to a great extent. Further the Indian populations containing pathotypes Ro1, Ro2 and Ro5 of *G. rostochiensis* and Pa1 and Pa2 of C. pallida can be managed by S. vernei source as it combines resistance to both these populations.

3. ROOT-KNOT NEMATODE

The root-knot nematodes, causing root galls are the most well known nematode parasites of plants. These are prevalent in all parts of the world, particularly in the subtemperage, subtropical and tropical regions affecting almost all agricultural crops including potatoes.

Distribution

These nematodes have been recorded from all the potato growing countries of the world and have been considered as one of the most important pest of commercial crops next only to potato cyst nematodes. In India,Dr.M.J. Thirumalacher observed scab like warts on potato tubers from Simla during 1950 for the first time and since then it has been recorded on potato from all the potato growing states of the country.

In 1989, Neal from Floride, USA recorded root-knot nematode on potato and designated it as Anguillula arenaria. The nematode was also termed as Heterodera radicicola, till Goodey in 1932 preferred to group all root-knot causing nematodes as H. mazioni. Later, the genus Meloidogyne was established by Chitwood in 1949, who described four most common and widely distributed, root-knot nematodes viz., M. incopnita, M. jayanica, N. Haple and M. arenaria. Now about 65 species of Melodiogyne are described throughout the world. Among these about 10 species are reported on potato and the most important root-knot species are the ones described by Chitwood in 1949. The infection of M. incognita and M. javanica in potato is more damaging as they are able to infect potato tubers in addition to roots. This infection causes warty out-growths, which are typical in potato which decreases the marketable value of the produce in addition to quantitative losses. Typically both species are wide spread throughout the country in all potato growing regions. The most dominant species *M. incognita* occurs both in hills and plains while *M. javanica* infection to potato is confined mainly to mid hills and plains where the temperatures are fairly on higher side. The infection of M. haple has been recorded on potato roots from hilly regions of Himachal Pradesh, Jammu and Kashmir, Uttar Pradesh and Tamil nadu where milder climatic conditions prevailed.

Biology

The 2nd stage juveniles hatched out from the egg masses infect the young roots. This results in the formation of giant cells from which the nematodes extract nourishment from the plant cells. The giant

cell and nematode development in the roots is associated with the formation of root-knot or galls. The female larvae enlarge gradually and undergoes four molts to become pear shaped structure. The male nematodes retain their thread like appearance which come out freely from the root system and helps in fertilizing the eggs of the females. The female nematodes are sedentary in nature and deposits about 300 to 400 eggs into a gelatinous matrix which is usually found adhering to the root galls. These eggs readily hatch and invades the fresh roots. At the time of tuber formation the freshly hatched tuners from nematode sick plots developed typical root-knot symptoms possibly because the larvae would have entered the tubers before suberization at harvest and developed during storage.

Under Simla conditions, *M. incognita* complete its life cycle in 25-30 days during April-September while in winter ie. October-March it takes about 65 to 100 days. This has been mainly due to the temperature which has also profound effect on the varietal distribution of larval populations in the soil. At Ranchi a hilly tract it took 28-35 days in June-July and 50-56 days in November-March months to complete one generation. However, at Patna the life cycle was completed in 35 to 45 days during November to February. In the hilly regions two generations are generally completed by the time of tuber formation. Hence, tuber infestation is invariably observed even in low infested fields. In plains tuber infestation could be low mainly because the crop duration is short and the available fresh roots are mostly preferred by the newly emerging larvae. This generally leads to the conclusion that the root-knot nematodes may be absent from a locality although they may be present on the roots. Further, hot summers in plains reduce the initial soil populations.

The eggs and larvae survive for more than 100 days even in the absence of hosts during summer months in Simla hills. This could be the reason for higher initial inoculum which could build up for subsequent tuber infestations. Experiments to study the effect of different levels per gram of soil resulted in 42.5 per cent yield reduction with 100 per cent tuber infestation. Nematode infested tubers on storing loose their weight more then uninfected tubers. Although post storage performance of infested tubers were normal, the number of sprouts produced were fewer compared to healthy tubers.

Interaction with micro-organisms

The root-knot nematode infection has been found to predispose potato plants for infection by early blight fungus *Alternaria solani* and brown rot bacterium *Pseudomonas solaneocearum.* The incidence of brown rot in the presence of *M. incognita* was 86% compared to 19.4% with bacterium alone. The plants wilted much earlier in the presence of nematodes. Further, it was observed that whenever brown rot disease was prevalent in the North Western hills, the soils contained fairly heavy populations of root knot larvae. The roots of such wilted plants exhibited prominent galling. It is suspected that the root-knot nematodes are helping in the spread and severity of brown rot disease in sirmour district of Himachal Pradesh, Bhowali and surrounding areas of Kumaon hills in Uttar Pradesh and Bangalore and Kolar districts of Karnataka state.

MANAGEMENT

The basic principle of nematode control programme is to achieve increased good quality produce with reduced nematode populations. Last one hundred years of consistent efforts either to completely control or eradicate root-knot nematodes from soil rhizosphere revealed that man has to be content living with the pest and only try to minimize its ill effects. And thus the following management strategies are suggested for root-knot nematode management in potatoes.

Cultural practices

a) Deep ploughing and drying of soil in the summer months facilitates the drying in infective stage larvae thereby reducing initial inoculum in the soil.

b) Adjustment of planting dates; Studies at Jalandhar have shown that planting in the 2nd week of October in autumn crop and early January in spring crop can limit the tuber infestation of the

root knot nematode. Under Simla conditions early planting of potatoes ie. during 3rd or 4th week of March reduces both root and tuber infestation without affecting the yield parameters.

c) Burning of trash before taking up tuber planting helps in not only sterilizing the soil but also enriches the soil. However, this method is practicable only in smaller holdings.

d) Growing of trap crops like *Tagetes patula* and *T. erects* (Africa marigolds) in between 2 or 3 rows of potato improves the crop performance and also reduces the root knot nematode infestation. The root secretions from these plants are nematicidal and thereby he nematode populations are reduced to manageable levels.

e) Though root-knot nematodes are polyphagous in nature with wide host range, there are a few crops like cereals and millets which do not get the infestation of *M. incognita*. Thus, crop rotation with a non host like maize, wheat, beans, etc. reduces nematode infestations.

f) Seed tubers from root-knot nematode infested fields should not be used. The movement of the soil and water from the infested fields should be avoided. The fields should be kept free from weeds since, root-knot nematodes have a wide host range and most of the weeds helps in the build up of the nematode. Thus, clean cultivation reduces the nematode infestation to a great extent.

Hots resistance

The most practicable approach for root-knot nematode management seems to be the use of host resistance. A large number of germplasm collections including tuber bearing wild *Solanum* species were screened for locating sources of resistance at Simla. These studies showed that an inter varietal hybrid HC-294 possessed resistance to root-knot nematode since there was inhabitation in the giant cell formation in the roots. Sources of resistance were also available in few lines of *G. tuberosum* sub species andigena and S. vernei. High degree of resistance was also found in *S. acaule, S. bulbocastanum, S. boliviense, S. acroscopicum, S. cardiophyllum, S. chacoense, S. gandarillassi, S. lighicaula, S. raphanifolium and S. spegazzinni.* Critical evaluation of commercial varieties and cultures have shown that the development and reproduction of root knot nematode was lowest in several advanced hybrids and efforts are underway to incorporate these resistance into commercial varieties.

Biological control

There have been extensive reports on the use of biotic agents such as fungi, bacteria, predacious nematodes and protozoans in the control of nematodes. However, efficient use of these biological phenomenon have not yet been fully exploited in root-knot nematode management. The fungus, Paecilomyces lilacinus has been found to be most effective for controlling *M. incognita* in potato while the bacteria Bacillus penetrans has also offered possibilities of bio-control. Endomychorrizal fungi such as *Glosus fasciculatus, G. mosse* and others have shown promise in reducing the root-knot nematode infestation and hence we can look forward for adopting a suitable biological method of approach for the management of this nematode in potato.

Chemical management

Earlier, application of DD @ 200 litre/ha, tEDP @ 90 1/ha and Nemagon @30 1/ha were found to be efficient in reducing root knot nematode under Simla conditions which were effective in the plains. Good control of the nematode has been achieved by applying carbofuran @ 3 kg ai/ha or aldicarb @ 2 kg ai/ha or ethoprop @ 10 kg/ha. The efficacy of these pesticides was more effective when they were applied in two equal split doses i.e. once at planting and another at earthing time.

Integrated approach

By practice, it has been observed that a single method of nematode control is uneconomical and it has been realised that proper blending of one or more methods has always been economical and effective in achieving better nematode management. This sort of approach should be aimed especially in potato particularly under Indian conditions since we have to keep in mind the various agro-ecological factors into account. Adopting any single method of nematode control is bound to affect the ecological

balance and hence various factors have to be carefully considered before advocating nematode management practices. However, by judicious application of above methods it is not difficult to manage root-knot nematode in potato for achieving higher production.

4. OTHER NEMATODES

The potato tuber worm *Ditylenchus destructor* was reported from Shillong in 1961. The nematode was recovered on tubers which had shown small greyish cracks with whitish glistening superficial tissues. Fortunately, this nematode has not been encountered anywhere else in India excepting in imported tubers and thus has been considered as one of the quarantine problems. Several other plant parasitic nematodes such as lesion, stunt, spiral, reniform nematodes are being constantly encountered during surveys of potato fields. However, not much information is available on their role as pathogens of potato. The presence of virus transmitting nematode genera such as *Longidorus, Trichodorus* and *Xiphinema* with potato culture may later be a constraint in disease free seed production.

Of late the pathogenicity of *Quinisulcius capitatus*, a stunt nematode frequently occurring in hilly tracts, was established on potato variety Kufri Jyoti at Simla. The nematode build up ranged from 5 to 8 times at initial inoculum levels of 10 to 1000 at 45 days. Concomittant to the nematode build-up, plant characters such as shoot length, fresh and dry weights of shoot and root reduced which affected the tuber production. The tuber reduction. The tuber reduction ranged from 14 to 29% by weight which was related to the reduction of dry weights of plant parts and was negatively correlated with nematode build up index. The spiral nematode, *Helicotylenchus dihystera* was also pathogenic to potato accounting for 9-27 per cent yield reductions in 90 days with 2-4 times build up. Both these nematodes are commonly occurring in major potato growing belts of potato in Himachal Pradesh, Karnataka and Tamilnadu and could be potential pests on a long run. Other parasitic nematodes constantly found in potato soils such as pin nematode *(Paratylenchus species)*, reniform nematode *(Rotylenchulus reniformis)*, lesion nematode *(Pratylenchus coffeae)* are already established pests to other crops and hence may also pose plant protection problems but certainly not to the extent of either cyst nematode or root-knot nematode.

5. CONCLUSIONS

Although 93 nematode species belonging to 40 genera are recorded to be associated with potato culture in India, not much has been done to understand their exact involvement in potato production, excepting in case of root-knot and cyst nematodes. The detailed surveys conducted in north-western Himalayas have shown that root-knot nematode is the major pest of potato and is also invariably associated with the brown rot disease caused by *Pseudomonas solanacearum*. The potato cyst nematode which was earlier restricted to hilly tracts of Tamilnadu, has now been encountered from neighbouring states of Karnataka and Kerala indicating a need for strengthening the domestic quarantine. Most of other nematodes are established pests in production of other crops. Hence, future lines of work on a national basis should be on the following lines :

Conduct organised surveys in potato growing areas to study the distribution of different plant parasitic nematodes and to identify the problematic areas for potato production: Identify the variations in root knot nematodes and potato cyst nematodes to establish the species and pathotypes/races specific to localities; Estimation losses due to different nematodes and establish the economic threshold levels; study the nematode survival, development and population dynamics in relation to different agronomic practices; Establish the interaction of these nematodes with other pathogenic fungi, bacteria and viruses and the predisposal factors if any, Locate the sources of resistance in tuber bearing *Solanum* species and produce resistant varieties suitable to different regions. Evolve an effective and economic mode of nematode management by integrating different management strategies both for plains and hills; and finally set up of an advisory service for proper nematode management in potato production.

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Tuber Crops

This is a heterogenous group of cultivated plants varying in different characteristics and representing different families of the plant kingdom. They form third most important food crop of man after cereals and grain legumes. These are identical only by producing tubers in the underground portion of the plant which are edible. The tubers are rich in carbohydrates and thus provide energy rich food. The tubers also in turn vary in size, shape, taste and in their utilities to man and to his animals. The different crops also vary in their duration, ability to grow successfully under different hostile environmental conditions such as near drought, poor soils, shades and under poor management conditions requiring less labour.

The most important tuber crops grown in India and the world over is cassava followed by sweet potato. Another important group is the yams and aroids. Other minor tuber crops grown in India are the Arrow root (*Maranta arundinacea*) winged beans (*Psophocarpus tetragonolobus*) and chinese potato (*Solenostemon rotundifolius).*

Cassava

Cassava is the only species of Manihot (*M.esculenta* Crantz) under cultivation. This is a native of Brazil (Smith 1968). North Amazonia has been reported to be the place of domestication (Nassar, 1978). Globally, about 153.69 million tonnes of cassava is produced from an area of 15.67 million ha. In India, cassava is restricted to the Southern and North-eastern regions, which is used as food, feed and also fodder and has a number of industrial uses. Cassava performs well in marginal soil with average or little

management. This is tolerant to a number of diseases, pests and also near drought conditions.

Sweet potato

Sweet potato is grown in all parts of the tropical and sub-tropical world and in warmer areas of the temperate region. In India it is grown in 19 states and two Union teritories but bulk of the area is confined to Orissa, Bihar and U.P. (Chadha and Nayar, 1994).

Yams

Two species of yams are mainly grown in India. They are the lesser yam (*Dioscorea esculenta*) and the greater yam (*D.alata*). Another yam, the white yam (*D.rotundata*) is recently introduced from Africa. There are other yams grown in different part of the world such as the yellow yam, (*D.cayensis)* grown in China. Spieces of *Dioscorea are* also grown for extraction of diosgene.

Aroids

In India *Colocasia esculenta* and *Xanthosoma sagitifolium* are grown predominently and is being used as vegetable in various parts of the country. The elephant foot yam, *Amorphophallus peoniformis* is another important aroid grown in different part of the country which is also used as a vegetable.

Nematodes on tuber crops

Nematodes on tropical tuber crops are almost a neglected group of pests due to various reasons. However loss caused by the nematodes are more severe than in rest of the cultivated crops because of the following reasons. Nematodes on these crops not only

reduce their yield but also quality of the tubers as the nematodes directly feed on the tubers. Infested tubers are smaller in size, often malformed with branching with irregular wart like protruberences on the tuber surface, all of these affect the marketability of the tubers. In most of the cultivated crops nematodes feed on roots and the quality of the produce is generally not affected. Beisdes nematodes multiply during transport and also during the post harvest storage and continue to cause further damage. Infested tubers were reported to loose 30% or more weight compared to healthy where it is only around 10%.

As the nematodes feed and multiply on the edible portion of the tubers it use the tuber tissue for its growth and multiplication. While peeling the tubers, the infested tissue looked reddish brown and upon cooking the taste also differed. All these make the farmer recognize that some problems were associated with a particular tuber and this prompted him to select the diseased variety or tuber out. As the nematode continue to multiply during storage seed material which were severely infested rot or dry up at the time of planting season. So the infested tubers were inadvertably selected out. These two type of selections helped to eliminate infested material which in turn has helped in the evolution of large number of resistance cultivars among tuber crops. A large variety of resistant tuber crops were already identified in cassava, sweet potato, yams and aroids. The occurrence of high degree of resistance to nematodes is an unique feature in tuber crops.

The harvesting of the tuber crops itself is unique in that the whole plant is uprooted while harvesting the tubers whereas in other crops only the produce is harvested and the plant remains in the field for some more time. The harvesting of tuber crops requires digging of the field which is almost equivalent to summer ploughing and usually the field is left fallow throughout the next summer and is again planted only in the next season. These

operations make the field inhospitable for parasitic nematodes and the residual population in soil is often wiped out. This is not the case with other crops where the plant remains intact in the field and hence residual population of nematodes and is ploughed only before the next planting season.

Various nematodes are associated with tuber crops and cause damage to the crops in the field and also during storage. Though nematodes were reported from different regions of the world on different crops, the importance of the nematode damage to the crop is under estimated in most of the cases. Lot of research efforts are to be provided for these crops to estimate the actual loss due to nematode and also for the control and management of nematode problems associated with different tuber crops. The need for concerted research effort of three of these major crops has been stressed recently by Sharma et al. (1997). Jatala and Bridge (1990) and Mohandas (1994) reviewed the work on nematodes on tuber crops extensively.

Cassava

A number of plant parasitic nematodes are reported to be associated with cassava through detailed report on yield loss and management of the nematodes in cassava are not available. *Meloidogyne incognita* and *M.javanica* are reported to be the most important and widerspread among all the nematodes (Mohandas, 1994). Other species of *Meloidogyne* reported on cassava are *M.arenaria* and *M.hapla*. Among *Pratylenchus*, *P.brachyurus, P.safaenis* are reported.

Other nematodes reported on cassava are *Rotylenchulus reniforms*, *Helicotylenchus erythrinae, H.dihystera* and *Scutellonema bradys* which are of little

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importance to the crop. Nematode species associated with cassava are reported by Caveness (1980).

Bridge 1987 reported that cassava is one of the resistant crops in general. However Bridge et al., 1991 reported that *M.incognita* was found infested in farmers field in Uganda. Coyne, 1994 recorded lossess upto 98% in storage root yield under heavy infestation by *Meloidogyne* spp. Caveness 1982 reported that light infestation with *Meloidogyne* spp. increased plant weight upto 10% whereas heavier infestion reduced plant height by as much as 52%.

Caveness 1981 reported that *M.incognita* race 2 and *M.javanica* significantly reduced stalk height stalk weight and storage root weight of two cassava cultivars.

Control of the nematodes using nematcides is not desirous in cassava especially because of the residues it may leave behind in the tubers and also in the enrivonment. As this is a long duration crops more than one application of the chemical will also be required.

Medina et al. (1992) tried Sincocin, Aldicarb, Carbofuran and ethoprop and found aldicarb @ 3 kg ai/ha gave best results for the control of root-knot nematode followed by aldicarb 2 kg ai/ha and ethoprop.

Utilizing resistant varieties appears to be the most desirable for the management of the root-knot nematode problem. A number authors reported resistance in cassava cultivars and germplasm accessions to the root-knot nematode.

Crozzoli PR reported that all ten cultiivars evaluated were susceptible; however their rate of reproduction varied from 4.1 to 21.9. They also reported tolerance to nematode infection in two cultivars.

On the otherhand Ponte et al. 1979 reported that out of 25 cultivars tested for resistance to *M.incognita* and *M.javanica*, 19 cultivars were immune, three were highly resistant. Only three cultivars were found to be susceptible.

Mohandas and Palaniswami (1996) reported resistance in four cultivars of cassava from Kerala.

The leaf, rind and fleshy tuber extracts of cassava were observed to possess nematicidal properties to the juveniles of *M.incognita*. At 1:1 and 1:5 concentrations all the three extracts were cent per cent lethel at 24 h. exposure. Even dilution of 1:50 and 1:100 were found to be lethel to the nematode at longer duration (Ramakrishnan and Mohandas, 1996). Ponte (1992) had earlier reported nematicidal and insecticidal properties in manipueira, a liquid by product of cassava flour production.

Sweet potato

Nematodes on sweet potato and the damage they cause are reviewed recently by various authors (Jatala and Bridge, 1990; Mohandas, 1994; Sharma et al., 1997). Species of *Meloidogyne* and *Rotylenchulus reniformis* cause reduction in yield and also quality of tubers the world over (Clark and Moyer, 1988). *Pratylenchus* spp. are reported to be very serious in Japan and certain pockets whereas *Ditylenchus destructor* and *D.dipsaci* are reported to be very serious in China.

Root-knot nematode

Meloidogyne incognita is the most important nematode attacking sweet potato. Other species of *Meloidogyne* include *M.javanica, M.hapla* and *M.arenaria*. Infestation by *Meloidogyne* causes reduction in yield and quality. Severe infestation also produces

deep longitudinal cracking on the tuber which affects the marketability. Often the galls produced by the nematodes are very small and hence escape the attention of casual observers. However reduction in yield due to the nematode is very high. In North carolina yield of sweet potato in the nematode infested sandy soils is upto one third compared to nematicide treated plots; cracked roots in infested plots were about 18% compared to 3% in treated plots (Neilsen and Sasser, 1959). Hall et al., 1988 reported double the yield of marketable tubers and 40% reduction in cracks in Meloidogyne incognita infested plots which is treated with nematicide before planting. Similarly in California preplant fumigation of infested plots were a regular feature before planting sweet potato which helped in increased yield and production of high quality tubers. In South Africa Kistner et al. (1993) reported 11.4% decrease in marketable yield due to infestation by *M.incognita* and *M.javanica.*

Resistance to M.incognita and M.javanica are reported in sweet potato from various countries and active breeding programmes are being conducted in US, Japan and China (Sun and Chen 1994) which had released high yielding nematode resistant varieties. A number of germplasm accessions, cultivars/varieties are resistant to the root-knot nematode in Peru and also in India.

Two dominent genes whihch are independent of each other control resistance in sweet potato (Shiotani, et al). They also reported that there was no significant differences in the larvel penetration in resistant and susceptible cultivars. Five days after inoculation a hyper sensitive reaction was detected in all the resistant clones with high percentages of necrotic lesions. Maluf et al. (1996) reported that most of the genotypes showed resistant to *M.javanica* whereas only a few were resistant to *M.incognita* race 2. Genotypic

correlations among resistances to various *Meloidogyne* isolates utilized were weak ranging from 0.11 to 0.57 suggesting independent control; Silveira et al. (1993) also reported resistance to races of *M.incognita* and *M.javanica* but none multiple resistance to all races. They also reported that genotypic correlation coefficients bewtween resistant to difference races and/or species were low indicating an independent control of resistance for the nematode races and species. Crozzoli et al. (1994) reported tolerance among three selection of sweet potato as these supported nematode infection and reproduction whereas in other selections tried root and top weights were suppressed. Gapasin et al. (1988) reported that more phenolics accumulated in root extracts of resistant cultivars following *Meloidogyne* infection.

Management

Control of nematodes on sweet potato using chemicals were restricted to preplanting fumigation with Methyl bromide which is practiced in California. Preplant nematicidal treatment of *M.incognita* nfested field doubled the yield of marketable sweet potato roots and also reduced proportion of cracked tubers by over 40% (Hall et al., 1988). Nemacu and Aldicarb were also found to be effective in controlling *Meloidogyne* species (Clark et al 1980; Gapasin 1981).

As very high degree of resistance to *M.incognita* and *M.javanica* is reported from the world over and high yielding released varieties are available in many countries including India, USA, China and Japan, these varieties may be rotated with susceptible crops. Plantng resistant sweet potato varieties helped in bringing down the population to a great extent. Subsequent susceptible crops like Okra, Coleus and African yam were found to be

less damaged (Mohandas et al., 1997). Mohandas and Ramakrishnan (1966) also reported that planting a high yeilding released variety of sweet potato viz. Sree Bhadra in an infested field helped in clearing the infested field free of the nematode and acted like a trap crop.

Rotylenchulus reniformis

R.reniformis possessed highest absolute density and highest prominent values on sweet potato in Orissa (Ray et al., 1990). The nematodes are found in large numbers in India by Verma and Prasad (1969) but nothing is known on yield loss and control (Mohandas, 1994). Gapacin and Valdez (1979) observed 60.6 oer cent yield reduction in pot culture experiments when 5000 larvae were inoculated. Walters and Barker (1994) studied the effect of two populations on sweet potato and found that both populations restricted storage root growth but enhanced shoot growth. Besides infestation by the nematode may cause cracking of storage roots (Clark and Wright, 1983).

Pratylenchus

Rajendran et al., 1972 reported high population of *Pratylenchus* sp. and *Hoplolaimus* sp. in soil and roots from Coimbatore, Tamil Nadu. *P.coffeae* is very serious in Japan in volcanic acid soils (Suzuki, 1989). Other species reported feeding on sweet potato were *P. flakkenss, P.brachyurus, P.penetrans, P.vulnus* and *P.zeae.* Auguiz and Canto-Saenz (1991) observed resistance to *P.flakkensis* among 20 sweet potato cultivars.

Ditylenchus

In China this nematode is a serious problem and programmes on management and breeding for resistance is in full swing. *Ditylenchus* spp. induce "brown ring" in storage root. The species involved are *D.destructor, D.dipsaci* in China.

A number of resistant accessions and varieties were reported from China (Wu and Zhang, 1990; Wang et al., 1995) Lin et al., 1993 observed that exudate secreted by the Oesophageal glands of *D.destructor* when infected with tubers of susceptible sweet potato the tissue around the iinoculated area became brown and the cells were destroyed. In resistant cultivars the walls turned brown and Parenchyma cells became work barriers.

Other nematode

Saveral other species of nematodes are found associated with sweet potato which are listed in detail (Clark and Moyer 1988) but their importance to the crop is not established.

Quarentine

Species of *Ditylenchus* which are reported to be very serious in China and in Japan are not reported from sweet potato in India. Steps has to be taken to prevent the entry of such nematodes through imported planting materials.

Yams

Three most important nematode pests of yams are Root-knot nematode, *Scutellonema bradys* and *Pratylenchus* coffeae. Root-knot nematode infestation produces deformed tubers with uneven surface whereas the other two nematode produce typical 'dry rot' of tubers. Nematode pests on yams and the work carried out had been reviewed by Bridge 1982; Degras 1993 and Mohandas 1994).

Root-knot nematode

Meloidogyne incognita is the major nematode species infesting yams the world over. in China *M.arenaria* is reported to be very serious on Chinese yam (Gao et al.,

1992). All the cultivated yam species are infested by the nematode. In India *Dioscorea esculenta, D.alata* and *D.rotundata* are found to be highly susceptible to the nematode. The nematode also grow and multiply during storage, causing further damage to the tuber (Mohandas).

Reduction in yield is reported by many authors from different countries.

Loss during storage is reported to be over thirty per cent whereas it is only around to ten per cent in healthy tubers. In *D.rotundata, D.alata* and *D.esculenta*, the tubers produced pronounced galls indicating that they continue to multiply during storage. Females of this nematode and its egg mass were surrounded by lignified cells in side the tubers in the above three species.

Resistance

As is the case with cassava and sweet potato resistance is very common in the yams in India. Very high degree of resistance is identified in *D.esculenta* and *D.alata* (Mohandas, 1997). Rajendran and Sivagami (1993) screened cultivars and reported no resistance from Coimbatore.

Management

Though cemical treatments control of these nematodes are effective, this may not be practical.

Selection of healthy seed material will be ideal.

Hot water treatment of setts used for planting is found to be effective in checking the nematode which increases germination percentage and also final yield of tubers.

Soaking the setts in 1200 to 2400 ppm of oxamyl for 40 minutes was most effective (Hutton et al., 1978 and Roman et al., 1984).

Resistant varieties only may be planted in infested fields. Mohandas (1997) reported that there was no damage to susceptible *D.rotundata* if this was preceeded by resistant Sree Bhadra variety of sweet potato.

The yam nematode

Scutellonema bradys is one of the most important nematode pests infesting the yams. This nematode is recorded from yams from India, West Africa, the Caribean and Brazil (Bridge, 1982). The neamtode produce 'dry rot' on yams (West, 1934). In field the damage is restricted to the outer thin layer of the tuber (Adesiyan, 1977). However in store, the nematode infection spreads and coalesce which encircle the tuber and could cause 80 to 100 per cent loss of stored yams in the Mid-West State of Nigeria (Adesiyan and Odihirin, 1975).

The lesion nematode

Pratylenchus coffeae is recorded from Jamaica , Puerto Rico and British Soloman Islands (Bridge 1982). The symptoms are very similar to that of dry rot caused by *S.bradys*.

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**Original not seen*

NEMATODE PARASITES OF MUSHROOMS

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1. INTRODUCTION

Edible mushrooms are fleshy sporophores of fungi belonging to the Class, Agaricales. Although there are several hundred species of mushrooms (including edible and non-edible forms), in India mainly three types of mushrooms are cultivated on commercial scale for table purpose. They are white button mushroom, *Agaricus bisporus*, Oyster mushroom, *Pleurotus* spp. and tropical paddy straw mushroom, *Volvariella* spp. Majority of the commercial units and all export oriented units are presently growing white button mushroom for domestic and export markets.

Button mushroom is having maximum acceptability both in fresh and canned forms, therefore, grown on wider scale. Oyster mushroom cultivation is confined mostly to small and marginal growers and the produce is sold fresh/dehydrated in the local market. Oyster mushroom is gaining popularity because of its wider growing temperature range (20-30°C), easier method of cultivation, low technology infrastructure requirement and relatively less susceptible to diseases and pests as compared to button mushroom. Paddy straw mushroom, commonly grown in hot/humid areas of Peninsular India, favours a temperature range of 35-40°C with high R.H.(85% and above). It grows well on paddy straw at normal conditions. In India, 80-85% of the annual total mushroom production of 35,000 tonnes(1996), is that of button mushroom, while 15-19% is of Oyster and the remaining 1% is of other mushrooms (Sharma, 1997). The importance of button mushroom in state-wise mushroom production can be visualised from the data given in Table 1.

Table 1: State-wise production of cultivated mushrooms in India (1996-97)*

Name of the state	Production (MT)	Type of mushroom
Jammu & Kashmir	400	*Agaricus*
Punjab	4000	*Agaricus*
Himachal Pradesh	500	*Agaricus*
Haryana	4000	*Agaricus*
Uttar Pradesh	4000	*Agaricus* and *Pleurotus*
Madhya Pradesh	2000	*Agaricus* and *Pleurotus*
Rajasthan	50	*Pleurotus*
Maharastra	7000	*Agaricus* and *Pleurotus*
Goa	1000	*Agaricus* and *Pleurotus*
Karnataka	600	*Agaricus, Pleurotus* and *Volvariella*
Tamil Nadu	10,000	*Agaricus, Pleurotus* and *Volvariella*
Kerala	100	*Pleurotus* and *Volvariella*
Andhra Prtadesh	2500	*Agaricus* and *Pleurotus*
West Bengal	250	*Agaricus* and *Pleurotus*
North Easatern states	1000	*Agaricus, Pleurotus* and *Volvariella*
Delhi/Pondicherry/Chandigharh/ others	1000	*Agaricus* and *Pleurotus*
Orissa	700	*Pleurotus* and *Volvariella*
Total	40,000	

***Dhar, 1997.**

The importance of nematode damage and economic losses in mushrooms are emphasised by the fact that button mushrooms, which occupy 80-85% of total mushroom production, are highly susceptible and Oyster mushrooms, which contribute 15-19% to total production, are relatively resistant to nematodes.

Nematode problems in mushroom are unique in a way, that the nematodes have not only adapted themselves fully with the ecological requirements of the crop but also multiply very rapidly to occur in high numbers in mushroom beds and capable of inflicting 100% crop losses. Further, most of the mushroom cultivation and production in our country is characterised by operation at small scale, as cottage industry by small and marginal farmers or by woman artisans in suburban regions, with unhygienic or sub-hygienic environment and not as a scientific and commercial production units. However, of late due to ever increasing demand for fresh as well as processed edible and

medicinal mushrooms, both in domestic and export-oriented market, the need for more scientific and commercially viable mushroom production technologies is growing accordingly.

In India, the first report about nematode damage to mushroom was made from Himachal Pradesh by Bhardwaj *et al.* (1972). With growth of mushroom industry in India for the last two decades, a number of instances of crop failures due to nematodes have been reported (Thapa *et al.*, 1977; Chhabra and Kaul, 1982; Seth, 1984). The unhygienic conditions of mushroom cultivation provide congenial atmosphere for many pests and diseases. Of these, the most dangerous are nematodes which, once enter the crop bed, cannot be eradicated without complete elimination of the crop. Their presence in the beds lead to very poor yield or total crop failures. In this regard, an intensive survey of mushroom farm at Solan revealed 84.4 per cent nematode infestation which led to extremely poor flushes in initial stages followed by total crop failures (Seth, 1984). The aim of this chapter is to highlight the concept of management of mushroom nematodes by understanding various aspects like occurrence of nematodes in mushroom, their sources of contamination and host parasite relationships.

2. IMPORTANT NEMATODES ASSOCIATED WITH MUSHROOMS

Based on feeding habits, the nematodes associated with mushrooms can be grouped into five categories (Table 2). Of these, myceliophagous and saprophagous nematodes are economically important as they are highly pathogenic to common mushroom fungi like *Agaricus* spp.(Sharma and Khanna, 1992).

2.1. Fungal feeding nematodes

In all, twenty one nematode species representing two orders (Aphelenchida and Tylenchida) have been reported to be harmfully associated with mushroom cultivation from various parts of the world. Among these, twenty species belong to four genera (*Aphelenchoides, Aphelenchus, Paraphelenchus* and *Seinura*) which come under the order Aphelenchida and one species, *Ditylenchus myceliophagus,* in Tylenchida (Table 3) are important.

Table 2. Nematodes associated with mushrooms

Feeding group	Source of contamination	Mode of feeding
Mycophagous nematodes (Fungal feeders)	Unpasteurized compost, casing soil, irrigation water, etc.	Suck the cell sap from the fungal hyphae and devitalize the mycelium thus responsible for reduction in sporophore yields.
Saprophagous nematodes	"	Most abundant nematode forms in the mushroom beds that feed upon microbes (mainly bacteria) and exert indirect harmful effects on mycelial growth and sporophore yields.
Predatory nematodes	Compost and casing soil	Feed upon other nematodes including mycophages and are thus beneficial to the crop.
Animal parasitic nematodes	Horse dung and chicken manure	Mainly the parasites of higher animals and do not affect the mycelium in any way.
Plant parasitic nematodes	Casing soil	Mere contaminants which do not feed upon fungal hyphae.

In India, so far the occurrence of eight species of *Aphelenchoides* besides *Ditylenchus myceliophagus* have been recorded from mushroom beds and the pathogenicity of all these species, except *A. asterocaudatus, A. minor* and *A. swarupi* have been demonstrated experimentally. *Aphelenchus avenae*, though found in cropping beds, occurs in low number and hence its pathogenicity is of doubtful nature. *Paraphelenchus myceliophthorus* and *Seinura winchesi* are two other genera which, though important as pathogens, have not so far been reported from India.

Table 3. Myceliophagous nematodes associated with mushroom

Nematode species	Pathogenicity	References
A. Tylenchida		
*Ditylenchus myceliophagus**	+++	Sharma *et al.*, 1985; Khanna, 1993
B. Aphelenchida		
*Aphelenchoides agarici**	+++	Seth and Sharma, 1986; Khanna and Sharma, 1988a
*A. asterocaudatus**	-	Bahl and Prasad, 1985
*A. composticola**	+++	Khanna and Sharma, 1988b; Khanna, 1991
*A. minor**	-	Seth and Sharma, 1986
*A. myceliophagus**	++	Seth and Sharma, 1986; Khanna and Sharma, 1988a
*A. neocomposticola**	++	Seth and Sharma, 1986; Khanna and Sharma, 1988b
*A. sacchari**	+++	Sharma *et al.*, 1981
*A. swarupi**	++	Seth and Sharma, 1986
Aphelenchus avenae	+	Rao *et al.*, 1992a
Seinura sp.	++	Seth, 1984

*Species reported from India; (-) Pathogenicity not studied; (+) Found to multiply on mushrooms; (++) Pathogenic and (+++) Highly destructive.

2.1.1. *Aphelenchoides* spp.

2.1.1.1. *Aphelenchoides agarici* Seth and Sharma, 1986

This is one of the most pathogenic species reported from Himachal Pradesh (India). A low initial inoculum of 10 nematodes could destroy the mycelium completely within 25 days at 28 ± 1°C (Khanna and Sharma, 1988a). In another experiment, extent of mycelial depletion was found to be directly proportional to the initial nematode count and time of inoculation during cropping. Earlier the stage of nematode infestation, greater was the loss of mycelium (Khanna and Sharma, 1988b).

2.1.1.6. *Aphelenchoides neocomposticola* Sharma and Seth, 1986

This nematode was first found damaging the mushroom mycelium in a mushroom farm at Shimla (HP), India. Though pathogenic, experimentally it has been recorded to be less destructive than *A. agarici, A. composticola* and *A. myceliophagus* (Khanna and Sharma, 1988b).

2.1.1.7. *Aphelenchoides sacchari* Hooper, 1958

This was reported by Paesler (1957) from mushroom beds. In India, this species was first recorded from cropping beds of white button mushrooms by Sharma *et al.* (1981). It is a highly pathogenic nematode found to reduce the sporophore yields by 94.5 per cent and delay the fructification by approximately two weeks under natural conditions. A yield loss of 50-100 per cent depending upon the initial nematode population has been estimated by Sharma *et al.* (1984).

It is a bisexual species that completes one life cycle (egg to egg) on an average in 12 days. The fertility period of female has been found to be 28 to 30.

2.1.1.8. *Aphelenchoides swarupi* Seth and Sharma, 1986

This fungal feeding species was for the first time found in a mushroom farm at Ambala (Haryana) where though brown wet pinheads were observed initially, no fruiting bodies were produced. An average of about 10,000 individuals/100 g of compost were counted in the beds showing total crop failure (Seth, 1984).

2.1.1.9. *Aphelenchus avenae* Bastian, 1965

This nematode is frequently present in low numbers in the compost and casing soil samples taken from cropping beds. Controversial reports are available as far as damaging capacity of this nematode is concerned. While McLeod (1968) found it multiplying well in mushroom pots without affecting the yield or duration of cropping, Hooper (1962) reported it to damage the mushrooms extensively thus harmful to the sprophore production.

2.1.2. *Seinura winchesi*

Paesler (1957) reported it from mushroom beds. Farkas and Balazs (1975) considered it to be pathogenic. In India, population of *Seinura* sp. were found from the

This is a bisexual species in which males are necessary for reproduction (Khanna and Sharma, 1992). It has a short life cycle of 8 days and many generations are repeated during single crop season (Seth, 1984). Though *A. bisporus* is most preferred host. In its absence, the nematode can survive to multiply itself on other fungi of the compost media like species of *Fusarium, Trichoderma, Gillaminello* and *Trichothecium* (Khanna and Sharma, 1989a).

2.1.1.2. *Aphelenchoides asterocaudatus* Das, 1960

Sumenkova (1964) first reported it from mushroom beds. In India, this was first reported from cropping beds by Bahl and Prasad (1985). Studies on its pathogenic potential have not been conducted so far.

2.1.1.3. *Aphelenchoides composticola* Franklin, 1957

This is the most prevalent nematode species found in almost all the mushroom growing countries of the world. In India, nearly all the mushroom growing states are affected by this nematode (Seth, 1984; Chhabra and Kaul, 1982; Khanna and Sharma, 1988b, Rao *et al.*, 1992b). An initial count of 500 individuals per 20 kg of compost at spawning time caused 95 per cent yield losses of sporophores (Khanna, 1991b). Goodey (1960) confirmed from his experiments that *A. composticola* was more destructive than *D. myceliophagous.*

2.1.1.4. *Aphelenchoides minor* Seth and Sharma, 1986

A few specimens of this nematode were observed when compost samples from the cropping beds of a mushroom farm at Srinagar (J & K), India, were analysed. The population recorded was too low to be cultured for multiplication, so its pathogenic potential is not known.

2.1.1.5. *Aphelenchoides myceliophagus* Seth and Sharma, 1986

The occurrence of this myco pathogen was first reported from a mushroom farm in Solan (HP), India. It is a highly destructive species and as pathogenic as *A. composticola.* An inoculum of 10 individuals are able to destroy the mycelium completely within 40 days (Khanna and Sharma, 1988b).

cropping beds of a mushroom farm at Solan (HP), India. In this case, though, the initial mycelial growth was normal, sporophore yields were reduced considerably (Seth, 1984).

2.1.3. Tylenchids

2.1.3.1. *Ditylenchus myceliophagus* Goodey, 1958

This is the oldest nematode reported to feed on mushroom mycelium (Newstead, 1906). Earlier, it was identified as *D. destructor* (Seinhorst and Bels, 1957) but later described as *D. myceliophagus* by Goodey (1958). The population of this species recorded from mushroom farms of northern India, though showed close resemblance to its original description but differed distinctly in some morphometrics and, therefore, has been described as *D. myceliophagus* 'Indian population' (Sharma *et al.*, 1985).

D. myceliophagus is a widely distributed nematode present in almost all mushroom growing belts of world. In India, it has been found to be distributed in mushroom farms in Himachal Pradesh, Jammu & Kashmir, Punjab, Karnataka, Andhra Pradesh and Tamil Nadu (Thapa *et al.*, 1981; Rao *et al.*, 1992b). It is one of the highly destructive species at an initial inoculum of 10-1000 individuals could cause 15-70 per cent mycelial depletion within 60 days (Sharma *et al.*, 1985). This species, though has a short life cycle and can multiply as rapidly as *A. sacchari*, is less pathogenic than *Aphelenchoides composticola* and *A. sacchari* (Sharma *et al.*, 1985).

2.1.4. Saprophagous nematodes

Saprophagous nematodes, belonging to the order Rhabditida, are mainly associated with mushroom cultivation. The important genera of common occurrence are *Rhabditis, Caenorbabditis, Cephalobus, Panagrolaimus, Diplogaster* and *Acrobeloides*.

These nematodes have often been recorded in huge proportions from severely damaged mushroom beds of almost all mushroom farms in India and elsewhere. However, the exact role played by them in mushroom cultivation is not well understood. The experimental evidences showing pathogenicity of these nematodes are still scant and of doubtful validity. The only effort made to demonstrate the pathogenic effects of *Rhabditis* species on *Agaricus bisporus* mycelium under aseptic condition is that of Chandel (1982) from India. He showed that the nematode multiplied 500 times on *A. bisporus* and depleted 50 per cent mycelium within 30 days. The study, though demonstrated both mycelial depletion and nematode multiplication on malt extract slants, but lacked in authenticating the reasons for such damage.

Elsewhere in the world, two schools of thoughts still exist. According to one although these nematodes are not the primary pathogens but their presence in high numbers in the mushrooms beds has been wrongly correlated with the crop failures (Hesling, 1966), the others have claimed them harmful to mushroom (Cairns and Thomas, 1950; Kux and Rempe, 1954; Blake and Cornoy, 1959; Han *et al.*, Klingler and Tschierpe, 1980). Further investigations to prove their exact nature of damage in mushroom crop are still needed.

2.1.5. Predaceous nematodes

Predatory nematodes, generally the mononchids, are often encountered in mushroom beds but their prevalence is mainly dependent on the population density of their prey. The predaceous nematodes do not harm mushroom. They have a beneficial role in mushroom production since they feed on other nematodes including the aphelenchids. No efforts have so far been made to use them as biological control agents against mycophagous nematode species attacking mushroom.

3. YIELD LOSSES

Yield losses and extent of damage due to various nematodes in mushroom production were widely studied and well documented in other countries, while in India, the data on yield losses in mushrooms is available to a limited extent on specific nematode species such as *Aphelenchoides composticola, A. sacchari* and *Rhabditis* spp. (Table 4). The economic losses in the production of sporophore fruiting bodies depend mainly on three factors : (1) nematode species and its pathogenicity, (2) nematode population densities, and (3) time of nematode infestation during mushroom cropping stage.

Table 4. Yield losses in mushrooms due to nematodes

Nematode species	Initial density	Cropping stage at the time of nematode entry	Yield loss (%)	Reference
I. Myceliophagous				
A. composticola	5×10^2	Spawning	95.0	Khanna, 1991b
	5×10^2	Casing	64.0	
A. sacchari	1×10^1	Spawning	98.2	Sharma *et al.*, 1984
	1×10^2		100.0	
	1×10^3		100.0	
	1×10^4		100.0	
	1×10^1	Casing	90.2	
	1×10^2		92.1	
	1×10^3		87.3	
	1×10^4		100.0	
D. myceliophagus	1×10^2	Spawning	89.0	Khanna, 1993
	5×10^2		90.0	
	1×10^2	Casing	40.0	
	5×10^2		50.0	
II. Saprophagous				
Rhabditis sp.	Nil	-	-	Rao *et al.*, 1992a
	4×10^3		76.3	

4. NATURE OF DAMAGE

4.1. Feeding behaviour

The fungal feeding nematodes pierce the hyphal cell wall (mycelium) by to and fro movement of their hollow needle like stylet, and suck the cell contents thus leaving the cell devitalized. After feeding upon one cell, the nematode shifts to another with the help of the moisture film present in the compost medium (Khanna, 1994). The optimum temperature for feeding and multiplication of nematodes ranges between 22-28°C and beyond 30°C they do not reproduce (Thapa and Sharma, 1987b). The nematodes multiply at a faster rate during spawn-run period (22-28°C) than the cropping (14-18°C) (Table 5). Multiplication rate and damaging potential of *A. agarici* when compared at two room temperatures (12-25°C and at 28 ± 1°C) showed higher pathogenic potential and higher reproductive capacity at 28°C as compared to room temperature (Table 6) (Khanna and Sharma, 1988a).

Table 5. Multiplication rate and damaging potential of *Aphelenchoides agarici* at different temperature

Temperature range (°C)	Days after inoculation	Mycelial damage (%)	Average nematode popualtion	Multiplication rate (x)
12-25	15	15.0	114.3	11.4
	30	56.7	482.0	48.2
	40	98.0	6349.7	634.9
28 ± 1	5	6.7	61.0	6.1
	15	48.3	272.3	27.5
	25	100.0	8175.0	817.5

Table 6. Mycelial damage and the nematode population at different temperatures (after 20 days)

Temperature (°C)	Nematodes			
	Aphelenchoides sacchari		*Ditylenchus myceliophagus*	
	Per cent damage	Population	Per cent damage	Population
15	40	2,470	50	7,677
20	80	5,689	70	10,920
25	90	23,399	80	12,090
30	40	70	20	0
35	0	0	0	0

4.2. Damage symptoms

Since the growers are reluctant to disturb the beds after casing, the early symptoms of nematode attack are overlooked and yield reduction is the first effect noticed by them. However, if observed in time, the following symptoms of nematode attack appear in the affected beds in succession.

i) Mycelial growth is sparse, patchy and mycelium turns stingy.

ii) The compost surface sinks

iii) Whiteness of spawn-run slowly changes to brown

iv) Sporphore flushes are poor and delayed

v) Alternate medium and low yields are obtained in succession of flushes depending on the initial population density of nematodes and stage at which infestation occurs

vi) There is decline in sporophore yields and suddenly there is no mushroom production.

5. NEMATODE MANAGEMENT

Cropping pattern of mushrooms is unique in the sense that crop grows in succession of flushes at the interval of 6-8 days, has short duration of 6-8 weeks and is more than often consumed fresh immediately after harvest. Thus a specific pest management strategy needs to be planned for management of nematodes associated with this crop.

5.1. Chemical control

Obviously, chemical control is the only choice once the mushroom is in cropping and being damaged severely by any pest. But in case of mushroom, any recommendation of chemical control requires great caution, since it is a short duration crop and is consumed immediately after harvest. Normally, application of toxic nematicides to mushroom beds is not recommended. If nematicides are to be used, they should be non-persistent and easy to apply.

The pesticides of chlorinated hydrocarbon group were the first to be used against mushroom pests. These were either mixed in the compost or in the casing or sprayed in between the flushes. BHC, Lindane, Kelthane, Aldrin, Nemagon, etc., were commonly used. Methyl bromide as a fumigant has been used as a compost pasteurizing agent killing almost everything including fungi, insect pests, nematodes, etc. (Read,1968).
organophosphorus compounds both as nematicides and insecticides. Thionazin @ 80 ppm when added in the compost gave an excellent control of *Ditylenchus myceliophagous* and *Aphelenchoides composticola* but residues were detected in sporophores (Sharma *et al.*, 1981).

Pesticides belonging to the carbamates have also been tried against the mushroom pests. Carbofuran has been tried successfully for controlling the myceliophagous as well as saprophagous nematodes in mushroom beds (Sharma *et al.*, 1981).Many chemicals have been tested and reported to be effective against mushroom nematodes (Shandilya *et al.*,

1975; Sharma *et al.*, 1981; Chandel, 1982; Chhabra and Kaul, 1982; Seth, 1984; Thapa and Sharma, 1987a; Kaul and Chhabra, 1992; Rao and Pandey 1991) and some of the chemicals have also been safe to the mycelium (Chandel, 1982; Seth, 1984; Grewal and Sohi, 1987; Thapa and Sharma, 1987a) but no significant increase in yields has been demonstrated under cropping conditions. The chemicals have been shown to leave a detectable amount of toxic residue (Bahl and Agnihotri, 1987; Kaur *et al.*, 1987). Thionazin at the rate of 80 ppm is the only recommended nematicide for the control of myceliophagous nematodes (Hesling, 1966) without residual toxicity (Reed, 1968). However, this nematicide has never been available to Indian mushroom growers. Therefore, at present, there is no chemical which can be recommended for nematode control in mushroom.

5.2. Biological control

The need to look in for alternative control measures to manage nematodes in mushrooms was realised in India due to the fact that non-availability of exclusive and non persistent nematicides are not available in the market and growing awareness among consumers for pesticide-free consumables.

Biological control, if exploited, has a great impetus in this crop. The possible biocontrol agents which can be useful in mushroom are:

i) Use of microorganism, and
ii) Use of plant parts/products

5.2.1 Use of microorganisms

Predatory nematodes, mites, fungi and bacteria are the possible microorganisms which can be made use of in checking nematode menace in mushroom. In India, no commerical use of nematophagous fungi has so far been recommended. The only attempt in this regards is from Solan (HP), where two nematophagous fungi, *Arthrobotrys irregularis* and *Candelalretta musiformis* isolated from spent compost, have been demonstrated highly effective in checking nematode multiplication on mushroom mycelium (Anon., 1987; Khanna and Sharma, 1990). The use of such fungi should, however, be recommended after their non-competitiveness with mushroom mycelium is established.

5.2.2 Use of plant parts/products

A good number of plants are known to possess nematicidal properties against mushroom nematodes (Nath *et al.*, 1982; Khanna *et al.*, 1988; Grewal, 1989) and their use probably would be the safest if recommended as part of compost ingredient. Some of the

studies conducted on these lines have shown that use of fresh leaves of karanj (5%) and neem leaf powder (2-5% w/w), when mixed in compost, resulted in nematode reduction and enhanced mushroom yields (Rao and Pandey, 1991; Sharma and Khanna, 1994). Incorporation of oil cakes like neem (*Azadirachta indica*), karanj (*Pongamia pinnata*), coconut (*Cocos mucifera*), castor (*Ricinus communis*) and groundnut (*Arachis hypogaea*) in compost before spawning has been found to enhance sporophore yield more as compared with nematicide applications (Rao *et al.*, 1991, 1992). These plant products not only check nematode multiplication but also improve physio-chemical properties of compost and provide more nutrition to the crop.

Table 7. Plant products used to control nematodes in mushrooms

Nematode	Plant Product used	Dose	Stage of Mushroom cropping	Reference
A. composticola	Neem, Slipper plant, castor and eucalyptus leaf powder	5%w/w	Compost ingredient	Nath *et al.*, 1982; Sohi *et al.*, 1987; Khanna *et al.*, 1988; Grewal, 1989.
A. composticola	Karanj leaves	5%w/w	Compost ingredient	Rao & Pandey, 1991
A. composticola	Neem leaf & cake powder	2%w/w	Compost ingredient	Khanna & Sharma, 1996
A. composticola	Neem cake	5%w/w	Compost ingredient spawning	Rao *et al.*, 1994; Khanna & Sharma, 1996
A. sacchari	Oil cakes (castor, coconut, ground nut, karanj and neem)	-	Compost ingredient	Rao *et al.*, 1991
A. sacchari	Karanj and neem oil	1 litre (0.5-1.0%)/ 10 kg	Compost ingredient	Rao *et al.*, 1994

5.3. Resistant strains

Resistance in mushroom against nematode parasites is characterised by a lower rate of nematode multiplication and mycelial damage, and was generally attributed to

hyphal diameter but according to more recent opinions, the resistance depends upon some unidentified biochemical attributes of the spawn (Sharma and Seth, 1993).

No strain of *Agaricus bisporus* has so far been found resistant to nematodes. Thapa *et al.* (1987) tested eight edible fungi against *Aphelenchoides sacchari* and *Ditylenchus myceliophagus*, and reported *Pleurotus sajor-caju* and *Stropharia rugoso-annulata* as resistant to both these nematode species. In case of *Flammulina velutipes, Agrocybe aegerita* and *Lentinus edodes,* though the mycelium was not destroyed, it changed its colouration to reddish brown. Among the various strains of *A. bisporus* and *A. bitorquis* tested, K 36 strian of *A. bitorquis* showed resistance to *A. sacchari* but not to *D. myceliophagus* (Table 5). Resistance in *P. sajor-caju* against *A.sacchari* and *A. agarici* has also been reported (Sharma and Chandel, 1984; Khanna and Sharma, 1989b).

5.4. Physical control

Use of heat has been most successful method of nematode control in mushroom cultivation. Its use during composting, sterilization of casing material and disinfecting the mushroom house after cropping is of utmost importance (Fig. 1). It is recommended that for making the compost free of nematodes, air and bed temperature in pasteurization room must be maintained at 60°C for atleast two hours and a 'Cook-out' of mushroom house at 70°C for 5-6 hours or 80°C for 30-60 minutes is necessary (Thapa and Sharma, 1981). Used trays and handling tools can be disinfected by dipping these in disinfectants like formalin or in cresylic acid. Dips of the appliances in boiling water for 1-2 minutes are sufficient for complete destruction of nematodes (Seth, 1984; Seth and Sharma,1986). Infested trays and tools can be sterilised either by steaming them in a room at 56-59°C air temperature for one and half hours or by dipping them in boiling water for 1-2 minutes (Khanna and Sharma, 1989b).

6. PROPHYLACTIC MEASURES

Once the nematodes find entry into the cropping beds, there is no method to eradicate them without destroying the crop. Looking into the limitations of nematode control in this crop, it is better if these organisms can be prevented from entering into the cropping system. Thus following precautions and practices, if adopted would be useful to manage the nematode in mushroom cultivation.

1. Mushroom farming should be done in properly ventilated rooms having wire mesh shutters to prevent the entry of flies.

2. Farm should have basic amenities like clean water supply, electricity and sewage disposal system.

3. Inside and surroundings of the mushroom house should be absolutely clean and free of flies, mites and other contaminants.

4. Composting yard must be cemented to prevent the direct contact of the compost with nematode infested soil. It must be washed thoroughly with some disinfectant after every stacking.

5. Composting platform should be away from the cropping rooms.

6. A small shallow cemented pit filled with 5 per cent formalin should be provided at the entrance of mushroom house for the persons entering the house to disinfest his/her feet (by dipping them in the disinfectant). Workers should frequently disinfect their hands and clothes.

7. Visitors should not be encouraged to touch sporophores, if flushes are in progress.

8. Wooden trays and implements must be disinfected before reuse. If cropping is being practised in polythene bags, their reuse should be avoided.

9. Casing soil should be properly sterilized before spreading it over the compost.

10. Spent compost should be avoided for reuse as casing soil and be thrown in the fields far off from the farm.

11. Thorough washing of mushroom farm/house with some disinfectant is a must before running the next crop.

7. FUTURE THRUST

Mushroom cultivation is relatively young and progressive industry in India. The facilities with most of the growers are meagre and their awareness about various nematode parasites, the sources of contamination etc., is limited. There are certain areas which need the attention of mushroom scientists and extension workers in near future for effective management of nematodes.

1. An awareness needs to be created among the mushroom growers about the nematode menace and their sources of contamination.

2. In depth studies on certain plants or their parts/products/extracts showing nematicidal properties as compost components and their effect on quality and yield of mushroom compared to the other control methods need to be initiated.

3. Some safe and handy nematicides should be evaluated for their low residual toxicity so that they can be recommended for application during various stages of cultivation.

4. The effect of commonly used pesticides and fungicides in mushroom production on the nematode populations need to be studied in order to reduce the load of synthetics and cost of production.

5. Among biocontrol agents, plants and fungi need to be exploited fully for nematode management in mushroom growing.

6. Emphasis should be laid on developing nematode resistant strains in commercially grown mushroom species.

7. The role of predatory nematodes as biocontrol agents need to be studied and their commercial use may be explored.

8. The role of saprophagous nematodes must be studied systematically in depth in order to establish their pathogenicity, mode of contamination, economic damage to mushroom production etc.

9. Development of simple technologies for hygienic cultivation of mushrooms and their popularisation.

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INFORMATION AVAILABLE ON MUSHROOM NEMATODES AND THEIR MANAGEMENT IN INDIA

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The following nematodes have been reported in mushroom from India:

		Loss cuased (%)
A.	Parasitic/myceliophagous Tylenchida	
1.	Ditylenchus myceliophagous	89
	Aphelenchida	
	Aphelenchoides agarici	–
	A.asterocaudatus	–
	A.composticola	95
	A.myceliophagus	–
	A.neocomposticola	–
	A.sachari	94.5
	A.swarupi	–
	A.minor	–
B.	Saprophytic	
	Acrobeliodes	–
	Caenorhabditis	–
	Cephalobus	–
	Diplogaster	–
	Penagrolaimus	–
	Rhabditis	–

MANAGEMENT STRATEGIES

Hygiene and sanitation: Cleaning of composting yard and spraying 2% formalin 24h prior to compost prepration has been found to check prevalence of nematodes in the composting yard. In addition disinfection of instruments, walls, floors and galleries with 4% formalin and use of clean spray water has also been found effective in checking nematodes.

Physical method:

1. Pasteurization of compost/casing material:

Proper pasteurization of compost and casing material, has been found to be one of the most effective steps in nematode control.

2. Cookout:

Cookout (70C for 10-12h) of the growing rooms at the end of cropping has been found effective in checking prevalence of nematodes, insect pests and diseases.

3. **Solar pasteurization:**

Solar pasteurization of casing material has been found to be cheap and best method of nematode control. Covering the casing layer (2-4cm thick) having 24% moisture on weight basis spread in sun with polythene sheet of 150 gauge thickness resulted in rapid increase of temperature to 60C in 4-5 hours, but in deeper beds (8-12 cm thick layer) solar exposure of two days are required. Nematodes were eliminated from beds irrespective of depth exposure and moisture after two days.

Chemical methods:

i) Mixing of Furdan 3G (1/2g per kg straw) at the time of final compost turing has been found to control the nematodes particularly in long method of composting.

ii) Dichlorvos (at 0.04%) under polythene cover for 144h has been reported to be efffective in controlling nematodes.

Biological methods:

Bioproducts/biopesticides:

i) Incorporation of dried leaves of Azadirachta indica, Cannabis sativa, Eucalyptus tereticornis and Ricinus communis @ 3kg/100kg of dry wheat straw have been found to reduce the nematode population below EIL.

ii) Neem cake @ 5% on w/w basis of compost when incorporated in nematode infested compost at spawning time has been found to hamper multiplication of nematodes.

iii) Addition of neem leaf powder @ 2% on w/w bais of compost has also been reported to reduce the nematode population.

Biological control:

i) The nematode trapping fungi Arthrobotrys irregularis and Candelalrella musiformis have been found to be highly effective in checking nematode multiplication.

ii) Cultivation of Pleurotus sajor-caju alongwith A.bisporus has been found to reduce the population of A.composticola.

Resistance:

Strain K-32 of A.bitorquis has been reported to be resistant againt nematodes.

Gaps in the information:

1. Quick and easy diagonostic technique for early detection.
2. Practically adaptable management strategies.
3. Lack of safe and effective nematicides.
4. Lack of information, role of mushroom flies in transmissior of diseases, nematodes and mites.
5. Lack of awareness about hygiene and sanitation/non-availability of cheap and effective germicides.
6. Lack of information on role of saprophytic nematodes.
7. Lack of resistant strains.

Technical Session - II

NEMATODE PARASITES OF PALMS

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COCONUT

1. Introduction

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

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

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

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

Of the 78 nematode species reported on coconut (Govindankutty and Koshy, 1979), the most important endoparasites are

red ring nematode Rhadinaphelenchus cocophilus and the burrowing nematode Radopholus similis.

2. Rhadinaphelenchus cocophilus

2.1 Historical background

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

2.2 Diagnostic features (Thorne 1961)

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

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

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

2.3 Systematic position

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

2.4 Distribution

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

2.5 Hosts

Though R. cocophilus is primarily found on coconut and oil palm, it has also been found to occur naturally in the date palm and cabbage palm (Haglay, 1962). Successful inoculations have been reported in a number of palms (Brathwaite & Siddiqi, 1975; Dean, 1979).

2.6 Life cycle

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

2.7 Survival

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

2.8 Dispersal

Fragments of diseased tissue from contaminated bodies of the palm weevil Rhynchophorus palmarum are deposited into the bases of leaf axils of healthy palms. The

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

Natural cannibalism in the larvae also affects the number of emerging weevils. The bacterium Micrococcus roseus Ali-Cohen in cedros wilt diseased palms produces disease in affected palm weevils. Moreover, some ground lizards also feed on the adult insects. The nematode dies in decomposing tissue of diseased palms and an unidentified fungal parasite exists for the nematode (Griffith & Koshy, 1989).

2.9 Nature of damage

2.9.1 Symptoms

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

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

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

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

2.10 Histopathology

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

2.11 Losses

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

2.12 Control

2.12.1 Biological

The vector weevil is found to be parasitized by several species of Rhabditidae or Heterorhabditidae throughout Latin America. Since the vector insects can be highly parasitized with the above nematodes selective pressure can be introduced against the vectors. Such measures are being employed in Trinidad with a species of Rhabditidae (Griffith & Koshy, 1989).

2.12.2 Chemical

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

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

2.12.3 Integrated

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

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

3. Radopholus similis (Cobb, 1893) Thorne, 1949

3.1 Historical background

The burrowing nematode, Radopholus similis was first described by Cobb (1893) as Tylenchus similis from necrotic root lesions of banana Musa sapientum received from Fiji in 1891. It was renamed as Radopholus similis by Thorne (1949) and Sher (1968), who confirmed it as the

type species of the emended genus. The nematode occurs in most tropical and sub-tropical areas of the world.

3.2 Diagnostic features (Thorne, 1961)

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

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

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

3.3 Systematic position

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

3.4 Distribution

R. similis has been reported from coconut palms in Florida, U.S.A., Jamaica, Sri Lanka and India (van Weerdt et al., 1959a; 1959b; Latta, 1966; Weischer, 1967; Koshy et al., 1978). Surveys conducted in coconut plantations in South India recorded 24 per cent incidence of R.similis in coconut (Sosamma, 1984; Koshy et al., 1978).

3.5 Hosts

The coconut isolate of R. similis has a wide host range which includes many weeds, crops, fruit trees and many palms (Table 1&2).Fortyeight species of plants belonging to fortyfive genera of seventeen families were recorded as hosts in India (Koshy & Sosamma, 1975; Sosamma & Koshy, 1977; 1981; Holdeman, 1986).

3.6 Biology

3.6.1 Life cycle

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

3.6.2 Survival and dispersal

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

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

3.6.3 Biotypes/Pathotypes

Two morphologically indistinguishable races of R. similis are known. One is the 'banana race' which parasitizes banana and not citrus and 'citrus race' which parasitizes both banana and citrus (Du Charme and Birchfield, 1956). But, the citrus race has been elevated to species rank and named Radopholus citrophilus because it has a haploid number of five chromosomes (n=5) against 4 (n=4) in banana race (R. similis) and it differed in protein patterns and pheromone mediated behaviour (Huettel et al., 1984). In addition there is a report of an R. similis population in Puerto Rico which has a haploid number of five (n=5) chromosomes not infesting five species of Citrus (Rivas & Roman, 1985). The coconut isolate of R. similis from Kayangulam and Kasaragod in Kerala, India is the banana race (Koshy & Sosamma, 1977) with a haploid number of 4 (n=4) chromosomes (Koshy, 1986).

3.6.4 Influence of environmental factors

Studies on population fluctuations of the burrowing nematode in coconut plantations in Kerala, India showed that infested coconut roots yielded maximum number of R. similis during October to November and minimum during March to July. A mean soil temperature below 25°C and light rainfall coupled with availability of tender fleshy roots are favourable for nematode multiplication (Koshy & Sosamma, 1978). The burrowing nematode multiplies well on coconut in loamy sand followed by riverine alluvium and least in 'Kari' soil and causes maximum plant damage in riverine alluvium and least in laterite soil (Sosamma & Koshy, 1985).

3.7 Nature of damage

3.7.1 Symptoms

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

Symptoms on roots are more specific. R. similis on infestation produces isolated elongate orange-coloured lesions on tender and semi-hard roots. Consequent to nematode parasitization and multiplication, these lesions enlarge and coalesce to cause extensive rotting of roots. Tender roots on heavy infestation become spongy in texture. On semi-hard orange coloured roots surface cracks are commonly seen. Lesions are not usually seen on the old, hard, dark brown roots. As high as 4,000 nematodes were recovered from one gram (one inch length) of main roots. The nematode also attacks the plumule, leaf bases and haustoria of seedlings. The drastic reduction in the number and mass of tertiary feeder roots on parasitisation by the nematode limits plant growth (Koshy & Sosamma, 1987; Koshy & Sosamma, 1996).

3.7.2 Histopathology

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

3.8 Interaction with other micro-organisms

The fungi Cylindrocarpon effusum, C. lucidum and Cylindrocladium clavatum have been recorded in association with lesions produced by R. similis in coconut roots. In

pathogenicity studies, C. effusum did not cause any appreciable damage to inoculated seedlings. But when it was inoculated simultaneously with the nematode, the rate of multiplication of the nematode and damage to coconut seedlings was reduced (Sosamma & Koshy, 1978; 1983; Koshy & Sosamma, 1987).

3.9 Losses

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

3.10 Control

3.10.1 Cultural

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

3.10.2 Plant resistance

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

3.10.3 Chemical

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

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

Application of phorate @ 10g a.i./palm in June-July and again in October-November increased 30 per cent yield of R. similis infested palms.

3.10.4 Biological

Studies with Paecilomyces lilacinus, Pasteuria penetrans and VAM have shown that these microorganisms can suppress nematode population and may become useful control agents.

3.10.5 Integrated

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

1. Application of cowdung farmyard manure, oil cakes and green manure to the basins. Crotolaria juncea may be cultivated in the basin and interspaces and used as a green manure
2. Application of phorate @ 10g a.i./palm in June-July and October-November
3. Avoid banana as a shade crop in coconut nurseries

4. Use of nematode-free planting material of coconut and other intercrops

5. Use of less susceptible/tolerant cultivars or their hybrids in infested areas

4. ARECANUT

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

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

4.1 Radopholus similis

4.1.1 Distribution

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

4.1.2 Nature of damage

a) Symptoms

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

b) Histopathology

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

4.1.3 Interaction with other micro-organisms

The fungus Cylindrocarpon obtusisporum was found in consistent association with lesions caused by R. similis in arecanut roots. Though the fungus in combination with the nematode caused more damage, it inhibited the rate of multiplication of the nematode (Sundararaju & Koshy, 1984; 1987).

4.1.4 Losses

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

4.1.5 Plant resistance

None of the 46 accessions of arecanut germplasm screened, is immune or highly resistant to R. similis. The cultivars Indonesia-6 (VTL - 11), Mahuva B and Andaman - 5 (VTL-29e) are tolerant to R. similis (Koshy et al., 1979; Sundararaju & Koshy, 1982b). The cultivar Indonesia - 6 (VTL - 11) and Singapore (VTL - 17) are known to yield 50% more nuts over local South Kanara variety (Anonymous, 1974). The hybrid VTL-11 x VTL-17 is highly resistant to R. similis (Sundararaju & Koshy, 1988b). Hence, thse cultivars could be recommended for R. similis infested areas.

4.1.6 Chemical

Application of aldicarb or fensulfothion @ 1g a.i./ seedling thrice a year for three years controlled R. similis population at the seedling stage. In adult palms

reduction in nematode population and 10 fold increase in yield was obtained by aldicarb @ 10g a.i./palm, DBCP @ 10 ml a.i./palm or fensulfothion 50g a.i./palm (Sunderaraju & Koshy, 1986).

4.1.7 Biological

The effect of the bacterium, Pasteuria penetrans on multiplication of R. similis on arecanut was studied. P. penetrans reduced the damaging effect of R. similis on arecanut seedlings on inoculation of both the organisms simultaneously (Geetha et al., 1990).

4.1.8 Integrated

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

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

5. OIL PALM

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

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

5.1 Rhadinaphelenchus cocophilus

5.1.1 Distribution

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

5.1.2 Nature of damage

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

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

5.1.3 Losses

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

5.2 Radopholus similis

Radopholus similis was found to infest roots of oil palm on artificial inoculation under greenhouse conditions (Koshy and Sosamma, 1975). Survey carried out in oil palm nurseries and in adult plantations in India indicated the

presence of 26 genera of plant parasitic nematodes. The root lesion nematode Pratylenchus coffeae was the predominant one. Radopholus similis was recorded from Kerala, Karnataka, Andhra Pradesh and Assam. The other major nematode species encountered from the rhizosphere of oil palm were Helicotylenchus sp., Tylenchorhynchus sp., Rotylenchulus reniformis and Aphelenchoides sp. (Sundararaju et al., 1995).

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

6. DATE PALM

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

6.1 Nematodes of Date Palm

The date palm is affected by numerous pests and diseases-wherever it is grown, but nematodes, with the exception of root knot nematodes, Meloidogyne spp., have not been well studied. However, nematodes have not been found to be a limiting feature in the countries with date as an ancient culture. Date palm is reported as a host for Radopholus similis (Koshy and Sosamma, 1975).

...18/-

6.1.1 Meloidogyne

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

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

6.1.2 Other nematodes

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

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Table 1: List of palms reported as hosts of the burrowing nematode Radopholus similis

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

Table 2. List of plants reported as hosts of the coconut isolate of *Radopholus similis*

Sl. No.	Plant species	Common name	Family
1.	*Adenanthera pavonia* L.	"Manchadi"	Leguminosae
2.	*Allium cepa* L.	Onion	Liliaceae
3.	*Amarantus viridis* L.	Green amaranth	Amarantaceae
4.	*Anthurium andraeanum* Linden	"Tail flower"	Araceae
5.	*A. digitatum* G. Don.		"
6.	*A. veitchii*	King anthurium	"
7.	*Arachis hypogaea* willd	Ground nut	Leguminosae
8.	*Areca catechu* L.	Arecanut palm	Arecaceae (Palmaxeae)
9.	*Cajanus cajan* L.	Pigeon pea	Leguminosae
10.	*Careya arborea* Roxb	"Perzhu"	Myrtaceae
11.	*Cocos nucifera* L.	Coconut	Arecaceae (Palmaceae)
12.	*Coleus parviflores* Benth	Chinese potato	Labiatae
13.	*Cucurbita pepo* DC. var. Arkachandan	Pumpkin	Cucurbitacea
14.	*Curcuma amada* Roxb	Mango ginger	Zingiberacea
15.	*C. domestics* Val. (*C. longa* L.)	Turmeric	"
16.	*Cyamopsis tetragonoloba* L.	Cluster bean	Leguminosae
17.	*Daucus carota* L.	Carrot	Umbelliferae
18.	*Desmodium tortuosum* DC var. EC. 28875		Leguminosae
19.	*Dioscorea esculenta* Burk	Yam	Dioscoreacea
20.	*Elaeis guineensis* Jacq	Oil palm	Arecaceae (palmaceae)
21.	*Erythrina indica* Lam.	Coral tree	Leguminosae
22.	*E. lithosperma* Blume		"

23.	Ficus religiosa L.	Banyan tree	Urticaceae
24.	Glycine max var. ELSO 41. Improved pelican, Bragg, Bae and Punjab	Soybean	Leguminosae
25.	Hybrid Napier (Penisetum purpurem x P. typhoides)	Grass	Gramineae
26.	Ipomaea batatas Pior	Sweet potato	Concolvulaceae
27.	Kaempferia galanga L.	"Kacholam"	Zingiberaceae
28.	Lagenaria vulgaris Ser	Bottle gourd	Cucurbitaceae
29.	Lathyrus sativus L.		Leguminosar
30.	Lycopersicum esculentum Mill	Tomato	Solanaceae
31.	Momordica charantia L.	Bitter gourd	Cucurbitaceae
32.	Musa paradisiaca L.	Plantain	Musaceae
33.	Myristica fragrans Houtt	Nutmeg	Myristicaceae
34.	Oxyza sativa L.	Paddy	Gramineae
35.	Phaseolus calcaratus Roxb.	Rice bean	Leguminosae
36.	Phoenix dactylifera L.	Date palm	Palmaceae
37.	Physalis minima L.	"Njodinjotta"	Solanaceae
38.	Piper betle L.	Betel pepper	Piperaceae
39.	P. nigrum	Black pepper	"
40.	Polyalthia longifolia Hook. f and Thomas	Indian fir	Anonaceae
41.	Rhaphis excelsa Walp.		Palmaceae
42.	Saccharum officinarum L. CO. 48	Sugar-cane	Gramineae
43.	Scindapsus aureus Lind & Andre		
44.	Solanum nigrum L.	"Mulaku thakkali"	Solanaceae
45.	Talinum cuneifolium Willd		Portulacaceae
46.	Tamarindus indica L.	Tamarind	Leguminosae

47.	*Trichosanthes anguina* L.	Snake gourd	Cucurbitaceae
48.	*Vicia faba* L. var. E.C. 5063	Broad bean	Leguminosae
49.	*Vigna sinensis* L.	Cow-pea	"
50.	*V. ungiculata* Walp.	Cow.pea	"
51.	*Xanthosoma sagitifolia*	Tannia	Araceae
52.	*Zea mays* L.	Maize	Gramineae
53.	*Zingiber officinale* Rosc.	Ginger	Zingiberaceae

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Nematode parasites of citrus and grapes

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1 Introduction:

Citrus fruits rank third in area and production after mango and banana with an estimated production of 2979.11 thousand metric tonnes from an area of 369.56 thousand hectares. There are many commercially grown *Citrus* spp. such as mandarins (*Citrus reticulata* Blanco), sweet orange (*C. sinensis* Osbeck), acid lime (*C. aurantifolia* Sw), lemon (*C. limon* Burn f), grape fruit (*C. paradisi* Macf)., pumello (*C. grandis*), etc. Although one or the other species of the citrus fruit is grown in almost all the states of India, but the major citrus growing states are Maharashtra, Andhra Pradesh, Punjab, Karnataka, North Eastern region, Uttar Pradesh and Tamil Nadu. Citrus is a highly sensitive crop and is attacked by number of insect pests, diseases and nematodes. These play major role towards the low productivity of citrus in India with national average of 8.06 tonnes per hectare as compared to 25-30 tonnes per hectare in other citrus growing countries.

Grapes also occupy an impotant place among the fruits grown in India. This is grown largely in Maharashtra, Karnataka, Andhra Pradesh, Punjab Haryana, Uttar Pradesh and some parts of Himachal Pradesh. The total production of grapes in India is about 4.08 lakh tonnes from an area of about 0.25 lakh hectares. The average national productivity is about 16.26 tonnes per ha. In this review nematode parasites of citrus and grapes in India are discussed.

2. Nematode parasites of citrus:

In India, as many as 122 species within 57 genera of plant parasitic nematodes have been reported to be associated with the rhizosphere of citrus plants. However, the proof of the pathogenicity is available for only four nematodes species. These are *Tylenchulus semipenetrans*, Cobb (Siddiqi,1961), *Pratylenchus coffeae* (Siddqi, 1964), *Hoplolaimus indicus* (Gupta and Atwal, 1972) and *Meloidogyne javanica* (Mani, 1986). Among these *T. semipenetrans* is the most important and widely distributed in citrus growing areas. Rest of the nematode species are location specific problem of citrus.

2.1 Citrus nematode(*Tylenchulus semipenetrans*):

The citrus nematode, *T. semipenetrans* was first discovered in California by J.R. Hodges in 1912. and was reported in detail by Thomas (1913). In India, this nematode was reported first time by Siddiqi in 1961 from Aligarh, Uttar Pradesh. Since then it has been reported from Delhi, Punjab, Rajasthan, Maharashtra, West Bengal, Assam (Chona *el al.*, 1965), Himachal Pradesh (Mukhopadhyay, 1970a), Sikkim (Edward and Rai, 1970), Orissa (Khuntia and Das, 1969), Haryana (Mukhopadhyay and Suryanarayana, 1969), Bihar (Prasad and Chawla, 1965), Karnataka (Swamy *et al.*, 1973), Kerala (Nair,

1965), Tamil Nadu (Muthukrishnan and Sivakumar, 1973) and Andhara Pradesh (Krishnamurthi Rao and Thammiraju, 1975)

2.1.1 Economic importance and losses:

T. semipentrans is the most impotant nematode among all the nematodes reported on citrus and is most widely distributed though out the world. This nematode is considered to be the cause of ' slow decline' of citrus and by controlling it, decline can be avoided (Bindra and Chhabra, 1968). This has also been reported to be associated with die back symptoms of citrus (Chona *et al.*, 1965). In india, yield losses due to *T. semipenetrans* under field conditions have not been estimated. However, Mukhopadhyay and Dalal (1971) could achieve 40-44% increase in yield of sweet lime by controlling this nematode. Cohn (1972) indicated that actual reduction in citrus yield world over could be avoided by 8.7-12.2%.

2.1.2 Economic threshold level:

Citrus is a perennial crop for which to find out economic threshold level is slightly difficult. This also varies from field to field depending upon the agropractices followed. In India, economic threshold level has not been estimated under field conditions. However, it has been estimated in California that soil stages (juveniles/100 g soil) below 800 represents a non damaging population level. The orhcards with more than 1600 juveniles/100 g soil may respond economical to nematicide treatments and at level more than 3600 during peak population growth period , treatment may improve yield substantially. The females per gram root are also used to define the damage level, with counts of < 300, >700 and >1400 representing low, moderate and high ranges, respectively. In Florida, it was estimated that yield was not measurably reduced if populations were below 2000 juveniles/100 cc soil during peak period of the soil population development (Dunan and Cohn, 1986).

2.1.3 Symptoms:

The symptoms of citrus nematode infestation depend on the over all management of the orchard and population level of the nematode. In general, symptoms resemble with nutritional deficiency such as reduction in tree growth and vigour, yellowing and shedding of leaves and undersized fruits. This nematode is reported to be the cause of citrus decline (Bindra *et al.*, 1967) and is also associated with the die back symptoms of citrus (Chona *et al.*, 1965). In new plantation the symptoms development is slow as the population build up takes the time. While effects of nematode infection are discernible early in replanting plantations on nematode infested site.

The heavily infected feeder roots are slighly thicker than the healthy roots and have a dirty look due to the soil particles adhering on the root surface with the eggmasses. These soil particle are not easily removed by washing. The cortex of heavily infested roots decay and gets sloughed off.

2.1.4 Diagnostic features:

T. semipenetrans is sexually dimorphic.

2.1.4.1 Juveniles: Juveniles are slender and straight to slight arcuate when relaxed. Head region rounded and continuous with body contour, cephalic sclerotization weak, median bulb well developed, stylet 11-15 um, cuticle finely striated, tail long pointed, genital primordial differently shaped in male and females juveniles from J2 onward.

2.1.4.2 Immature female: Body vermiform, ventrally curved posteriorly, size below 0.5 mm, cephalic scrlotization, stylet and oesophagus similar to juveniles, vulva very posteriorly situated, genital tract single, excretory pore very posteriorly slightly anterior to vulva, tail conical, no anus or rectum.

2.1.4.3 Mature female: Anterior part embedded in root tissue, posterior part outside the tissue, enlarged with thick cuticle, excretory pore and vulva very posterior, excretory cell well developed and produces gelatinous matrix, genital tract convoluted with several eggs, no anus and rectum.

2.1.4.4 Male: Body vermiform, short and slender, cephalic sclerotisatiobn, stylet and oesophagus reduced, spicule slightly curved, no bursa, tail conical pointed.

2.1.5 Systematic position:

Nematoda, Secernentea, Tylenchida, Criconematina, Tylenchuloidea, Tylenchulidae, Tylenchulinae, Tylenchulus.

2.1.6 Biology:

T. semipentras is a semi endoparasitic nematode. The juveniles feed ectoparasitically and become immature females. These immature females penetrate their anterior portion into the cortex. The life cycle varies depending upon temperature and host. It completes its life cycle in 48-55 days on rough lemon (*Citrus jambhiri*) at 24.36^{o}C-36.75^{o}C. Female lays about 95 eggs and hatch after about 16 days. First juvenile stage is completed within the eggs and second stage juveniles come out which are of two types, longer and slender developing into females and shorter and wider developping into males (Jagdale *et al.*, 1986).

2.1.7 Host parasite relationship:

The second stage juveniles feed ectoparasitically for 17-25 days on the epidermal cells and become immature females. Then the anterior portion of the body is penetrated by dissolution of cell wall. The new cortical cells grow into the spaces as penetration advances. The feeding zone consists of empty cortical cells surrounded by 6-8 nurse cells with granular cytoplasm, large nuclei and nucleoli. The feeding zones are usually confined to the cortex (Mishra and Edward, 1977).

2.1.8 Races/Biotypes:

Based on different reports and studies on the infectivity of citrus nematode on different hosts world over four races of *T. semipentrans* have been proposed by Inserra *et al.* (1980). 1. 'Poncirus Biotype' which reproduces on *Citrus* spp., *P. trifoliata* and their hybrids, grapes, but not on olive; 2. 'Citrus Biiotype' which reproduces poorly on *P. trifoliata*, but infects *Citrus* spp., Carrizo and Troyer citrange, olive and persimmon; 3.'Mediterranian Biotype' which is close to citrus biotype, but does not reproduce on olive; 4. 'Grass Biotype' reproduces only on grass, *Andropogon rhizomatus*. Indian

population of the nematode is considered related to mediterranean biotype, but in actual how many biotypes exist in India is not worked out.

2.1.9 Hosts:

Mainly host range is confined to Rutaceae family. A total of 75 Rutaceous species mainly citrus and citrus hybrids are the hosts of this nematode. Other non Rutaceous hosts reported from India are grapes (Reddy and Singh, 1978b), *Clerodendron inerme* (Nand *et al.*, 1994), *Jasminum sambac* (Bajaj *et al.*, 1988), *Garcina mangostana* (Chawla *et al.*, 1980).

2.1.10 Ecology and population fluctuation:

The active population development period may vary from place to place depanding upon agroclimatic conditions. In Haryana, two peaks in October and April have been recorded on *C. sinensis*. (Baghel and Bhatti, 1982). In Delhi, maximum populations have been recorded on *C.aurantifolia* in August (Prasad and Chawla, 1965). While contrary to these reports one peak of nematode population has been recorded in Maharashtra in January-February on *C. reticulata* grafted on *C. jambhiri* (Singh, 1997a).

The distribution of *T. semipenetrans* in the rhizosphere of citrus trees is related with the active root zone. The maximum nematode populations are observed at a distance of 90 cm from tree trunk and upto 30 cm depth (Chhabra, 1978; Baghel and Bhatti, 1982), though, *T. semipenetrans* have been observed upto the depth of 180 cm (Chawla and Sharma, 1984). Shrama and Sharma (1981) reported maximum concentration of population at 30 cm diatance from tree trunk in top 30 cm soil irrespective of plant age.

The population density is also related with the decline condition of the trees. Usually the population is more on the trees at initial stage of decline as compared to the population at advance stage of tree decline. This is mainly due to reduction in root mass in the advance stage of decline (Chona *et al.*, 1965; Bindra *et al.*, 1967; Mani, 1994; Singh, 1997c). The nutritional level of plant also influences the nematode population. The low levels of N and P result in higher population while higher dose of K favours high nematode population (Mangat and Sharma, 1981).

2.1.11 Survival and means of dissemination:

T. semipentrans is extremely sensitive to lack of moisture and high temperature. Most of the juveniles are killed if infected roots and soil are exposed to sun during summer. Under field conditions, the nematode survives mainly on the left over roots. In the absence of host, at 3 bars moisture stress, 9-27% of *T. semipenetrans* juveniles could survive after 450 days (Gaur and Sehgal, 1988). While at 30 bars of moisture stress at 40^{o}C, only 5% of the populations could survive after 7 days (Sehgal *et al.*, 1990).

The dissemination of this nematode to newer areas is mainly through infected nursery plants. The irrigation water, particularly, flood irrigation is the prime source for its spread from plant to plant within the orchard. This can also spread through contaiminated impliments.

2.1.12 Interaction with other micro organisms:

Root rot fungi present in the soil are found to aggravate the damage in the presence of *T. semipenetrans*. The nematode helps weakly pathogenic fungi like *Fusarium* to cause secondry infection of roots (Chhabra, 1972). Mishra and Edward (1977) reported that there was severe root damage when *T. semipenetrans* was accompanied with *Fusarium oxysporum* and *Macrophomina phaseoli*. Chandel and Sharma (1989) reported that *F. solani* and *T. semipentrans* when added simultaneously or *T. semipenetrans* followed by *F. solani* caused more damange to plant than done.

2.1.13 Control measures:

2.1.13.1 Physical Methods:

The nematode can be controlled by dipping the bare roots of citrus seedlings in hot water at 45°C for 25 min or 46.7°C for 10 min (Bindra *et al.*,1967). During summer by exposing the soil to hot sun can control the nematodes substantially (Sehgal *et al.*,1990).

2.1.13.2 Organic ammendments:

Application of certain indigenous plant products, non edible oil cakes such as castor, neem, cotton cakes and other organic wastes can improve the growth and reduce population of *T. semipentrans*. Application of neem cake @ 20 kg/tree at an interval of four months can effectively reduce the nematode population (Mani and Dakshinaswamy, 1986).

2.1.13.3 Use of botanicals:

A number of plants possess nematicidal properties. Different plant parts and their extract have been tested against *T. semipenetrans* by different workers. Aquous and methol garlic extracts were toxic to *T. semipenetrans in vitro* (Nath *et at.*, 1982). The extracts of leaves, stem and buds of *Datura stramonium, Ipomea carnea, Tagetes patula* and *Lowsonia alba* caused 50-100% mortality at 4 mg/ml or 1:5 dilution after 48 hrs. (Kumari *et al.*, 1980). Similarly, water extract of *Calotropis procera* and *Nerium oleander* and essential oil of *Cymbopogon grasses* have been found toxic to *T. semipenetrans* (Sangwan *et al.*, 1985; Verma *et al.*, 1989). Castor (*Ricinus communis*), oak (*Calotropis procera*) and Datura (*Datura stramanium*) chopped leaves applied @ 20 and 40 g/kg soil in 9 sq meter area around tree trunks can result in reduction of nematode population and increase the yield (Baghel, 1995).

2.1.13.4 Biological control:

Several nematophagous fungi such as *Arthrobotrys cladodes*, *Dactylaria* sp., *Monacrosporium gephyrophagum*, *Laginidium* sp. etc can trap the *T. semipenetrans* and could be exploited for nematode control (Gowda *et al.*, 1982). Endoparasitic fungus, *Paecilomyces lilacinus* is a potential biocontrol agent for controlling citrus nematode (Mani *et al.*, 1989). Vesicular arbuscular mycorrhizal fungus is a symbiotic fungus, *Glomus moseae* when added to the soil with *T. semipenetrans* in *Citrus jambhiri* limited the nematode development and partially nutralized the adverse effect of the nematode (Baghel *et al.*, 1990).

2.1.13.5 Plant resistance:

Use of resistant rootstocks offers a practical and effective mean of nematode control provided these are accepted commercially. Many rootstock germplasm have been screened by different workers for locating the resistance against *T. semipenetrans*. Trifoliate orange, *Poncirus trifoliata* is highly resistant to *T. semipenetrans* (Chhhabra and Bindra, 1974; Reddy and Singh, 1978a; Singh, 1997). Intergeneric hybrids of *P. trifoliata* with *Citrus limonoa* viz., CRH-3, CRH-5 and CRH-41 are also resistant to *T. semipenetrans* (Reddy *et al.*, 1987, Singh, 1997b). Other hybrid such as Troyer citrange, Carrizo citrange and Citrumelo 4475 are moderately resistant (Reddy and Singh, 1978a, Mani and Reddy, 1987).

2.1.13.6 Chemical control:

In early seventies, fumigant nematicides such as DBCP, DD etc. tested against citrus nematode were very effective (Chhabra and Bindra,1971; Mukhopadhyay and Dalal, 1971). Due to health and environmental reasons these fumigants are banned now.

Other non fumigant compounds like carbofuran, ethoprophos, profos, phorate, fensulfothion, dimethoate etc. have also been tested against citrus nematode under field conditions. Dichlofenthion @ 45 l/ha reduced the nematode population by 80% (Mukhopadhyay, 1970b). Mukhopadhyay and Dalal (1971) achieved 97.6% control by ethoprophos when applied @ 40 kg ai/ha and 39.9% increase in yield of sweet lime during second year. Chhabra *et al.* (1977) found fensulfothion very effective @ 30 kg ai/ha in controlling the nematodes on pumello and increased the yield by 68-76%. Carbofuran @ 6 kg ai/ha reduced the nematode populations by 67.5% and increased the yield by 60.6% (Baghel, 1995).

2.1.13.7 Integrated pest management:

Different oil cakes such as neem, castor, karang when integrated with parasitic fungi *Paecilomyces lilacinus* (Reddy *et al.*, 1991), *Verticllium chlamydosporium, V. lecanii* (Reddy *et al.*, 1996a), antagonistic fungus, *Trichoderma harzianum* (Reddy *et al.*, 1996b) and VA mycorrhiza, *Glomus fasciculatum* (Reddy *et. al*,1995) gave better plant growth and more nematode reduction in acid lime under glass house conditions. Neem cake @ 1 kg/plant combined with carbofuran at 2kg/ha reduced 33.0% nematode population and increased the yield by 33.8 % (Baghel, 1995).

2.14 Method of diagnosis:

For detecting the infestation of citrus nematode, the soil samples should be collected when the population develops the maximum in the particular area. The soil samples along with fibrous roots should be taken upto the depth of 30 cm at the drip line of the tree showing the symptoms and from the adjacent healthy tree for the comparison. The soil should not be too dry or too wet. The soil samples can be processed using Cobb's modified decanting and sieving technique. The mesh sieve used for this should not be less than 400 to avoid the loss of juveniles as these are very small and slender. Also for better recovery of the nematodes, the processed samples should be kept at 25^{o}C as the high as well as low temperature can affect the nematode recovery (Mangat and

Bhatti, 1988). Nematode infection can be observe on the roots by staining them with acid fuschin in boiling lactophenol for half minute.

2.2 Root-knot nematodes (*Meloidogyne* spp.):

Root-knot nematode, *Meloidogyne* sp. was the first nematode to be reported on citrus in India. Thirumala (1956) reported that *Meloidogyne* sp. causes considerable damage to citrus in Andhra Pradesh when a susceptible crop like tobaccco and bhindi are grown as intercrops. Chitwood and Tung (1960) observed root-knot nematodes resembling *M.africana* from Delhi and proved its pathogenicity to Citrus. Kumar *et al.* (1971) reported that *M. incognita* multiplied on *Citrus aurantifolia,* but not on *C. jambhiri* and *C. reticulata*. Reddy *et al.* (1981) reported *C. aurantifolia* as host of *M. indica*. *M. javanica* is the problem of acid lime and sweet orange in Andhra Pradesh (Mani, 1986). The nematode infested trees are poor in vigour, unthrifty in appearance and show severe stunted growth. The plant fails to flower even after several years of planting. Small conspicous galls are formed on the fibrous roots.

Citrus reticulata, Rangpur lime, Rough lemon, Sexton, Thertriton tangalo and Volkaner lemon are not infected with *M. javanica* (Reddy, 1992). The nematode can be checked by using nematode free seedlings and avoiding the intercropping with nematode susceptible crops like vegetables. Application of neem cake @ 20 kg/tree at an interval of four months can effectively reduce the nematode population (Mani and Dakshinaswamy, 1986).

2.3 Lesion-nematodes (*Pratylenchus* spp.):

Out of three species viz., *Pratylenchus coffeae, P. brachyurus* and *P. vulnus* reported to damage citrus plants, *P. coffeae* is the most pathogenic. Siddiqi (1964) reported *P. coffeae* as the cause of root rot of citrus in Uttar Pradesh and experimentally it has been shown that the young plants of *C. limon* and *C. sinensis* show poor growth when infected with *P. coffeae*.The suitable hosts of this nematode are *Citrus limon, C.sinensis, C. reticulata* and banana. *P. coffeae* has also been reported from Haryana, Punjab, and South India. The adults and juveniles are found in the cortical tissue of the feeder roots where a tiny brownish black lesion is formed which gradually expands to girdle the rootlets. In the field, the damage can be severe. O'Bannon and Tomerlin (1973) reported 49-80% growth reduction in young trees upto 4 years depending upon different rootstocks. The number of fruit bearing in initial years ranged from 3 to 20 folds difference in infected and non infected trees. The population of *P. coffeae* can be effectively reduced by applying aldicarb or carbofuran @ 4kg ai/ha (Baghel and Bhatti, 1983).

2.4 Lance nematode (*Hoplolaimus indicus*):

Hoplolaimus indicus is reported from india only. Gupta and Gupta (1966) reported first time *H. indicus* from the soil around the roots of *C. sinensis* from Ludhiana, Punjab. *H. indicus* at 1000 numbers per 500 g soil caused the reduction of citrus, however, significant reduction occurred only when the initial population was 2000 (Gupta and Atwal, 1972). The maximum nematode populations were observed in roots and soil of 10-20 years old trees showing initial decline symptoms. While low

populations were associated with 1-5 years old trees at the initial stage of decline and 10-20 years old trees with the advanced stage of decline. Besides citrus, a number of field crops are the host of this neamtode.

3. Future lines of research:

1. The population threshold level of *T. semipenetrans* on different varieties under different soil types need to be worked out for effective control measures.

2. *Tylenchulus semipentrans* is ecomonically important and widely ditributed throughout India, but how much economic losses are being caused by this neamtode in India need to be worked out.

3. The dessemination of nematodes to newer areas is mainly through nusery plants. There is need to develop methodologies for obtaining nematode free seedlings through nematode management at nursery level.

4. With the emphasis on drip irrigation system to save the water in citrus plantations, there is need to work out etiology of nematodes under changed irrigation system and also work out the efficient use of nematicides through low volume irrigation system for controlling nematodes.

5. The biological control of citrus nematode has not been explored well. Intensive research is needed on this aspect.

6. Except citrus nematode, no other nematodes on citrus have been given due attenstion in India. Systematic survey of parasitic nematodes associated with citrus plants, their densities and pathogenic potential need to be worked out.

7. Very often other soil microorganisms involve with infection of the citrus nematode causing more damage to the plants. *Fusarium* sp. , a weak pathogen is reported to cause more damage in presence of citrus nematode, but there is also need to study the associative effects of citrus nematode with *Phytophthora* sp. which is the cause of very severe problem of root rot in citrus.

8. There is need to integrate different methods of nematode control and find out their workability under field conditions.

4. Nematode parasites of grapes:

Several nematodes have been proved pathogenic to grapes in different parts of the world. These include, root-knot nematodes (*Meloidogyne* spp.), lesion nematodes (*Pratylenchus* spp.), dagger nematodes (*Xiphinema* spp.) , citrus nematode (*Tylenchulus semipenetrans*), and *Paratrichodorus* spp. In India, barring few sporadic reports, not much work has been done on nematode problems of grapes.

4.1 Root-knot nematodes (*Meloidogyne* spp.):

The species of root-knot nematode reported to cause economic damage in grapes are *M. incognita, M. javanica* and *M. arenaria*. These species are world wide distributed. Other species reported on grapes are *M. hapla, M. thamesi* and *M. nataliei*. In India, root-knot nematodes are widely distributed on several field crops. On grapes these have been reported from Haryana, Maharashtra, Andhra Pradesh and Tamil Nadu.

The root knot infection is not manifested by typical above ground symptoms. The root system shows localised galls on feeder roots, young secondary roots and root tips. *M. incognita* stimulates the production of many new rootlets above the infection site resulting into hairy root condition. Lamberti *et al.* (1990) reported declining orchards heavily infected with *M. javanica* in South Africa. The roots were distorted and swollen forming small galls. In glass house studies, *M. incognita* was able to reduce the dry weight of Carignane at inoculum level of 2000 juveniles per plant (Arredondo, 1992).

Generally the grapes are own rooted vines, but the use of resistant rootstocks can check the nematode population and increase the yield. Vines grafted on rootstocks resistant to root-knot nematode viz., Creek, Ridge and Schwarzmann yielded 45, 25 and 14% more yield than own rooted vines (Hedberg, 1977). Black Champa, Salt, Crick, Dogridge, Hur and Calcuttia have been reported resistant to root-knot nematodes in India (Darekar and Patil, 1982, Anon., 1995). The application of carbofuran @ 3kg ai/ha or phorate @ 6 kg ai/ha can reduce the root-knot nematode population by 51.8% and increase the yield by 120.19% (Anon., 1995).

4.2 Root-lesion nematodes (*Pratylenchus* spp.):

A number of root-lesion nematode species such as *P. scribneri, P. pretansis, P. minyus, P. brachyurus, P. thornei* and *P. vulnus* are associated with grapevines, but the last one is economically important.

P. vulnus causes lesions in the cortical parenchymas. The lesions initially appear in brown spots turning black later on and girdling the roots. Adults, juveniles and eggs are found within the lesions particularly in necrotic areas of the cortex. *P. vulnus* moves intracellularly. Inoculation of 1000 nematodes per vine has been reported to reduce the root and shoot growth (Pinochet *et al.*, 1976; Pinochet and Raski, 1977). The combined inoculation of *P. vulnus* and *X. index* @ 1000 and 500 nematodes, respectively, per vine caused more stunting of shoot and root growth compared to individual inoculations (Pinochet *et al.*, 1976).

4.3 Dagger nematodes (*Xiphinema* spp.):

Xiphinema index is the important nematode parasite of grapes. Other species of this nematode associated with grapevine include, *X. americanum, X insigne, X.*

diversicaudatum, X. mediterraneum, X. vuttenezi, X. brevicolle, X. brevicoides, X. italiae, X. turcicum and *X. pachitaicum.*

X. index feeds preferably at the root elongation zone causing browning and swelling of the root tips. Epidermis and cortical cells collapse at the feeding site and show necrosis. This nematode is migratory ectoparasitic nematode and the length of feeding at one place may very from several minutes to several days. The root already fed attracts the nematodes causing crowding at one site (Weischer and Wyss, 1976). *X. index* is able to cause damage at low inoculum level of 20 juveniles/plant (Akopyan *et al.*, 1987). Under Indian conditions, the pathogenicity of *X insigne* was proved on grapevine by Lal *et al.*, (1982). In pot experiment, *X. insigne* reduced the plant growth after 60 days when the inoculum level was 5000 nematodes per pot. The root tips were swollen, bent and sometimes blackened.

Dagger nematodes, besides damaging the plants directly, have also been proved to transmit viruses. *X. index* was the first nematode reported to transmit grapevine fan leaf virus (Hewitt *et al.*, 1958). *X. americanum* is reported to transmit grape yellow vein virus (Teliz *et al.*, 1966).

4.4 Citrus nematode (*Tylenchulus semipentrans*):

Tylenchulus semipenetrans, the major nematode parasite of citrus has also been reported on grapes. It has been reported on grapes from Maharashtra (Darekar *et al.*, 1990) and south India (Reddy and Singh, 1978). The feeding of the nematode on roots is characterized by the dirty look of the roots due to soil particles attached with the eggmasses as in case of citrus roots. The roots may bent irregularly and become necrotic in later stages. Kalisahebe, Tas and President verieties of grape are resistant to *Tylenchulus semipenetrans* (Darekar and Patil, 1982).

4.5 Paratrichodorus spp.:

Paratrichodorus minor, P. christiei and *P. pachydermis* are found to be associated with grapes. The feeding of these nematodes cause necrosis, browning and stubby root systems even at inoculum level of 100 nematodes per pot. At higher inoculum levels, these nematodes cause 'chimera symptoms (Pinochet *et al.*, 1976; Hafez *et al.*, 1979).

5. Future lines of research:

1. Systematic and extensive survey of parasitic nematodes associated with grapes in different states need to be taken up to know the distribution and population densities of potential nematode parasites of grapes in India.

2. There is need to estimate the losses caused by nematode in grapes.

3. There is need to study the biology, symptomatology, economic threshold levels , population dynamics of potential parasitic nematodes in grapes.

4. Work out the management of economically important nematodes of grapes.

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NEMATODE PARASITES OF SPICES

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INTRODUCTION

Spices are aromatic dried roots, rhizomes, bark, buds, seeds, berries or other plant parts. They get their characteristic odour from volatile constituents in the plant materials. Spices are used for seasoning and preserving food, besides their use in confectionaries, medicines, perfumes and cosmetics.The center of origin of the 'king of spices', black pepper and the 'queen of spices', cardamom is India. India is a major producer of ginger, turmeric, chillies and seed spices also and the country exported about 2.02 lakh tones of various spices valued at Rs. 785.89 crore up to 1995-96. India's export earnings from spices touched an all- time record of Rs. 1130 crore during 1996-97. However, the productivity of many spice crops is low in India due to several factors of biotic and abiotic nature. Plant parasitic nematodes are one of the biotic factors responsible for the low productivity in almost all spice crops. Plant parasitic nematodes not only cause direct damage to the host roots but also are involved in a number of complex diseases involving fungi, bacteria etc. Although, nematode damage is quite significant in a number of spice crops, nematological research in India has been limited to major spice crops like black pepper, cardamom, ginger, turmeric and to a lesser extent to seed spices like coriander, cumin, fennel, fenugreek etc. Very limited information is available on nematodes and their damage potential in tree spice crops like cinnamon, nutmeg, clove, allspice etc. Recently Ramana and Eapen (1995;1998) reviewed the nematological investigations in spices and condiments.

Among the large number of plant parasitic nematodes reported on spice crops, very few nematode species like *Meloidogyne* spp., *Radopholus similis, Pratylenchus* sp., *Rotylenchulus reniformis, Helicotylenchus* sp., *Tylenchorhynchus* sp. are commonly associated with a variety of spice crops. In spices cultivation, root-knot nematodes *(Meloidogyne* spp.) occupy a unique place since these nematodes infest almost all spice crops. The following is a brief review of work carried out on various aspects of nematode problems in spice crops.

NEMATODES ASSOCIATED WITH SPICES

Although a sizeable number of plant parasitic nematodes have been recorded in association with spices, only a few species can be considered as economically important. Among these, the most important nematodes are root knot nematodes, *Meloidogyne* spp., the burrowing nematode, *Radopholus similis* and the lesion nematodes, *Pratylenchus* spp.

2.1 Root knot nematodes, *Meloidogyne* spp. Goeldi, 1892

Meloidogyne spp. are obligate endoparasites of great economic importance, prevalen throughout the tropical and subtropical countries.

a. *Diagnostic features* : All the species induce galls on infesting plant roots. Sexually dimorphic. Female: Body white, round to pear-shaped with short projecting neck, characteristic cuticular patterns (perineal pattern) around vulva and anus. Excretory pore anterior to median bulb. Ovaries paired, prodelphic and convoluted. Eggs are laid in a gelatinous matrix secreted by rectal glands.

Male: Vermiform, with a length of about 0.7-2.0 mm. Cephalic region with distinct labial disc. Stylet strong with large knobs. Tail,rounded, bursa absent, one or two testis. First stage moults within the egg.

Juvenile: Second stage juvenile vermiform, migratory and infective. Cephalic region with a distinct labial disc. Tail with conspicuous hyaline region. Second and third moults occur within the cuticle of second stage juvenile. These stages are sedentary and swollen, stylet absent and with a tail spike.

b. *Systematic position*: Nematoda, Secernentea, Tylenchida, Tylenchina, Heteroderoidea, Meloidogynidae, *Meloidogyne*.

c. *Biology*: Eggs laid in the gelatinous matrix develop into 1 st stage larvae which moult inside the egg giving rise to second stage juveniles. These juveniles penetrate host plants and establish a feeding site within the pericycle and vascular tissues. The juveniles undergo three further moults and become spherical. The adult female, after about 15-30 days of feeding, lays large number of eggs in a gelatinous matrix. Most species reproduce by parthenogenesis or by a combination of parthenogenesis and amphimixis.

d. *Races pathotypes*:The North Carolina Differential Host Test using five differential hosts can delineate root knot nematode populations. There are four races in *Meloidogyne incognita* while two races are seen in *M.arenaria*. Race 1 of *M.incognita* and race 2 of *M.arenaria* are more prevalent. In India race 1 of *M.incognita* is dominant (Sharma & Gill, 1992). Preliminary evidence for the presence of races in *M.javanica* is reported recently (Sharma, Smith & Mc Donald, 1995). However, there is no report on the race status of various root knot nematodes affecting spices.

2.2 Burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne, 1949

R.similis is one of the most important and destructive root parasites. The nematode causes extensive damage to root cortical tissues but contamination by microorganisms leads to root decay. It occurs throughout tropical and warm temperate regions mainly because of man made dispersal through infested plant materials.

a. *Diagnostic features:* Small nematodes (less than 1 mm), migratory endoparasites of roots, causing dark brown lesions on roots. Sexual dimorphism in anterior region.

Female: Vermiform, cephalic region low, continuous or slightly offset, framework strongly

sclerotised. Stylet well developed. Oesophgeal glands elongated, dorsal to intestine, median bulb well developed. Didelphic, amphidelphic ovaries, vulva median at 55-65% of body length. Tail elongate - conoid to sub-cylindroid.
Male: Vermiform, migratory, not parasitic. Cephalic region high, rounded and more offset, cephalic sclerotisation reduced, stylet slender, degenerated oesophagus. Single testis, spicule paired, bursa terminal or sub-terminal. Tail more tapering than that of female.
Juvenile: Vermiform, migratory and parasitic. Well developed stylet and oesophagus.

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

c. *Biology*: All stages, except the adult nematode, are infective. Feeding activities are restricted to the cortex, causing discolouration and severe damage allowing secondary invasion by other microorganisms. Life cycle is completed in 25 days at a temperature range of 25-28^{0}C (Geetha, 1991).

d. *Races/Pathotypes:* The two morphologically indistinguishable races of *R.similis,* 'banana race' and 'citrus race' were proved as sibling species. They differ in chromosome number, genetic variability in protein, host preference and behaviour and the 'citrus race' has been named as *Radopholus citrophilus* (Huettel, Dickson & Kaplan, 1986). There are several reports on the presence of additional races within the 'banana race' based on differences in reproductive fitness and pathogenicity. Recently PCR based RAPD studies had indicated the existence of two gene pools within the *R.similis* isolates (Fallas *et al.*, 1996; Hahn, Burrows & Wright, 1996). The presence of different 'host types' of *R.similis* is also reported from India (Venkitesan, 1976; Koshy & Jasy, 1991).

2.3 Lesion nematode, *Pratylenchus* spp. Filipjev, 1936
Species of *Pratylenchus*, generally known as lesion or meadow nematodes, are tropical and subtropical in distribution and attack several important crops. Like burrowing nematodes these are also migratory endoparasites. They damage the root system by direct feeding and through their destructive secretions. The root injury is aggravated by the attack of other soil borne microorganisms.

a. *Diagnostic features*: Small nematodes (less than 1 mm long).There is no marked sexual dimorphism in the anterior region. Cephalic region low, usually flattened. Oesophageal glands lobe like and mostly on ventral side of the intestine.
Female: Vermiform, vulva posterior (usually at 70-80%), single, anteriorly directed ovary. Tail subcylindrical to conoid, terminus broad to narrowly rounded or truncate.
Male: Vermiform, migratory, oesophagus well developed, tail short, bursa enveloping tail terminus. Spicules slender and arcuate.
Juvenile : Vermiform, migratory and parasitic.

b. *Systematic position* : Nematoda, Secernentea, Tylenchida, Tylenchoidea, Pratylenchidae, Pratylenchinae, *Pratylenchus*.

c. *Biology*: All stages from J_2 onwards may enter the host root. The nematodes feed mainly on cortex cells and form cavities containing colonies of nematodes of all stages. The root parts where these nematodes multiply often assume a dark red or brown colour, caused by the necrosis of the invaded cells and also invasion of secondary pathogens like fungi and bacteria. Some species reproduce sexually while others are parthenogenetic. It takes about 3-4 weeks to complete the life cycle and the nematodes can survive in the absence of host plants for several months.

d. *Races/Pathotypes*: There are several reports of intra specific variations in *Pratylenchus*. But this can be due to the high variability in diagnostic characters.

3. NEMATODES OF BLACK PEPPER (*Piper nigrum* L.)

Plant parasitic nematodes belonging to 30 genera and 54 species were reported in association with black pepper. In India, 17 genera were reported by Sundararaju, Koshy and Sosamma (1979). In the extensive surveys conducted during 1980's in the major pepper growing areas in Kerala and Karnataka, 14 genera of plant parasitic nematodes were found in association with the crop (Ramana & Mohandas, 1987; 1989). However, among these only very few species like *Meloidogyne incognita, Radopholus similis, Trophotylenchulus piperis, Rotylenchulus reniformis* and *Helicotylenchus* spp. are predominantly associated with the crop in India (Venkitesan, 1976; Jacob & Kuriyan, 1980; Ramana & Mohandas, 1987; 1989). In other black pepper growing countries like Malaysia, Indonesia, Sri Lanka and Brazil, *Meloidogyne* spp. and *R. similis* assumed economic importance in black pepper cultivation since these nematodes are responsible for slow decline disease, a major threat to the crop.

3.1 Root knot nematodes, *Meloidogyne* spp.

Three species of root knot nematodes viz., *M.incognita*, *M.javanica* and *M.arenaria* are reported on black pepper. Among the three species, *M.incognita* is the most commonly and widely distributed nematode in black pepper gardens in all pepper growing countries. Delacroix (1902) first reported the occurrence of root-knot nematodes in black pepper from Cochin-China (presently a part of Vietnam). In India, association of this nematode with black pepper in Wynad, Kerala was first reported by Barber (cited by Ridley, 1912) followed by Butler in 1906 (Butler, 1906) and Ayyar (1926). Subsequent surveys also revealed the predominant occurrence of this nematode in all pepper growing areas in Kerala and Karnataka (Kumar, Viswanathan & D'Souza, 1971; Venkitesan, 1972; Jacob & Kuriyan, 1979; Ramana & Mohandas, 1987; 1989). This nematode was found in 69.8 and 53.8% of black pepper gardens in Kerala and Karnataka, respectively (Ramana & Mohandas, 1987; 1989).

a. *Symptoms*: Barber (cited by Ridley, 1912) while investigating the decline disease of black pepper in Wynad, Kerala observed a series of tumors (galls) on the roots caused by nematodes (*Heterodera radicicola=Meloidogyne incognita*) and these tumors decay resulting in the loss of root system. These nematodes are sendentory endoparasites feeding on vascular tissues

and cause hypertrophy and hyperplasia, both on thick primary roots and fibrous roots. On thick primary roots, due to multiple infection by nematodes, the whole length of the root turn into a gall. Many adult females with egg masses are seen situated deep below the epidermis, when the galled root is split opened longitudinally (Mohandas & Ramana, 1987). Root knot nematode infested vines show stunted growth, yellowing of leaves and decline in vigour and productivity. In severely infested vines the leaves show dense yellowing of interveinal areas with deep green veins (Ramana, 1992; Ramana, Mohandas & Eapen, 1994).

b. *Host parasite interactions*: Histopathological studies showed that *M.incognita* occupied the stelar portion of the roots and the characteristic giant or syncytial cells are formed (Mustika, 1990). Accumulation of high concentration of total phenols was reported in plants inoculated with *M.incognita* (Ferraz, Orchard & Lopes, 1984). Besides, root knot nematode infestation resulted in the physiological changes of the plant like reduced absorption and translocation of elements like P, K, Zn, Mn, Cu and also accumulation of Ca and Mg in the leaves (Ferraz, Lordello & Santana, 1988). Ferraz, Lordello and Gonzaga (1989) also found that chlorophyll content in the leaves of the nematode infested plants was significantly low affecting the growth of the plants. Similarly several changes in the levels of amino acids, organic acids and sugars were also observed in *M.incognita* infested plants (Ferraz, Orchard & Lopez, 1984; Freire & Bridge, 1985 b).

c. *Economic importance*: Pathogenicity of root knot nematode on black pepper has been established by several workers in pot culture under green house conditions. The nematode caused significant reduction in all growth parameters (Koshy *et al.*, 1979; Mohandas & Ramana, 1983). An inoculum level of 100-1000 juveniles of *M. incognita* was found highly pathogenic to black pepper seedlings (Freire & Bridge, 1985 c). Pathogenicity tests conducted under simulated field conditions on grown up vines showed that the nematode caused significant reduction in the growth and yield (37 to 46%), when the plants were inoculated with 10,000 to 1,00,000 nematodes and the plants showed foliar yellowing with interveinal chlorosis (Mohandas & Ramana, 1991). Similar reduction in the growth of pepper vines was reported by others also (Winoto, 1972; Jacob & Kuriyan, 1980). In Para, Brazil, about 90% of black pepper vines were infected with root knot nematodes, mostly *M.incognita* (Ichinohe, 1975).

d. *Population fluctuation, survival and dissemination*: *M.incognita* population in black pepper gardens reaches maximum during December/January (Ramana, 1992). Pepper being a perennial crop, the nematodes can survive well in the agroecosystem. Other intercrops and common weeds in black pepper gardens are also good hosts of root knot nematodes. The major means of dissemination is through infested planting materials and human activities.

3.2 Burrowing nematode, *Radopholus similis*

The burrowing nematode, *Radopholus similis* is a serious nematode pest of several horticultural crops with a wide host range. Goodey (1936) first reported that black pepper is a host of *R. similis*. Van der Vecht (1950) while investigating the disease known as 'yellows', which was responsible for the death of 20 million pepper vines in Bangka islands

in Indonesia, found that *R. similis* was responsible for the disease. In India occurrence of the nematode in black pepper plantations was reported by D'Souza, Viswanathan and Shamanna (1970). Later surveys conducted also showed its wide distribution in all pepper growing areas in Kerala and Karnataka (Kumar, Viswanathan & D'Souza, 1971; Venkitesan, 1972; Koshy, Sundararaju & Sosamma, 1978; Ramana & Mohandas, 1987; 1989). It is also a serious pest on black pepper in other pepper growing countries like Malaysia (Reddy, 1977), Thailand (Sher, Chunram & Pholcharoen.1969) and Sri Lanka (Gnanapragasam *et al.*, 1985).

a. *Symptoms: R. similis* is a migratory endo parasite and infect black pepper roots. The nematode prefers succulent root tips for invasion and could infest black pepper roots within 24 h. under artificial inoculation (Venkitesan & Setty, 1977). Dark brown lesions are produced at the sites of infection and the nematodes move inter and intra cellularly in the cortical root tissues producing large necrotic areas throughout the root. All stages of the nematode (egg to adult) are found in the root lesions. Due to severe infestation, the plants lose almost all vital roots and are left with a bunch of decayed root mass (Venkitesan & Setty, 1977; Mohandas & Ramana, 1987). As a result, the roots lose their function and will not be able to absorb moisture and nutrients from the soil medium and plants express above ground symptoms such as foliar yellowing, defoliation and retarded growth.

b. *Host parasite interactions*: *R.similis* penetrates through root tips and cortical cells surrounding the nematode turn necrotic and some xylem vessels were plugged with gum like substances. Nematodes migrate intercellularly and intracellularly making tunnels in the cortical tissues (Venkitesan, 1976; Venkitesan & Setty, 1977; Freire & Bridge,1985 a; Mustika, 1990).

c. *Economic importance*: In studies conducted under green house conditions, inoculation of *R.similis* to pepper plants resulted in the reduction of plant growth, number of leaves, nodes, leaf area and dry weight of shoot and root. Plants inoculated with higher inoculum level completely lost the roots leaving only a few rotten roots (Venkitesan & Setty, 1977). Under simulated field conditions on grown up vines, *R. similis* caused typical symptoms of slow decline disease viz., foliar yellowing, defoliation and die back and the severity of these symptoms increases with increase in inoculum level and time. The nematode caused significant reduction in height (0.21 to 19.63%), number of primary shoots (13.23 to 56.61%), dry weight of shoot (24.7 to 60.83%), leaf (25.34 to 77.1%), root (33.47 to 81.88%) and yield (0.33 to 59.47%) in plants inoculated with nematodes @ 100 to 10,000/ plant (Mohandas & Ramana, 1991).

d. *Population fluctuation, survival and dissemination*: *R. similis* population in black pepper roots from a pure pepper plantation showed maximum nematode level during September-October and minimum during April-June. Rainfall and number of rainy days had significant influence on the population build up of the nematode (Mohandas & Ramana, 1988). Highly susceptible crops like banana, coconut, arecanut grown along with black pepper plantations enhance nematode multiplication and population build up. According to Koshy (1986) the

burrowing nematode on citrus and banana can survive up to 17 months even under clean fallow and deep ploughing. Females could survive longer periods than the juveniles in moist soil (Brichfield, 1957; Hannon, 1963; Blake, 1969; Vilsoni, 1979). The coconut isolate could survive in host free conditions for 3 months depending on the soil moisture (Sosamma & Koshy, 1986).

3.3 Other nematodes of black pepper

Besides *M. incognita* and *R. similis*, several plant parasitic nematodes like *Helicotylenchus* spp., *Rotylenchulus reniformis, Tylenchulus semipenetrans, Xiphinema* spp., *Macroposthonia onoensis* were also reported in association with black pepper rhizosphere soils. However, their economic importance in pepper cultivation has not been established. Recently, a new semiendoparasitic nematode, *Trophotylenchulus piperis*, infesting black pepper roots in India was described (Mohandas, Ramana & Raski, 1985). This nematode so far has not been reported from any other pepper growing country. It is a semiendo parasite, distributed widely in Kerala and Karnataka (Ramana & Mohandas, 1987; 1989). The adult females, covered with hard brown cases with mucilagenous sticky mass are found on the roots. Nematode infestation results in shrinkage and drying of the root portion at the site of infection. But no clear cut symptoms could be observed on the above ground plant parts (Ramana & Eapen, 1997).

3.4 Nematode interactions with other organisms

'Slow decline' disease of black pepper, though primarily attributed to infestation by *R.similis* and *M.incognita*, other microorganisms like *Fusarium* sp. and *Pythium* sp. were also reported in association with this disease (Hubert, 1957; Bridge, 1978; Winoto, 1972; Freire, 1982; Lopes & Lordello, 1979; Hamada, Harikata & Uchida, 1985; Sheela & Venkitesan, 1990; Mustika, 1990;1992; Varughese & Anuar, 1992; Nambiar & Sarma, 1977). However, the possible role of *Fusarium* sp. in the 'slow decline' disease complex in India could not be established (Ramana ,Sarma & Mohandas, 1992). Holliday and Mowat (1963) could not find any relation between *M. javanica* infestation and foot rot caused by *Phytophthora palmivora* in pepper plantations in Sarawak, Malaysia. Winoto (1972) observed that plants infested with root knot nematodes were more susceptible to *Phytophthora* infections. Recent studies in India also showed that feeder root loss caused by *R.similis, M.incognita* and *Phytophthora capsici* either alone or in combinations lead to slow decline in black pepper (Anandaraj, Ramana & Sarma, 1996).

3.5 Nematode management

Being a perennial crop, the nematode management in black pepper is more difficult. Measures like crop rotation and fallowing are impractical in these situations.

a. *Cultural practices*: Several cultural and cultivation practices are extremely useful for the management of nematode parasites of black pepper.

i. Use of nematode free planting materials: Healthy, nematode free black pepper rooted cuttings can be raised by sterilizing the nursery soil mixture with solar heat, steam or soil fumigants (Ramana, Mohandas & Eapen, 1994). Promising isolates of biocontrol agents like

VAM fungi, *Trichoderma* spp. etc. can be incorporated in the nursery soil mixture (Anandaraj & Sarma, 1994; Sarma *et al.*, 1996; Eapen & Ramana, 1996; Ramana & Eapan, 1998). Besides, use of nematicides like phorate or carbofuran is also recommended to bring down the nematode population in the nursery (Mohandas & Ramana, 1987).

ii. Phytosanitation: Diseased plants in a garden should be destroyed along with the root mass. Barber (cited by Ridley, 1912) suggested that all the galled roots and underground plant parts should be collected and burned and on no account replanting should be done in these pits for many years. Mother vines for raising nurseries should be selected from healthy and nematode-free gardens. The rooted cuttings should be checked for the presence of nematodes and the nematode infested roots should be pruned or heavily infested materials can be discarded.

iii. Organic amendments and mulching: Addition of organic mulches improves the water holding capacity of the soil, besides enhancing the fertility status and microbial activity in the soil. The chemicals released during the decomposition of organic materials can be toxic to nematodes. Mulching with green manure plants reduced nematodes and the incidence of disease in pepper plantations (Hubert 1975; Litzenberge & Lip, 1961; Wahid 1976; de Waard,1979; Ichinohe, 1980;1985; Jasy & Koshy,1992).Growing non host plants like *Macroptillium atropurpureum, Centrosema pubescens, Clitoria tetnatia, Cajanas cajan, Arachis hypogea, Crotalaria* sp., *Derris elliptica, Indigofera hirsuta* and *Tagetes patula* as cover crops reduced nematode populations in several countries (Ichinohe, 1985; Mustika, 1991; Ramana, 1992). Application of neem oil cake @ 2 kg/vine twice a year along with fertilizers was found highly effective in suppressing root knot nematode populations (Ramana, Sarma & Mohandas, 1992).

iv. Cultivation practices: Several intercrops and live standards commonly used in pepper gardens are very good hosts for the above nematodes. These plants harbour high populations of nematodes and control is not that easy in such situations. Use of non living standards or nematode resistant plant species to trail black pepper vines is a good line of approach. Similarly nematode susceptible inter crops like banana, ginger, turmeric, cardamom, arecanut etc. should be avoided in pepper gardens.

b. *Host resistance*: Cultivars like Balancotta, Belantung, Cheriakaniakkadan, Jambi, Kalluvally and Hybrid 10 (hybrid of Balancotta & Kuching) were less susceptible to root knot nematodes (Kueh, 1986; Paulus *et al.*,1993). Kuching appeared to be tolerant to *M.incognita* and *R.similis* (Mustika, 1990; 1991). A germplasm selection, Ottaplakkal 1, was found tolerant to *M.incognita* and has been recommended for release as 'Pournami ' (Ramana & Mohandas, 1986; Ravindran *et al.*, 1987). In Sri Lanka a variety, PW-14, was reported totally immune to *R.similis* (Gnanapragasam, 1989). Source of resistance has been reported in related species like *Piper colubrinum* (against *R.similis* and *M.incognita*) and *P.aduncum* (against *M.incognita*) (Ramana & Mohandas 1986; Paulus *et al.*, 1993; Ramana, Mohandas & Eapen, 1994). Wild species *P.hymenophyllum* and *P.attenuatum* recorded least root reduction and minimum nematode multiplication on testing with *R. .similis* (Venkitesan & Setty, 1978).

c. *Chemical control*: Though fumigants are useful in eradicating nematodes in pepper nurseries, granular nematicides are generally used for control of nematodes of black pepper. Several nematicides such as phenamiphos (Nambiar & Sarma, 1980), aldicarb sulphone, phorate, DBCP (Venkitesan & Setty, 1979; Venkitesan & Charles, 1980), aldicarb, phorate and corbofuran (Mohandas & Ramana, 1987; Ramana, Mohandas & Eapen, 1994) were found effective in India. Carbofuran, phenamiphos and oxamyl were found effective in Malaysia (Kueh, 1979; Kueh & Teo, 1978) while aldicarb and carbofuran were found good in Brazil (Ichinohe, 1980). Several nematicides were reported to be controlling nematodes in Indonesia (Mustika & Zainuddin, 1978; Long, 1986). However, several of these nematicides are banned and are not available in the market.

d. *Biological control*: Though not a replacement for nematicides, this has become an essential component of the integrated nematode management programmes. A large number of biocontrol agents have been identified in recent years which have very good potential for suppressing nematode populations. These include, several species of VAM fungi (Manjunath &Bagyaraj, 1982; Anandaraj & Sarma, 1994; Anandaraj, Ramana & Sarma,1991;1996; Sivaprasad *et al.*, 1990; 1992; NRCS, 1991), *Paecilomyces lilacinus* (Friere & Bridge, 1985 d; Geetha, 1991; Ramana, 1994; Sosamma & Koshy, 1995), *Trichoderma* spp. (Eapen & Ramana, 1996; IISR, 1995), *Verticillium chlamydosporium* (Sreeja, Eapen & Ramana,1996), *Pasteuria penetrans* (Geetha,1991; Sosamma & Koshy, 1995; IISR, 1996) and several other bacteria (Sheela, Venkitesan &Mohandas, 1993; Eapen, Ramana & Sarma, 1997).

4. NEMATODES OF CARDAMOM (*Elettaria cardamomum* Maton)

Plant parasitic nematodes belonging to 20 genera are reported on cardamom. Among these, the most important and more widely distributed are the root knot nematodes (*Meloidogyne* spp.). Other nematodes of common occurrence are *Helicotylenchus* spp. and *Rotylenchulus reniformis*. *Radopholus similis* and *Pratylenchus coffeae* are other two important nematodes, generally observed in mixed plantations of cardamom with arecanut and coffee, respectively.

4.1. Root knot nematode , *Meloidogyne* spp.

The first report on the occurrence of root knot nematodes in cardamom plantations was in 1970 (D'Souza, Visvanathan & Shamanna, 1970). Subsequently there were several reports on their wide spread distribution in cardamom nurseries and plantations (Koshy *et al.*, 1976; Kumar, Viswanathan & D'Souza,1971; Sundararaju, Koshy & Sosamma,1979; Viswanathan, Kumar & D'Souza, 1974; Ali, 1984;1986; Ali & Koshy ,1982). The predominant species was *Meloidogyne incognita* while *M.arenaria* and *M.javanica* have restricted distribution.

a. *Symptoms:* Root galling is the characteristic below ground symptom. Root growth is retarded when nematode infestation is severe. Root galling and other abnormalities are significantly greater in young seedlings than in adult plants (Ali, 1986; Eapen, 1992; Koshy & Bridge, 1990). Suppression of secondary root production and abnormal branching are commonly observed in mature plants. As in many other crops, root damage caused by these nematodes

is reflected in the general appearance of the plant, though they are non-specific. Stunted growth, poor tillering, narrowing and yellowing of leaves, drying of leaf tips and margins etc. are some of the aerial symptoms attributed to nematode infestation (Eapen, 1994). Patches of stunted or weak plants are observed in 'sick' nurseries and infested plantations. Root knot nematode also causes poor germination in nurseries and poor establishment on transplanting.

b. *Economic importance:* Root knot nematode infestation is reported to cause more than 50 per cent reduction in germination (Ali & Koshy, 1982). About 40 per cent of infested seedlings fail to establish in secondary nurseries (Koshy & Bridge, 1990). Studies under simulated field conditions showed 46.6% yield loss at an initial inoculum level of 4 nematodes/100 cm^3 soil (Eapen, 1994). Ali (1987) also reported 32 to 40 per cent yield loss in unprotected cardamom plants.

4.2 Interactions with other organisms

M.incognita predisposes plants to *Rhizoctonia solani* infections, leading to rhizome rot and damping off, prevalent in cardamom nurseries (Ali & Venugopal, 1992; 1993). However, nematodes had no role in *Pythium* infections. Cardamom plants infected with 'Katte' disease (a viral disease) supported 5-10 times more *M.incognita* population (Ali, 1989).

4.3 Nematode management

Nematode problems in cardamom nurseries and plantations should be tackled differently. The main objective of nematode management in plantations is to bring down the nematode population to below economic threshold or non injurious level, while eradication should be the goal in nurseries.

a. *In nurseries:* Soil fumigants like MBr, Durofume, EDB etc. can be used for disinfesting the nursery beds (Ali & Koshy, 1982; NRCS, 1986; Eapen, 1994). Soil solarization is also another means for reducing the initial nematode load (NRCS, 1993-1994; Eapen, 1994). Apart from controlling plant parasitic nematodes, these two techniques are effective against other soil borne pathogens and weeds. Supplementing soil solarization with organic amendments or biocontrol agents also gives better protection (NRCS, 1994). Biocontrol agents like *Trichoderma* spp. *Paecilomyces lilacinus* and *Verticillium chlamydosporium* were proved to be effective in suppressing root knot nematodes of cardamom (Eapen & Venugopal, 1995; Eapen & Ramana, 1997).

Fallowing, summer ploughing, shifting of nursery sites etc. are some simple options for minimizing nematode problems. In heavily infested nurseries non volatile nematicides like carbofuran, phorate etc. are recommended (Ali, 1986;1987; Jacob & Chandrasekharan, 1984; Koshy *et al.*, 1979).

b. *In plantations:* The basic strategies for tackling nematode problems in cardamom plantation are exclusion or avoidance, eradication or containment, population manipulation and the decision to take no action. The most effective means for limiting nematode damage and

their spread is the use of healthy, nematode-free planting materials. Such seedlings have a better chance of establishing, surviving and yielding higher than the infested plants. Phytosanitation also has a key role to play.

Eradication or containment can be achieved through selective application of nematicides in heavily infested or 'sick' patches within a plantation. Several chemicals have been evaluated for their efficiency to control or eradicate root knot nematodes of cardamom (Ali, 1987; Jacob & Chandrasekharan, 1984; Venkitesan *et al.*, 1989; Eapen, 1994). Application of phorate @ 2.5-5.0 g a.i/clump reduced root knot nematode incidence and increased the yield by more than 40% (Eapen, 1994). Repeated application are needed for desired results. These chemicals work best when used at the required rates and in all cases, well incorporated into the top soil, having adequate moisture.

Root knot nematode population in plantations can be manipulated so as their level never reaches above the economic threshold. This can be achieved by maintaining the organic status of the soil by way of regular incorporation of mulch and plant residues. Use of organic cakes like neem oil cake can also regulate the nematode population and improve the growth and yield of the plant (Ali, 1987). Incorporation of organic materials fortified with biocontrol agents like *Trichoderma* spp., *P. lilacinus*, *V.chlamydosporium* etc is another excellent option to prevent the nematode build up (Eapen & Ramana, 1997).

5. NEMATODES OF GINGER (*Zingiber officinale* Rosc.) AND TURMERIC (*Curcuma longa* L.)

Plant parasitic nematodes belonging 17 and 20 genera were reported on ginger and turmeric, respectively. Among them, root knot nematodes, lesion nematodes and burrowing nematodes are quite serious problems. *Xiphinema basiri* was also found to be pathogenic to turmeric (Rajeswari & Muthukrishnan, 1990).

5.1 Root knot nematodes, *Meloidogyne* spp.

Root knot nematode infestation in ginger was first reported by Nagakura (1930) while in turmeric it was reported first by Ayyar (1926). The predominant species is *M.incognita* while *M.hapla* and *M.arenaria* are also reported to be pathogenic to ginger (Kaur, 1987; Kaur & Sharma, 1988).

a. *Symptoms*: Stunting, chlorosis, poor tillering and necrosis of leaves are the common symptoms of nematode infestation in ginger and turmeric. The affected plants mature, dry faster and die prematurely than healthy ones, leaving a poor crop stand at harvest. Fresh ginger roots are invaded along the entire length, while in fibrous roots nematode infestation takes place in the area of differentiation. Infested ginger rhizomes have brown, water soaked areas in the outer tissues (Huang, 1966; Cheng & Tu, 1979), while turmeric rhizomes loose their bright yellow colour (Mani, Naidu & Madhavachari, 1987).

b. *Host parasite interactions*: In ginger abnormal xylem vessels and parenchyma with thickened cell walls are observed in all root knot nematode infested tissues except in rhizome (Routaray, Mahapatra & Das., 1987). *M.incognita* enters the cortex and stelar regions forming giant cells (Lanjewar & Shukla, 1988). These giant cells showed karyotic nuclear divisions and had thickened cell walls. Corky wounds are found at infection sites in differentiated rhizomes and fresh roots (Huang ,1966; Shah & Raju, 1977). In turmeric also root knot nematodes induced giant cell formation leading to formation of characteristic galls.

c. *Economic importance*: *M.incognita* is widely distributed in ginger fields and causes a loss of 46.4% (Charles, 1978) and 74% reduction in rhizome weight under artificial inoculation studies (Parihar, 1985; Sudha & Sundararaju, 1986). The economic threshold level of this nematode varied from 2 nematodes per gram of soil to 50 larvae per 100 ml soil (Parihar & Yadava, 1986; Routaray, Mahapatra & Das, 1987 ; Kaur, 1987; Sudha & Sundararaju, 1986). Significant reductions in growth and yield of turmeric were noticed in plants inoculated with >1000 root knot nematode juveniles per plant (Sudha, Koshy & Sundararaju, 1989). When four varieties of turmeric were tested against *M.incognita*, maximum reduction (18%) of fresh rhizome weight was observed in Suvarna at a Pi=2 juveniles per gram of soil (NRCS, 1993).

5.2 Burrowing nematode, *Radopholus similis*

Radopholus similis was first reported in ginger by Hart (1956). Its widespread distribution in ginger fields of Kerala was suggested by Charles & Kuriyan (1979). There are several reports on its presence in turmeric fields also.

a. *Symptoms*: *Radopholus similis* produce small, shallow, shrunken water soaked lesions on roots (Vilsoni, Mac Clure & Butler, 1976; Sundararaju, Sosamma & Koshy,1979). Turmeric roots damaged by *R.similis* become rotten and most of these decayed roots retain only the epidermis lacking cortex and stelar portions. Shallow, water soaked brownish areas are seen on the surface of rhizomes (Sundararaju, Sosamma & Koshy, 1979). Infested turmeric rhizomes are of yellow colour compared to the golden yellow colour of healthy rhizomes. Infected plants show loss of vigour, poor tillering and stunting.

b. *Host parasite interactions* : The burrowing nematodes migrate intra cellularly producing large infection channels or galleries within the rhizomes (Vilsoni, Mac Clure & Butler, 1976).

c. *Economic importance* : In ginger, an initial level of 10 nematodes per plant caused 39.8% reduction in rhizome weight (Sundararaju, Sosamma & Koshy,1979), while in turmeric an initial population of 10 nematodes per plant caused 35-46 per cent reduction in rhizome weight (Sosamma, Sundararaju & Koshy, 1979). Infected rhizomes are the main source of inoculum and aid in the dissemination of the nematode.

5.3 Lesion nematode, *Pratylenchus* spp.

Several species of *Pratylenchus* namely, *P.brachyurus, P.coffeae, P.indicus, P.pratensis* and *P.zeae* are reported on ginger and turmeric (Charles, 1978; Rama & Dasgupta, 1985; Kaur & Sharma, 1988; Kaur, Sharma & Khan, 1989; Sarma, Nambiar & Nair, 1974;

Venkitesan & Charles, 1982; NRCS, 1993; Das & Das, 1986). Recently ginger rhizomes from Sikkim and turmeric rhizomes from Andhra Pradesh were found to be heavily infested with *Pratylenchus* spp. (Ramana & Eapan, unpublished).

a. *Symptoms*: *Pratylenchus coffeae* infestation caused yellowing of leaves in ginger (Kaur & Sharma, 1990). Dry rot like symptoms were also seen in ginger rhizomes. Dark, brown necrotic lesions can be observed within the infected rhizomes. In advanced stages of infections the turmeric rhizomes are discoloured, less turgid with dry rot symptoms (Sarma, Nambiar & Nair, 1974).

b. *Economic importance*: *P.coffeae* is reported to cause 'ginger yellows' disease prevalent in Himachal Pradesh (Kaur & Sharma, 1990). The incidence of these nematodes in rhizomes of ginger and turmeric is of great concern as this may lead to wide spread distribution through seed rhizomes and crop loss.

5.4 Interactions with other organisms

Incidence of rhizome rot of ginger caused by *Pythium aphanidermatum* is reported to be severe when rhizomes are infested with nematodes like *M.incognita* and *P.coffeae* (Dohroo, Shyam & Bhardwaj,1987). However, Doshi & Mathew (1987) could not observe any interaction with these two organisms. Similarly there was no interaction between *M.incognita* and *Pythium myriotylum* also (Lanjewar & Shukla, 1985). Recent studies have shown that, ginger plants inoculated with root knot nematodes developed disease symptoms early on inoculating with *Pythium aphanidermatum* (IISR, 1997). Basal sheath rot, a new disease of ginger is suspected to be caused by the combined infection of *Aphelenchus* sp. and *Fusarium* sp. (Magar & Mayee, 1988). Bacterial wilt of ginger caused by *Pseudomonas solanacearum* is also influenced by *M.incognita* (Samuel & Mathew,1983) even though there are reports contradictory to it (IISR, 1996).

5.5 Nematode management

An integrated approach involving several measures like selection of nematode free, healthy rhizomes to judicial application of nematicides can be adopted for control of nematodes of ginger and turmeric. Considering the fact that 'clean' spices with 'zero' level of pesticides are preferred in world market, the chemical control option should be given the lowest priority. Careful integration of the following practices will be useful for achieving this goal.

a. *Physical*:
reduce the nematode incidence in ginger [illegible]
1971; Chen, Li & Lii, 1986). Soil solarization recommended for control of soil borne diseases is also useful for controlling nematodes in ginger and turmeric fields.

b. *Cultural*:Nematode free planting materials should be selected from fields of known history. *In vitro* ginger plantlets are used to get rid of the root knot nematode problem in S.Africa (Nel, 1985). Mulching or applying well decomposed cattle manure or poultry manure or compost or neem oil cake reduced nematode build up (Colbran, 1974; Kaur, 1987; Sterling

1989; Mohanty, Mahapatra & Patnaik, 1992). Suitable crop rotations can also be formulated for this purpose as recommended by Haynes and others (1973) in Fiji.

c. *Host resistance*: In turmeric, several cultivated types and breeding lines were found to be resistant to *M.incognita* (Mani, Naidu & Madhavachari, 1987; Mani & Sri Hari, 1989). A wild related species, *Curcuma zedoaria* is more resistant to *M.incognita* (race 1) (Chen, LI & Lii, 1986). However, in ginger no resistant/tolerant lines are identified against any of the nematode pests (Charles & Kuriyan, 1982; Routaray & Mahapatra, 1988). Recently a few lines of ginger were found resistant in a preliminary evaluation (IISR, 1996).

d. *Chemical:* Soil fumigation (Colbran, 1961; 1962; 1968; Pegg, Moffett & Colbran,1974; Milne, 1979) or application of granular pesticides like fenamiphos (Colbran, 1972; Willers, 1985; Kaur, 1987) or dip treatment with fenamiphos (Willers, 1991) are all recommended for control of nematodes of ginger. In turmeric application of nematicides like carbofuran (Mani, Naidu & Madhavachari,1987), DBCP and phenamiphos (Patel, Makadia & Shah,1982) were effective in reducing nematode incidences.

6. NEMATODES OF SEED SPICES

Several genera of nematodes are reported on coriander (11 genera), fenugreek (10 genera), celery (11 genera) and dill (12 genera). However, no nematodes are reported on aniseed while only a few genera of nematodes are reported on cumin (5 genera), fennel (2 genera) and caraway (3 genera). Root knot nematodes attack all these crops and are of much economic importance in most of them. In celery, nematodes like *Aphelenchoides* spp., *Aphelenchus* sp .*Paratylenchus* spp. and *Pratylenchus penetrans* are the important nematode parasites and severe crop losses are caused if the plants are infected in the early stage of crop growth (Murga, Venturo & Espinoza,1990; Roan & Gonzalez, 1990; Kueuth & Schrameyer, 1991). *Ditylenchus dipsaci* caused severe losses on celery in Italy (D'Errico, Nicotina & Mahamoud, 1991; Vovlas, Melillo & Catalono, 1993). Fenugreek is highly susceptible to *Pratylenchus zeae* also (Shafshak *et al.*, 1985).

6.1 Root knot nematodes, *Meloidogyne* spp.

M.incognita causes significant reductions in yield of coriander (52%), cumin (43%) and fennel (42%) (Midha & Trivedi, 1991). An inoculum level of 100 nematodes/pot was found highly pathogenic to coriander (Midha & Trivedi, 1988). Fenugreek is highly susceptible to *M.javanica* (Paruthi, Jain & Gupta, 1987). *M.hapla* causes severe problems in celery (Starr & Mai, 1976; Biessar, Rinne & Pottre,1983). Coparasitism by *M.hapla* and *Pythium polymorphon* causes severe root necrosis in celery (Starr & Mai, 1976).

6.2 Nematode management

As these crops are seasonal , the nematode management strategy should be to reduce the initial nematode level in the soil by integrating various measures. The first and foremost is the use of nematode resistant/ tolerant types. Several resistant varieties/selections are identified

in fenugreek (Sharma & Trivedi, 1988; Sharma, Mathur & Bhargava, 1989), coriander (Midha & Trivedi, 1988 c) and cumin (Midha & Trivedi, 1989) against root knot nematodes. Fennel is resistant to *M.javanica* while cumin and coriander are moderately resistant (Paruthi, Jain & Gupta,1987). Cultural practices like incorporation of leaf powders also reduced root galling and enhanced plant growth in fenugreek (Sharma & Trivedi, 1992). Crop rotations also can be employed in short term crops like seed spices. Biocontrol agents like *Paecilomyces lilacinus* also reduced root knot nematodes in fenugreek (Sharma & Trivedi, 1989).

7. NEMATODES OF TREE SPICES

Not much is known about the nematode damage in tree spices like clove, nutmeg, cinnamon, allspice etc. except for some survey reports and host records (Goodey, Franklin & Hooper, 1965; Kumar, Viswanathan & D'Souza,1971; Sharma & Loof, 1974; Bridge, 1978; Sundararaju, Koshy & Sosamma,1979). However, the presence of root knot nematodes on cinnamon, nutmeg and clove; *Pratylenchus* sp. on clove and cinnamon and *R.similis* on nutmeg has to be taken seriously and they have to be studied intensively in tree spice nurseries.

8. CONCLUSIONS

In general, plant parasitic nematodes damage almost all spice crops leading to severe crop losses. As in other crops nematode induced damages are difficult to differentiate in spice crops also, since nematodes are one of the several factors that impair the functions of the roots. Nematological investigations are mostly concentrated on major spice crops and very little attention was given to the nematological problems of seed and tree spice crops. But these studies are also mainly on surveys and host range of the nematode species infesting spice crops. So the trend has to be changed and diverted to more applied aspects relevant for the management of nematodes. Information on various aspects of biology, population variability, mode of survival of the nematodes infesting spice crops is lacking. These informations are highly useful in developing effective and ecofriendly integrated nematode management (INM) programmes. It is also worthwhile to exploit the host resistance available in many spice crops either in cultivated or wild related species using advance techniques in cellular and molecular biology. Hence nematological investigations on these high valued crops has to be further strengthened and intensified in the coming years.

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Nematode Parasites of Betelvine and Their Control

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Abstract : - Betelvine (*Piper betel* L.) is a perennial creeper indigenous to the Indian subcontinent. Grown over 40,000 ha., with an annual turn over of Rs. 700 crores, betelvine forms an important cash crop of the country. Betelvine is primarily grown under two cultivation systems: in the natural forest ecosystem on live standards like *Sesbania grandiflora, S. susban, Erythrina indica, Bombax malbaricum* etc. or in artificial conservatories known as 'Barajs' or 'Bheets'. The perennial nature of the crop, well drained moist soil, cool and shady microclimatic atmosphere of the gardens provide congenial conditions for build up of nematodes parasitic on betelvine. So far over 39 species of plant nematodes have been found associated with betelvine, which include such harmful ones like *Meloidogyne incognita* (Kofoid & white, 1919) Chitwood, 1949, *Rotylenchulus reniformis* Linford &Oliveira, 1940 and *Radopholus similis* Thorne, 1949. Bulk of the research work on betelvine nematodes is now being carried out through the AICIRP (Betelvine) project of ICAR with emphasis on assessment of yield losses and nematode management, *M. incognita* topping the list, followed by reniform and burrowing nematodes.

It has been seen that root-knot nematode alone can bring about losses in leaf yield from 16.8 to 50.2% and with *Sclerotium rolfsii*, twig mortality upto 84% as against only 64% due to the fungus alone in different locations. Reniform nematode has been also seen to act synergistically with *Colletotrichum capsici* in bringing about root necrosis and rotting upto 40% as against only 20% by the fungus alone.

Soil applications with oil cakes of neem, castor, karanj, mustard or even groundnut @ 1 ton/ha or green leaves of neem, castor or *Calotropis* or sawdust @ 2 tons/ha have been found equally effective like granular carbamate nematicides @ 1.5 kg a.i/ha. Based on residue analysis data, a safe period of 50-60 days is essential between application of these chemicals and consumption of leaves if at all chemical is to be used. This leaves no scope for their application in established, productive gardens. Oviparasitic fungus *Paecilomyces lilacinus* when applied for three times at quarterly intervals through castor or neem oil cake media, the latter taken @ 500 kg per ha each time has been quite effective in reducing root knot nematode damage. It has also been useful against burrowing nematode in preliminary pot culture trials. Resistance to root-knot nematode has not been so far located in betelvine (barring Awani pan cv in Assam). In betelvine female plants are rare and the usual propagation is through twig cuttings from male plants. With the present stride in genetic engineering and biotechnology, transferring resistance into betelvine from unrelated exotic germplasms against plant parasitic nematodes looks fairly optimistic. VAMs, *Trichoderma viride, Pasteuria penetrans* etc. are coming up as new generation bio-control agents along with *P. lilacinus* and can be incorporated into INM systems with organic amendments and limited chemical use.

* * *

A DECADE OF NEMATODE RESEARCH UNDER AICRP-BETELVINE

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Betelvine (*Piper betle* L.) commonly known as 'Pan' is cultivated in moist, tropical and sub-tropical regions of India. Its leaves are used for chewing purpose. Several parts of the plant, are also known for their medicinal value. It is cultivated commercially either under forest eco-system with live support or in artificially created shaded condition, locally known as 'Barejas'.

Among the quick growing plants used for shade and live support, *Sesbania grandiflora* and *Leucaena glauca* often act as collateral hosts for many insect pests and diseases. Moist humid shaded conditions favourable for crop growth also favour a variety of diseases of fungal, bacterial and nematode origin. The recurrent disease leads to a complete destruction and crop failure after a few years.

Since betelvine is grown under shade, high atmospheric humidity and moderately high temperature, the conditions are very congenial for development of diseases. Further more, the high soil moisture, concentrated atmospheric humidity, shade and large plant population within the barej, encourage high inoculum potential of soil borne organisms. The crop is thus vulnerable to attack by several pests, pathogens and also plant parasitic nematodes reducing its productivity considerably. Nematodes are considered as very important and destructive under light textured soil condition. The research work carried out on nematode problems of betelvine during 1987-1997 is presented below:

Survey: It was observed that plant parasitic nematodes either singly or in association with various micro-organisms cause reduction in quality and quantity of produce, sometimes leading to serious wilt disease. Betelvine wilt caused by root-knot nematode assumed prominence more than half a century back in South India in 1926. Subsequently, *Meloidogyne incognita* has been reported on betelvine from various parts of the country. The other economically important plant parasitic nematodes are *Rotylenchulus reniformis* which produces unthrifty growth of plants, and *Hoplolaimus indicus* which produces stunted growth. The pathogenic relationship of 3 nematodes with betelvine have been investigated in the wire-house

under pot culture conditions at OUAT, Bhubaneswar centre. In addition to these 3 plant parasitic nematodes, spiral nematode (*Helicotylenchus incisus*), ring nematode (*Criconemella ornata*), lesion nematode (*Pratylenchus coffeae*), stunt nematode (*Tylenchorhynchus brassicae*), sheath nematode (*Hemicriconemoides* sp.), dagger nematode (*Xiphinema insigne*), *Dorylaimus* sp., *Rhabditis* sp., *Scutellonema* sp. and saprozoic forms were also found from the rhizosphere of betelvine grown in different parts of the country.

So far 20 species within 15 genera of plant parasitic nematodes have been reported in association with betelvine crop from many parts of the country. However, most of these nematodes are not known as pathogens of betelvine and their relationship with the host plant still remains to be established. Among the different nemic diseases of betelvine at present the root-knot disease caused by *Meloidogyne incognita* seems to be a major problem prevalent in most of the plantations having sandy loam soil, at times causing heavy loss to the farmers. Root-knot affected plants become stunted in appearance, bearing yellowish coloured small sized leaves and swollen aerial roots in clusters when the affected plants are uprooted, deformed roots with prominent galls and swellings are observed. In some cases, roots are very much reduced in size and number and are observed frequently in different stages of rotting caused by bacterial and fungal infections. Eventually the affected plants wilt and die.

ASSESSMENT OF YIELD LOSS DUE TO NEMATODE

The experiment was conducted for three years in naturally infested field with heavy population of *M. incognita* at various AICRP centres using paired plot technique. There were two treatments, treated and untreated replicated 16 times. Carbofuran (4 kg ai/ha) was applied in rows at the time of lowering and thoroughly mixed in the soil of control plots. Prior to the incorporation of carbofuran the soil samples were collected from both the treated and untreated plots for recording pre-treatment larvae population of *M. incognita* in soil.

Yield loss due to nematode diseases was estimated to be 23.64% at AAU, 3.9-10.80% at APAU, 20.03-26.99% at MPAU, 28.65-54.40% at JNKVV, 38.09-40.28% at OUAT and 34.40-38.27% at TNAU.

Table 1. Yield loss (%) due to nematode infestation in various centres

Centres	Percentage loss (Range)
AAU	23.64
APAU	3.9 - 10.80
JNKVV	28.65- 54.40
MPAU	20.03- 26.99
OUAT	38.09- 40.28
TNAU	34.40- 38.27

HOST RESISTANCE TO ROOT-KNOT NEMATODE, *M. incognita*

A replicated pot culture experiment was conducted at different centres to screen different betelvine varieties against root-knot nematode, *M. incognita*. Freshly hatched 1000 Juveniles were inoculated to the soil having single 50 day old vine/pot. Observations on their gall index, number of egg masses per plant and number of larval population per plant were recorded 45 days after inoculation. Considering the above characteristics it was found that no variety showed resistant reaction to *M. incognita* infestation. However, Sanchi (red) Berhampuri, Bilhari, Halishahar sanchi (WB) and Awanipan (Assam) exhibited moderate reaction at OUAT.

At APAU, 4 pungent and 4 non-pungent varieties were tested. The results revealed that all the 8 varieties were found susceptible to root-knot nematode. However, the 4 pungent varieties viz., Kakair (Bihar), Bangla (MP), Karapaku (AP) and Gachi pan (Assam) exhibited comparatively lower infestation than the non-pungent varieties.

At AAU, seven betelvine varieties screened were (i) Assamiya pan (ii) Awani pan (iii) Sanchi pan (iv) Khasi pan (v) Bangla pan (local) (vi) Karbi pan (vii) Calcutta Bangla pan. However, non of the cultivars screened was found free from nematode attack. Although the variety Awani pan was found to be less vulnerable to the attack of root-knot nematode.

At MPAU, seven varieties screened were Kapuri, Bangla (WB), Ramtek Bangla, Kalipatti, Maghai, Karapaku and Kuljedu. The results showed that all the varieties were infested by M. incognita

to varying degrees. The root-knot index was lowest in Kuljedu. Kapoori showed significantly highest root-knot index.

At TNAU, three varieties such as Kapoori , Vellai pachaikodi and Karuppu pachaikodi were screened. The results revealed that the variety Karpoori was found to be highly susceptible while Karuppu pachaikodi showed moderately resistant reaction.

INTEGRATED CONTROL OF NEMATODE POPULATION IN SOIL (NEW GARDEN)

A field experiment was conducted to find out suitable control measures against root-knot nematode, *M. incognita*. This experiment was conducted in RBD with 7 treatments replicated thrice for a period of three years. Observations were made on the soil population of *M. incognita* 12 months after the application of the treatments and leaf yield were also recorded.

A combined treatment of neem cake (0.5 t/ha), carbofuran (0.75 kg ai/ha) and NPK (150:100:50) was found to be the best uniformly at five locations of experimentation (OUAT, APAU, MPAU, JNKVV, TNAU). At AAU, due to non availability of neem oil cake, mustard oil cake was used to replace neem oil cake. Result revealed that mustard cake plus carbofuran reduced the nematode population to a maximum extent in soil at 360 days after treatment. Root-knot index was also minimum in the same treatment. However, number of leaves/vine, weight of leaves and height of plant were more in saw-dust plus carbofuran treatment.

INTEGRATED CONTROL OF NEMATODE IN OLD GARDEN:

A field experiment was conducted for 3 years on the integrated control of root-knot nematode, *M. incognita*. The experiment was designed in RBD with 9 treatments replicated thrice. Treatments were various dosages of neem cake, saw dust, fertilizers and in their combinations. The neem cake, saw-dust and fertilizers were incorporated in the soil at the time of lowering of vines. The soil and root samples were collected from each treatment prior to the application of the amendments for recording pre-treatment larval population of root-knot nematode, *M. incognita* in soil and also root-gall count. The soil and root samples were collected after 12 months of application of the treatments for obtaining post-treatment larval population of *M. incognita* in soil and root gall count. Observations on nematode population in soil and root-gall counts and yield were recorded.

At OUAT, JNKVV, MPAU and APAU, it was found that soil amendment with neem cake at 2 tons/ha observed to be the most effective treatment in significantly reducing the larval population, root galls and increasing yield in all the 3 years of the study conducted. At AAU, application of mustard oil cake at 2 tons/ha was most effective in reducing the larval population of *M. incognita* after 360 days and increasing the leaf yield.

STUDIES ON INTERACTION OF ROOT-KNOT NEMATODE, *M. INCOGNITA* WITH OTHER MICRO-ORGANISMS:

OUAT Bhubaneshwar (RKN + *Colletotrichum capsici*)

The experiment was conducted for 3 years on potted betelvine plants grown in sterilized soil in wire house. The pure culture of a root isolate of *C. capsici* (cc) and root-knot nematode (RKN) *M. incognita* alone and in different combinations were tested. The trial was replicated 5 times with 6 Nos of treatments including a control check. Observations were recorded upto 6 months on root-knot index, root-rot score, nematode population and yield of betelvine.

Data showed that the root-knot indices were highest after 180 days of inoculation in case of the treatment, where RKN and CC were inoculated simultaneously. Whereas the root-knot indices were found to be lowest in case of the treatment where RKN was inoculated 3 weeks after the inoculation of *C. capsici*. Maximum rotting of the roots was observed in the treatment of inoculation of *M. incognita* + *C. capsici* after 3 weeks which was significantly higher compared to the rest of the treatments. Highest recovery of the nematodes was marked from the pots inoculated with both the organisms simultaneously. Percent decrease in no. of leaves over control was recorded to be highest in case of the treatment where RKN was inoculated alone and simultaneous inoculation of both the organisms respectively.

Typical foliar symptoms of yellowing of leaves and vines, suppression of apical growth, leathery appearance of the leaves were noted in plants where the root-knot nematode was inoculated initially followed by the inoculation of *C. capsici* in both the years.

APAU, Chinthalapudi (RKN + *Fusarium* sp.)

The culture of *F. solani* at 8 g of mycelium/pot and the second stage larvae of *M. incognita* at 1000/pot were inoculated either individually or in combinations to 60 day old potted vines.

Data recorded at 180 days after inoculation indicated that there was no significant increase in the mortality of vines when only nematodes were inoculated. However, there was significant reduction in the growth of the vines.

On the other hand, significantly increased mortality of vines was recorded when the vines were inoculated with *F. solani* and there was no significant additive pathogenic effect on vines when the nematodes and fungus were inoculated simultaneously/different intervals when compared to individual fungal/nematode inoculation.

AAU, Jorhat (RKN + *Rhizoctonia solani*)

Assamiya betelvine cultivar was raised in 15 cm diameter earthen pots containing 2 kg of double autoclaved soil (sandy loam). Sixty days old uniformly grown well established vines were inoculated with *M. incognita* (1000/pot/vine) and *Rhizoctonia solani* (0.25% mycelial mat per kg soil) alone and in combinations. Filtered water was used for irrigating the pots. Observations on different growth parameters and disease index were recorded upto 90 days. The results revealed that when *Rhizoctonia solani* was inoculated 21 days after *M. incognita* reduced the growth of the plants and maximum root galls were observed. These two pathogens acted as synergist.

STUDIES ON POPULATION THRESHOLD IN RELATION TO DISEASE INTENSITY FOR MAJOR NEMATODES:

OUAT, Bhubaneshwar (*Rotylenchulus reniformis*)

Disease free cuttings (3 nodes) of commercially cultivated variety "Godibangla" susceptible to *Rotylenchulus reniformis* were raised in 20 cm plastic pots containing 2 kg of autoclaved soil. Sixty days old vines were inoculated with 0, 1000, 5000, 10,000, 15,000 and 20,000 pre adult stages of nematodes of *R. reniformis* per plant in each pot and replicated four times. A set of uninoculated control pots were also maintained. The vines were uprooted after 150 days after inoculation.

The observations on plant growth characters, yield representing both number and weight of leaves per vine, number of eggs and larvae per 5 g root, nematode population in soil were recorded.

The results revealed that significant reduction in plant growth characters particularly in length, and dry weight of both shoot and root in all the population density levels. There was significant reduction of yield of betelvine both number and weight of leaves per vine with respect to progressive increase of the inoculum level of the reniform nematode. The final nematode population in soil, eggs and larvae population on roots were increased with increase in levels of initial inoculation.

Symptoms were prominent at population levels of 20,000 nematodes/plant. The rate of nematode multiplication decreased with increase in the levels of initial inoculum may be due to greater competition for food and area. The vines in the control pots were healthy and the leaves were larger in size clearly indicating the destructive potential of reniform nematode, *R. reniformis* on betelvine.

AAU, Jorhat (*M. incognita*):

Healthy plants of cultivar Bangla pan (local) were grown on 20 cm pots containing 2 kg of autoclaved soil. Sixty days old plants were inoculated with freshly hatched active second stage juvenile of *M. incognita* in log series of 0, 100 and 1000 larvae per pot. Nematode suspension was poured by making 4 holes around the base of the vine and covered with fresh autoclaved soil. The vines were uprooted after 150 days of inoculation and different growth parameters, root gall index, nematode populations etc., were recorded.

Results showed that number of galls were produced in initial inoculum level of 10,000 nematodes. All growth parameters were also lowest in the 10,000 nematodes inoculum level. Higher the initial inoculum higher was the disease development.

APAU, Chinthalapudi (*M. incognita*):

The results indicated that the growth of the vine and the development of the root system were significantly affected at a population level of 10,000/pot or 5000/kg of soil. The growth of the vine was not significantly affected upto the population level

of 1000/pot. However, there was significant reduction in the size of the leaf at a population level of 1000/pot was evidenced by the reduction in fresh weight of 100 leaves.

JNKVV, Jabalpur (*M. incognita* and *R. reniformis*):

This experiment was conducted on potted plants. 100 larvae/pot of *Meloidogyne* sp. and 200 larvae/pot of *Rotylenchulus* sp. were added to each pot separately. Observations were recorded 5 months after inoculation.

The results indicated that no. of leaves reduced to 15 as against 23 leaves per plant in control and 19.66 leaves per vine infested with *R. reniformis*. Similarly, the fresh weight and dry weight of root and shoot reduced in vines infested with *Meloidogyne* and *Rotylenchulus*. The visual root-knot index was 25% in both cases as compared to control where there was no infestation.

TNAU, Sirugamani (*Helicotylenchulus incisus*):

A pot culture experiment was conducted to study the population threshold in relation to disease intensity of spiral nematode *Helicotylenchulus incisus*. Fresh 3 nodded cuttings of the susceptible Karpoori variety were planted in pots containing sterilised soil and kept in humidity chamber for rooting. Two months after planting the vines with uniform growth were utilized for the experiment. The treatments were 0, 100, 1000 and 10,000 no. of *H. incisus* per pot. The nematodes were inoculated at the rhizosphere of the vines by making 4 holes around the base of the vine and covered with sterilised soil. The experiment was laid in RBD and replicated 5 times.

The observations were recorded five months after inoculation. Growth parameters viz., plant height, fresh weight of shoot and root, dry weight of shoot and root no. of leaves/vine and weight of hundred leaves were recorded.

Significant reduction in plant growth parameters were observed in vines inoculated with 1000 and 10,000 nematodes of *H. incisus*. However, the reduction was very high in vines inoculated with 10,000 nematodes. Similarly, maximum reduction in no. of leaves were also observed in vines inoculated with 10,000 nematodes. The vines inoculated with 100 nematodes did not bring about any significant difference in plant growth parameters as well as leaf yield.

BIOLOGICAL CONTROL OF ROOT-KNOT NEMATODE, *M. INCOGNITA* USING PARASITIC FUNGUS, *PAECILOMYCES LILACINUS*

POT TRIALS

OUAT, Bhubaneshwar :

The pot culture experiment was conducted for three years. It was evident from the results that the growth characters like shoot length, shoot weight, root length and root weight were found to be maximum in treatment inoculated with 8 g of *P. lilacinus* per kg soil. The leaf yield (no.of leaves) and weight of leaves were also found to be maximum in the same treatment inoculated with 8 g of *P. lilacinus* per kg soil. Root knot indices and nematode population were also recorded minimum in *P. lilacinus* 8 g per kg soil treatment.

TNAU Sirugamani :

Results of this experiment indicated that 8 g of *P. lilacinus* per kg of soil was at par with carbofuran at 1.5 kg ai/ha treatment in increasing vine length and weight, root weight and no. of leaves per vine and in reducing gall index and nematode population.

AAU, Jorhat :

Results of this centre revealed that all the growth and yield parameters were maximum in the *P. lilacinus* (4 g/ha + Carbofuran 0.75 kg ai/ha) treatment which was followed by *P. lilacinus* (8 g/kg soil) treatment.

BCKV, Kalyani:

Results indicated that growth and yield characters were highest in P.lilacinus (4 g/kg soil). Similarly, lowest root knot index was also recorded in the same treatment.

JNKVV, Jabalpur:

Results from the centre clearly indicated that *P. lilacinus* (8 g/kg) was found to be the best in improving all the growth and yield parameters and reducing the nematode population as well as root knot index.

MPAU, Sangli:

Results of this centre showed that application of *P. lilacinus* 8 g per kg of soil was found to be the best in minimizing the nematode population and improving the leaf yield, shoot length, shoot weight, root length and root-weight.

FIELD TRIALS

Field application of *Paecilomyces lilacinus* inoculated oil cake thrice at 500 kg/ha reduced root-knot index and produced maximum vine growth and leaf yield in AAU whereas in OUAT and JNKVV it was next best to carbofuran (1.5 kg ai/ha) application in reducing the root knot index, however, both the treatments were equally good for leaf yield.

CONTROL OF NEMATODE *M. INCOGNITA* BY USING CHOPPED PLANTS

Seven plant species such as *Achyranthus aspera, Phyllanthus niruri, Azadirachta indica, Calotropis procera, Ricinus communis, Xanthimum strumarium* and *Datura stramonium* were used at the rate of 40 g/ kg soil and compared with carbofuran at 1.5 kg ai/ha treatment in controlling the nematodes.

Results indicated that *Calotropis* leaves proved effective to reduce nematode population at APAU and TNAU. However, *Azadirachta indica* leaves was found efficient at OUAT, JNKVV and TNAU.

IPM OF ROOT KNOT NEMATODE:

Application of oil cakes (500 kg/ha) with soil drench of carbofuran (0.1%) and three applications of *P. lilacinus* inoculated oil cakes (500 kg/split/ha) were at par with carbofuran (1.5 kg/ha) in AAU, JNKVV, TNAU, RAU, OUAT centres with respect to root knot index and leaf yield (Table 2).

PATHOGENICITY OF *ROTYLENCHULUS RENIFORMIS* IN BETELVINE:

Increase in the nematode population from 100/kg of soil onwards decreased the growth and yield of the vine in JNKVV, OUAT and RAU. Maximum reduction in growth and yield was observed when the inoculum rate was 5000 nematodes/kg of soil.

Table 2. Comparison of IPM and chemical nematode control methods with respect to root-knot index and leaf yield (No. of leaves/vine)in betelvine.

Centres	Control: Oil cake (500 kg/ha)		Carbofuran (1.5 kg ai/ha)		Oil cake (500 kg/ha) + soil drench of carbofuran (0.1%)+ 3 inoculated oil cake with P.L. (500 kg/split/ha)	
	Leaf yield	RK index	Leaf yield	RK index	Leaf yield	RK index
AAU	15.50	4.25	17.75	3.00	20.25	2.25
JNKVV	5.12	4.50	7.04	3.25	6.70	2.75
OUAT	20.00	1.50	50.00	0.40	48.00	0.50
RAU*	21.25	4.25	25.75	2.00	24.25	1.75
TNAU	106.52	5.00	113.76	3.20	117.92	2.40

*Differences between the treatments were statistically non-significant.

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Technical Session - III

NEMATODE PARASITES OF BANANA

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1. INTRODUCTION:

Banana is a wonder berry forming staple food of millions providing a more balanced diet than any other fruits or vegetables. It is believed that banana originated in India, especially bispecific clones, and crossed to Africa from east to west, during the period of Islamic conquest. Banana is the most important fruit crop of India having both consumptive and religious uses. All parts of the banana is used and owing to its multifaceted uses and high returns to small holders, it is referred as **"Kalpatharu"** (A Plant with Virtues). India has emerged as the largest producer of banana with total production of 10.4 million tonnes per annum from 3.96 lakh hectares having share of 32% of the total fruit production. While banana as known to adopt very quickly and produce high yields under favourable conditions, it is, however prone to attack by different pathogens like fungi, viruses, bacteria and nematodes. Among these, plant parasitic nematodes constitute one of the major limiting factors to banana production causing extensive root damage resulting in serious economic losses. Considerable work has been done on the nematode problems and their management on banana which are presented in this chapter.

2. MAJOR NEMATODE PESTS ON BANANA :

A total of 71 species of nematodes belonging to 33 genera are reported to be associated with the rhizosphere of banana from India. The most destructive and widely distributed nematode is the burrowing nematode, *Radopholus similis* followed by root-lesion nematode, *Pratylenchus coffeae*. The other economically important nematode pests of banana which have some regional differences are the spiral nematode, *Helicotylenchus multicinctus, H.dihystera*, cyst nematode, *Heterodera oryzicola*, root-knot nematode, *Meloidogyne incognita, M. javanica* and reniform nematode, *Rotylenchulus reniformis*.

2.1 Burrowing nematode, *Radopholus similis* (Cobb, 1893) Thorne, 1949:

The burrowing nematode, *Radopholus similis* is one of the most important pathogens attacking banana in the inter tropical zone of production. Vegetable propagation using infested corms or suckers has disseminated this nematode pest throughout the world except in West Africa, Central America, Israel and Taiwan. Although a number of nematode species infect bananas and plantains *R.similis* is considered to be the main nematode problem of intensive commercial bananas, especially Cavendish types, oriented towards export markets.

2.1.1 Distribution:

The burrowing nematode is widely distributed in India associated with banana. The first occurrence of the nematode was reported on banana from Palghat district of Kerala by Nair *et al.*, 1966 which caused yield losses upto 41 per cent. Subsequently this nematode was reported from banana in Tamil Nadu (Rajagopalan and Chinnarajan, 1976), Karnataka (Venkitesan, 1976), South India (Koshy *et al.*, 1978), Andhra Pradesh (Parvatha Reddy and Khan, 1987), Maharashtra (Parvatha Reddy and Singh, 1980), Gujarat (Sethi *et al.*, 1981), Madhya Pradesh (Tiwari and Dave, 1985), and Lakshadweep Island (Sundararaju, 1995), So far, the burrowing nematode has not been associated with banana from North Eastern region. But recently *R.similis* has been reported from Dwarf Cavendish banana in Tripura (Mukherjee *et al.*, 1994).

2.1.2 Economic Importance:

Parasitisation of *R.similis* causes gross reduction in the quality and quantity of yield. The application of DD and EDB separately at planting time in *R.similis* infested plots in French Guinea had increased the yield from 22.5 to 40 and 26.7 to 37.15 metric tonnes/ha respectively (Vilardebo, 1957). In Central America, an increase of 17,000 lbs of fruit production/acre/year occurred in the burrowing nematode free banana plots (Wehunt and Edwards, 1968). Similar observation made by Mass (1969) at Surinam had also shown that 100 per cent burrowing nematode infestation of banana reduced the yield to 30 tonnes/ha/year, whereas plantation with three per cent nematode infestation had yielded 73 tonnes/ha/year. In India, *R.similis* infestation on banana is responsible for 30.76 to 41 per cent yield loss in banana (Rajendran and Naganathan, 1977; Nair, 1979; Vadivel *et al.*, 1987 ; Parvatha Reddy *et al.*, 1992).

2.1.3 Symptoms:

Burrowing nematode infested banana plants exhibit general decline, stunting, premature defoliation, unthriftiness and carry small bunches and fruits. Symptoms on roots are more specific exhibiting small cuticular sunken lesions on young cord roots. On older roots, surface cracks apear. These shows extensive reddish brown lesions in the cortex when cut longitudinally. They cause decay and death of distal cells. This deadly pathogen is well established in the banana tracts where soil and temperature conditions are favourable. They topple over easily during wet and windy weather because of inadequate anchorage. Heavy nematode burdens will affect plant vigour which will result in smaller bunches with shorter fingers and longer periods elapsing between the ratoon crops (Gowen, 1979). Foliar symptoms of nematode damage may not be dissimilar from those attributed to water logging, weed competition, nutrient deficiencies or other pests and diseases.

2.1.4 Biology:

R. similis is a migratory endoparasitic nematode which completes its life cycle in 20-25 days in the root and corm tissues of banana. All larval stages and adult females are active and infective whereas males are unable to infect roots (Loos, 1962). Although all the stages remain vermiform, sexual dimorphism is apparent with adult males being somewhat degenerated.

2.1.5 Population fluctuation:

Maximum population of *R.simlis* occurs during drier months and minimum during or after heavy rain. Soil temperature at a depth fo 30 cm did not influence population size (Jimenez, 1972). Similar result was obtained by Sundararaju (1997) on banana at Trichy.

2.1.6 Host parasitic relationship:

The nematode penetrates the root by using a spear in its mouth to make a hole in the cell wall. It then moves into the cell and proceeds to feed on the cell contents. Once it has killed these cells, it moves on to feed on more healthy cells. This movement and feeding produces the charateristic reddish brown lesions throughout the cortex. Three to four weeks after infection, where extensive cavities have been formed, one or more deep cracks with raised margins appear on the root surface. The nematode infects only the cortex of the root and not the stele. Eventually the root system may be reduced to a few short stubs.

2.1.7 Culturing:

The burrowing nematode population isolated from banana was easily cultured on carrot discs, containing one per cent water agar (Boncato and Davide, 1980; Sundararaju, 1996). It can also be cultured on banana fruit callus (Brown and Jessey, 1985).

2.1.8 Survival and Spread:

R.similis was found to survive in soil for 13 months even where the banana plants were removed and controlled the weeds (Keetch *et al.*, 1975). The suckers removed for transplanting from nematode infected banana clumps and planted in new areas produced infected plants. The transmission of the organisms is therefore presumed to be through suckers used for propagating the crop vegetatively.

2.1.9 Association with other micro-organisms:

The incidence of Panama wilt caused by *Fusarium oxysporum* f.sp. *cubense* was doubled in Gros Michel banana, when *R.similis* was added to the soil (Newhall, 1958) and wilt symptoms appeared faster on *R.similis* infected banana (Loos, 1959). Eleven generae of fungi were isolated from banana roots infected with *R.similis*, but only *F. oxysporum* and *Rhizoctonia solani* were consistantly

obtained (Stover, 1966). *F.oxysporum* alone was unable to invade intact banana root cells, but colonized when cortical parenchyma cells were wounded mechanically or by the nematode (Blake, 1966). The constant association of *Cylindrocarpon musae* with *R.similis* was reported from all banana growing regions of the world (Booth and Stover, 1974). Recently, the fungus *Cylindrocladium* has been found to be pathogenic on banana in the French West Indies causing lesions similar to those of *R.similis*, the association of the two parasites caused severe damage (Sarah *et al.*, 1996).

2.1.10 Losses:

Forty one per cent reduction in bunch weight was noticed when *R.similis* population reached 146 nematodes per 10 g root (Anonymous, 1979). Sathyanarayana (1982) studied the pathogenicity of *R.similis* on banana variety Nendran and found that an initial inoculum of 1000 nematodes per banana plant at 45 days after planting is sufficient to cause considerable reduction in yield and other plant growth parameters. The correlation of plant growth components to bunch weight in banana infested with *R.similis* carried out by Charles *et al.*, 1985(b) revealed that increased nematode population directly reduced the yield and adversely affected vegetative characterisation.

2.1.11. Control:

2.1.11.1 Sucker Treatment: Paring and treating with carbofuran @ 1.2 g a.i. per sucker resulted in low incidence of *R.similis* and highest yield (Rajendran and Naganathan, 1977). Sucker dip treatment with neem oil @ 0.1 and 0.2 per cent for 10 minutes before planting resulted in maximum reduction of nematode population next to paring and pralinage and application of carbofuran @ 1g a.i. per plant one at planting and two more applications at an interval of three months. (Charles and Venkitesan, 1992). Complete disinfection is achieved by 'double paring' followed by a dip in monocrotophos solution at 0.5% for 30 minutes and later dried under shade for 72 hrs before planting (Anonymous, 1989a).

Removal of infected roots and tissues alongwith some of surrounding healthy tissue by paring and disinfecting them in hot water at 55°C for 20 mts before planting has been found to be more effective in controlling the nematodes (Ravichandra and Krishnappa, 1985b). In Kerala the common practice of 'Sun drying' the rhizomes before planting has been shown to be effective in the control of nematodes (Koshy, 1986).

2.1.11.2 Adult plantation:

2.1.11.2.1 Chemical methods : Different chemicals tested for the control of burrowing nematode attacking banana plants include DBCP, Phorate, Phenamiphos, Aldicarb, Aldicarb sulfone, Carbofuran etc. But at present, Carbofuran and Phorate are the most effective and popular granular nematicides used against banana nematodes. Nair (1979) has shown the reduction in the population of banana nematodes with application of carbofuran,

phorate and phenamiphos at 2 g a.i./plant. Ravichandra and Krishnappa, (1985a) reported that single application of phenamiphos either at 2,4 or 6 g a.i/plant or carbofuran at 6 g a.i./plant were effective in reducing the burrowing nematode population and improving plant growth. Ravichandra *et al.*, (1987) tested the efficacy of four chemicals viz. Prophos at 12 g/plant, Carbofuran at 40 g/plant, Phorate at 12 g/plant and Decamox at 24 g/plant against the burrowing nematode on banana and found that all the chemicals were effective in minimizing the nematode population both in soil and roots. Ethoprop at 2 and 3 g a.i./plant and carbofuran at 1.2 g a.i./plant were found to reduce the nematode populations and increase the yield of banana (Venkataramana *et al.*, 1992).

2.1.11.2.2 Non-chemical methods:

i. Cultural methods: Fallowing for three months after banana harvest effectively suppressed the burrowing nematode population, while flood fallowing for five months destroyed not only burrowing nematode but also *Fusarium* sp. (Rajendran *et al.*, 1979).

Oil cakes of neem, mahua, castor, karanj etc. have shown special potentiality in reducing the nematodes. Application of neem cake @ 400 g per plant once at planting and second after four months reduced the population of *R.similis* and increased the bunch weight (Nair, 1979; Ravichandra and Krishnappa, 1985b).

Mulching with black polythene at 20% moisture depletion recorded highest yield with low population of *R.similis*. Intercropping with sunhemp, coriander, marigold or lucerne reduced the nematode population in root and increased plant growth and yield (Vadivel *et al.*, 1987). Charles *et al.*, (1985a) reported that growing *Crotalaria juncea* resulted in low population of *R.similis* in roots alongwith better vegetative growth and yield of banana plants.

Crop rotation with paddy, sugarcane, green gram, cotton or turmeric suppressed the nematode population and increased the yield (Rajendran *et al.*, 1979). Leaf extracts of *Glyricidia maculata, Ricinus communis, Crotalaria juncea, Glycosmis pentaphylla, Azadiracta widica, Kalanchoe pinnata, Piper betle* and *Moringa oleifera* were lethal to *R.similis* (Jasy and Koshy, 1992; Sreeja, *et al.*, 1996)

ii. Physical methods: Disinfection of suckers in hot water at 55°C for 20 minutes before planting has been effective to avoid the introduction of nematode inoculum to new areas (Ravichandra and Krishnappa, 1985b).

iii. Biocontrol methods : The promising biological agents identified against nematodes are the fungus, *Paecilomyces lilacinus*, VA mycorrhiza, *Glomus fasciculatum* and bacterium, *Pasteuria penetrans*. The inoculation of VA mycorrhiza, *G.fasciculatum* was found to be effective in reducing nematode populations and increase the vegetative growth characters. Even

the lesion number and lesion index caused by the nematodes were significantly lower. The mycorrhizal plants had higher NPK, reducing the total sugars per gram of root which are known to offer resistance against most plant pathogens (Umesh *et al.*, 1988). Application of neem cake @ 500g with *Glomus mosseae* 25 to 30 chlamydospores per g of inoculam was found to be most effective in reducing the nematode population both in soil and roots of banana (Paravatha Reddy *et al.*, 1996).

iv. Resistant Varieties: Tetraploids selected from crosses between wild bananas (diploid male parent) and Gros Michel (triploid female parent) show considerable resistance to *R.similis* as well as to Panama wilt disease. A new variety, Bodles Altaport (Gros Michel x Pisang lilin) has an extensive root system to withstand strong wind and is more resistant to *R.similis* than Lacatan. Banana cultivars Kadali, Padalimoongil, Kunnan, Thenkunnan, Ayiranka Poovan, Pey Kunnan, Pisang Jari Buaya, Tongat, Vennettu Kunnan, Anai Komban and Palayankodan have been reported to be tolerant/resistant to the burrowing nematode (Charles *et al.*, 1983; Ravichandra and Krishnappa, 1985c ; Vadivel *et al.*, 1987; Parvatha Reddy *et al.*, 1991; Sudha and Sundararaju, 1996).

v. Integrated Managment: The present day trend is more on the integration of different methods of management for more economical and practical utility in order to achieve higher production. In this direction, integration of paring of banana suckers and hot water treatment (55°C for 10 minutes) followed by neem cake @ 1 kg/plant and carbofuran 3G @ 30g/plant after planting alongwith the biological agent viz. *Glomus fasciculatum* @ 50g culture (having 500 chlamydospores per plant) and bacterium *Pasteuria penetrans* @ 100g soil was found to be the most effective in reducing the nematode population in roots and soil as well as lesion index and thereby increased banana fruit yield (Bharatha, 1990; Chennabasappa, 1994).

2.2. Root lesion nematode, *Pratylenchus coffeae* (Zimmerman, 1898), T.Goodey, 1951:

Several species of lesion nematodes are known to attack bananas but *Pratylenchus coffeae* has considered to be one of the important pests next only to the burrowing nematode.

2.2.1 Distribution :

The root lesion nematode, *P. coffeae* has wide distribution in India mainly associated with plantains (AAB). It is known to occur in Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Guajarat, Orissa, Bihar and Assam (Rajendran *et al.*, 1979; Sundararaju, 1996). *P. thornei*, the other important species was found to infest banana plants from Assam only (Choudhury, 1985).

2.2.2 Symptoms:

Pratylenchus coffeae has more similarities with *R.similis* and often its damage is attributed to *R.similis*. The symptoms on roots of banana caused by *P.coffeae* are similar to that of *R.similis*. Both *R.similis* and *P.coffeae* are associated with the black head toppling disease of banana. Plants with severely damaged primary roots are more likely to be blown over in windstorms or fall during heavy rain and the risks of uprooting increase as the fruit nears maturity (Gowen, 1979).

2.2.3 Biology:

The root lesion nematode is also a migratory endoparasitic habit which completes its life cycle in about 27 days at 25-30°C. The optimum temperature for reproduction is 29.5°C. All larval stages and adults stages are infective.

2.2.4 Culturing :

The lesion nematode can be cultured in-vitro on carrot discs (Pinochet *et al.*, 1995). Carrot discs allow the rearing of high numbers of *Pratylenchus coffeae* isolated from banana roots.

2.2.5 Population fluctuation:

Maximum population of *P.thornei* was recorded in January and minimum in the months of May and June (Choudhury and Phukan, 1990). Similar finding was reported by Sundararaju (1997) with *P.coffeae* on banana.

2.2.6 Survival and spread :

Pratylenchus coffeae can survive in moist soil for eight months in the absence of host plants (Colbran, 1954). After banana plantation is removed, the nematodes in the corms may probably survive for as long as these remain unsucculent. The nematode did not survive extended storage at temperature over 38°C. The nematode spreads from one locality to another through planting material as well as through water that drains from infested areas to non-infested areas.

2.2.7 Host parasitic relationship:

The root lesion nematode enter the roots by using a stylet in its mouths to make a hole in the cell wall and feeds on cortical cells resulting in the production of dark lesions in the cortex. The main primary feeder roots are affected. The corm is also similarly infected resulting in necrosis of the outer tissues.

2.2.8 Interaction with other pathogens:

The fungus *Fusarium oxysporum* f.sp. *cubense* caused little damage by itself but was destructive to roots in the presence of *P. coffeae* (Vadivel *et al.*, 1987). This clearly indicates the existence of synergistic interaction between the nematodes and wilt pathogens in banana.

2.2.9 Control:

Since both *P.coffeae* and *R.similis* have similar life cycles, feeding habits as well as symptoms produced on roots, control measures suggested for *R.similis* may be followed for *P.coffeae* except is varietal resistance.

2.2.10 Resistant varieties :

Pisang Jari Buaya was found to be resistant to R.similis but highly susceptible to *P.coffeae* (Pinochet and Rowe, 1978). Cultivars such as Kunnan, Vennettu Kunnan, Tongat, Pey Kunnan, Then kunnan, Nattu poovan, Karpuravalli, Pidi Monthan, Chirapunji and hybrids 74 (Nalli x Pisang Lilin), H.21, H.55, H.59, H.65, H.84, H.89, H.109, H.110 were found tolerant/resistant to *P.coffeae* (Vadivel *et al.*, 1987; Anonymous, 1991; Nirmal Johnson and Sathiamoorthy, 1996).

2.3 Spiral nematode, *Helicotylenchus multicinctus* (Cobb, 1893), Golden, 1956:

The spiral nematode, *Helicotylenchus multicinctus* was found to infest on all varieties of banana throughout the tropcis and sub-tropics. In sub-tropical regions, *H.multicinctus* may be the major nematode problems such as in Israel and Taiwan where *R.similis* is absent. It causes serious decline of banana and is responsible for 33.83 % loss in yields, 55.88% loss in number of fruits per bunch and delayed fruiting by 134 days (Vadivel *et al.*, 1987).

2.3.1 Distribution :

Helicotylenchus multicinctus has been reported from Kerala, Tamil Nadu, Karnataka, Bihar, Orissa, Maharashtra and Madhya Pradesh (Rajendran *et al.*, 1979; Nayar, 1984; Sundararaju, 1992; Tiwari and Dave, 1985) wheras *H.dihystera* was more prevalent in Assam (Choudhury, 1985).

2.3.2 Symptoms:

Spiral nematodes tend to feed closer to the surface of the roots than either burrowing or lesion nematodes. Therefore, the lesions that they cause are usually found just under the epidermis of the root and do not penetrate into cortex as it is seen in the case of lesions produced by *R.similis* and *P.coffeae*. On infestation by nematode, it causes extensive root necrosis, die-back and disfunction leading eventually to the death of the

plant. This nematode prefer cooler temperature and predominantly associated with banana where and when *R.similis* is not dominant or absent.

2.3.4 Biology:

The spiral nematode takes 35-37 days for the completion of the life cycle from egg to adult at a soil temperature ranging from 22.6 to 33°C. Feeding as host roots by the second stage larva was essential for the completion of the life cycle. All stages of the nematodes except the eggs were observed inside the roots.

2.3.5 Population fluctuation:

Maximum population of *H.dihystera* was recorded in the month of March and minimum in December (Choudhury and Phukan, 1990). Similar finding was reported by Jones (1980) with *H. multicintus* on banana.

2.3.6 Host parasitic relationship:

The adults and larvae penetrate the epidermis of the root within 36 hrs of inoculation. Both male and female feed directly on parenchyma cells resulted the cell walls distorted or ruptured. Evacuated cells together with those near nests of eggs, soon become discoloured and characteristic necrotic lesions appeared on the roots.

2.3.7 Survival and spread:

The nematode easily get introduced into virgin land with banana soil and corms usually brought from old infested plantations.

2.3.8 Association with other pathogen:

Nayar (1984) reported the association of *H.multicinctus* and *R.similis* in bunchy top of banana plants caused by virus. He observed that the nematode infest the contents of pith and phloem cells and move through the resultant cavities. Nematode was not found in healthy plants.

2.3.9 Control:

The control measures of both chemical and non-chemical methods suggested for the control of *R.similis* may be followed for *H.multicinctus* and *H.dihystera* except the use of varieties.

2.3.10 Resistant varieties :

Cultivars Ney vannan, Sirumalai, Peyan, Gros Michel, Karpuravalli, Robusta, Rasthali, Kunnan, Kullan, Vennettu Kunnan and hybrids 94, 100, 106, 109 (All Matti x Tongat) and Hybrid 74 (Matti x Pisang Lilin) are reported to be tolerant /resistant to *H.multicinctus* (Vadivel *et al.*, 1987). Cultivars Pat Kapuria

Mendhi, Kathia and Athiakol were reported to be resistant to *H.dihystera* in North Eastern states (Ray and Parija, 1987; Choudhury and Phukan, 1993).

2.4 Cyst nematode, *Heterodera oryzicola* (Rao and Jayaprakash, 1978):

The cyst nematode, *Heterodera oryzicola* which was originally reported on rice crop in Kerala, was later on found to attack banana variety Nendran and causes serious economic losses (Charles, 1989).

2.4.1 Distribution :

The occurrence of cyst nematode was reported for the first time on banana variety Nendran in Kerala(Charles and Venkitesan, 1984). Subsequently this nematode was reported on banana cultivars Saldathi and Njalipoovan from Goa (Koshy *et al.*, 1987) and in Nendran from Tamil Nadu (Sundararaju, 1996).

2.4.2 Symptoms :

The cyst nematode attack the fine lateral tertiary feeder roots and do not attack the fleshy main roots and rhizome. The nematode infested plants exhibited stunted growth bunch choking and poor bunch qualities resulting curved fingers compared to the sraight ones in healthy plants.

2.4.3 Biology:

The second stage juvenile invade the tertiary tender roots, feed and develop to maturity and reproduce. The infective juveniles were also observed to develop into adults after they had partially penetrated the root tissues. It completes one life cycle in 23 days at 27°C. The second stage juvenile after invasion develop into males and females in 12 and 17 days respectively. The average number of eggs produced per individual adult female is 197 in the cyst body and 88 in the egg sac (Charles and Venkitesan, 1993).

2.4.4 Survival and spread:

The cyst nematode survive in the soil as cyst which protect the viable eggs contained in it. When the right environmental conditions prevail, the egg hatches and the infective larvae emerge out and feeds on the tertiary roots of banana. The nematode is transmitted through suckers from infected field to uninfested areas.

2.4.5 Host status :

The nematode is known to infect banana (Cv. Nendran), paddy, *Cynodon dactylon* and *Kyllinga monocephala* (Charles and Venkitesan, 1990). This creats practical difficulties in adoption of crop rotation with banana in rice fields.

2.4.6. Control:

The nematode can be controlled by treatment of suckers either by using hot water or chemical before planting as suggested for the control of *R.similis*.

2.5 Root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) Chitwood, 1949:

Most of the banana varieties are hosts to the root-knot nematodes which can cause considerable deformation and stunting of roots but not reported to cause yield reductions in banana. But recently, it was reported that the root-knot nematode, *Meloidogyne incognita* induced 20.59 per cent loss in banana fruit yield in Gujarat (Anonymous, 1996) and 30-35 per cent yield loss in Tamil Nadu (Jonathan *et al.*, 1997).

2.5.1 Distribution:

The root-knot nematode, *M.incognita* is known to have wide distribution in major banana growing regions in the states of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Gujarat, Maharashtra, Madhya Pradesh, Orissa,Bihar and Assam (Rajendran *et al.*, 1979; Mani *et al.*, 1984; Tiwari and Dave, 1985; Anonymous, 1989b; Choudhary, 1985) whereas *M.javanica* is confined mainly to mid hills and plains where the temperature are higher.

2.5.2 Symptoms:

The root-knot nematode infested plants remain stunted growth with pale yellow narrow leaves exhibiting bushy appearance. Under severe infection, leaf margin gets dried leading to splitting of dried portion. Profuse galling with egg masses are seen in root system. Such palnts have late fruiting with reduced number of hands having small size fruits (Anonymous, 1996).

2.5.3 Biology :

The root knot-nematode is a sedentary endoparasite, which completes its life cycle in 20-25 days. An adult female lays 200-300 eggs via gelatinous matrix inside the root cortex close to the epidermis. The second stage larvae invade the primary and secondary roots feed and develop to maturity and reproduce (Jonathan *et al.*, 1997).

2.5.4 Survival and spread:

The nematode easily get introduced into virgin land through infested banana suckers usually transported from old infested plantations.

2.5.5 Interaction with other pathogens:

The root-knot nematode in association with panama wilt pathogen, *Fusarium oxysporum* f.sp. *cubense* can cause more than 50 per cent yield loss in banana cv. Rasthali (Jonathan *et al.*, 1996).

2.5.6 Control:

Planting material should be treated with either hot water or chemical before planting as routine measure to control nematodes as in the case of treatment details suggested for the control of *R.similis*. All the popular cultivars grown in Tamil Nadu and Gujarat are found susceptible to root-knot nematodes. (Jonathan *et al.*, 1997; Patel *et al.*, 1996).

2.6 Other nematodes:

The reniform nematode, *Rotylenchulus reniformis* the most common species occurring on banana in West Bengal (Mukhurjee and Dasgupta, 1983) was found to occur in all major banana growing regions in the country (Tiwari and Dave, 1985; Sundararaju, 1992). It feeds the secondary or tertiary roots of banana and cause necrosis and destruction of feeder roots. In field plots where *R.reniformis* was the predominant parasitic nematode, yield reduction of 19.3 tonnes per ha was obtained (Parvatha Reddy, 1994). The other important nematodes which are closely associated with banana are *Rotylenchus* Sp., *Hirschmaniella oryza*, *Tylenchorhynchus coffeae*, *Hoplolaimus indicus*, *Paratylenchus* sp. but their pathogencity was not investigated (Mukherjee and Dasgupta, 1983; Choudhury, 1985; Sundararaju, 1996; Ray and Parija, 1987).

3. QUARANTINE :

Banana will continue to be introduced to new areas not only in the higher latitude where cool winters are the major constraints but also to those drier tropical regions where with irrigation the crop may be grown in the absence of the leaf spot pathogens. The enforced use of propagation by tissue culture should prevent the further spread of *R.similis* and *P.coffeae*. Strict quarantine measures must be adopted to ensure this.

4. FUTUROLOGY :

Considering the pathogenic nature of the burrowing, root lesion, spiral and root-knot nematodes, it is essential to take necessary precautions to prevent its spread to other banana growing areas through infested soil and roots adhering to suckers. The suckers removed for transplanting from nematode infected banana clumps and planted in new areas produced infected plants. The transmission of the organisms is therefore presumed to be through suckers used for propagating the crop vegetatively. Control of nematodes results in better establishment of the transplants and uniform growth of plants. It is evident from the information given above, that among five important nematodes, burrowing, root-lesion, and root-knot nematodes are the major threat to banana cultivation in Tamil Nadu as well as in India. Hence, it is suggested that general awareness programmes such as multinational large scale demonstrations on nematode management and constant guidance to growers as well as extension workers with the help of Radio and Television need to be initiated.

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OCCURRENCE AND DISTRIBUTION OF *RADOPHOLUS SIMILIS* ASSOCIATED WITH BANANA IN MADHYA PRADESH AND ITS IMPACT ON BANANA CULTIVARS

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Abstract:

Five major plant parasitic nematodes were identified which were associated with banana crop of eight districts exhibited perdominance of *Radopholus similis* and *Meloidogyne* spp. in samples of banana in Dhar district, *Patylenchus coffeae* in Durg and *Rotylenchus reniformis* and *Helicotylenchus multicinctus* in Bhind and Khaundwa districts respectively. Distribution of *R. similis* was maximum in districts of Chhatisgarh plains, however one district of Malwa showed its occurrence in each collected sample. The crop growing in Medium and deep black soil yielded more incidence as compared to shallow and medium black soil. Cultivar Basai showed favourable host but local banana donot support the population of *R. similis* significantly.

Introduction:

Banana occuppied 10% area uunder different agro-climatic zones of Madhya Pradesh among the fruit and vegetable but the area of Khargone, Dhar and Khandwa districts of Nimar valley is seriously suffering due to this pest. However, Bilaspur Durg, Raipur and Raigarh of chhatisearh plains are declining gradually due to seriousness of this nematode, *Radopholus similis*. Prevalance of this nematode has been established in every banana growing area in the country. A preliminary survey showed its first presence in banana of Bilaspur mostly with the Robusta cultivar (Tiwari & Dave, 1986). Later, nematode-specific survey of *R. similis* yielded its occurrence and distribution in some more pockets of Nimar valley. This study was undertaken in all banana growing localities to identify its incidence and distribution in different soil types and agroclimatic zones of Madhya Pradesh.

MATERIALS AND METHODS:

Soil and root samples were collected between November to February from different localities of eight districts viz. Bilaspur (38), Bhid (42), Dhar (41), Durg (27), Khandwa (69), Khargone (75), Raipur (16) and Raigarh (29) and analysed by Cobb's sieving and decanting methods for the soil samples; whereas roots of 1 to 2 cm sectors were incubated at 20 ± 3 C in BOD incubator. Regular counting of the nematode was carried after identification. During collection of the samples, cultivars were identified and population was estimated.

RESULTS AND DISCUSSION

Three hundred thirty six samples collected from eight districts of four agroclimatic zones viz,Chatisgarh plains (Bilaspur,Durg,Raipur and Raigarh), Gird (Bhind),Malwa (Dhar) and Nimar Plateau (Khandwa and Khargone) revealed occurrence of five important genera viz. *Helicotylenchus multicincutus, Meloidogyne spp., Pratylenchus coffeae, Radopholus similis and Rotylenchulus reniformis*. However,none of the samples of Bhid, Khandwa, Khargone,Dhar showed occurrence of *R. similis, R. reniformis* and *Meloidogyne* spp. respectively. Samples collected from Chhatisgarh Plains and Malwa Plateau exhibited population of *R.similis* between 40 to 58;*R.reniformis*,16 to 50;*Meloidogyne* spp. 14 to 29.except Raipur;*P.coffeae*,18 to 44 and *Helicotylenchus multicinctus* 13 to 79,however *H.multicinctus* (69-90),*P.coffeae* (52-55) and *R.similis* (24-26) was predominance in Nimar Plateau.Occurrence of *R.similis* and *P.coffeae* were maximum in Dhar(58);Bhind (*R.reniformis*);and *Meloidogyne* in Durg districts (Table 1).

PLANT PARASITIC NEMATODES ASSOCIATED WITH BANANA IN M.P.

DISTRICTS	ASSOCIATED GENERA				
	R.s.	R.ren.	P.c.	Mel.	H.mul.
Bilaspur	50	28	22	33	14
Bhind	00	50	39	44	79
Dhar	58	20	00	60	64
Durg	46	41	41	18	18
Khandwa	24	00	00	52	90
Khargone	26	00	00	55	69
Raipur	40	20	00	18	22
Raigarh	50	16	14	29	13

Data summerized in Table 2 indicated that incidence and distribution of *R.similis* in banana area of Chhatisgarh plains may be alarming the seriousness of this pest on banana cultivation declining during the last five years. The frequency of occurrence of this pest ranged between 46 to 58 per cent as compare to Nimar Plateau (24 to 26),where the banana occuppied more than 60 % area under cultivation,however the samples from Malwa Plateau yielded highest incidence with the small area of Dhanpuri. The samples collected from Gird regions did showed presence of *R.similis*,however *P.coffeae* and *H.multicinctus* were found to be more number with each samples. *Meloidogyne* spp. was confined to the local cultivars in this regions.

Soil type played important role for the growth and development of the crop. In fact to analyze status of *R.similis* associated with banana growing in different soil types the samples were pooled to find out the extent of frequency of occurrence revealed that medium and deep black soil supported its frequency (48.35) in the districts viz.;Bilaspur,Dhar, Khandwa, Khargone and Raipur than the districts viz., Bhind Durg and Raigarh having shallow and medium black soil (18.21). However frequency of occurrence of other genera in Madhya Pradesh were 36.75,22.00.14.50,39.00 and 48.11 per cent of *R.similis,R.reniformis,Meloidogyne* spp.,*P.coffeae* and *Helicotylenchus multicinctus* respectively.

RADOPHOLUS SIMILIS ASSOCIATED WITH BANANA IN DIFFERENT AGROCLIMATIC ZONES

Agroclimatic zone	R.similis
Chhatisgarh plains	46-58
Gird	00
Nimar plateau	24-26
Malwa	58

ASSOCIATION OF R.SIMILIS DIFFERENT SOIL TYPES OF M.P.

Soil type	R.similis
Medium and deep black	29
Shallow and medium black	28

Cultivar Basai and Srimanti occuppied major area in Nimar Plateau, whereas robusta and chinichampa in chhatisgarh plains,sone and local banana in pockets of Madhya Pradesh. Sone cultivar is highly susceptible to *Meloidogyne incognita* forced to undertake impact of common cultivars growing in the state and extent of association of important plant parasitic nematodes. Analyzed samples revealed that robuta and Basai favoured the reproduction with the high (80) frequency;local to the R.reniformis;sone Srimanti and robusta *P.coffeae* (65) and chinichampa,robusta and local for the *H.multicinctus* (100% Fig 1).

Our study indicated that as the formers thaught to shift for the fruit crops to fetch high returns by simply planting the infested suckers to new localities may bring more area under nematode infestation. however during last 10 year there were no incidence of *R.similis* in Khandwa district but high return forced to the farmers to adopt high yielding cultivars and without proper seed certification such lossess may extend even more than 50% in the Madhya Pradesh.

Future thusts: Seed certification programme in plaqntation crop like banana. Advocation of feasible and economic techique for the cultivation keeping pesticide free package and identification of local bio-control agents and their multiplication on the mass scale.

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NEMATODE PARASITIES OF ORNAMENTAL CROPS

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1. INTRODUCTION

With the liberalization of Indian economy, the domestic floricultural trade, which hitherto remained an unorganized sector, became an organised sector with the active participation of corporate giants. The establishment of state-of-art hi-tech floricultural units in early 90's for intensive cultivation of cut flowers contributes about Rs. 60 crores of valuable foreign exchange today which is likely to touch Rs. 100 crores mark by the end of this century. Various government agencies are actively involved in the promotion of this sector and are highly committed to resolve the teething problems.

The world demand for floricultural products is approximately US $ 40 billions and cut flowers contribute nearly 60% (US$ 25 billions) to the global trade. India's share in the world flower market is about 0.7% which is contributed mainly from open cultivation.

The area under floricultural crops is about 70,000 ha and another 500 ha of climatic control greenhouse are available for growing quality flowers for export. Many corporate houses (more than 100) have set up 100% export oriented units with an investment of more than Rs. 1000 crores. With this India is emerging as one of the powerful forces in world flower trade. India is bestowed with natural advantages like favourable weather conditions, soil, cheap labour which are likely to make a real mark in International trade.

Floriculture is an intensive type of agriculture wherein the income per unit area is much higher than any other agricultural product if it is done in a scientific way. The area used for production of ornamental plants is low, but the cash returns are high because of the intensive cropping. The major flower growing states are Karnataka, Tamil Nadu, West Bengal, Andhra Pradesh, Rajasthan and Maharashtra. The flowers grown in large areas include jasmine, rose, marigold, chrysanthemum, crossandra, champak, tuberose, gladiolus and aster. New crops like lilies, tulips, anthurium, carnation, gerbera, etc., area also findings potential place in the foreign market. With the rapid development in urban planning and hotel industry, there has been an increasing demand for cut flowers and

ornamentals. The cut flowers followed by live plants, cut foliage, seeds and bulbs have got an immense potential for export to Western countries where the cost of production is comparatively high. India exports roses, gladioli, carnations, chrysanthemums, lilies and jasmines to Gulf, Germany, France, England, Netherlands and Singapore.

2. NEMATODES AND THEIR IMPACT ON ORNAMENTAL CROPS

Monoculture, the common feature of the ornamental crops, provides congenial environment for one or the other nematode, the population of which if unchecked may touch an alarmingly high level and may even wipe out whole crop. Apart from this even a low nematode population may render the planting stock like tuberose and gladioli bulb, unmarketable. The infested planting material may also act as a carrier of some nematode genera/species of quarantine significance to newer areas. In U.S.A. losses in ornamentals due to nematodes were estimated to the tune of $ 60 million annually (Hague, 1972). Throughout the world in ornamental crops, plant nematodes are responsible for 11.1% losses (Sasser and Freckman, 1987). However, in India, there is no precise information about the losses in ornamental crops alone.

Ornamenatls like other crops harbour a multitude of nematode fauna of which some nematodes based on their intrinsic potentials have caused tremendous economic losses. Nematodes like *Ditylenchus dipasaci* has been reported to be responsible for completely wiping out the narcissus industry of Britain (Hague, 1972). *Meloidogyne* spp. on gladioli, *Aphelenchoides ritzemabosi, Belonolaimus longicaudatus* and *Trichodorus* sp. on chrysanthemum in U.S.A., *Xiphinema americanum* on roses in U.S.A. and *Xiphinema diversicaudatum* in Western Europe have been listed as the major pests resulting in considerable growth reduction (Hague, 1972).

A perusal of literature indicates that little information is available from India on these noxious pests. Hence, keeping in view the importance of these pests, a review at this stage would help to identify the progress made as also to pin-point our major deficiencies and gaps from the view point of practical approach to management of these pests.

2.1. Root-knot nematodes, *Meloidogyne* spp.

Root-knot nematodes are found in all crossandra (*Crossandra undulaefolia*) growing areas like Tamil Nadu, Karnataka and Andhra Pradesh. The nematode is responsible for 25.62% and 21.64% loss in number of flowers and weight of flowers, respectively (Khan and Parvatha Reddy, 1992b). Infected plants are stunted with dried peripheral branches bearing smaller chlorotic leaves almost turning to white in later stages (Rajendran *et al.*, 1976). Roots exhibit severe galling. Inflorescences are small and

sometimes fail to produce flowers. *M. incognita* interact synergistically with wilt fungi *Fusarium oxysporum* and *F. solani* and results in premature death of crossandra plants (Khan and Parvatha Reddy, 1992a).

M. incognita, M. javanica and *M. arenaria* have been reported as the major limiting factors in successful tuberose (*Polyanthes tuberosa*) cultivation in Tamil Nadu (Sundarababu and Vadivelu, 1988b), while *M. incognita* and *M. javanica* were potential pests in Karnataka (Khan and Parvatha Redy, 1992a). Affected plants exhibit stunting, yellowing and drying up of leaves and rotting of bulbs (Jayaraman *et al.*, 1975). Further, the emergence of side shoots from the bulbs was also affected. In severely infected plants, the emergence of spike is suppressed and 65% reduction in top growth occurred (Sundarababu and Vadivelu, 1988b). *M. incognita* was responsible for 13.25, 9.87, 14.30, 13.78 and 28.58% reduction in plant weight, number of flowers, spike length, spike weight and number of bulblets, respectively (Khan and Parvatha Reddy, 1992b). The incidence of gladiolus scab caused by *Pseudomonas marginata* increased in the presence of *M. javanica* (Elgoorani *et al.*, 1974).

Parvatha Reddy *et al.* (1979) reported *M. incognita* causing heavy damage to gladiolus. Severe galling on roots results in yellowing of leaves which subsequently leads to stunted growth. The nematode invades roots, daughter corms and cormels which develop after flowering and the nematodes would survive in corm tissue in the soil as a source of inoculum for next season (Parvatha Reddy *et al.*, 1979).

M. incognita is one of the serious limiting factors in commercial cultivation of carnation and gerbera under polyhouse conditions. Most of the highly fetching exotic cultivars of carnation and gerbera from Europe have shown 40 to 60% mortality in polyhouse beds due to root-knot nematode infection in and around Bangalore (Nagesh and Parvatha Reddy, 1996). The nematode interacts with soil-borne fungi such as *Fusarium* spp. and *Rhizoctonia solani* in causing wilt/root-rot complex in carnation and gerbera.

M. incognita was pathogenic to *Jasminum sambac* and *J. flexile* (Rajendran and Rajendran, 1979). The roots exhibited very small swellings and enlarged rootlets. The minute galls were more in *J. sambac*. Pale coloured leaves and dieback symptoms were noticed.

M. arenaria and *M. javanica* have been reported on chrysanthemum (Sen and Dasgupta, 1977; Chandwani and Reddy, 1967).

M. incognita was recorded on Rose (*Rosa indica*) from Aligarh (Alam *et al.*, 1973) and *M. javanica* from Delhi (Prasad and Dasgupta 1964).

2.2. Lesion nematodes, *Pratylenchus* spp.

P. delattrei was frequently associated with crossandra crop exhibiting stunting , chlorosis of leaves and wilting. The leaves showed mottled appearance which turned to brown and becoming pinkish eventually. Later the leaf tips dried and entire leaves turned yellow and shed. The plants were devoid of side shoots and remained completely defoliated. The roots exhibited brown to black lesions. Heavily infested plants did not produce tertiary spike and thereby flower yield is reduced (Srinivasan and Muthukrishnan, 1975). *Fusarium solani* and *F. oxysporum* are invariably associated with the lesions caused by *P. delattrei* (Khan and Parvatha Reddy, 1992a). Srinivasan and Muthukrishnan (1975) also opined that crossandra decline in Tamil Nadu occurs due to *P. delattrei* and *F. solani* complex. Srinivasan (1974) found that wilt symptoms appeared earlier when nematodes were added two weeks prior to *F. solani*.

Rashid and Khan (1975) reported that *P. coffeae* is responsible for heavy root damage which subsequently lead to poor growth of chrysanthemum. Stunting of plants with pre-mature yellowing and drying of leaves are common above-ground symptoms. Flower size is also reduced. *P. coffeae* infects and remains confined to the cortical cells. Parenchymatous cells are completely destroyed due to nematode feeding. The presence of *P. coffeae* has been found to aggravate the disease severity of *Pythium aphenidermatum* and *Rhizoctonia solani* (Hassan, 1988). Edward *et al.* (1969) reported *P. chrysanthus* associated with root-rot of chrysanthemum.

Sundarababu and Vadivelu (1988a) encountered *P. zeae* associated with poor growth of rose plants. The affected plants showed chlorotic symptoms, poor and stunted growth with necrotic lesions on roots. *P. zeae* was reponsible for 69.6, 36.4, 59.6 and 33.3% reduction in shoot length, shoot weight, root-length and root weight, respectively. Prasad and Dasgupta (1964) found *P. pratensis* in the roots of rose plants exhibiting stunted growth.

2.3. The reniform nematode, *Rotylenchulus reniformis*

R. reniformis was observed in high density and frequency in tuberose growing areas of Karnataka. At higher inoculum level, the reniform nematode could cause reduction in flower yield (Khan and Parvatha Reddy, 1992a). *R. reniformis* was also recorded on chrysanthemum (Swarup *et al.*, 1967).

2.4. The spiral nematode, *Helicotylenchus dihystera*

H. dihystera causes heavy damage to crossandra roots and is responsible for decline.

2.5. The needle nematode, *Longidorus africanus*

In Crossandra, *L. africanus* causes stunting of plants, branching, swelling and darkening of root tips (Muthukrishnan *et al.*, 1977).

2.6. The burrowing nematode, *Radopholus similis*

Khan and Parvatha Reddy (1989) recorded a high population of *R. similis* from stunted *Jasminum pubescens* plants in Bangalore. Roots of infected plants exhibited yellow to brown lesions. In some cases blackening also occurs. Infected plants become severely stunted. Branches become dry with chlorotic leaves which ultimately drop.

2.7. The bud and leaf nematode, *Aphelenchoides ritzemabosi*

A. ritzemabosi causes considerable damage to the foliage of chrysanthemum, zinnia salvia, aster and dahlia (Gill and Sharma, 1976). The veins hinder nematode movement within leaves and thus the characteristic symptoms take the form of interveinal discolouration. These are pale green at first, gradually becoming yellow and then dark brown or black as the leaf dies.

2.8. Dagger nematodes, *Xiphinema* spp.

X. diversicaudatum population had a correlation with stunting of rose plants (Prasad and Dasgupta, 1964). Muthukrishnan *et al.* (1975) considered *X. basiri* as the potential causative agents for unproductive flowers of *Rosa chinensis*.

2.9. *Apratylenchoides homoglans*

A. homoglans was reported on the roots of chrysanthemum from Karnataka (Siddiqi *et al.*, 1991). The species is a new record to the world and the genus a new record to India.

2.10. Other nematodes

Tylenchorhynchus vulgaris and *Heterodera mothi* have been reported on chyranthemum (Upadhyay and Swarup, 1972; Khan and Husain, 1965). Bajaj (1989) reocrded *Tylenchulus semipenetrans* on *Jasminum sambac* from Haryana. *Hoplolaimus galeatus, Helicotylenchus nannus, Tylenchorhynchus dubius, Hemicycliphora typica* and *H. labiata* were most frequently encountered species on roses (Prasad and Dasgupta, 1964; Muthukrishnan *et al.*, 1975).

3. NEMATODE MANAGEMENT

3.1. Cultural control

Intercropping of crossandra with enemy plant like marigold significantly reduced the root-knot and lesion nematode population both in soil and roots (Khan and Parvatha Reddy, 1992b). Application of farm yard manure has been found to reduce the lesion nematode population in crossandra. Rotation of crossandra with spearmint which is a poor host of *Longidorus africanus* would reduce the needle nematode popualtion (Kolodge *et al.*, 1987).

3.2. Biological control

The parasitic fungus, *Paecilomyces marguandi* grown on paddy seeds at 2 g per kg soil gave effective control of root-knot nematode infecting crossandra (Khan and Parvatha Reddy, 1992b).

3.3. Host resistance

Ohkawa and Saiguasa (1981) found that *Rosa indica* (Major) and *R. multiflora* (60-5) were resistant to *Pratylenchus penetrans* and *P. vulnus*, respectively. They also reported that rose cv. Mavetti to be resistant against *M. hapla*.

3.4. Chemical control

3.4.1. Nursery bed treatment

Nursery bed treatment with phorate, aldicarb, fensulfothion and carbofuran each at 5 g per m^2 gave good and healthy crossandra seedlings free from *Pratylenchus delattrei* (Vadivelu and Muthukrishnan, 1979).

3.4.2. Bare root-dip treatment

Dipping of bare roots of rose in 0.1% solution of fenamiphs for 30 min. gave considerable reduction in root-knot infection (Dale, 1973). Dipping of gladiolus corms in thionazin or fensulfothion solution (0.5 g a.i. per litre) gave reduced root-knot nematode infestation (Overman, 1970). Root dip treatment for 8 hr. in 0.05 to 0.1% solution of aldicarb, carbofuran, fensulfothion, fenamiphos or phorate protected crossandra seedlings from *Pratylenchus delattrei* for 30 days after transplanting (Vadivelu and Muthukrishnan, 1979).

3.4.3. Soil treatment in the main field

Application of aldicarb 10 G at 1 kg per 100 m^2 was effective in reducing the population of *Pratylenchus penetrans* and as a result rose flower production was increased by 16 per cent (Johnson and Clanaham, 1974). Carbofuran, phorate, fenamiphos and disulfotan at 1 g per plant effectively controlled *P. delattrei* and increased flower yield of crossandra (Vadivelu and Muthukrishnan, 1979). Carbofuran at 2.5 kg a.i./ha was found to be effective against root-knot and lesion nematodes on crossandra under field conditions (Srinivasan and Muthukrishnan, 1976).

Aldicarb and phorate each at 1.5 kg a.i./ha were effective in controlling *Aphalenchoides ritzemabosi* on chrysanthemum (Gill, 1981). For the control of *M. incogntia* on tuberose, aldicarb, fensulfothion and phorate all at 20 mg a.i. per plant were effective and increased flower yield. Application of Vorlex (400 litres per ha) by broadcast method resulted in better flower yield of gladiolus (Overman, 1967).

3.4.4. Foliar application

Foliar application of methyl parathion, chlorpyriphos and quinalphos each at 0.05% were effective in the control of *Aphalenchoides ritzemabosi* infecting zinnia and chyrsanthemum (Gill, 1981; Gill and Walia, 1980).

3.5. Integrated Nematode Management

Integrated management of root-knot nematodes infecting crossandra was achieved by rational combination of a bicontrol agent (*Trichoderma harzianum* or *Verticillium chlamydosporium*) with a nematicide (aldicarb) or oil cake (neem cake) (Khan and Parvatha Reddy, 1992b). Integration of neem, karanj and castor cakes with VAM, *G. mosseae* significantly enhanced plant growth parameters and flower yield of

crossandra, root colonization and sporulation of VAM. The above treatments also reduced root-knot nematode multiplication and root-galling (Nagesh and Parvatha Reddy, 1997).

Integration of vesicular arbuscular mycorrhizae (VAM) such as *Glomus mosseae* or *G. fasiculatum* with neem cake or/and aldicarb gave effective management of root-knot nematodes infecting tuberose (Khan and Parvatha Reddy, 1992b). Integration of *Paecilomyces lilacinus* with 5% neem leaf extract increased plant growth parameters and flower yield of tuberose. The above treatment also reduced root galling and increased per cent egg parasitization by *P. lilacinus* (Nagesh *et al.*, 1996).

Application of phorate at 4 g a.i. per plant during May and September, pruning and incorporation of 20 kg FYM per plant increased the yield of jasmine by 50 per cent and reduced the root-knot nematode population by 70 per cent (Sundarababu, 1992).

Integration of *P. lilacinus/Trichoderma harzianum* at 0.5 l per m^2 (aqueous spore suspension containing 2 x 10^4 spores per ml) with neem cake at 0.5 kg per m^2 or fenamiphos at 2 g a.i. per m^2 increased plant growth parameters and flower yield of carnation and gerbera. The above treatments also increased root-knot egg parasitisation by the parasitic fungi (Nagesh and Parvatha Reddy, 1996).

4. FUTURISTIC APPROACHES

More emphasis need to be placed on the following aspects in future.

4.1. There is considerable lacuna in our knowledge about nematodes associated with ornamental crops. Intensive and systematic surveys of ornamental crops should be conducted with the dual objectives of determining the incidence, prevalence and severity of such diseases and the geographical distribution of the nematode involved. This would go a long way in developing an advisory diagnostic service for the farmers.

4.2. Adequate emphasis should be given to studies on the biology and host-parasite relationship of major nematode pests which may lead to formulation of control methods on sound basis.

4.3. Studies have to be carried out on biotypes and on intraspecific variation in nematodes already known to be of economic importance in ornamental production in India

4.4. Techniques for precise determination of damage thresholds of populations and assessment of crop losses have to be standardised.

4.5. Work on disease complexes involving nematodes be intensified with adequate collaboration between nematologists and plant pathologists.

4.6. Data has to be generated on crop rotation as a method of nematode management. The effect of deep summer ploughing, field sanitation and other cultural practices, hot water treatment of planting material, are the areas which needs more attention in the coming years.

4.7. Regulatory and quarantine measures against introduction of exotic nematode pests needs to be strengthened.

4.8. The use of neem products for the management is highly economical since it can be used for seed dressing, nursery bed treatment, seedling bare-root dip treatment or foliar application. Neem products form ideal components in the integrated nematode management. Their effectiveness has also been proved against disease complexes involving nematodes and fungi. Research on the use of neem products for the management of nematodes on ornamental plants needs intensification.

4.9. There is a great need to develop varieties which are resistant or tolerant to nematodes. Varietal screening and subsequent breeding programmes should be intensified. Fundamental investigations in relation to biochemical and physiological basis of resistance may also be taken up.

4.10. Attempts should be directed towards biological control. *Paecilomyces lilacinus, Verticillum chlamydosporium, Pasteuria penetrans*, VAM fungi have been identified all over the world as a potential biocontrol agents against plant nematodes. The possibility of using these biocontrol agents against nematodes infecting ornamental crops should be explored.

4.11. Development of integrated nematode management models for ornamental crops should be taken up. Research on the use of tolerant/resistant cultivars, parasitic fungi and bacteria, organic amendments/plant products and vesicular arbuscular mycorrhizae should be evaluated and if acceptable to the farmers should be popularised through demonstration plots.

4.12. Creation of increased awareness among farmers regarding nematode problems on ornamentals crops through extension services, literature, audio-visuals in local languages, demonstrations in farmer's fields and training programmes; strengthening of various extension programmes in nematology under lab-to-land and training and visit systems have to be explored.

5. CONCLUSIONS

In conclusion, it is hoped that this brief study has succeeded in bringing into sharper focus the significance of plant parasitic nematodes as one of the important limiting factors in the production of ornamental plants in India. On a "per hectare" basis, the crops dealt with in this chapter are some of the most expensive. Estimates of loss attributable to the direct effect of nematodes in producing unmarketable crops is about 11% for ornamentals. All these crops are grown in almost continuous monoculture and the value of the crops warrants expensive phytosanitary measures. These crops are subject to many fungal root rots as well as nematodes and thus control measures should always take into account both types of pathogens. In this context, neem products hold promise since they are effective on both nematodes and fungi.

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Nematode Parasites of Arid Zone Fruit Plants.

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Introduction

The crop losses due to plant parasitic nematodes in arid fruit crops are not precisely known. Preliminary studies showed occurence of root knot nematode like complex in pomegranate (Jat and Jain, 1987).

Root knot nematode in pomegranate

Nematode infected plants get stunted growth, shorter internode and reduced leaf size (Jat and Jain,1987). Leaves become chlorotic and give burning appearance. Rosette like structures on branches is a characterstic symptom in affected plants. In such plants numerous galling on roots confirm the parasitization of *Meloidogyne* spp. However, their impact on fruit loss has not been studied.

Mechanism of nematode infestation

Species like *Meloidogyne* remain attached to one point in the tissue throughout their lives. Males may or may not penetrate the roots but the females invariably get established in roots and responsible for the destruction of the host. The *Meloidogyne* species has the greatest morphological adaptation to get the parasitism. When nematode starts feeding in the host, a group of cells develop into characteristic symptom around the head of the parasite. The host cytoplasm becomes dense and the size of nucleus enlarges considerably. Cell wall of such tissues are usually affected. Ultimately extensive hyperplasia is induced which results in the formation of characteristic cells as galls in root system.

Ecology and spread

In general, a life cycle of *Meloidogyne* spp is completed in 25 days at 27°C, but it takes longer time at lower and higher temperatures. The greatest number of root-knot nematodes are usually in the root zone from 5 to 25 cm below the surface (Agrios, 1988). It has been reported that temperature at 27°C for rapid growth and 35°C for reproduction. The optimum temperature for egg hatching is 30°C (Ahmed and Khan, 1964). In dry soil galling of roots is slow with continuous parasitism (Parris, 1948). All these favourable conditions are prevailing in arid region of the country for nematode parasitism. The second stage larva may migrate from within the galls to adjuscent parts of the root or they may emerge from the root and infect other roots of the same or adjuscent plants. Anything that moves or carry particles of infested soil may spread the nematode problem.

Root knot nematode *Meloidogyne* spp.

The adult male and female root-knot nematodes *Meloidogyne* spp are easily distinguishable. The males are worm like and about 1.2-1.5mm long by 3.0-3.6 mm in diameter. The females are pear shaped and about 0.40-1.3 mm long by 0.27-0.7 mm wide. Females are more parasitic and lays eggs (500) in a gelatinous substances produced by nematodes. The second stage larvae egg highly infective in susceptible roots (Agrios, 1988).

Management of nematode diseases in arid fruits

1. Attempts have been made to develop resistant lines in crops such as tomato (Thomson and Smith, 1957; Wistead and Barhan, 1957) against *Meloidogyne incognita*. Attempts were made to screen pomegranate cultivars for their resistance under natural conditions. An incidence of (10-26%) root-knot nematode *(Meloidogyne sp)* in pomegranate was recorded at Jobner (Pareek, 1993). Subsequently resistant cultivars like Jalore Seedless and P-26 were found to be susceptible (Pareek, 1995). Thus durable resistance in pomogranate is not available.

Screening of pomegranate cultivars resistant to nematode under natural conditions at Jobner.

Cultivar	PDI	Reaction(1993)	1995
Bassein Seedless	25.50	S	S
Dholka	9.00	Ms	Ms
Ganesh	18.00	Ms	Ms
G-137	21.66	S	S
GKVK-1	33.00	S	MS
Jalore Seedless	4.00	R	MS
Jodhpur Red	40.00	S	S
P-23	8.10	MS	S
P-26	5.00	R	MS

(Pareek, 1993)

2. It will be difficult to control the nematodes in soil as well as in plants by employing application of heat, irradiation , osmotic pressure etc. Thomson et al (1960) found that application of dry heat at 45°C for 30h could eliminate root-knot nematode. Under arid conditions therefore, summer ploughing will be useful to eliminate the cysts or eggs to some extent. But work needs to be done to standardize time, temperature etc.

3. All plant pathogenic nematodes are obligate parasites. Absence of hosts for two to three years may therefore, eliminate the parasites. But this is very difficult in fruit crops. However studies can be initiated on intercropping with other non host plants. It has been suggested that planting *of Crotalaria* may reduce the nematode damage due to toxic exudate effect from its roots. Oostenbrink et al (1957) found that *Targetes patula* and *T. erecta* grown between plant rows resulted in better growth of perennials. Rohde and Jenkins (1957) suggested that *Asparagus* exudes a nematicidal chemical from its roots. Effect of intercropping with such crops can be studied for arid fruits crops

4. Some chemicals were tested for the control of nematodes. Earlier infestation can be checked by chemical treatment of seeds and nursery pants with systemic nematicides. The most promising nematicides are carbon disulphide, Chloropicrin and Carbofuron. However,attempts are needed to quantify concentration, time of application of the chemicals and their deleterious effects in arid zone fruits crops.

5. One of the best alternative in recent years is biological control. Many types of bacteria have been investigated against plant parasitic nematodes (Stirling, 1991). The fungi *Verticillium chlamydosporium* (De Leij et al (1992), *Pacilomyces lilacinus* (Jatala, 1986) and the bacterium *Pasteuria penetrans.* (Sayre & Starr 1988) have shown promising agents for the control of nematodes. Recently oliogo bacteria such as *Bacillus* spp (Backer et al.,1988), Fluorescent pseudomonads (Oostendorp and Sikora, 1990) and *Pseudomonas chitinolytica* (Spigel et al, 1991) have shown to inhibit the penetration of nematode in roots and reduce the root galling. Recently Yuji Oka et al (1993) studied the control of root knot nematode *Meloidogyne javanica* by *Bacillus cerens.* Such approach may help in arid fruit crops also.

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NEMATODE PARASITES OF IMPORTANT MEDICINAL AND AROMATIC PLANTS

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Medicinal and aromatic plants are high valued renumerative crop being used as raw materials for flavouring, pharmaceutical,perfumery and cosmetic industries of the world. Most tropical countries have large arable areas, diversed climate, variety of soil and topography, which contribute for sustaining cultivation of various medicinal and aromatic plants. Some of these important medicinal and aromatic plants are also cultivated in different part of Asia, Africa, Europe and United States.In the last two and a half decades, the global demand of medicinal and aromatic plant industries have prospered and these industries hold a commendable position in the economic world because of continuous research and development works. Most of the farmers in tropical and subtropical countries of the world are now growing these medicinal and aromatic plants as nonconventional crop . Most of these plants also serve as foreign exchange earner. Mints, lemon grass, palmarosa, citronella, senna, tropane alkaloid bearing plants, davana and basil constitute the major share in terms of production and acreage. Several other medicinal and aromatic plants like geranium, patchouli, belladona, yams, serpgandha ,mulathi, ammi, rose etc. are restricted in acreage and region, because of their different climatic and geographical requirements.

Phytonematodes constitute a very small group (about 10%) of the total nematode species. A plant growing in soil is often attacked by one or more species of phytonematodes. Generally, these nematodes are present in and around the roots of their host plants or in the stem , leaves and seeds . Phytonematodes generally affect the production and economy of the crop in many ways, such as, :(i) deterioration in

quality and reduction in the productivity of the crop (ii) need of additional fertilizers and irrigation (iii) application of nematicides to check its spread and (iv) impediment of production of trade by phytosanitary regulation (Vinciguerra, 1979).

A large number of plant parasitic nematodes, such as, Tylenchorhynchus vulgaris and Meloidogyne spp. followed by Longidorus pisi, Pratylenchus thornei, Hoplolaimus sp., Tylenchus sp. and Helicotylenchus sp., Hirschmaniella sp., Heterodera larvae, Xiphinema sp. and Trichodorus sp. have been reported in the rhizosphere of different medicinal and aromatic plants(Pandey, 1994).

MINTS (Mentha spp.)

Mints, a group of aromatic plants belonging to family Lamiaceae, are used by man since antiquity (Guenther, 1949). There are six type of mints which are commercially cultivated in Asia and other parts of the world. These are : Japanese mint (Mentha arvensis L. Subsp. haplocalyx Briquet var. piperascens Holmes.), Pepper mint (Mentha piperita L.), Spear mint (Mentha spicata L.), Scotch spearmint (Mentha cardiaca Baker), Bergamot mint (Mentha citrata Ehrh.) and common garden mint (Mentha viridis L.).

NEMATODES OF JAPANESE MINT :

Japanese mint and its different cultivars are cultivated on large scale in Argentina, Australia, Brazil, China, Gautemala, Paraguay, Japan and India for the production of menthol. In India about two and half decades ago, the entire requirement of Japanese mint oil and its principle constituent, menthol were met through imports. Recently, sincere attention has been made by Central Institute Of Mediicinal and Aromatic Plants (CIMAP) for the large scale cultivation and now in India Japanese mint is being commercially cultivated in approximately 21000 ha. of land in

different parts of the country .

ROOT-KNOT NEMATODES (Meloidogyne spp.)

In 1938, Burher for the first time reported Mentha arvensis as host of Meloidogyne species. In India its commercial plantation suffers severely from root-knot disease caused by Meloidogyne incognita and M. javanica , especially in tarai region of Uttar Pradesh and poses a serious threat to the production of menthol in the country (Pandey, 1989, Pandey et. al. 1992). This root-knot disease dessiminates through planting materials and mostly occurs in between January and February. It has also been noticed that sandy soil favours more infection than clay soil. None of the cultivars of Japanese mint have been so far found resistant against root-knot nematode (Meloidogyne spp.). The frequency of occurrence of M.incognita was always greater than M.javanica (Haseeb and Pandey, 1989c).The plants infected by M.incognita produced less oil yield and its quality was adversely affected (Pandey,1989;Pandey et. al. 1992).

SYMPTOMS

The major disease symptoms in field conditions are occasional yellowing of leaves, stunting and wilting of the plants. In underground parts small to big galls of various sizes have been reported (Fig.1).This root-knot disease of Japanese mint was observed in almost all the cultivated areas in India (Pandey, 1989). But the variation in disease intensity varied greatly from cultivar to cultivar and location to location. Extensive survey has been made by Pandey et.al. (1992) for the severity of root-knot diseases in mint growing areas of Uttar Pradesh and found most severe infection of root knot nematode on Japanese mint at Lucknow, Barabanki, Badaun and Muradabad, whereas lowest infection occurs in Nainital district.

BIOLOGY

The root-knot nematode (M.incognita) takes 28-30 days to complete its life cycle in the root of Japanese mint at a temperature range 23-30° c under glasshouse conditions. Pandey (1989) for the first time studied the population fluctuation of different plant parasitic nematodes in the rhizosphere of Japanese mint in relation to seasonal changes. Population of root-knot nematode larvae (Meloidogyne sp.), stunt nematode (Tylenchorhynchus vulgaris) lesion nematode (Pratylenchus thornei) and needle nematode (Longidorus pisi) fluctuate greatly from season to season and cultivar to cultivar. The highest population of Meloidogyne larvae has been reported in the rhizosphere of M.arvensis followed by T.vulgaris, P.thornei and L.pisi respectively . In further studies Pandey (1989) reported that most of the population of plant parasitic nematode in mint crop were found at 0-15 cm soil depth as compared to 15-30 and 30-45cm soil depth respectively.

For the first time Pandey (1989) established the pathogenicity of M.incognita on different cultivars of M.arvensis viz. MA-1, MA-2, MA-3, MA-4, MA-5, and MAS-1. Studies revealed that with the increase in initial population densities (Pi) of M.incognita, there was significant decrease in root/shoot length, fresh/dry weights, oil yield, chlorophyll a,b and total as well as rate of photosynthesis (Pandey, 1989; Pandey et. al. 1992). They further reported that with increase in population densities of nematode ,there was significant decrease in nematode reproduction and increase in root-knot indices (RKI) and highest RKI and severe root galling at highest inoculum density of M.incognita (30,000/5kg soil).

LOSSES

Root-knot nematodes(M.incognita and M.javanica) are reported in the roots of most of the cultivars of Japanese mint and cause 25-

30% oil yield reduction in India. The quality of Japanese mint oil was adversely affected by nematode infection.

CONTROL

Root knot disease caused by M.incognita has been managed through application of oil seed cake (Pandey,1989; 1995 ; Pandey et. al., 1992). They reported that neem oil seed cake at the rate of 750-1000kg/ha was found useful for enhancing the growth/oil yield of Japanese mint and also significantly reduced the root knot nematode population on the crop. Pandey (1995) studied the effect of different organic materials and pesticides on the infection potential of root knot nematode and oil yield of M.arvensis. He reported that maximum oil yield was recovered from neem cake treated soil followed by dried leaf powder of Adhotoda vasica and Murrya koenigii as well as aldicarb, furadon and bavistin, respectively.

NEMATODES OF PEPPERMINT AND SPEARMINT:

Peppermint (Mentha piperita L.) and spearmint (Mentha spicata Huds.) yielded peppermint and spearmint oil by steam distillation of their leaves.Oils of these mint are extensively used in pharmaceutical , flavour and food industries of the world.

ROOT LESION NEMATODES (Pratylenchus sp.)

These mint species are highly susceptible to Paratylenchus hamatus, Pratylenchoides laticauda, Pratylenchus penetrans, P. scribeneri, and P.thornei infection (Skotland and Menzies, 1957; Faulkner, 1962; Pandey, 1997). Meloidogyne incognita and M.javanica were also found to be associated with these mint species (Pandey, 1994b).

SYMPTOMS

Infested plants show stunted plant growth, burning of the leaves and small to long leasions on the root system. Infected root portion were very much reduced and brown to red lesions have been observed on the suckers (Fig. 2).

BIOLOGY

Bergeson and Green (1979) reported that P.penetrans was mainly responsible for the reduction of herb and root growth of peppermint and spearmint species in Indiana, USA and further elaborated that all test cultivars of peppermint are highly susceptible to P.penetrans. Rhoades (1983) established pathogenicity of P.scribeneri on M.spicata. Pinkerton (1984) in his greenhouse studies reported that P.penetrans significantly reduced crop yield of M.spicata. In his experiment he reported that M.spicata cv. Murroy Mitcham is highly susceptible while Todd Mitcham was found to be intermediate and Black Mitcham is most tolerent species to P.penetrans infection. Inserra and Rhoades (1984) reported that four nematode species viz. Dolichodorus heterocephalus, P.scribeneri, Belonolaimus longicaudatus and Paratrichodorus christiei associated with the Mentha spicata in Florida , U.S.A. and caused serious damage to the crop under field conditions.

Studies conducted in CIMAP, Lucknow reveal that M.piperita and M.spicata harbour population of different plant parasitic nematode in the rhizosphere (Pandey, 1994b, 1997). Large number of experiments were carried out on nematode and fungus interaction and it has been reported that with the association of fungi the disease intensity has been increased and plant growth was significantly reduced (Bergeson, 1963; Faulkner and Skotland, 1965; Faulkner and Bolander, 1969).

A large number of other phytoparasitic nematodes were also reported to be associated in the root rhizosphere of peppermint and spearmint (Goodey, 1940, Horner and Jenson, 1954; Skotland and Menzies, 1957). Esmenjaud et. al. (1990) found that three peppermint species viz. M.piperita var. mitcham clone 52, M.piperita sylvestris var. hongroise clone 59 and M.piperita officinalis var. blanche clone 108 proved to be good host of Pratylenchoides laticauda and significant damage occurs by these phytoparasitic nematodes in USSR.

LOSSES

Bergeson (1963) for the first time established pathogenicity of P.penetrans on M.spicata and reported a reduction of foliage and root/stolon growth up to 34% and 66% respectively.

CONTROL

Rhoade(1984) conducted an experiment to control P.scribeneri on M.spicata by using some nonfumigant nematicides viz. carbofuran, fenamiphos or oxamyl at the rate of 5.6 to 11.2 kg/ha. A significant control of P.scribeneri on M.spicata has been acheived by these pesticidal chemicals. But fenamiphos was found to be the most effective nematicide followed by turbefos. He further reported that the total foliage yield of the crop was found to be inversely proportional to the number of nematodes in soil and root. Ingham et. al. (1988) conducted an experiment to control the Pratylenchus sp., P.penetrans by using Vydate 2E(Oxamyl) at the rate of 1lb/acre, Mocap 6E or 10G (Ethophos) at the rate of 3 or 6lb/acre. They found that ethophos at the rate of 6lb/acre was highly effective to reduce the population of P.penetrans in soil and root. However oxamyl was found significantly active to reduce the population of Pratylenchus species. Other control experiments were also carried out with the use of some herbicides, pesticides and other control methods to reduce the phytoparasitic nematode population on peppermint and spearmint

respectively (Horner and Jenson, 1956; Faulkner, 1962; Jatala and Jenson, 1974; Lisetakaya, 1985; Pinkerton et. al. 1988; Inserra and Rhoades, 1989; Esmendjaud et. al. 1989; Gokte and Mathur,1990).

NEMATODES OF SCOTSCH SPEARMINT, BERGAMOTMINT AND GARDENMINT:

Scotsch spearmint (Mentha cardiaca(S.F. Gray, Baker) ,Bergamotmint (M.citrata Ehrh.) and Gardenmint (M.virdis L.) are also affected by number of plant parasitic nematodes (Anonymous, 1984-85, Haseeb and Pandey, 1989). Horner and Genson (1954) reported association of M.hapla, Pratylenchus sp., Aphelenchoisdes sp. and Longidorus sp. with these mint species and further they established the pathogenicity of M.hapla on M.cardiaca. Skotland and Menzies (1957) reported the association of P.hamatus, Tylenchorhynchus capitatus, Trichodorus sp. with M.cardiaca and reported potential damage to the crops.In India the most important nematode pathogen of Scotsch spearmint and Gardenmint is M.incognita and Bergamotmint is highly affected by P.thornei (Anonymous, 1986).

NEMATODES OF DAVANA

Davana (Artemisia pallens Wall.) belonging to family ateraceae is an aromatic herb considered most important due to its high valued essential oil. The main constituents of its oil are cadinene, cinnamate, cinnemoyl, fenchyl alcohol, 10-11 phenols or acids, linalool, eugenol,geraniol and various sesquiterpenes. The crop is cultivated on a large scale in USA, Europe , Japan and India. In India it is mainly cultivated in Andhra Pradesh, Kerala and Tamil Nadu.

ROOT-KNOT NEMATODES

Haseeb and Pandey (1989b) for the first time reported that M.incognita and M.javanica are the most serious constraints for the

successful cultivation of davana.

SYMPTOMS

The root-knot infected plants show a gradual decline characterized by stunted plant growth, yellowing of the leaves and fewer tillers. In the nurseries,more than 50% of the seedlings were attacked with second stage larvae of root-knot nematodes, resulting in severe loss to the planting material. Light to heavy root-knot galling was noticed on the root system with reduced lateral roots. The severely infested plants generally produced less flowers/ flower buds than a healthy plant (Fig. 3).

LOSSES

In davana M.incognita causes more than 50% oil yield reduction(Haseeb and Pandey, 1990).

BIOLOGY

Haseeb and Pandey (1989) reported that 1 larvae/2g soil of M.incognita is the economic threshold level for this crop. In their pathogenicity tests, they reported 52% oil yield reduction of davana at the highest inoculum level of M.incognita. Sandy soil and continuous availability of soil moisture proved to be very congenial for the rapid multiplication and development of root-knot nematodes on davana.

CONTROL

Efficacy of aldicarb, bavistin, carbofuran, orthoprophos, onchol (benfuracarb), Rugby (cadusafos),neem cake, castor cake and mahua cake towards M. incognita on A.pallens (Pandey, 1994a). Significant control of root knot nematode and enhancement in growth/oil yield of

davana were obtained in neem cake and aldicarb treated soil folllowed by other treatments.

NEMATODES OF PATHCHOULI :

Patchouli (Pogostemon cablin Benth. Syn. patchouli Pallet.var. sauvis Hook) is one of the most important essential oil bearing plant used in the perfumery industries as a base because of its fixative property.

ROOT-KNOT NEMATODES

The important nematode pests which severely affect the commercial plantation of patchouli are Meloidogyne incognita , M.javanica, M.hapla and Pratylenchus brchyurus.

SYMPTOMS

Plants were infected at the early stage of the growth. Patchouli plants infected with root knot nematodes show stunting, chlorosis, wilting and defoliation. Root-knot galls are very small (2 mm) or the surrounding galls coalesce to form big galls (Fig. 4).

BIOLOGY

The multiplication rate of M.incognita was greater in sandy-loam soil than clay soil. Digwanti and Momota (1991) reported that M.incognita, M.hapla and Pratylenchus brchyurus are the most important nematodes of P.patchouli in West Java.

LOSSES

Krishnaprasad and Reddy (1979,84) reported that the threshold

level of M.incognita was 40 juveniles/g soil. They reported 52% loss in dry weight of patchouli by M.incognita.

CONTROL

Krishnaprasad and Reddy (1984) used Aldicarb-Sulfone, Aldicarb-Fensulphothion, Carbofuran, Cytrolan AC-92 and AC-100 at the rate of 3.6 and 10 kg a.i./ ha as pre or post inoculation treatment for the control of root knot disease of patchouli. Sarwar et. al. (1984) used Fehnsulphothion, Carbofuran, Aldicarb, Nemagon, Metham Sodium, Phenimiphos to control the M. incognita on patchouli. Carbofuran was highly effective against M. incognita . Neem oil seed cakes at the rate of 4 tonnes/ha proved better than other oil seed cakes for increasing the growth and yield of the crop and reducing the M.incognita population (Sarwar, et. al., 1984). Mucuna prurita as a rotational crop with patchouli was found an effective management too for root knot nematodes in the field. Summer fallowing was also used as good method for keeping M.incognita population below threshold levels . Kumar and Nanjan (1984) applied aldicarb, carbofuran or phorate at the rate of 2 or 3 kg a.i./ ha to control Helicotylenchus duhystera on P.patchouli. They found a significant control of spiral nematode on the crop and observed an increase in the foliage yield of the crop in all the treatments.

NEMATODES OF BASIL :

Basil (Ocimum basilicum L.) produces high quality oil which is used in perfumery, cosmetics and pharmaceutical industries of the world. The major constituents of its oil are 43-50% linalool, 18-33% menthyl chavicol, 5-6%eugenol and iso eugenol. Whereas the minor constituents are alpha and beta pinene, camphor and gerenol. The other species of Ocimum such as Ocimum sanctum, O. canum, O.grattissium and O.kilmandcharicum are also extensively cultivated.

Basil is highly affected by M.incognita and M.javanica infestation (Balasubramanium and Rangaswami, 1964).

SYMPTOMS

Light to severe gallings are visible on the root system of infected basil plants . The infected plants are stunted with smaller leaves, reduced and stubby root system and lesions along the root axis and at the root tip (Haseeb and Pandey, 1987; Rhoades, 1988).

BIOLOGY

Lamberti and Garibaldi (1977) reported that Aphelenchoides ritzemabosi (Schwartz) Steiner caused injury to basil. Rhoades (111) reported from Florida, USA that M.incognita, Belonolaimus longicaudatus and Pratylenchus scribneri multiplied well and caused significant reduction in foliage and root growth of Ocimum basilicum. The population of Paratrichodorous christiei decreased the foliage but it did not effect the root growth. Dolichodorus heterocephalus and Hoplolaimus galeatus have no significant effect on the plants. A large number of other plant parasitic nematodes are found to be associated with these crops (Pandey, 1994b).

CONTROL

Use of oil seed cakes and pesticides was reported for control of M.incognita on Ocimum basilicum (Haseeb et. al. ,1988). Neem cake at the rate of 1gN/kg soil proved effective in managing M. incognita. Increased growth and oil yield of O.basilicum was obtained with aldicarb, carbofuran and mahua cakes, respectively.

NEMATODES OF GERANIUM :

Geranium (Pelargonim graveolens L.) is one of the important sources of an expensive essential oil used in high grade soap, perfumery and cosmetic industries because of its agreeable and profound strong rosy aroma. It is a chief source of a rhodinol.

ROOT-KNOT NEMATODES

The crop is highly affected by M. incognita, M. hapla and Helicotylenchus dihystera.

SYMPTOMS

Root-knot nematode infected plants generally show stunting, burning of lower leaves, yellowing and severe galling on the root system. M.incognita and M.hapla are the most important nematodes pathogens associated with the decline of crops yield (Arumugam and Kumar, 1979).

LOSSES

It has been reported that M.incognita and M.hapla causes 50% reduction in oil yield of geranium.

CONTROL

Kumar and Nanjan (1985) carried out field experiments to control different phytoparasitic nematodes on geranium by applying aldicarb, carbofuran, phorate and quinalphos at the rate of 2 or 3 kg/ha after four months of transplanting the cuttings of the plants. They reported that aldicarb at the rate of 3 kg/ha effectively controlled the population Scutellonema conicephalum, Meloidogyne hapla and Helicotylenchus dihystera and increased the foliage (22.7t/ha) and

oil yield (27.2 kg.ha) of geranium as compared to control (3.6t/ha, 16.4 kg/ha), respectively. When they compared the cost to benefit, at the above said rate they found phorate as one of the best nematicides when applied at the rate of 2kg/ha followed by aldicarb 3kg/ha. The cost benefit ratio was lower for carbofuran and quinalphos.

NEMATODES OF AROMATIC GRASSES

Cymbopogon species are the important aromatic grasses belonging to family graminae . More than 140 species of Cymbopogon have been reported all around the world (Sobti, et.al., 1982). Essential oil obtained by distillation of leaves, is widely used in perfumery and pharmaceutical industries of the world. This oil also serve as the natural source of valuable active components i.e. citronellal, in citronella oil , geranil in palmarosa oil and citral in lemon grass oil. The most important cymbopogon species are as follows which are extensively cultivated in different parts of India.

1. Lemon grass (Cymbopogon flexuosus (Nees ex Steud.) Wats
2. Palma rosa (Cymbopogon martinii (Roxb.) Wats
3. Citronella (Cymbopogon wintrianus Jowitt.

Earlier, no work has been conducted on the association of plant parasitic nematodes with these crops. Various phytoparasitic nematodes have been reported to be associated with diseased plants of lemon grass, citronella and palmarosa (Anonymous, 1985).

In field , nematode infested lemongrass, citronella and palmarosa plants were found to be stunted, chlorotic and numbers of branches were very much reduced. Yellowing and burning of leaves are the most common symptoms in lesion and stunt nematode infested plants.

The most dominant species of plant parasitic nematodes in the

root rhizosphere were Tylenchorhynchus vulgaris, Pratylenchus thornei and Helicotylenchus sp.(Anonymous, 1985). Studied were also made on the population dynamics of different plant parasitic nematodes associated with different cultivars of lemongrass, citronella , palmarosa and khus respectively. In the studies T.vulgaris and P.thornei were found important pathogens causing hinderance in the cultivation of these grasses.

NEMATODES OF HENBANES :

Henbanes (Hyoscyamus muticus, H.niger and H.albus) are the chief source of tropane alkaloid such as hyoscine, hyoscyamine and atropine. The hyoscine and its derivatives have been used in different pharmaceutical industries, since they are having anticholinergic, antiphasmodic and mydriatic properties. The agrotechnology for large scale cultivation has been developed by my Institute.

ROOT-KNOT NEMATODES

These plants are heavily infested by two species of root-knot nematodes namely viz. Meloidogyne incognita and M.javanica (Haseeb and Pandey, 1989a).

SYMPTOMS

In the field, infested plants show chlorosis and stunted growth with fewer and smaller leaves and flowers. In underground parts small to big galls of various sizes have been reported (Fig. 5,a,b).

BIOLOGY

Pathogenicity of M.incognita and M.javanica was established on H.muticus and H.niger under glasshouse conditions (Haseeb and Pandey,

1989a). Five juveniles/g of soil of either nematode caused significant damage to both the species of henbane. Pandey (1990) reported a severe damage to H.albus by M.incognita.

LOSSES

Pandey (1990) reported 20% reduction in herbage yield of different henbane species.

CONTROL

Experiments were carried out on the control of root knot nematode of black and egyptian henbane by Pandey et. al.(1996, 97). With the use of different vesicular-arbuscular fungi viz. Glomus aggregatum, G.feasiculatum and G.mosseae a marked reduction in the potentiality of root knot nematode (M.incognita) was observed and a enhanced herbage yield of the plant was also noticed (Pandey et. al., 1997).

Other than the above listed plants, several other plants are also known for their economic potentialities in pharmaceutical, perfumery and cosmetic industries of the world. The most important phytonematodes associated with them were also reported (Pandey, 1994b).

FUTURE PROSPECTS :

The cultivation of medicinal and aromatic plants has been considerably increased in many tropical and subtropical countries of the world, which is due to increased use of inorganic fertilizers, pesticides and development of improved plant production technologies. Recently the diseases caused by plant parasitic nematodes have become a limiting factor in their production in our country. Although chemical control of phytonematodes proved effective,it cannot be

recommended to the farmer because of costs and the lack of advanced delivery systems. The unavailability of these nematicides and the hazardous effects on environment are also important problems affecting their use in most of the developing nations. If environmentally safe pesticides become available in future at a low cost, increased use could be expected. A new generation of nematicides are needed which should be effective, safe and cheaper.

It is very encouraging that for two of the most economically important nematodes of medicinal and aromatic plants, i.e., root-knot nematodes (Meloidogyne incognita & M. javanica) and root lesion nematode (Pratylenchus thornei), resistant or tolerant germplasms are available (Pandey, 1993). These germplasms could be exploited in future plant breeding programmes for developing resistance against phytonematodes. Rhizobacteria, endophytic and egg parasitic fungi have been proven efficient to control root knot and cyst nematodes under experimental conditions(Sikora, 1992). Such areas should be exploited in future biocontrol research programmes. Any low cost technology for the nematodes control would be acceptable to tropical farmers. Research in the following direction should be accelerated in the field of medicinal and aromatic plants.

(i) Intensive survey of the root and rhizosphere association of phytonematodes with medicinal and aromatic plants.

(ii) Crop loss assessment of different medicinal and aromatic plants due to phytonematodes.

(iii)Urgent need of developing disinfestation methods for transplanting plant material.

(iv) Introduction of internal qurantine for endoparasitic nematodes.

(v) Creation of a general awareness about different biocontrol

agents among extension and research workers.

(vi) Development of suitable and acceptable crop rotation using resistant and tolerant medicinal and aromatic plants.

(vii) Need of collaborative interdisciplianry research for the management of these pests and pathogens.

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Technical Session - V

PROCEEDINGS OF THE GROUP MEETING OF NEMATOLOGISTS WORKING ON HORTICULTURAL CROPS

General Chairman: Dr. Gopal Swarup
Retd. Professor and Head
Division of Nematology
IARI, New Delhi

The group meeting of Nematologists working on Horticultural Crops was inaugurated by Dr.R.N.Pal, Assistant Director General (Plantation Crops), ICAR, New Delhi and the function was presided over by Dr.K.U.K. Nampoothiri, Director, CPCRI, Kasaragod. Dr.Pal in his inaugural address emphasised the following points:

1. Though large number of crops are known to suffer huge losses due to plant parasitic nematodes, precise estimates on crop losses are not available.
2. There have been very little information available on the residues left in the products of nematicide treated crops.
3. Use of biocontrol agents for the control of nematodes requires immediate attention in view of environmental pollution.

Dr. Pal informed the nematologists that ICAR Headquarters will be looking forward for concrete suggestions and action plan regarding nematological research on Horticultural Crops.

Dr.K.U.K. Nampoothiri in his presidential address briefed the nematologists about the important nematode problems on plantation crops and research accomplishments of Nematology Section at CPCRI.

The main objective of the group meeting is to make uniform methods of control for the same nematode disease on the same crop, as far as possible, by various agencies like Agricultural Universities and ICAR Institutes by the general concensus of the agencies involved. There were five technical sessions.

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Technical Session I

1.	Nematode parasites of vegetable crops	Dr. Sharad M. Srivastava
2.	Nematode parasites of potato	Dr.K. Krishnaprasad
3.	Nematode parasites of tuber crops	Dr.C. Mohandas
4.	Nematode parasites of mushrooms	Dr.M. Nagesh

Technical Session II

1.	Nematode parasites of palms	Dr.Sosamma Varghese
2.	Nematode parasites of citrus and grapes	Dr. Bansa Singh and grapes
3.	Nematode parasites of spices	Dr.K.V. Ramana
4.	Nematode parasites of betelvine	Dr. Sadasiv Ray
5.	A decade of nematode research under AICRP on betelvine	Dr. Satyabrata Maiti

Technical Session III

1.	Nematode parasites of banana	Dr.P. Sundararaju
2.	Predominance of burrowing nematode Radopholus similis in banana crop of M.P. and its impact on cultivars	Dr.S.P. Tiwari

Technical Session IV

1.	Nematode parasites of ornamental crops	Dr.M. Nagesh
2.	Nematode parasites of medicinal and aromatic plants	Dr.M.S. Sheela
3.	Studies on root-knot disease of tuberose caused by Meloidogyne sp. in Northern Karnataka	Dr.S. Lingaraju
4.	Distribution and analysis of phytoparasitic nematodes in pointed gourd growing areas of Eastern Uttar Pradesh,India	Dr.A.C. Verma

Technical Session V

Finalisation of package of practices for Integrated Management of Nematodes on various Horticultural crops. Nursery treatment, treatment at transplanting, direct

seeding (dosage, frequency of application of chemicals, method, time and dosage of application of bioagents in nursery and field).

The plenary session was chaired by Mr.V.T. Markose, Director, Coconut Development Board, Kochi. The general chairman, Dr. Gopal Swarup presented the various recommendations emanated from various technical sessions of the group meeting of nematologists working on horticultural crops held from 16-17th January 1998 at Central Plantation Crops Research Institute, Regional Station, Kayangulam.

I. Nematode Parasites of Vegetable Crops

1. Growing Tagetes patula var. Orange Gate or Climax Terreador is suggested as a method for reduction of Root Knot Nematode Meloidogyne incognita Race 2 and 4 population in Pointed Gourd (Trichosanthes dioica Roxb.) in eastern U.P.

2. Application of Carbofuran @ 0.3 g a.i./m^2 is recommended for the control of root knot nematode on vegetable nursery (tomato, brinjal and chillies).

3. Application of Neem cake 750-1000 kg/ha fortified with 5 kg paddy grains colonised with Paecilomyces lilacinus is recommended for the control of root knot nematode on vegetables in Karnataka.

4. Application of Pasteuria penetrans root powder 5 g containing 10^6 spores/g at the time of sowing is suggested for the control of root knot nematode on tomato nursery.

5. Crop rotation with Sweet Potato var. Sree Bhadra (95 days duration) against Meloidogyne incognita and M. javanica under field condition is suggested for root knot nematode control in vegetable crops.

6. Crop rotation with Tagetes patula var. Orange gate, Calcutta Yellow, Orange bay, Orange jacuet or Climax terreador or Upland Rice is recommended for the control of M. incognita infesting Brinjal.

7. Soil solarisation with clear polythene film of 100 gauge for 15-30 days in nursery beds for the control of root knot nematode on vegetables is recommended for all parts of India except Himachal Pradesh, Jammu & Kashmir, West Bengal and hilly regions of Assam. Soil moisture should be brought to field capacity before putting the film and soil temperature should be above 45°C.

8. Resistant varieties

Tomato: Hisar Lalit, FNR-7 in Haryana and Punjab

II. Nematode parasites of potato

1. "Kufri Thenmalai" is identified as tolerant to Pa-2 of Globodera pallida and Ro-1 and Ro-2 of G. rostochiensis in Nilgiris.

III. Nematode parasites of Tuber Crops

1. Sweet potato var. Sree Bhadra is recommended for growing in fields infested with Root knot nematode as it acts as a resistant trap crop.

2. Resistant varieties:

Cassava:	"Malayan Dwarf", "Sree Prakash"
Sweet potato:	"Sree Bhadra", "Sree Vardhini" and "Sree Nandini"
Colocasia:	C-9, "Sree Rashmi"
Yams:	Dioscorea alata - "Sree Keerthi"
	D. esculenta - "Sree Latha"

IV. Nematode parasites of mushrooms

1. Incorporation of Neem cake @ 5% on w/w basis of compost at spawning time for the control of mushroom nematodes.

V. Nematode parasites of palms

Coconut

Nursery: Two application of Phorate @ 25 kg a.i./ha, one in September/Decermber and second in May/June in R. similis infested nurseries

Main field: Application of Phorate @ 10 g a.i./palm twice in a year during May-June and September-October

2. Tolerant varieties: Jawa Tall x Malayan Dwarf Yellow, San Ramon x Gangabondam, Jawa Giant x Kulasekharam Dwarf Yellow, Kulasekharam Dwarf Yellow x Jawa Giant

Arecanut

Tolerant varieties : VTL-11, VTL-17, Mahuva B, Andaman 5 and hybrid VTL-11 x VTL-17

VI. Nematode parasites of citrus and grapes

1. Growing onion/garlic in basin area of citrus is recommended for the control of Tylenchulus semipenetrans

2. Application of Neem cake @ 1 kg + Carbofuran 2 kg a.i./ha (basin area) at the time of initiation of flowering followed by light irrigation.

3. Basin area to be treated with Carbofuran @ 4 g a.i./tree just before flowering followed by light irrigation

4. Application of carbofuran @ 3 kg a.i./ha around the basin area just after the pruning is recommended for the control of root knot nematode on grapes

VII. Nematode parasites of Spices

Black Pepper

Main field: Application of Phorate @ 3 g a.i./vine
Soil solarisation followed by incorporation of VAM, Glomus fasciculatum multiplied on sorghum roots for 3 months at 15-20 g of chopped roots per kg soil.

Cardamom

Nursery: Carbofuran @ 0.5 g a.i./m^2 + soil solarisation followed by incorporation of 15 days old culture of Trichoderma harzianum multiplied on coffee husk @ 500 g/ bed size of 3 x 1 m.

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VIII. Nematode parasites of Betelvine

1. Application of Neem cake @ kg/ha + Carbofuran 0.75 kg a.i./ha alongwith NPK 150:100:50 for controlling M. incognita in new gardens and for existing gardens, neem cake or mustard cake at 2 ton/ha is recommended.

IX. Nematode parasites of Banana

1. Sucker treatment:

   (a) Hot water treatment for 20 min. at 55°C after removing the side roots

   (b) Paring followed by dipping the suckers with mud slurry/cowdung followed by sprinkling carbofuran @ 1.2 g a.i./sucker

   (c) Double paring followed by a dip in monocrotophos 40EC solution at 0.5% a.i. for 30 min. followed by shade drying for 72 hrs before planting

Crop rotation with paddy or sugarcane is recommended for the control of R. similis/Pratylenchus coffeae on banana.

X. Nematode parasites of ornamental crops

1. Application of P. lilacinus spore suspension at one litre per m^2 (10^6 spores/ml) with neem cake @ 1 kg/m^2 before planting is recommended for the control of root knot nematode on carnation and gerbera

2. Application of phorate @ 1 g a.i./plant 15-30 days after transplanting for the control of Pratylenchus delattrei on crossandra

Research priorities identified on Horticultural crops are as follows:

1. Since lot of work was carried out on root-knot nematode nematologists should try to concentrate on other nematodes viz. R. similis, Rotylenchulus reniformis, Pratylenchus coffeae, P. delatteri and Tylenchulus semipenetrans.

...7/-

2. The Chairman also suggested that the biology of Potato Cyst Nematode under Nilgiri condition may be taken up by Central Potato Research Station, Ooty.

3. Whenever Phorate or Carbofuran is recommended for the control of nematodes, residue analysis should be carried out. Therefore, application of pesticides should only be recommended when the products are free from residues below the detectable level.

4. Whenever work on Root knot nematode is carried out, the race status of the population should also be mentioned.

The following institutes/scientists were identified for proposing Cess Fund Scheme for ICAR funding on various horticultural crops:

Crop	Nematode	Institute/Scientist identified
1. Banana	1. *R. similis* 2. *Helicotylenchus muticinctus* 3. *Pratylenchus coffeae*	Dr.P.Sundararaju, NRCB, Trichy
2. Vegetables	*Rotylenchulus reniformis*	Dr.N.Nagesh, IIHR, Bangalore
3. Tomato, Chilli	"	Dr.S.P.Tiwari, JNKV, Jabalpur
4. Vegetables	"	Dr.S. Ray, OUAT Ludhiana
5. Tomato	"	Dr.P.K. Sakuja, PAU, Ludhiana
6. Betelvine	"	Dr.A. Acharya, OUAT, Bhubaneswar
7. Pointed gourd	*M. incognita*	Dr.A.C. Verma NDUAT, Faizabad

The following centres were identified to work on *Pratylenchus coffeae* on different crops:

Banana	NRCB, Trichy; IIHR, Bangalore, TNAU, Coimbatore
Ginger & Turmeric	IISR, Calicut
Citrus	NRCC, Nagpur; TNAU, Coimbatore

Turmeric	JNKV, Jabalpur
Potato	CPRS, Muthorai
Tuber Crops	CTCRI, Trivandrum

The Chairman requested Dr.P.K.Koshy, Head, CPCRI(RS), Kayangulam to submit a scheme on Development of Protocol for isolation, mass multiplication and field application for different bioagents viz. P. lilacinus, P. penetrans, VAM etc.

The work on Entomopathogenic Nematodes is to be at TNAU, CPCRI, HAU, JNKV and NRCB.

Dr.K.U.K. Nampoothiri, Director, CPCRI, suggested that the proceedings of this group meeting (including the articles) may be compiled and published as a Technical Bulletin of CPCRI.

Since plant parasitic nematodes are becoming more serious and are being observed to be wide spread in different parts of the country, it has been felt that there is a greater need to bring about awareness not only amongst the cultivators but also amongst the students in the Agricultural colleges and Universities. In this context, the group felt great concern at the recommendations of the Meeting of Deans of Agricultural Colleges of State Agricultural Universities held last at Hyderabad where Nematology Courses in undergraduate curriculum have not found any place. Therefore it was decided to bring this matter to the notice of the Director General and Deputy Director General (Edn.), ICAR with request to include atleast two compulsory courses in Nematology in the under-graduate curriculum which is being uniformalised by the ICAR for adoption at all State Agricultural Universities.

NEMATOLOGY GROUP MEETING ON HORTICULTURAL CROPS

PROGRAMME

16-1-1998 (Friday)

900 to 1000 hr : Registration

1000 to 1040 hr : Inauguration

Invocation

Welcome: Dr.PK Koshy, Head, CPCRI RS Kayangulam

Inauguration: Dr.RN Pal, Asst.Director General (PC)

Presidential Address: Dr.KUK Nampoothiri, Director CPCRI

Felicitations: Dr.Gopal Swarup, Retd. Prof. & Head, Divn.of Nematology, IARI

Vote of Thanks: Dr.VK Sosamma, Sr. Scientist

1040 to 1100 hr : Tea Break

1100 to 1315 hr : Technical Session I

Chairman : Dr. Gopal Swarup

Rapporteur : Miss J. Gulsar Banu
Dr.S.P. Tiwari

1. Nematode parasites of vegetable crops - Dr. Sharad Mohan
2. Nematode parasites of Potato - Dr.K.Krishna Prasad
3. Nematode parasites of Tuber crops - Dr.C. Mohandas
4. Nematode parasites of Mushrooms - Dr.M. Nagesh

1315 to 1415 hr : Lunch Break

1415 to 1530 hr : Technical Session II

Chairman : Dr.K. Krishnaprasad

Rapporteurs : Dr.S. Lingaraju
Dr.Sharad Mohan

1. Nematode parasites of palms - Dr.VK Sosamma
2. Nematode parasites of citrus & grapes - Dr.Bansa Singh
3. Nematode parasites of spices - Dr.KV Ramana
4. Nematode parasites of betelvine - Dr.Sadasiv Ray
5. A decade of Nematode Research under AICRP on Betelvine - Dr.Satyabrata Maiti

1545 to 1700 hr : Tea Break

Technical Session III

Chairman : Dr.Sadasiv Ray

Rapporteur : Dr.Nagesh
Mr. Santhosh J. Eapen

1. Nematode parasites of Banana - Dr.P. Sundararaju
2. Predominance of burrowing nematode, Radopholus similis in banana crop of M.P. and its impact on cultivars -Dr.SP Tiwari

17-1-1998 (Saturday)

930 to 1100 hr : Technical Session IV

Chairman : Dr.K.V. Ramana

Rapporteurs : Dr.Sudha Sukumaran
Dr.Bansa Singh

1. Nematode parasites of ornamental crops : Dr.M. Nagesh
2. Nematode parasites of Arid zone fruit plants : Dr.Nallathambi
3. Nematode parasites of Medicinal and aromatic plants : Dr.Rakesh Pandey
4. Studies on root-knot disease of tuberose caused by Meloidogyne sp. in northern Karnataka - Dr.S. Lingaraju

1110 to 1115 hr : Tea Break

1115 to 1315 hr : Technical Session V

Chairman : Dr.Gopal Swarup

Rapporteur : Dr.Rajeswari Sundarababu
Dr.P.K. Sakuja

Finalisation of package of practices for Integrated Management of Nematodes on various horticultural crops. Nursery treatments, treatment at transplanting, direct seeding (dosage, frequency of application of chemicals, method, time and dosage of application of bioagents in nursery and field).

1315 to 1415 hr : Lunch Break

1415 to 1700 hr : Plenary Session

Chairman : Dr.V.T. Markose, Director, Coconut Development Board

Rapporteur : Dr.R.K. Walia
Dr.G. Rajendran

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1. Session reports by Chairman of Sessions I to V.
2. Concluding remarks : Chairman
3. Vote of Thanks

18-1-1998 (Sunday)

Field trips to Burrowing nematode infested gardens in back water areas of Kuttanad.

List of participants

1. Dr.R.N.Pal
   Asst. Director General (Plantation Crops)
   Indian Council of Agricultural Research
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2. Dr.K.U.K. Nampoothiri
   Director
   Central Plantation Crops Research Institute
   Kudlu P.O., Kasaragod-671124, Kerala

3. Dr. Gopal Swarup
   Retd. Head
   Division of Nematology
   Indian Agricultural Research Institute
   New Delhi-110012

4. Dr.Bansa Singh
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5. Miss J. Gulsar Banu
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6. Miss D.Jayasree
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8. Dr.P.K.Koshy
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9. Dr.K.Krishnaprasad
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11. Dr.S.Lingaraju
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13. Dr.M.Nagesh
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17. Dr.K.V. Ramana
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18. Dr.Sadasiv Ray
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19. Dr.P.K. Sakuja
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20. Mr.Santhosh J. Eapen
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21. Dr.Sharad M. Srivastava
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22. Dr.Satyabrata Maiti
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