THREE DECADES OF NEMATOLOGY IN KERALA

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AICRP ON PLANT PARASITIC NEMATODES WITH INTEGRATED APPROACH FOR THEIR CONTROL

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Printed : **2012**

Contributors : **Scientists of AICRP (Nematodes)**
Three decades of Nematology in Kerala released during Biennial Workshop of AICRP held at AAU, Anand from 20-21 January 2012.

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Published by : **ICAR and KAU**

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Printed at : **Akshara Printers**
Vanchiyoor, Thiruvananthapuram

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PREFACE

The All India Co-ordinated Research Project on Plant Parasitic nematodes was started in Kerala Agricultural University in 1977 in the Department of Agricultural Entomology, College of Agriculture, Vellayani. In the initial stage, the centre carried out research on the association of plant parasitic nematodes on economically important crops of Kerala. The mission of the project is to enhance crop production through nematode management. The mandate of the project is to conduct co-ordinated trials for reducing crop losses caused by nematode pests and to demonstrate the nematode management technologies through on farm trials.

Apart from the designed co-ordinated trials, the centre undertakes nematological problems of local importance. Six projects were taken up with the aid of other funding agencies for solving the problems of farmers. Fourteen technologies developed were validated and included in the package of practices for adoption to the farming community. Post graduate research programmes were undertaken on Nematology. Twenty four students were awarded M.Sc degree and four were awarded Ph.D degree during this period. This publication on Three Decades of Nematology in Kerala covers the achievements in Nematology in the Kerala Agricultural University under the AICRP on plant parasitic nematodes for the last 30 years. It provides useful information to the research workers and extension personnels that will definitely help to plan future strategies in plant protection.

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Director of Research
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ACKNOWLEDGEMENT

I immensely thank the Project Co-ordinator (AICRP) for his keen interest and guidance for the preparation of this document. I specially thank our Hon'ble Vice Chancellor for the support given to carry out these research programmes. I also thank the Director of Research, Director of Extension and Dean, College of Agriculture, Vellayani for the help rendered. Thanks are also extended to all the former and present scientists of AICRP on Plant Parasitic Nematodes with integrated approach for their control.

4/1/2011

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Vellayani,
04-01-2012.

THREE DECADES OF NEMATOLOGY

INTRODUCTION AND HISTORY

Plant parasitic nematodes constitute an important group of pests in agro-ecosystems. The existence of this wonder group among animals was known even from antiquity. India's ancient history (Ray, 1986, 1992) and early Chinese literature bear testimony to this. Interestingly, most of the nematodes referred to in early history were the relatively large vertebrate parasites. Still, a few reports indicated that phytonematodes too were known in the early days.

The early developments in phytonematology were mainly confined to the temperate regions. In this topic, the science began with the description of nematodes from Oceania during the late nineteenth and beginning of the twentieth century. Cobb (1981) reported nearly 30 species of nematodes from rhizosphere and plant tissues of banana grown in Fiji and described new species like *Radopholus similis* and *Helicotylenchus multicinctus*. Treub (1885) and Van Breda de Hann (1902) identified *Meloidogyne javanica* and *Hirschmanniella oryzae* from Java, Indonesia. Nowell (1919, 1902) established the etiology of the red ring disease of coconuts in the Caribbean islands. Another finding in the early part of the century, which had a profound effect on Nematology, was the recovery of *Rotylenchulus reniformis* from the pineapple fields of Hawaii in 1935 (Luc *et. al.*, 1993). This led to the development of effective nematicidal soil fumigation in the early 1940's. Subsequently, Nematology laboratories were established in many subtropical and tropical countries like South Africa and India and work on nematodes gained momentum.

Nematology in India

Origin of phytonematology in India can be traced back to the report of Barber, the then Economic Botanist working at Coimbatore on root-knot nematode infesting tea in South India in 1901. Butler (1906) identified root-knot nematode

attack on black pepper in Kerala. Further, Dastur reported a disease in rice caused by *Ditylenchus angustus* in 1919. Reports of Ayyar (1926, 1993 and 1934) on *Meloidogyne spp.* infesting vegetables and other crops, Dastur (1936) on *Aphelenchoides besseyii* on rice and Jones (1961) on the golden nematode of potato, *Heterodera (Globodera) rostochiensis* from Nilgiris were other remarkable landmarks in the history of nematology in the country (Seshadri, 1986).

In spite of the early observations, organized research on plant parasitic nematodes started only in the early sixties. Several important developments led to the expansion of the science in India. Among these, the pioneering work on nematode survey and taxonomy by workers at Aligrah, Hyderabad and New Delhi, like Siddiqi, Jairajpuri, Das and Khan during 1959-65 not only laid sound and stable foundation for the growth and development of nematology in the country but also brought Indian nematology on the international map. Till date, 640 species of Tylenchids, 78 species of Aphelenchids, 72 species of Longidorids and 8 species of Trichodorids have been recorded (Bajaj, 1999). Reports of nematode damage to a variety of crops made by workers from time to time and the increased realization on the role of the nematodes in limiting agricultural production too contributed to the development of nematological studies. Twenty three species belonging to major genera like *Meloidogyne, Radopholus, Ditylenchus, Heterodera, Rotylenchus, Hoplolaimus* and *Helicotylenchus* were identified as important pests, causing 7.2 to cent per cent loss in several cash and life sustaining crops in India (Patel *et al.*, 1999).

Organization of the International Nematology Course at IARI in 1964 and the South East Asian Postgraduate Nematology Courses between 1967 and 1979 and initiation of nematology teaching in the State Agricultural Universities during the same period laid the foundation for nematological teaching in India. Establishment of the Nematological Society in India in 1969 and the starting of publication of the Indian Journal of Nematology together with the organization of a series of national symposia were instrumental in creating awareness on the relevance of the subject. The establishment of the AICRP on nematode pests of crops and their control at 14 centres

in 1977 strengthened the research activities in the country. Further, the nematological units were established in several traditional and Agricultural Universities and ICAR institutes and these institutions made significant advances in basic and applied nematology.

Now, when the nematological research in the country is more than a century old, the science has come a long way from its initial stage of hesistancy. Today, this branch of agricultural discipline stands at the threshold of a mega change, gearing to reap benefit from the molecular and computer oriented hi-tech research in tune with the present day trend.

Nematology in Kerala

The events that led to the origin of nematology in India marked the beginning of the science in Kerala too. Reports of root-knot nematode infesting tea (Barber, 1901) in Devala and pepper (Butler, 1906) in Wayanad paved the way for concentrated research on this pest. However, progress of nematological investigations in the state was slow for the next fifty years as has been in other parts of the country.

The establishment of the Agricultural College and Research Institute at Vellayani in August 1955 along with the report of E.G W. Jones in 1962 on the occurrence of *G. rostochiensis* on potato from Nilgiris kindled fresh enthusiasm in the study of nematodes. In 1964, late Dr. M. R. G. K. Nair, Professor & Head of Agricultural Entomology, College of Agriculture, Vellayani and Dr. K, Mathan, Principal Scientist, Central Plantation Crops Research Institute (CPCRI), Kayamkulam attended the First International Nematology course at I.A.R.I, New Delhi and subsequent report of the burrowing nematode, *R. similis* on banana by Nair and his team in 1966 had a far reaching effect impact.

An array of nematodes has been recorded from the rhizosphere of various crops in Kerala since the first report of the root-knot nematode. Despite the occurrence of several species in appreciable densities, only a few have emerged as important pests in the State. These include the root-knot nematodes, the burrowing nematode, the rice root-knot nematode, the cyst nematodes, the reniform nematode and the lesion nematode.

Root-knot nematode

Meloidogyne spp.

The root-knot nematode comprising of more than 60 species is universally acclaimed as the most important nematode pest of crops. Though more than 11 species are prevalent in India, *M. incognita* and *M. javanica* have the widest host range. In Kerala, *M. incognita* is wide spread and infests crops like vegetables (okra, brinjal, tomato, gourds, chilli and amaranthus), pulses, plantation crops (tea, pepper, ginger, cardamom and turmeric), tuber crops (cassava, sweet potato, colocasia, amorphophallus, coleus and yams like *Diascoria esculenta, D. alata* and *D. rotundata*) ornamental plants (jasmine, anthurium and orchids) and medicinal plants (*Piper longum, Kaempferia galanga*, *Plumbago rosea*, *Ocimum* spp., *Rauwolfia serpentina* etc). Besides *M. incognita, M. javanica* is known to infest cardamom and pepper. Recently *Trophotylenchulus piperis* and *M. graminicola* have been reported to infest black pepper and rice respectively.

Besides the direct damage caused to crops, the nematode infestation augments several diseases of plants. *M. incognita* is seen associated with the slow wilt disease of pepper and rhizome rot disease of ginger. The nematode also predisposes cardamom plants to *Rhizoctonia solani* infection, which causes damping off and rhizome rot in the primary nursery. On the contrary, root-knot nematode infestation enhanced in katte affected cardamom plants.

Burrowing nematode, R. *similis*

The burrowing nematode, *R. similis* that occurs in most of the tropical and sub-tropical regions of the world is one of the most destructive pests of crops with an extensive host range in India. The nematode causing typical lesions and rotting of roots is a major pest of plantation crops (coconut, arecanut and oil palm), spices (black pepper, cardamom, ginger and turmeric), betel vine, banana, ornamental plants (anthurium and orchids) and several medicinal plants in Kerala. It is also involved in the toppling disease of banana and slow wilt disease of pepper.

Rice- root nematode, *Hirschmanniella* oryze

The rice root nematode, *Hirschmanniella* sp. is a well recognized pest of rice. The migratory endoparasite that degenerates the normal functioning of roots is distributed throughout the world in about 46 rice growing countries including India. The species *H. oryzae* is one of the most important and early recorded nematode pests of rice field of the State occurring with a frequency distribution of 22 to 85 per cent and accounting for 5-19 per cent loss in yield. Besides the direct damage caused, infestation by the nematode predisposes rice plants to the sheath blight and sheath rot diseases.

Rice cyst nematode *Heterodera oryzicola*

The cyst nematodes are one of the most important and destructive nematode pests of agricultural crops all over the world. More than 75 species belonging to the genera *Heterodera*, *Globodera* and *Cactodera* have been recorded globally. Even though more than 20 species are prevalent in India, only three species viz., *H. oryzicola*, *G. rostochiensis* and *G. pallida* have been observed in Kerala.

The rice cyst nematode *H. oryzicola* was reported for the first time on rice in India from Palakkad district of Kerala. The nematode has been recorded from the paddy fields of all the districts in the state and accounts for drastic reduction in yield. Extensive cultivation of rice with presence of optimum conditions for development of the nematode in the state presents a potential danger to rice cultivation. The rice cyst nematode was reported from banana during 1984 from Marakkal, Thrissur district. The banana plants raised in reclaimed paddy field are also prone to infestation by the nematode. *G. rostochiensis* and *G. pallida* are important pests of potato.

Reniform nematode, *Rotylenchulus reniformis*

The reniform nematode, *R. reniformis* first detected and described by Linford and Oliveira in 1940. Ranks next to root-knot nematode, has been recovered from the rhizosphere of vegetables like okra, brinjal and cowpea, pineapple, banana, papaya, ginger, turmeric, tuber crops,

ornamentals and medicinal plants in Kerala. Yet, its infestation sets major hurdle only in the production of vegetables and cowpea in the State.

Root lesion nematode

Pratylenchus spp.

Universally, the root lesion nematode *Pratylenchus spp*. ranks high among the economically important nematodes on account of their ubiquitous distribution, wide host range, migratory endoparasitic nature and ability to cause damage in small numbers. Among 36 species reported from India, only *P. coffeae, P. indica. P. thronei* and *P. zeae* are of serious concern in the country.

The lesion nematode, *P. Coffeae* has been found associated with coffee, tea, ginger, turmeric, oil palm and tuber crops like cassava, sweet potato, yams, aroids and coleus in Kerala.

Realising the importance of nematodes as pests of crops and the urgent need for formulating suitable control measures, Nematology sections/ Divisions were established at Kerala Agricultural University (KAU), Central Plantation Crops Research Institute (CPCRI), Kayamkulam, Indian Institute of Spices Research (IISR), Kasaragod and Central Tuber Crops Research Institute (CTCRI), Trivandrum. The work carried out in these institutions accelerated the growth of Nematology in the State.

Systematic research work on nematodes of agricultural crops was initiated in Kerala Agricultural University consequent to the introduction of a scheme to establish a Nematology laboratory at College of Agriculture, Vellayani in 1965. Initial research efforts in the field unveiled several nematode problems in different crops. Decline symptoms observed in the orange plantations in the high ranges was diagnosed as the citrus decline caused by a semi-endoparasitic nematode, *Tylenchulus semipenetrans*. Root knot nematode attack was recorded in ginger, banana, pepper and pulses. A new disease of rice in the Kollam district was diagnosed to be the symptoms caused by white tip nematode, *Aphelenchoides besseyii*. Rice root-nematode, *H.oryzae* was recorded in serious proportions from different parts of the State.

In 1969, a separate section was created in Department of Agricultural

Entomology, College of Agriculture, Vellayani to streamline research activities in Nematology. Research on nematode was intensified with the formation of the Kerala Agricultural University in 1972. Random surveys were undertaken in different districts to identify the nematodes associated with various crops. The root-knot nematode, *M. incognita* was found infesting bhindi, brinjal, tomato, gourds and other vegetables, sugarcane, pulses, banana, pepper, ginger and cardamom; the burrowing nematode, *R.similis* infesting banana, sugarcane, pepper, ginger, coconut, cardamom and lemon grass; the root lesion nematode, *Pratylenchus spp.* infesting banana, rice, sugar cane and ginger; the spiral nematode, *Helicotylenchus spp.* infesting brinjal, pepper, bhindi, banana and ginger; the rice root nematode *H. oryzae* and the cyst nematode, *H. oryzicola* infesting rice and *Hoplolaimus spp.* infesting sugar cane, were some of the important nematodes identified during the period.

Increasing realization on the importance of the organisms as pest of crops led to the establishment of a centre of the All India Co-ordinated Research Project on Nematode Pests at Vellayani in 28-06-1977, financed by the Indian Council of Agricultural Research. Implementation of the project led to an upsurge in the research activities on plant parasitic nematodes.

The major objectives were

- To conduct co-ordinated investigations on important plant parasitic nematodes.
- To identify the nematode fauna with particular reference to economically important crops and to record their frequency of occurrence and develop State wise distribution maps of nematodes.
- To validate and document crop losses at varying nematode densities.
- To determine damage thresholds of economically important nematodes, population dynamics and nature of host parasite relationship.

- To evaluate the germplasm collections for their degree of resistance to nematodes.
- To develop economically viable and feasible methods of integrated nematode management practices.

The project continues to function in the Nematology section of the College of Agriculture, Vellayani. With the introduction of the National Agricultural Research Project (NARP) at the Regional Agricultural Research Station (Southern Region), Vellayani in 1982, location specific nematode problems were taken up with a view to assess the damage potential of nematodes in a multi-cropping system like homesteads and to generate suitable technologies to manage them. Detailed studies were conducted on the distribution pattern and seasonal population fluctuation of nematodes in different crop combinations and soil types.

2. STAFF POSITION

Designation	Name of Personnel	Period	
		From	To
Nematologist/ Associate Professor	Dr. T.S. Venkitesan	28-06-77	22-08-79
	Dr. K. John Kuriyan	23-08-79	05-09-83
	Shri. K.K. Ravindran Nair	01-12-83	02-06-92
	Dr. K. John Kuriyan	06-09-83	01-06-92
	Dr. P.B. Gopinath	02-06-92	25-06-92
	Dr. M.S. Sheela	26-06-92	till date
Asst. Professor	Smt. T. Nalinakumari	01-07-77	28-08-78
	Shri. Muraleedhara Prasad	07-08-78	28-08-78
	Smt. Suma Kuruvilla	07-08-78	25-08-78
		18-10-78	16-04-79
	Shri. Job Satyakumar Charles	28-08-78	09-07-80
	Smt. M.S. Sheela	17-04-79	14-03-82
	Smt. Ushkumari. R	19-07-82	31-05-86
	Smt. Jiji. T	01-09-90	20-03-94
		29-05-98	17-08-11
	Smt. Mercy J. Nedumpara	07-09-90	30-07-92
	Smt. Anitha. N	21-03-94	29-12-96
	Smt. Hebsybai	19-08-80	22-08-90
		12-08-92	06-06-97
	Shri. Arthur Jacob	23-06-97	08-09-98
	Smt.K.S.Prameela	09-09-98	14-12-00
	Shri. Krishna Kumar. R	20-01-97	10-04-97
	Dr. K.D Prathapan	15-11-00	21-08-11
	Dr.Nisha.M.S	18-08-11	till date
	Dr.Narayana.R	22-08-11	till date
Field/ Farm Asst	Shri.C. Brigidson	08-11-77	11-04-78
	Smt.B. Leela Bai	11-04-78	16-04-79
	Shri. R. Satheesan	17-04-79	29-04-82
	Shri. H. Gopinathan	18-01-83	18-08-86
	Shri. S. Prabhakaran	19-08-86	10-06-87
	Smt. K.S. Sujatha	11-06-87	09-05-89
	Shri. D. Sivaprasad	10-05-89	10-07-96
	Shri. K.S. Pratheepan	01-01-97	22-04-97
	Dr. Sharada.S	18-02-10	16-05-11
	Shri. Valsan. P.U	17-11-98	31-12-04
Lab Attender	Shri. N. Sreedharan Nair	08-02-78	12-10-81
	Shri. R. Sivanandan	22-04-82	30-04-87
	Shri. P. Thankayyan	01-05-87	30-04-95
	Shri. samkutty	01-07-95	11-11-95
	Shri. Suresh	30-08-06	4-12-09
	Shri. K. Jayakumar	24-05-10	till date

3. SIGNIFICANT RESEARCH FINDINGS IN THE LAST THREE DECADES IN THE AREAS OF:

3.1 Survey, documentation and occurrence of hot spot areas of economically important plant parasitic nematodes in the state.

Random surveys conducted in different crops have yielded valuable information regarding the occurrence and distribution of predominant plant parasitic nematode species associated with economically important crops. It is established that rice root and rice cyst nematodes are widely distributed through out the state and are important factors limiting paddy cultivation in Kerala. Similarly root-knot and reniform nematodes have been recorded in high densities from almost all vegetable growing situations. The burrowing nematode, lesion nematode, root-knot nematode and spiral nematode have emerged as major production constraints in fruit crops (banana) and spices like pepper, cardamom, ginger and turmeric. Further, occurrence of certain nematode species, which were previously recorded as merely associated with some plants in certain localized area are now found to have wider distribution and host range. Random surveys of aromatic and medicinal plant recorded the occurrence of burrowing and root-knot nematode and observed gradual spread of nematodes.

Paddy

Regular and systematic surveys of all the rice growing tracts located in various districts of Kerala State were done during the period from 1978 to 1994. Soil and root samples were collected from 1534 different locations in all the district of the state Thiruvananthapuram, Kollam, Alappuzha, Pathanamthitta, Idukki, Kottayam, Ernakulam, Thrissur, Palakkad, Malappuram, Kozhikode, Wayanad , Kannur and Kasargod. Rice root nematode, *H.oryzae* occurred in all paddy growing tracts in the state located in 14 districts and frequency distribution of 22 to 85 per cent. Minimum distribution was seen in Idukki (22 per cent) and maximum in Wayanad district (85 per cent).

Rice cyst nematode, *H.oryzicola* was present in 11 districts of the state, the frequency of distribution ranged from 5 to 35 per cent. The districts in which the nematodes seen were Thiruvananthapuram (17 per cent), Kollam (14 per cent), Alappuzha (5 per cent), Idukki (5 per cent), Pathanamthitta (14 per cent), Kottayam (5 per cent), Ernakulam (5 per cent), Thrissur (15 per cent), Palakkad (14 per cent), Malappuram (35 per cent), and Kozhikode (6 per cent). The other nematodes found attacking rice was *Helicotylenchus spp.*, *Tylenchorhynchus* spp., *Hoplolaimus*, *Criconemoides* spp, *Caloosia* spp., *Hemicycliophora* spp. and Aerolaimids.

Fruit Crops

Random survey for plant parasitic nematodes in fruit crops were conducted from 1978 to 1997 in crops like banana, pine apple, and papaya.

Banana

A state wide survey was initiated to estimate the nematode fauna in the rhizosphere of banana. The burrowing nematode, *R. similis* and the cyst nematode, *H. oryzicola* are the two widely occurring nematodes on banana and they are well distributed in Thiruvananthapuram, Thrissur, Kollam and Kottayam districts. The frequency of burrowing nematode ranged from 43 to 67 per cent and cyst nematode from 25 to 37 per cent. The other nematodes found attacking banana was *M. incognita, R. reniformis, Helicotylenchus spp., Hoplolaimus spp. and Tylenchorhynchus spp.*

Pineapple

Soil and root samples collected from the root zone of pineapple in different locations in Thiruvananthapuram and Kollam districts revealed the presence of reniform nematode, *R. reniformis* only and frequency distribution was 20 and 64 per cent respectively.

Papaya

Survey conducted at Thiruvananthapuram and Kollam districts recorded the occurrence of *H. multicinctus* and *R. reniformis* and their population ranged from 0-37 and 0-85 per 200g soil and the frequency distribution of the above two nematodes were 67 and 75 per cent respectively.

Spices

Results of the survey done in

different districts of Kerala yielded valuable information regarding the distribution and occurrence of predominant plant parasitic nematode species associated with ginger, *Zingiber officinale*, Roscoe and turmeric, *Curcuma longa* L. It is now established that root-knot and burrowing nematodes are important factors in limiting successful cultivation of spices in Kerala.

Ginger

Extensive survey of major ginger growing tracts located in eight districts of Kerala was done during the period from 1980 to 1997. Five hundred and three soil and root samples were collected from different locations in Thiruvananthapuram, Kollam, Pathanamthitta, Kottayam, Ernakulam, Thrissur, Kozhikode, and Wayanad districts. The results revealed that root-knot; burrowing and reniform nematodes were the predominantly occurring nematodes in ginger rhizosphere. The percentage frequency of occurrence of burrowing and root-knot nematodes in different districts ranged from 0-67 and 30-79 respectively. Seven more genera of plant parasitic nematodes namely *R.reniformis,Helicotylenchussp.,Pratylenchusspp, Tylenchorhynchus sp, H. indicus, Criconemoides sp* and *Xiphinema* were found in the rhizosphere of ginger in Kerala. Community analysis of three frequently occurring species namely *M. incognita, R. similis* and *R. reniformis* in ginger rhizosphere was done as per the method developed by Norton (1978). The analysis was done based on the data collected from five major districts namely Thiruvananthapuram, Ernakulam, Thrissur, Kottayam and Waynad. *M. incognita* had the highest prominence value (PV) and absolute frequency of occurrence (AF) in Ernakulam, Thrisssur, Kottayam and Wayanad districts. The PV ranged from 2071 to 7280 with an AF distribution of 40 to 100 per cent. The population data also revealed that *R. reniformis* too had high PV in Ernakulam, Thrissur and Wayanad district (1516 to 3907). However in the case of *R. similis,* PV was above 1000 only in Ernakulam district (PV-1039).

Turmeric

Regular and systematic surveys of major turmeric growing tracts were conducted from 1987 to 1997. Soil and root samples of turmeric were collected from different locations in Thiruvanathapuram, Kollam, Pathanamthitta, Kottayam, Ernakulam, Thrissur, Wayanad and

Kozhikode districts.There was predominant occurrence of root-knot and burrowing nematodes. In addition to these nematodes, three more genera namely *R. reniformis, Helicotylenchus sp.* and *Tylenchorhynchus sp.* were seen associated with turmeric. The community analysis of the three most frequently occurring species namely *R.similis, M.incognita* and *R.reniformis* collected from five major turmeric growing districts namely Thiruvanathapuram, Ernakulam, Thrissur, Kottayam, and Wayanad revealed that relative density (RD) of *M. incognita* ranked first followed by *R. reniformis* and *R. similis*. Density of *M. incognita* was very high in Thiruvananthapuram (94 per cent), Kottayam (92 per cent) and Ernakulam (77 per cent) districts. In Wayanad, *M. incognita* and *R. reniformis* were present in equal density. Generally RD of *R. similis* was low in the five districts.

The parameters, density and frequency convey limited meaning independently. But these two parameters can be related to give the prominence value (density x frequency = PV) which is of importance. Again *M. incognita* had high PV in most of the districts (Thiruvananthapuram-572, Ernakulam-1516 and Kottayam-523). *R. reniformis* had a high PV in Thrissur district (858). Compared to these two nematodes, PV of *R. similis* was low in five districts.

Aromatic and Medicinal plants

Extensive surveys of aromatic and medicinal plants were conducted in Thiruvananthapuram, Kollam, Kottayam, Pathanamthitta, Ernakulam, Thrissur, Malappuram and Kozhikode districts. Periodical survey conducted revealed the frequent occurrence of burrowing and root-knot nematode in sixteen economically important medicinal plants grown all over the state. The percentage distribution of burrowing nematode ranged from 50-100 in plants like *Justicia gendrusa, J. betonica* and *Holopeltia integrifolia*. The occurrence of root-knot nematode was very frequent in thirteen medicinal plants commonly grown in Kerala and their percentage frequency of occurrence ranged from 17 to 100.The host range studies were also conducted and the plants were categorized.

Among the forty two plants studied, 26 were recorded as susceptible to root-knot nematode, three were susceptible to burrowing nematode while ten plants

were found attacked by both root-knot and burrowing nematodes. They are *Cymbopogan flexosus*, *Piper longum*, *Ocimum spp.*, *Adathoda spp.*, *Aloe barbadensis*, *Coleus vettiveroides*, *Asparagus sp.*, *Rauolfia serpentina*, *Solanum indicum* and *Alpinia calcarata*.

Identification of hot spots

Paddy

Studies were conducted to identify hot spot areas of plant parasitic nematodes in different crops in Kerala during the period 2001-2006. Cyst nematode, *Heterodera oryzicola* was widely distributed in Kannur, Wayanad, and Palakkad districts. The hot spot areas identified were Pullari in Kannur, Karimbil, Kodenchery in Wayanad district, Alathur, Pattambi and Palamcode in Palakkad districts, Puttadi and Anakkara in Idukki district. In addition to cyst nematode, root knot nematode, *Meloidogyne graminicola* was also widely distributed in Kannur, Wayanad, Palakkad and Idukki districts. Hot spot area of infestation was identified as Perumpadavu in Kannur, Kodenchery and Tharuvana in Wayanad, Nenmeni, Alathur, Palmkode and Pattambi in Palakkad and Puttadi and Anakkara and Chettukuzhi in Idukki districts. Other predominant nematodes recorded were *Hirschmanniella oryzae*, *Helicotylenchus* sp. *Hoplolaimus* sp. and *Caloosia*. The survey conducted at Alappuzha district revealed that there was no hot spot area of infestation of rice root nematode, *H. oryzae*, rice cyst nematode, *H. oryzicola and root-knot nematode, M. graminicola* (fig 1).

Banana

H. oryzicola

The survey conducted revealed that *H. oryzicola* was uniform in Kasargod, Kannur and Wayanad districts, though the population was low in certain locations. The hot spot areas identified were Cheemeni and Kanhangad in Kasaragod, Kakkavayal and Kodenchery in Kannur, Pattambi and Althur in Palakkad districts respectively.

Based on the population level of *H. oryzicola*, seventeen locations were identified as hot spot areas. Cyst nematode was first reported from Thrissur district (Kannra) and it spreads to nearby district like Marakkal, Mannuthy and Ollur in the same district and then near by district like Ernakulam, (Kothamangalam, Asamannur), Palakkad (Alathur) and Idukki (Pampadumpara). It was then spread to other areas through banana suckers from Mannuthy seed farm, Pampadumpara horticultural farm etc.

Fig. 1 Hot Spot of Nematode Infestation

R. similis

Hot spot areas are confined to southern districts (Thiruvannthapuram and Kollam). This nematode was first reported from Vellayani and then spread to nearby areas. Hot spot areas were Balaramapuram (CRS), Kattakkada, Ottasekharamangalam, Palode, Cherunniyoor etc in Thiruvananthapuram district. In Kollam district the hot spot areas were Ethikkara, Anchal, Punaloor and Kottarakkara.

Pepper (*Piper nigrum*)

M. incognita

This nematode was reported to be widely distributed. The distribution was uniform in different districts except Malappuram, Palakkad and Kasargod. In these districts the area of pepper gardens are limited. Maximum damage of pepper garden due to *M. incognita* and slow wilt disease was observed in Wayanad, Idukki and Kottayam districts. The incidence of slow wilt disease was seen in Ernakulam and Pathanamthitta districts though no hot spot areas of infestation of *M. incognita* was seen in these districts.

Ginger (*Zingiber officinale*)

In ginger, *M. incognita* is the major nematode problem throughout the state. The infestation was severe in the southern and central region than northern zone. In Thiruvananthapuram district, the hot spot areas identified were Palode, Kilimanoor and Nanniyode. The cultivation in the wet land situation rotating with vegetables in these areas increase nematode population, hence this situation. In Kollam district the hot spot areas being Kulathupuzha, Nilamel, Kottarakkara and Karunagapally. In Pathanamthitta, Kottayam, Idukki, Ernakulam and Thrissur the cultivation was mostly in upland condition and hot spot areas were confined to that situation. Minor incidence of *R. similis* was noted in almost all the locations especially in root before the rhizome development. *R. reniformis* also noted in roots collected from Kulathupuzha and Wayanad areas.

Turmeric (*Curcuma longa*)

The survey data was scanty and confirmed to four southern districts only. Major nematode recorded in the rhizosphere was *M. incognita*. Three hot spot areas identified were Kattakkada in Thiruvanathapuram district and Kulathoopuzha and Madathara in Kollam district.

Kacholam (*Kaempferia galanga*)

M. incognita and *R. similis* are the major nematodes found in the rhizosphere of Kacholam. This is the most susceptible host for the above nematodes. The hot spot areas of infestation of root-knot and burrowing nematode were confined to Thrissur district (Herbal gardens in Thrissur, Marakkal, Pattikadu etc.)

Thippali (*Piper longum*)

M. incognita and *R. similis* were the major nematodes found in the rhizosphere of thippali. Most frequently occurring nematode was *M. incognita*. There were 13 hot spot areas of infestation of this nematode. The hot spot areas are confined to the herbal gardens in Thiruvananthapuram, Kollam, Kottayam, Thrissur, Palakkad, and Malappuram. The hot spot area of *R. similis* infestation was also located in the above district except Thiruvananthapuram. These four areas are the seed farms from where the seedlings were distributed to other areas.

Koduveli (*Plumbago rosea*)

M. incognita was the most frequently occurring species with eleven hot spot areas distributed in Kollam, Alappuzha, Pathanamthitta, Kottayam, Ernakulam, Thrissur, Palakkad and Malappuram district. Heavily root-knot infested areas are noticed in herbal gardens of Malappuram district especially Kottakkal and Mannarkadu herbal gardens of Kottakkal Aryavaidya pharmacy.

3.2 Impact of economically important nematode populations on crop health and yield losses.

Crop Loss

The retrievable yield loss due to important nematode pests on various crops like rice, cowpea, ginger and turmeric were assessed.

Paddy

Rice root nematode *H. oryzae*

Field trials were conducted to evaluate the yield loss due to rice root nematode, *H. oryzae* on rice during 1979 to 1983 in comparison with protected crop with carbofuran @1 kg a.i. /ha. Experiments in Kharif season were conducted in nematode infested field at Instructional Farm, Vellayani using the variety 'Triveni'.

An avoidable loss of 14 to 19 per cent in grain yield and 15 per cent in production of productive tillers was obtained during

Rabi 1979. In Kharif production of 7.9 to 22.5 per cent in weight of grain and 6.2 to 13.8 per cent reduction in the production of tillers. The trials conducted during 1983 showed a yield reduction of 5 to 19 per cent with same levels of population of *H. oryzae*. There was significant negative correlation (-0.9593) between nematode population in the root and yield of paddy.

Rice cyst nematode, *H. oryzicola*

The losses due to rice cyst nematode, *H.* oryzicola under microplot and field level were assessed during 1981 and 1983. The yield were compared with control plots maintained by the application of carbofuran granules @ 1 kg per ha at 7 and 50 days after transplanting.

An initial level of 210 to 426 *H. oryzicola* larvae per 200g soil sample showed adverse effect on the biometric characters and yield of the plant. The yield contributing biometric characters like root weight and productive tillers were reduced by 39 and 18 per cent respectively and these adverse effects were directly reflected on the yield of paddy (fresh weight of grain) to a tune of 19 – 43 per cent. There was a negative correlation of -0.370 between the soil population of *H. oryzicola* and average yield per plot and significant negative correlation (-0.464) between the number of cysts in the root and average yield per plant in protected crop.

When the experiment was conducted in the normal rice agro-ecosystem in farmer's field average loss of 20 to 26 per cent and 12 to 23 per cent in grain and straw respectively was reported. There was reduction of 15 to 17 per cent in plant height and 15- 16 per cent in productive tillers were also noticed.

Brinjal

Root knot nematode, *M. incognita*

Field trials were conducted to determine the extent of damage caused by root-knot nematode, *M. incognita* in brinjal. The avoidable yield loss was compared in with control plots treated with carbofuran @ 3 kg a.i/ ha. An avoidable yield loss of 20 and 22 per cent in terms of weight of fruits and number of fruits respectively was obtained at an initial population level of 248/ 250 g soil. The biometric characters like height of plants and number of leaves were reduced by 29 and 32 per cent

respectively.

Cowpea

Field trials were conducted to compare the yield of cowpea in infested and treated (carbofuran treated @ 2 kg a.i/ ha) field for estimating the avoidable loss in yield due to nematode infestation.

An initial field population of M. incognita (270 larvae per 200g soil sample) along with *R. reniformis* (273/200g soil) reduced the yield of pods by 33 per cent. When the population ranged from 117 to 413 the reduction in pod yield was 7.7 to 40 per cent (1993-95). Another trial conducted during 1995-97 revealed that an initial *R. reniformis* population of 78 to 196 per 200g resulted in a yield loss of 7 to 37 per cent.

Ginger

Root knot nematode, *M. incognita*

Field trial was conducted to evaluate the yield loss due to root-knot nematode by comparing the yield of ginger in infested plots and control plots treated with carbofuran @3 kg ai/ ha. An initial population of 166 *M. incognita* and 63 *R. reniformis* per 200 g of soil reduced the yield by 43 per cent (1991-93). When the trial was repeated during 1993-95, a yield loss of 11.5 per cent was reported at an initial population level of 345 *M. incognita* per 200 g soil. The experiments conducted during 1997 revealed that an initial population of 210 *M. incognita* larvae per 200 g soil sample resulted in an yield loss of 33 per cent. The yield loss of 5-62 per cent was obtained in different fields with initial population of root-knot nematode ranging from 89 to 365 / 200 g soil.

Turmeric

Root knot nematode, *M. incognita*

An initial population of 241 *M. incognita* per 200 g soil resulted in an avoidable yield loss of 33 per cent (1991-93). In 1993-95 showed that an initial *M. incognita* population of 237 per 200 g soil resulted in 20 per cent reduction in yield of turmeric. An yield loss of 22 per cent with an initial population of 201 *M. incognita* per 200 g was obtained in 1995-97.

3.3 Nematode management technologies developed, validated and included in the package of practices of the University against economically important nematodes for adoption by the farming community.

The following recommendations

for the control of plant parasitic nematodes were included in the State level package of practices of Kerala Agricultural University.

Rice

1. Nursery treatment with carbofuran @ 1Kg a.i. /ha and seedling root dip in 0.2% dimethoate for 6 hours before transplanting for managing rice root nematode.

Okra

2. Application of saw dust / paddy husk @ 500 g per plant, neem leaves/ eupatorium leaves @ 250g/ plant in the basins 3 weeks prior to planting and watering daily for managing rice root-knot nematode.

3. Application of neem / eupatorium @ 15t / ha two weeks before sowing for controlling root-knot and reniform nematodes.

4. Seed treatment with *B. macerans* @ 3 % W/W of seeds for the management of nematodes. Seed treatment with *B. macerans* @ 3 % W/W of seeds + drenching pits with 2% solution of the formulated product of *B. macerans* 30 days after sowing (concentrated starch solution may be used as sticking agents for seed treatment) in the endemic areas of root-knot infestation.

Brinjal

5. Nursery treatment with *Bacillus macerans* @ 25g/m^2+ drenching with 2% solution of formulated product of *B. macerans* 7 days after sowing for managing root-knot nematode.

Cowpea

6. The root knot nematode and reniform nematode associated with cowpea can be effectively managed by the application of neem and eupatorium leaves @ 15 t/ha, two weeks before sowing.

Banana

7. Paring banana suckers and dipping in hot water @ 55^{0}C for 20 minutes and application of neem cake 1 kg/ plant or carbofuran 0.5 g a.i/ha for the control of nematode complex in banana.

Ginger

8. Application of carbofuran @ 3.3g/m^2 or neem cake (200g/m^2) at the time of planting and neem cake (100g/m^2) 45 DAP in endemic areas of nematode infestation.

Pepper

9. Application of *B. macerans* @ 1.2X 10^8 cells/ vine just before monsoon period for controlling root-knot nematode.

Thippali (*P. longum*)

10. Application of (*P. fluorescens*) formulated product @ 5g / pit or carbofuran @ 0.5g/ plant at the time of planting of the rooted cuttings (10g/m^2)

Kacholam (*K. galanga*)

11. Rhizome treatment with *B. macerans* formulated product @ 3%W/W of seed material for managing nematodes.

12. Mulching with neem/ glyricidia/ clerodendron @ 5 kg/ m^2 30 days after planting.

Chethikoduveli (*P. rosea*)

13. Application of *P. fluorescens* 10 g/ pit at the time of planting for managing root-knot nematode.

Coleus

14. Deep ploughing of the field in summer (30-45 cm) and crop rotation with non preferred hosts like tapioca and sweet potato (var. Sree Bhadra) for controlling root-knot nematode.

Amorphophallus

15. Seed material treatment with *B. macerans* @ 3g/kg or *P. lilacinus* @ 3g/kg can be recommended for root-knot nematode management.

Research Highlights

a. Solarization of nursery beds was found as a highly effective technique for controlling nematodes in transplanted crops like brinjal, chilli, tomato.

b. Screening programmes for the identification of sources of resistance to root-knot nematode in okra, brinjal, tomato, chilli, pepper and ginger were undertaken and varieties with some degree of tolerance were identified.

c. Organic amendments like oil cakes of groundnut, castor, neem and mustard; soil conditioners like coconut husk powder, paddy husk powder, lemon grass waste, cashew shell powder and sugar cane bagasse; green leaves of mango, glyricidia, neem, clerodendron and eupatorium were identified to have either nematostatic or nematicidal properties.

d. Integrated nematode management strategies involving seed or nursery treatment, deep ploughing and application of granular insecticide in the main field were evolved for the control of nematode pests of okra and brinjal.

e. *Bacillus macerans, B. circulans, B. coagulans, B. subtilis, B. pumilis* and *B. licheniformis* were

isolated from root-knot nematode. First three bacterial antagonists were reported for the first time in India and later three were reported from Kerala for the first instance.

f. Techniques for mass multiplication of *B. macerans* and *P. lilacinus* have been standardized and formulations were developed for distribution to the farmers. The efficacy of a native isolate of *P. fluorescens* (Pf1) in controlling root-knot nematode too was established.

g. Among nematode antagonistic fungi, mycorrhizal fungi like *Glomus fasciculatum, G. etuniatum, G. constrctum, G. mosseae, G. monosporum* and *Acaulospora morroweae* proved potent in controlling root-knot nematode infesting cowpea, amaranthus, brinjal, pepper and ginger. Seven nematophagous fungi viz., *Alternaria alternata, Drechslera tetramera, Trichoderma viride, Syncephalastrum racemosum, Curvularia lunata, P. lilacinus* and *Beauveria bassiana were* identified as highly pathogenic to cyst nematode H. *oryzicola*.

h. Indigenous isolates of the entomopathogenic nematode *Heterorhabiditis spp*. was extracted from paddy soil and pests from different localities and established its potential in pest of paddy.

Host resistance

Host resistance is an essential component of integrated nematode management approach. The screening of available germplasm of different crops against important nematodes has yielded valuable information on sources of resistance in important vars/lines.

Tomato

The lines EC-490125 was highly resistant. The lines EC-490127, EC-25772, EC-16790, EC-3904, PAU-6 and PAU-10 were resistant to root-knot nematode, *M.incognita*. The tolerant varieties are Rossol, VFN-8, Phenni (Punuui 442), Campbell–25, Sonita, SL-120, F-38-E2, Kewalo, Anahu, Marsol, Martarum, Punjal NR- 7, Montabo, Ronita and Ace. The lines PAU – 1 (7-3-1-7), PAU – 2 (1-6-1-4), PAU- 3(3-6-3-1-7), PAU- 4 (8-2-1-2-5) and PAU -5 (2-1-2-4) were also found tolerant.

Okra

The varieties Pb-236, Arya Lakshmi, Pusa Savani, lines NBPGR-TCR-770, NBPGR-TCR-852, NBPGR-TCR-937, K-198370, K-198297, K-117297,

K-117300 and K-117314 were resistant to root-knot nematode. The tolerant varieties/ lines were IC-9857, IC- 9825, IC -9858, IC -22250, IC-27868, EC-16939, EC-169334, EC-169433, IC-169404, EC- 329371, EC-329369, EC-169357, IC-45836, IC-329364 and IARB-02.

Brinjal

The line IC-111023 was found to be highly resistant. Varieties/ lines viz. IC-285142, IC-249330, Round Br, IC-467273, IC- 136024, IC-249357, IC-24036, IC-90922 and IC-249387 were resistant. SM-258, SM-212, SM-253, Pant Samrat were moderately resistant. The tolerant varieties/ lines were 363- 14-16, type 3482-2-4-10, 12AAU- 14939, 480-13-1-2,449-1-8,555-8, Ghatika white, Maroo Marvel, SM- 6-7 and Pbr-91-2.

Chilli

The variety CO-4 was highly resistant and other varieties Indira chillies and C-DCL were found resistant to root-knot nematode, *M. incognita*. The tolerant lines were C- 70A, G-96-4-9-3-1, G- 82-2-1-3, CA-1068, CA- 2123, B-70-A, CA-2057, CA-2104 and CA-2210.

Mungbean

The tolerant varieties/ lines were ML-70, PIM5-2, PIM6, ML-x62, ML-3, ML-68, ML-80, PIM5-1, PIM 5-3 and PIM 5-4.

Pumkin

The tolerant varieties were Arka Chandran, Hyb-1, S-124 and CM-14.

Cucumber

ARC- 1 was moderately resistant.

Nursery bed treatment

Effect of nursery bed treatment together with seedling root dip by nematicides for controlling the rice root nematode was studied during 1978 to 1987. From the above trials nursery treatment with methamsodium (250 l/ha) + seedling root dip (0.2 per cent) with phenamiphos for six hours and nursery treatment with carbofuran 1 kg a.i/ha+ carbosulfan seedling root dip for half an hour is very effective. Effect of nursery treatment + main field treatment with nematicides in controlling rice root nematode, *H. oryzae*, were carried out during 1981 to 1987. Nursery treatment with carbofuran 1 kg a.i/ ha + main field application of carbofuran

1 kg a.i/ha at 50 days after planting effectively increased the yield of paddy (29 per cent) and reduced the nematode population (76 per cent).

Efficacy of different granular nematicides for the management of rice cyst nematode was tested in the field during 1982 to 1995. Screening trial was conducted with aldicarb, carbofuran, diazinon, phorate and ethoprop @ 1 kg a.i/ha. Application of carbofuran, phorate, aldicarb at 7 and 50 days after planting significantly reduced the nematode population both in soil and root which in turn increased the yield of paddy by 29 to 53 per cent. Application of carbofuran @ 1kg ai per ha at 7 and 50 DAP too effectively reduced the nematode population and increased the yield of paddy (1993-95).

Demonstration trial on integrated management of *H. oryzae* in rice by nursery bed and main field treatments with carbofuran in two locations revealed that highest yield was recorded by nursery treatment + main field treatment giving 21.7 and 14.6 per cent increase over untreated in location one and two respectively. Nursery treatment alone gave 5.34 to 13.35 per cent increase in those locations.

Demonstration trial conducted during 2003-05 revealed that the nursery bed treatment with carbofuran @ 0.3 g a.i. per m^2 and field application of carbofuran @ 1 kg a.i / ha at 45 DAT significantly increased the yield of grain and straw. Increase in yield of grain ranged from 5 to 18.5 q/ha in different locations. The additional income due to this treatment ranged from Rs 7950/- to Rs 15425/-per ha.

Efficacy of nursery bed treatment for the management of root-knot nematode, *M. incognita* was tested in field level during 1979 to 1987 with different types of nematicides at varying doses. In the first set of experiment carbofuran @ 0.4 g a.i per m^2 followed by aldicarb 0.4 g a.i per m^2 and metham sodium @ 25 ml per m^2 gave maximum protection of root-knot nematode in root and also significant improvement in yield. From the next two trials, it is seen that aldicarb 0.2 g a.i per m^2 recorded the same amount of protection of seedling and improvement in yield. Compared to other chemicals in reducing the nematode population in soil as well as root, aldicarb @0.2 g a.i/ m^2 was found sufficient.

Seed treatment

To evaluate the efficacy of seed treatment with nematicides and fungicides for the control of root-knot nematode on okra, field experiments were conducted during 1980 to 1985. The nematicides aldoxycarb, carbofuran, and aldicarbsulfone @ 3 per cent w/w and fungicides captol, carbendazim and thiram 0.2 per cent w/w were tested alone and their combinations. In the first trial aldoxycarb+ captofol gave maximum yield (65 per cent) and aldoxycarb + thiram showed maximum reduction in nematode population (89 per cent). When the experiment was repeated (1983 and 1984) carbofuran 3 per cent w/w + thiram gave maximum increase in yield (55 and 104 per cent in number and weight of fruit respectively) and maximum reduction in nematode population (91 and 79 per cent in root and soil respectively). Seed soaking with nematicides (oncol, marshal, dimethoate, dimecron and monocrotophos) @ 0.1 per cent for six hours showed that carbosulfan (0.1 per cent) reduced the gall formation (40 per cent).

Demonstration trial on seed dressing treatment on okra for the management of *M. incognita* revealed that seed treatment with carbosulfan @ 3%w/w increased the yield of bhindi. The incremental income in this treatment ranged from Rs.31, 941/- to Rs.81, 300/- per ha. In summer ploughed field along with seed dressing with carbosulfan (25ST) gave 51 per cent increase in the yield of bhindi fruits.

Cultural methods

Effect of nutrient management

Soil application of organic and inorganic fertilizers especially nitrogen on the management of rice root nematode was studied under field condition. Nitrogen was applied in organic form as ammonium sulphate and calcium ammonium sulphate and organic form as water hyacinth to give 60 kg of nitrogen per ha. The results indicated that application of water hyacinth gave maximum reduction in population of *H. oryzae* in the soil, 50 days after planting (34 per cent) and at harvest (14 per cent). This reduction in soil population was reflected on the grain yield of paddy (80 per cent increase over untreated).

Effect of crop rotation

Paddy

A field trial laid out to explore the potential of crop rotation strategy in

the management of rice root nematode *H. oryzae* in rice based cropping system. Seven cropping sequences were studied and in each sequence paddy was raised during the first and second crop seasons. During the third crop season other crops like daincha, green gram, groundnut, cowpea, sesamum and okra were raised. The results indicated that rotation with different crops and fallow reduced the population of *H. oryzae*. When the third crop was paddy and gradual build up of the nematode population was observed. Subsequently during the thrird crop season, when crops like daincha, green gram, groundnut, sesamum and cowpea were raised, nematode population was considerably reduced. Fallowing too was also effective. Paddy-paddy-okra rotation maintained the population of the nematode. Evidently daincha, green gram, groundnut, sesamum and cowpea are poor hosts of *H. oryzae* and they can be successfully used in third crop season for the management of *H. oryzae*

Vegetables

Crop rotation studies revealed that when bhindi and brinjal crops were raised in heavily root-knot infested field after sweet potato var. Sreebhadra, the population of nematodes in soil was reduced from 21 to 47 per cent and this reduction in population of nematode was reflected in the increase in yield of bhindi and brinjal crops to a tune of 21-22 per cent.

Management of root knot-nematode in vegetable based cropping system by adopting crop rotations/ cropping sequence revealed that in the first year rotation, the population of *M. incognita* ranged from 37 to 99 per 200g in various cropping sequences having trap crop as against 112 in susceptible check (okra- brinjal- okra) in the first year rotation. After the second year rotation *M. incognita* population was reduced to 73 to 106 in 200 g soil as against 143 in susceptible check. The average root-knot index in various treatments ranged from 1.2 to 2.0.

Effect of organic amendments

Effect of organic amendments viz., oil cakes of castor, mustard and neem for the management of root-knot nematode in brinjal was studied under field condition. The various method of application of the above oil cakes was also evaluated. Highest yield was obtained in spot application of neem cake in furrows (150g/furrow). Of the two methods of application of organic

amendments, spot application was found superior to furrow application.

Integrated nematode management

Brinjal

The combined effect of nursery treatment + cultural practices + spot application of nematicides revealed that maximum yield of brinjal was obtained in plants raised in methamsodium (25 ml sq.m) treated nursery, planted normally ploughed field with spot application of aldicarb @ 1 kg ai/ha. This was closely followed by deep ploughing + treated seedling + no aldicarb.

Combination of ploughing and exposure to sunlight for 15 days + treated nursery seedling gave significantly higher yield in brinjal (78 per cent increase in weight of fruits).

Nursery treatment + soil solarization revealed that root-knot nematode problem in brinjal can be effectively tackled at nursery level. Seedling raised in carbofuran treated nursery established well and were less prone to nematode infestation and boosted the yield by 32 per cent over untreated.

The effect of treatment of neem cake + granular nematicides was also studied under field condition. Aldicarb or carbofuran 1 kg ai/ ha + neem cake 200 kg/ ha was found to increase the yield of brinjal by reducing the nematode infestation.

Nursery treatment with carbofuran @ 0.3 g ai per m^2 + soil solarization for 15 days + application of neem cake @ 200 kg per ha was effective in reducing the nematode population and increasing the yield (above 90 per cent).

Demonstration trial on brinjal for comparing the effect of biological control agents of root- knot nematode, *P. fluorescens* and *G. fasciculatum* revealed that there was 13 and 20 per cent increase in yield due to above two bio agent respectively over untreated in location one and 7.8 and 23.44 per cent increase in location two respectively.

The trials on the biological control of root-knot nematode in brinjal revealed that the effect of all the bio pesticides was statistically on par. But carbofuran showed its superiority. Bio pesticide application improved the yield in comparison with the untreated. Maximum yield was recorded

in *P. chlamydosporia* giving 53.89 per cent increase over untreated. The incremental yield ranged from 19 to 24 q/ha with ICBR ratio 1:1.35 to 1:1.56. In the next season *T. harzianum* (cfu 2x 10^6) @ 2.5 kg /ha recorded the maximum yield with an yield increase of 15.4 per cent. This was followed by *P.chlamydosporia* (cfu 2x 10^6) @ 2.5 kg/ha which recorded an yield increase of 9.3 per cent.

Bhindi

The effect of *T. harzianum* only showed statistical superiority over the untreated. Maximum weight of fruits was recorded in *T. harzianum* followed by *P. lilacinus*. The effect of other treatments was not enough to get statistical significance. However, *T. harzianum* showed 43.23 per cent increase in yield over untreated and 25 per cent yield increase in *P. lilacinus*. The ICBR is high in *T. harzianum* (1:2.3). The nematode population in root and soil also showed reduction. Maximum reduction in *T. harzianum* (26.09) followed by *P. lilacinus* (23.21). From these two trials *T. harzianum* is the best treatment followed by *P. lilacinus* (Fig. 2).

Tomato

Integrated management of root-knot nematode in tomato by solarisation and addition of botanical materials revealed that under solarized condition the germination percentage was uniform and highest (97 to 100 per cent). There was drastic improvement in the vigour (weight) of seedlings ranging from 71.67 to 158.33 g in various treatments. Yield in terms of weight of fruits revealed that maximum yield was recorded in Ipomea leaf treated plot (410.79 g) followed by carbofuran (396.28g) and eupatorium (389.91g). Maximum reduction in nematode population in soil was recorded in carbofuran (63/200g) followed by sebufos (65/200g). Among the green leaves lowest value was recorded in eupatorium (77/200 g) followed by neem leaf (82/200g).

The effect of oil cakes on the yield of tomato and population of nematodes in root and soil showed that there is no statistically significant variation in solarized and non solarized condition. The yield in terms of weight of fruits in non solarized and solarized condition showed significant variation. Maximum weight was observed

in castor cake followed by jatropha cake and the effect of these two treatments was on par and even better than carbofuran. Number of fruits also showed same trend of results. The ICBR ratio in various treatments ranged from 1:4.5 to 1:5.2.

Bitter gourd

Among the oil cakes tested neem and jatropha cake are effective for the management of nematodes infesting bitter gourd. The studies revealed that application of various oil cakes in bitter gourd treatment improved the yield of bitter gourd to the tune of 28.14 to 80.45 per cent over untreated. In various treatment the yield ranged from 82 to 115 quintals per ha. The root-knot index was high (2.6). The ICBR in various treatments ranged from 1:2.5 to 1:3.12.

Cowpea

Efficacy of integration of pesticidal seed treatment with summer ploughing or deep ploughing and no ploughing for solarised and non solarised conditions respectively revealed that maximum pod yield was noticed in carbosulfan 3 per cent w/w seed dressing followed by carbosulfan 0.1 per cent seed soaking for 4 hrs in solarised and non solarised conditions. But these treatments were on par giving 69 and 63 per cent and 53 and 63 per cent increase respectively in both solarised and non solarised condition and these two treatments were statistically on par and superior to untreated.

Demonstration trials on the management strategies with seed treatment in cowpea against phytoparasitic nematodes (*M.incognita* and *R. reniformis*) revealed that seed soaking with carbosulfan 25 EC @ 0.1 % for four hours recorded maximum yield in two locations. The percentage increase due to this treatment was 22.5 and 47.4 per cent respectively. Seed dressing with carbosulfan @ 3% w/w also increased the yield (12%) in two locations.

Demonstration trial in farmers field on the management of phytoparasitic nematodes (*M. incognita* and *R. reniformis*) through botanicals and chemicals revealed that carbosulfan seed dressing @ 3%w/w was found superior to neem seed kernel powder seed dressing and seed soaking with nimbicidine (0.2%) and carbosulfan (0.1%).

Demonstration trial on management of phytoparasitic nematodes through botanicals/ chemicals revealed that

in cowpea, carbosulfan seed dressing was the best treatment followed by seed soaking with nimbicidine and carbosulfan showing an yield increase of 44.44, 36.11 and 19.44 per cent respectively (2003-04).

Demonstration trial on management strategies with seed treatment in cowpea against phytoparasitic nematode conducted during 2004-05 revealed that seed dressing with carbosulfan @ 3%w/w increased the yield of cowpea to a tune of 26.3 to 32.5 per cent in two locations. But seed soaking treatments gave 21-27.5 per cent increase in yield.

Integration of pesticidal treatment with summer ploughing/ deep ploughing in cow pea against *M. incognita* and *R. reniformis* conducted during 2004-05 revealed that maximum yield was recorded in carbosulfan 3% w/w seed dressing followed by carbosulfan 0.1% seed soaking for 4 hours in solarised and non solarised condition. These treatments showed 32.7 and 17.1 per cent increase in yield over untreated in summer ploughed plots and 38.67 and 33.77 per cent in non ploughed plots. Comparatively higher yield was obtained in summer ploughed plots than non ploughed plots.

Banana

For developing an integrated nematode management strategy chemicals, non chemical methods, cultural practices, organic amendments etc were combined. With this objective, experiments were conducted during 1989 to 1996. In the first set of experiments sucker treatments (paring + hot water treatment at 55°C for 20 min.) were compared with spot application of neem cake 1 kg/ plant and carbofuran @ 0.5 g ai per plant (16.6 g formulated product). In this experiment all the above treatment and their possible combinations reduced the nematode population on soil and root but the yield data did not show significant improvement. In the second set of experiments (1990-91 and 1991-92) phenamiphos 1 g ai/ plant (10 g formulated product) was added to all treatments in the first set at 90 days after planting. But this addition of nematicides did not have any significant effect on the reduction of nematode population in soil and yield. Though the attack of these nematodes in the root was significantly reduced it did not result in significant yield increase.

Studies conducted during 1991-1992 revealed that for sucker treatments

(paring + hot water treatment) together with application of neem cake or carbofuran was very effective in managing the nematode population in soil and root resulting significant improvement in the yield of banana (above 50 per cent increase over untreated). The effect of sucker treatments + neem cake + carbofuran and sucker treatments + carbofuran was on par in reducing the nematode population and increasing the yield of banana as observed in 1994-95. The pooled analysis of the data from 1991 to 1996 revealed the effect of sucker treatments (paring + hot water treatment) together with the application of carbofuran and neem cake alone in managing the nematode population in soil and root as well as increasing the yield of banana above 50 per cent. This two can be recommended for managing the infestation of *R. similis* and *H. oryzicola* in the field. The additional income computed to various treatments revealed that sucker treatment (paring+ hot water treatment) alone fetch an additional income of Rs.13 /- per plant, while addition of neem cake as basal dose (1 kg per plant) together with sucker treatment increased the income to Rs.19/- per plant and income due to application of phorate or carbofuran at basal or at 20 DAP along with sucker treatments ranged from Rs.14/- to Rs.19.6/-. Thus initial elimination of nematodes from planting material (sucker) is a prime component in an eco friendly and economic way of management of nematodes in banana.

A management trial in banana using bioinoculants revealed that *T. viride* showed maximum girth (35 cm) followed by *P.fluorescens* (34.160) and these two were statistically on par and better than untreated. The yield in terms of bunch weight also did not vary significantly. Maximum yield was obtained in *T. viride* (8kg) and it is not as effective as the chemical treatment carbofuran, but same as the standard check (paring + hot water treatment + carbofuran +neem cake). The nematode population in root showed that there was no added advantage in pit application of bioagents in sucker treated cases. Any one of the treatments (sucker treatment or pit application) is sufficient to reduce the nematode population. The yield in terms of bunch weight showed significant variation. Maximum yield was recorded in *Bacillus macerans* pit application (8.33 kg) followed by *B. macerans* sucker treatment (8.27 kg) and all other treatments were statistically on par and better than untreated, except

P. fluorescens pit application.

The experiments on management of root-knot nematode in banana by biocontrol agents showed that application of *T. viride* @ 2.5g / plant at the time of planting + 45 days after planting was very effective in managing the nematode population and increasing the yield and this treatment was on par with the recommended practice of paring + hot water treatment of suckers+ neem cake and carbofuran. But this treatment showed numerical increase over the biocontrol agent. The other characters also showed the same trend.

The experiments on biocontrol of root-knot nematode associated with banana revealed that application of *P. fluorescences* and *T. viride* as basal dose at 45 DAP increased the bunch weight to a tune of 23.79 to 26.62 per cent when compared to untreated. The single application of the above bio-agents at basal or at 45 DAP increased the yield from 10.3 to 21.96 per cent (2004-05).

Demonstration trial in the farmers field on the management of nematode complex on banana revealed that paring and hot water treatment of suckers at 55°C and application of carbofuran @ 0.5g ai/plant (16.5g) and neem cake (1 kg/plant) recorded highest yield in two locations. There was no added benefit on the application of neem cake in increasing the yield of banana.

The demonstration trial for the management of nematodes in banana revealed that paring + hot water treatment + carbofuran + neem cake increased the yield to a tune of 0.27 to 4.075 kg per plant accounting to an increase of 750 to 10187.5 kg/ha. The incremental income per plant also worked out and it ranged from Rs 5.4 to 73.35. Two demonstration trials were conducted in farmer's field during 2007-08. The results showed that the increase in yield of banana ranged from 2.2 kg to 3.75 kg/plant in paring + hot water treatment + Carbofuran + neem cake. The percentage increase ranged from 27.5 to 44. The ICBR is high in paring + hot water treatment + Carbofuran (1:5.1 to 1:6.1). The neem cake application is costly; hence the ICBR is low in paring + hot water treatment + Carbofuran + neem cake.

For the management of nematode associated with banana paring + hot water treatment + neem cake is effective followed by paring + hot water treatment + Carbofuran.

Ginger

To evolve a suitable integrated management strategy for the nematodes attacking ginger, field experiments were conducted from 1990-1997. The effect of neem cake and carbofuran alone and their combinations at various time of application for managing the nematodes associated with ginger were studied. The results of the two experiments revealed that neem cake 1 t/ ha at planting + carbofuran 1 kg ai/ ha at 45 DAP effectively controlled the nematode population in soil as well as in root and the effect of this treatment was on par with carbofuran alone treatment at planting. When the experiments were repeated for two more years the results confirmed that application of neem cake 1 t/ha at planting + carbofuran 1 kg ai/ha at planting+ neem cake 1 t/ ha at 45 DAP significantly reduced the nematode population in soil and root and also improved the yield of ginger. The pooled analysis of the data also showed that the two treatments involving combination of carbofuran (1kg ai/ha) and neem cake (1 ton/ ha) either applied basal or at 45 DAP decreased the *M. incognita* population in soil and root samples and this in turn improved the rhizome yield of ginger. These two were statistically on par and superior to other treatments.

1.4 Population dynamics and community analysis and behaviour of nematodes under different cropping systems.

1.5 Pest risk analysis.

Pest risk analysis data revealed that white tip nematode of rice *Aphelenchoides besseyii* was not detected from any of these paddy areas in the State. All the state seed farms in Kerala were surveyed for detecting the presence of this nematode.

Rice

In rice, pest risk analysis was carried out at seven locations viz., Puttadi in Idukki district, Alathur, Nenmeni, Nalleppalli, Perumattti in Palakkad district and Nemom, Ullamath in Thiruvanathapuram district.

In Puttadi an average loss of 1 ton per ha was recorded at population level of 214 *M. graminicola* / 200 g soil.

In Alathur an average loss of 1 ton per ha was recorded at a population level of *M. graminicola* 122 per 200 g and *H. oryzae* 71 per 200 g.

In Nenmeni an average loss of 0.5 to 1 ton per ha was recorded at population level of *M. graminicola* 217 per 200 g and *H. oryzae* 210 per 200 g.

In Nallepalli an average loss of 0.5 to 1 ton per ha was recorded at a population level of *M. graminicola* 275 per 200 g and *H. oryzae* 120 per 200 g.

In Perumatti an average loss of 0.5 to 1 ton per ha was recorded at a population level of *M. graminicola* 295 per 200 g and *H. oryzae* 29 per 200 g.

In Nemom an average loss of 1.5 ton per ha was recorded at a population level of *M. graminicola* 321 per 200 g, *H. oryzae* 121 per 200g and *M. incognita* 29 per 200 g.

In Ullamath an average loss of 0.75 ton per ha was recorded at apopulation level of *M. graminicola* 211 per 200 g and *H. oryzae* 121 per 200 g.

Banana

In banana, pest risk analysis was carried out at four locations, Chaikkottukonam, Chengal, Kalatharakkal and Palode in Thruvanathapuram district. In Chaikkottukonam a yield reduction of 3 kg per plant was recorded at population level of *R. similis* 122 per 200g, *H. multicinctus* 217/200g and *M. incognita* 43 per 200 g soil.

In Chengal a yield loss of 3-5 kg per plant was recorded at population level of *R. similis* 266 per200 g, *H .multicinctus* 217 per 200 g and *M. incognita* 29/200 g.

In Kalatharakkal a yield loss of 5-7 kg/plant was recorded at population level of *R. similis* 214/200g and *H. multicinctus* 398/200g.

In Palode a yield loss of 3-5 kg/ plant was recorded at population level of *R. similis* 327/200 g, *H. multicinctus* 328/200g and *M. incognita* 265/200g.

Bitter gourd

In bitter gourd, trials were carried out at Cheruvathoor, Karindalam of Kasargod district, a crop loss of 10-15 ton per ha was recorded at a population level of *M. incognita* 247/200g and *R. reniformis* 216/200g.

Pepper

In Pepper trial carried out at Ookode in Thiruvanthapuram district a reduction in yield of 30% was recorded at population level of *M. incog*nita 267/200g and *R. similis* 14/200g.

Yam

In yam trial carried out at Aakkulum in Thiruvanthapuram district, loss of 60% in seed material and 30% in field was recorded at a population level of 322 to 378/200 g soil of *scutellonema bradys*

4. SUCCESS STORIES

In Idukki and Palakkad districts of Kerala state, the nurseries of paddy during Kharif 2007 were badly affected by nematode together with *Helminthosporium* blight. Farmers unknowingly sprayed fungicides, but no recovery or rejuvenation of seedlings. Later it was diagnosed as infestation by root-knot nematode, *Meloidogyne graminicola*. Application of carbofuran @ 2 kg a.i/ha was recommended and 50 per cent of the nursery seedlings were saved by this. For the next season, application of neem cake @ 200g nursery was recommended before sowing as a prophylatic method. During Rabi 2008 and Kharif 2009 the infested plots were monitored and infestation level was low and below the economic injury level.

In Neyyattinkara, one of the prominent banana cultivated area in the state of Kerala, 75 per cent of total area was found heavily infested with burrowing nematode, *R.similis*. Toppling symptoms were observed in 10 per cent of the plant and remaining with small bunches having less than 5 kg. Since it is an organically cultivated area , application of *Pseudomonas fluorescens/ Bacillus macerans* @ 10g/ plant as pit application along with irrigation water and drenching with either of the above two (2 per cent solution) twice at 45 days interval was recommended. These treatments saved young plants in nematode infested area and got comparatively higher yield (9.5 kg/ plant as against 7 kg/ plant in sucker treatment (paring) alone (Fig 3).

In Palode area, red banana variety was heavily infested with *R. similis* (314 per 200g) and majority of plants (90%) were toppled with cent per cent damage. Remaining plants were seemed unhealthy with small bunches having 3 to 5 kg in weight. Crop rotation with tapioca and vegetables were recommended in heavily infested area.In areas having moderate level of infestation (*R. similis* 211/ 200g) on farm trials were conducted using bioinculants drenching, chemicals etc. and the plants are now in healthy condition (recovered infestation) (Fig 4).

In yams heavy infestation of yam nematodes *Scutellonema bradys* was found in

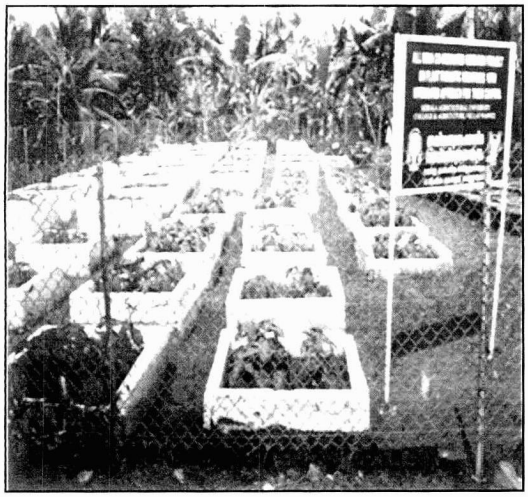
the fields as well as seed material on storage. The population ranged from 322 to 378 per 200g in different locations. Denematization and soil solarisation were recommended in small areas and in some areas seed material treatment with biological control agents like *Bacillus macerans* and *Trichoderma viride* were recommended.

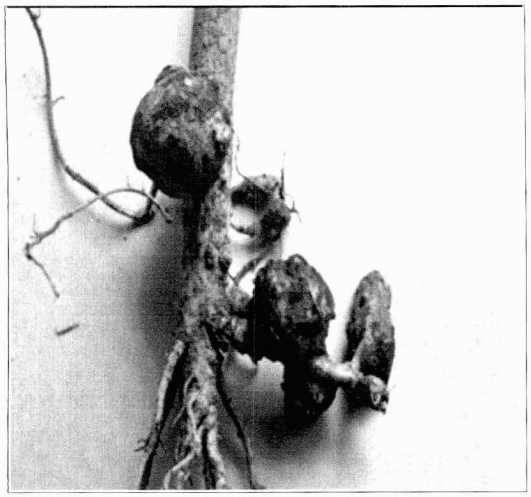
During Rabi 2009, in Nenmeni area of Palakkad District, paddy fields especially nursery was badly affected by rice root-knot nematode, *Meloidogyne graminicola*. Farmers were given awareness training on the early detection and management of nematode in nursery and also the advantages of crop rotation. Sample choice of non host crops (green gram, cowpea, black gram tapioca) suitable for the location was also made available. Some of them selected non host crops especially legumes and some farmers applied neem cake as prophylactic measure and 10% of farmers applied carbofuran 3 G @2 kg/ha before sowing seeds in nursery in infested area. The seedlings were well protected and transplanted area become free from nematode infestation by main field treatment with carbofuran @ 1 kg ai / ha. Thus the infestation of this nematode was contained in Palakkad District only. The paddy fields in neighbouring districts like Malappuram and Thrissur were monitored and were free from this nematode infestation.

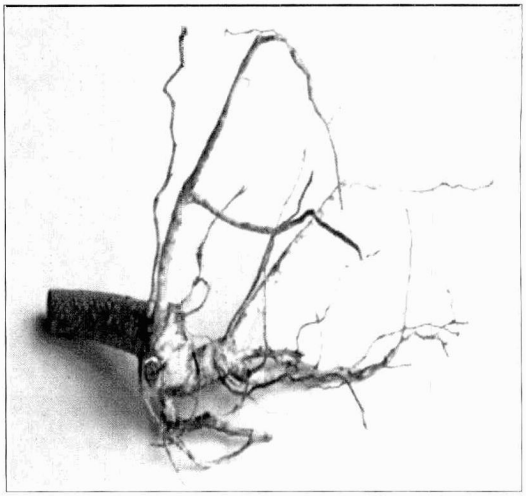
Pepper yellowing (slow wilt disease) was managed by the applicationof biocontrol agents viz *Pseudomonas fluorescens, Bacillus macerans* as evidenced in Fig 5, and infested plants in untreated area.

Paring + neem cake (fig 2, plate 4) application and crop rotation with tapioca also managed nematode infestation in banana. The sucker treatment like paring was adopted by seventy five percent of farmers growing nendran variety of banana susceptible to burrowing nematode, *Radopholus similis* was reported in 1965 by Nair *et al* from banana for the first time in India.

Pest risk analysis data revealed that white tip nematode of rice *Aphelenchoides besseyii* was not detected from any of these paddy areas in the state. All the state seed farm in Kerala were surveyed for detecting the presence of nematode.

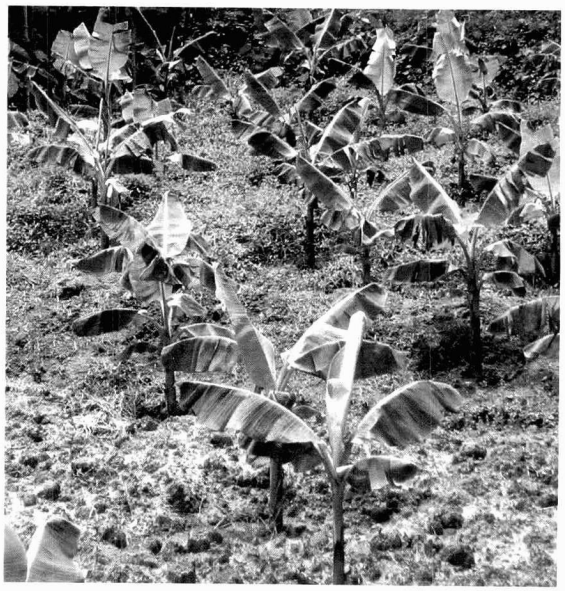






Untreated **Treated**

Fig. 2 Effect of *Trichoderma harzianum*(seed treatment + field application) on Bhindi (Okra)



Infested Banana

Treated Banana

Effect of paring suckers in banana

Toppling

Infested plant

Treatment

Recovered plant

Fig. 4 *R. similis* infestation in red banana and its management

Infested Pepper

Treated Pepper

Fig. 5 Management of *R. similis* infestation in pepper

5. NEWER PROBLEMS IDENTIFIED

White tip nematode of rice *Aphelenchoids besseyii* was reported from Kollam District of Kerala by Mamman et al (1979).

Rice cyst nematode, *Heterodera oryzicola* infestation on banana was first reported in Thrissur district in 1989 (Job Sathyakumar Charles and Venkitesan)

Five bacteria *viz Bacillus macerans, B. circulans, B. coagulans, B. pumilus, B. licheniformis* were reported as effective pathogens against root-knot nematode. The first three were first reported from India for the first time and later two from Kerala (Sheela and Venkitesan, 1990).

Emilia sonchifolia was identified as a new host of *M. incognita* (Nisha and Sheela, 2002)

Chethikoduveli *Plumbago rosea* was reported as a susceptible host of *M. incognita* in 2002

African coriander (*Eryngium foetidum*) was identified as a new host of *M. incognita* (Santhosh *et.al.*, 2004)

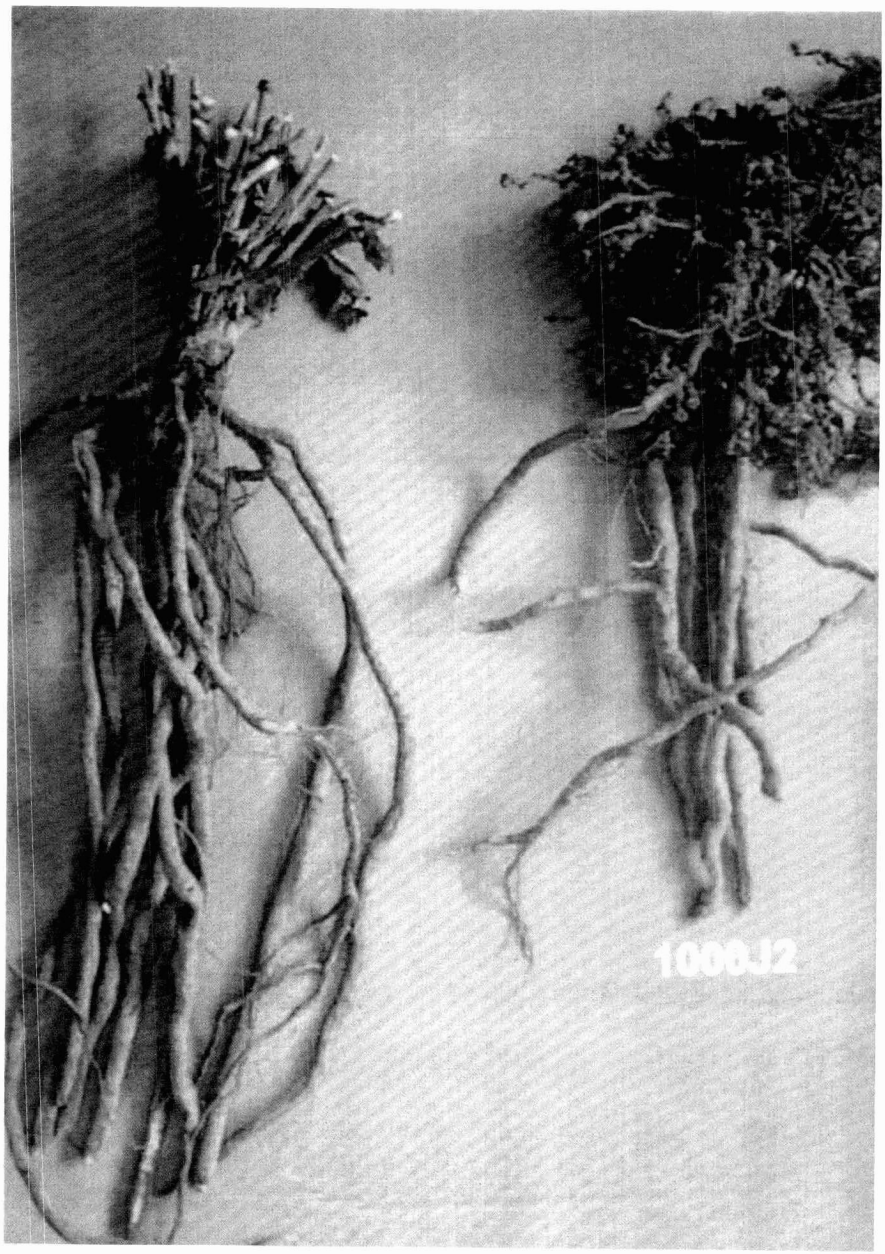
Rice root-knot nematode *Meloidogyne graminicola* was first reported in Kerala from Idukki district in 2005 (Sheela, *et al* 2005)

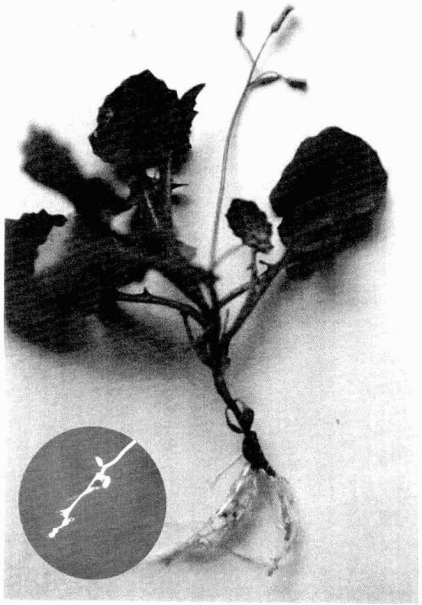
Yam nematode *Scutellonema bradys* was first reported from white yam in Kerala from Thiruvananthapuram district in 2008 (Sheela, *et al* 2008)

Meloidogyne graminicola infestation in Palakkad

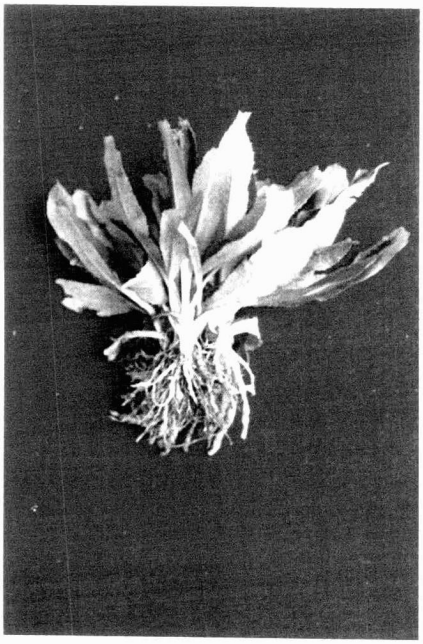
Radopholus similis infestation in multiple cropping system

Root-knot in *Plumbago rosea*

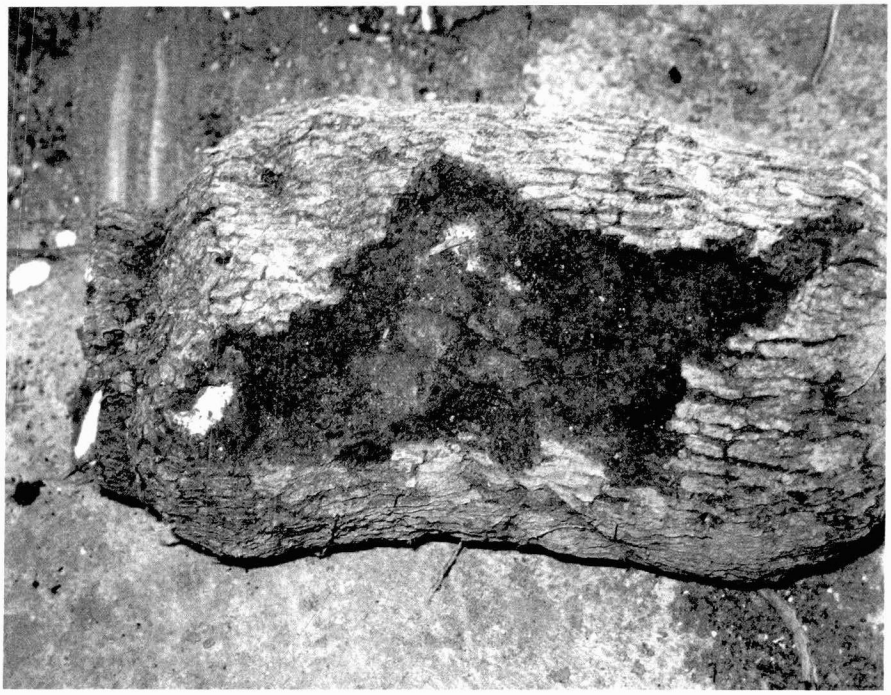


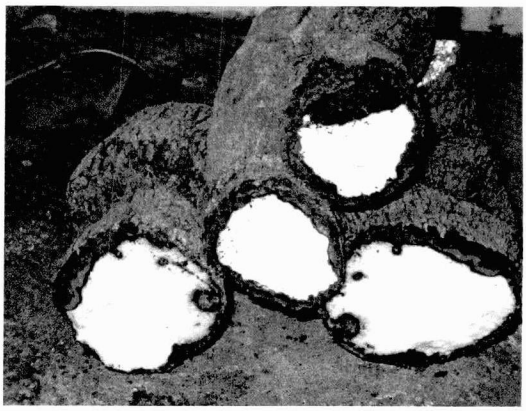


Root-knot infestation in *Emilia sonchifolia*



Root-knot infestation in *Eryngium foetidum*





Scutellonema bradys infestation in yam

6. TEACHING

Catalogue No.		Title of the Course	Credits	Course Teacher
PhD				
1	Ag.Ent.709	Insect Ecology	2+0	Dr.M.S.Sheela
2	Ag.Ent.710	Insect resistance to Plant	2+1	Dr.M.S.Sheela
3	Ag.Ent.715	Nematode morphology and taxonomy	2+1	Dr.M.S.Sheela
4	Ag.Ent.716	Nematode ecology and control	2+1	Dr.M.S.Sheela
M.Sc				
1	Ag.Ent.601	Insect morphology and physiology	3+1	Dr. Jiji.T
2	Ag.Ent.609	Pest and pest control	1+1	Smt.K.S.Pramila
3	Ag.Ent.612	Ecology and biology of soil invertebrates	2+1	Dr. Jiji.T
4	Ag.Ent.613	Plant Nematology	2+1	Dr. M.S.Sheela Dr. Arthur Jacob
5	Ag.Ent.614	Nematological techniques	1+1	Dr. Arthur Jacob and Dr. M.S.Sheela
6	Ag.Ent.501	Insect morphology	2+1	Dr. K.D. Prathapan
7	Ag.Ent.520	Plant Nematology	2+1	Dr. M.S.Sheela
8	Ag.Ent.502	Insect anatomy, physiology and nutrition	2+1	Dr. Jiji.T
U.G. Courses				
1	Ag.Ent.406	Non-insect pests and their control	1+1	Dr. M.S.Sheela and Dr. Arthur Jacob
2	Ag.Ent.304	Economic Entomology	2+1	Smt. K.S. Premila
3	Ag.Ent.203	Ecology and pests management	1+1	Dr. Jiji.T
4	Ag.Ent. 101	Fundementals of Entomology	1+1	Dr. Jiji.T
5	Ag.Ent.1101	Introduction to Entomology	2+1	Dr. K.D. Prathapan
6	Ag.Ent. 1201	Fundementals of Entomology	2+1	Dr. Jiji.T and Dr. K.D. Prathapan
7	Ag.Ent.4112	Introductory Nematology	1+1	Dr. M.S.Sheela and Dr. Jiji.T
8	Ag.Ent.3204	Plant Parasitic Nematodes, other non insect pests and their management	1+1	Dr. Jiji.T

7. EXTENSION ACTIVITIES

1. **Farm advisory work**:-The centre investigated the problem areas of Wayanad, Idukki and Palakkad districts for yellowing symptoms in paddy nursery and main field. Forty samples each were collected from above and the nematode population was estimated. Soil and root samples were also collected from nearby areas (recalaimed paddy land) for identifying the field problems. Nematodes identified were *Radopholus similis*, *Helicotylenchus* sp., *Meloidogyne graminicola*. *Rotylenchus reniformis, Hirschmanniella* sp., *Tylenchorhynchus* sp., and *Hoplolaimus* sp. The nematode population of *M. graminicola* ranged from 20-245, *R.similis* 6-113, *Hirschmanniella* 2-265, *Helicotylenchus* 60-325 and *Rotylenchus* 35-160 per 200g soil samples. The nematode population *Tylenchorhynchus* and *Hoplolaimus* were negligibly low. Proper management stratagies were recommended to the farmers. The root-knot nematode was first reported from paddy from these areas in Kerala. The same was reported in Indian journal of Nematology.

The yellowing symptom of paddy nursery was reported from the Director of Agriculture, Govt. of Kerala. Devastating syptoms are seen in Idukki and Palakkad district during October 2003 and February 2004 respectievely. Complete damage of seedlings in nursery was reported from 10 locations in Idukki district. During next season saved the seedlings in same area by proper management. The maladies were diagnosed as due to nematode infestation especially by *M. graminicola*. Proper management measures were also recommended based on the crop conditionbased on the availability of water and drainage facility.

A nematode infested banana plot in Chaikottukonam was visited; soil and root samples were collected and estimated the nematode population. An integrated management method was recommended and demonstrated. Paring and hot water treatment of suckers was demonstrated to VFPCK farmers in Perumbazhuthur and Chaikottukonam on 07-07-06 & 08-07-06 respectively.

Three samples received from pepper research station, Panniyur, Kannur district was processed for nematodes. Two samples

were heavily infested with burrowing nematode. Recommendation were given for the management especially with neem cake and *Bacillus macerans, during* January 2011

2. **Awareness to farmers:** Farmers were given awareness about nematode infestation on different crops by publishing articles in Malayalam in monthly publications namely "Kerala Karshakan" (Kerala Farmer). First one was published about nematode on spices, second on "Practical Application of EPN for the management of Insects associated with vegetables in Kerala", third one is on nematode problems in rice and fourth on nematode management in banana.

3. **Awareness to policy makers**: Nematological investigation in Kerala Agricultural University with special reference to biological control of nematodes and EPN for biological control of insects was presented in the Executive Committee of Kerala Agricultural University on 11-01-06. Discussions on policy interventions were held for development of nematology in Kerala.

4. **Sale of biocontrol agent**: Agricultural Production Commissioner, Government of Kerala, released the biological control agent (*Bacillus macerans*) effective against root-knot nematode in vegetables, spices etc. A packet was handed over to a progressive farmer in the presence of Director of Research, Kerala Agricultural University.

5. Demonstartion trial was conducted in the farmers' field to demonstrate various technologies to the farmer groups in Krishi Bhavans from 2001 to 2006 as detailed below;

a. Soil solarisation in brinjal nursery (2001-2003)

b. Paring and hot water treatment of banana suckers (2001-2003)

c. Nursery treatments of bioagents, *P. fluorescens* (2002-2006)

d. Seed treatment in bhindi with Carbofuran (2001-2006)

Demonstrated nematode management practices in banana (paring and hot water treatment) to the members of the farmers club of Naruvamoodu, Thiruvanathapuram district.

6. Agrifare: In connection with Agrifare 2007 organized by the College of Agriculture, Vellayani, farmer's seminars were conducted during 26th to 30th

Dr. M.S. Sheela served as the Convenor of the seminar committee. The details are as follows:-

a.	26-12-2007	-	Profitable technologies in rice production
b.	27-12-2007	-	Profitable technologies in coconut production
c.	28-12-2007	-	Profitable technologies in rubber production
d.	29-12-2007	-	Profitable technologies in vegetable production
e.	30-12-2007	-	Environment friendly cultivation practices.

December 2007.

7. Two CDs were prepared about the extension activities and research highlights of AICRP, in the name of "About nematodes and Nimavirakale ariyan" (Malayalam), and were released by Sri. K.R. Viswambaran IAS, Vice chancellor, Kerala Agricultural University on 11.05.2010 on the occasion of the inauguration of Biocontrol Laboratory. Shri. Mullakkara Ratnakaran the Minister for Agriculture and Dr. Sashi Tharoor M.P were also present on the occasion

Trainings organized

International

1. International refresher course on Participatory approaches for integrated crop management in tropical horticultural crops was jointly organized by Wageningen University and Research, The Netherlands and Kerala Agricultural University on 24th October - 4th November 2011 at Thiruvananthapuram. Dr. Sheela.M.S was the Course Director. Participants from seven countries *viz* Phillippines, Indonesia, Vietnam, Thailand, Egypt, Srilanka and India participated in the programme to analyze the integrated crop management and supply chains of selected horticultural crops for sustainable development of Horticulture.

Farmers training

1. Two batches of training of three days duration was organized to farmers at College of Agriculture, Vellayani on the "Diagnosis of nematode diseases and their management". Twenty five

and twenty three farmers each were participated in the training conducted during January 9-11, 2003 and February 22-24, 2004 respectively.

2. In connection with the DST project, organized two day training on nematode management on vegetables and banana was organized at Chaikkottukonam on 4th and 5th June 2008.

3. Trainings attended

International

Dr. M.S. Sheela, attended the International training on Integrated Pest Management and Food safety at Wageningen University and Research, The Netherlands fom May 21st to June 5th in 2007.

Dr. M.S. Nisha and Dr. R. Narayana attended International refresher course on Participatory approaches for integrated crop management in tropical horticultural crops organized by Wageningen University and Research, The Netherlands and Kerala Agricultural University fom 24th October to 4th November 2011 at Thiruvananthapuram.

National

Dr. M.S.Sheela attended national training on techniques on mass production of biocontrol agents for the management of pests and diseases on 1988 at TNAU, Coimbatore.

Dr. M.S. Sheela attended training on Instructional technology at ANGARU, Hyderabad on 13-19 June 2000.

Dr. M.S. Sheela attended training on prioritization of Agricultural research and impact analysis at NCAP and CARD'S at TNAU, Coimbatore on 8-12 October 2001.

Dr. M.S. Sheela and Dr. Jiji. T attended one week training on the integrated pest management in vegetables during September 2004 at NCIPM, New Delhi.

Dr. M.S. Sheela attended ten days training on 'Mass production of entomopathogenic nematodes at PDBC, Bangalore during November, 2004.

Dr. T. Jiji attended national training course on mass production technology of biocontrol agents at NCIPM, New Delhi on February 2008.

Dr. M.S. Sheela attended the meeting of module preparation of Rural Agricultural work Experience (RAWE) programme of B.Sc Hons (Ag) students. She also attended the research advisory council meeting of women scientist's cell of Kerala Council for Science Technology and Environment,

Govt. of Kerala.

Dr. M.S. Sheela attended training on pest risk analysis at IARI New Delhi for seven days in 2009.

Dr. T. Jiji attended training on the Identification of important plant parasitic nematodes, Department of Nematology, C.C.S Haryana, Agricultural University, Hisar, during May 2010.

Workshop organized

The XIII biennial workshop of the All India Co-ordinated Research Project on Nematodes was organized during 7-8 November 2005. Twenty five dignitaries and sixty Nematologists attached to various AICRP centers attended the same. Group leaders discussion was also organized on the 9th November 2006 to finalize the technical programme. For creating awareness on the programme publicity was given to All India Radio, print media, Kerala Agricultural University news letters. Workshop report and recommendations were published in Current Science.

Workshop attended

National

The Scientist of AICRP attended II to XIV Biennial workshop and group meeting conducted from 1981 to 2009.

Dr. M.S.Sheela attended the Grower-Industry Linkage of medicinal and aromatic plants conducted at Ernakulam on 12th and 13th December 2007 organised by AMPRS, Odakkali and Spices Board, Kerala.

Dr. M.S.Sheela attended the performance evaluation of AICRP's coming under plant protection co-ordination group at the College of Horticulture, Vellanikkara on 27th February 2008 and presented the research highlights of the AICRP(Nem).

Dr. M.S.Sheela attended the project advisory Committee meeting of Department of Science and Technology, Govt. of Kerala from 20th February to 2nd March 2008 at Madurai kamaraj University. The research highlights of the DST project was presented

Dr. M.S.Sheela attended National Seminar on Role of Women in Science- opportunities and challenges jointly organized by DST and KSCSTE and presented a paper on "Women in Agriculture"on 5 -2- 2009

Dr. M.S. Sheela attended a National seminar on climate and Development organized by Kerala Agricultural University, State Planning Board and Govt. of Kerala at Trivandrum from 29 to 30th June 2009.

Dr. M.S. Sheela attended a National Seminar on Promotion of Cultivation and Marketing of Medicinal plants organized by National Medicinal Plant Board on 18th and 19th July 2009 at Kanakakunnu Palace, Trivandrum.

All scientists of AICRP attended the ZREAC meeting of NARP southern zone on 30- 31st July 2009.

Seminar organized

National symposium on nematodes: A challenge under changing climate and Agricultural Practices was organized at Kerala Agricultural University from 16th -18th November 2011 at Kovalam. Dr. Sheela M.S acted as the local organizing secretary. Dr. Narayana and Dr. Nisha presented the research papers.

Seminar attended

International

Dr. M. S. Sheela, attended International Symposium on Technological advancement in banana/ plantation production and processing- India International at Kerala Agricultural University on 20-24 August 1996.

Dr. M. S. Sheela, attended *International Conference on Vegetables*, Nov. 11-14, 2002 IIHR and Indian Society of vegetable Science Foundation, Bangalore.p. 268.

Dr. M.S. Sheela, attended the Global Eco-meet- Prithvi 2005 on February 19th to 28th at Thiruvananthapuram.

Dr. M.S. Sheela, attended second International Rice Congress on 9 to 13 October 2006 at New Delhi.

Dr. M.S. Sheela, attended the XVI th International Plant Protection Congress at Glasgow Scotland from 15th to 18th October 2008 and presented one research paper.

Dr. M.S. Sheela, attended the Fifth International Congress on Nematology from 13th to 18th July, 2008 at Brisbane, Australia.

Dr. M.S. Sheela, attended the International Conference on Bio 2010 at Bangalore on 2nd to 4th June 2010.

National

Dr. M. S. Sheela, attended national seminar on strategies of Pest Management at IARI, New Delhi from 21 to 23, 1981.

Dr. M.S. Sheela and Dr. Hebsybai attended National conference on Epidemiology and control of rice diseases from 17 to 18 December 1982 at College of Agriculture, Vellayani.

Dr. M. S. Sheela and Dr. John Kuriyan

attended National conference on plant parasitic nematodes of India- Problems and progress at IARI, New Delhi on 17-20 December 1986.

Dr. M.S. Sheela and Dr. Hebsybai participated in National symposium on recent approaches on Integrated Management of Agricultural crops from 6th to 7th August, 1993 at CCSHAU, Hissar.

Dr. M.S. Sheela, attended Horti-National-95 at Thiruvanathapuram on 23-24 January, 1995

Dr. M.S. Sheela, attended National symposium on technological advancement in Rice production at Kerala Agricultural University from 17 to 19 June 1996.

Dr. M.S. Sheela and Dr. Jiji. T participated in National Congress on Centenary of nematology in India- Appraisal and Future plans at IARI, New Delhi on 5th to 7th December, 2001.

Dr. M.S. Sheela, participated in 12th Swadeshi Science Congress at CTCRI, Thiruvananthapuram on 5th to 7th November, 2002.

Dr. M.S. Sheela, attended symposium on Nema 100 Kerala on 21-22 February 2002 at CPCRI, Kayamkulam.

Dr. M.S. Sheela, participated in NATP Interactive workshop on IPM from February 26th to 28th 2003 at IARI, New Delhi.

Dr. M.S. Sheela, participated in National symposium on Paradigms in nematological research for biodynamic farming from 17th to 19th November, 2004 at GKVK, Bangalore.

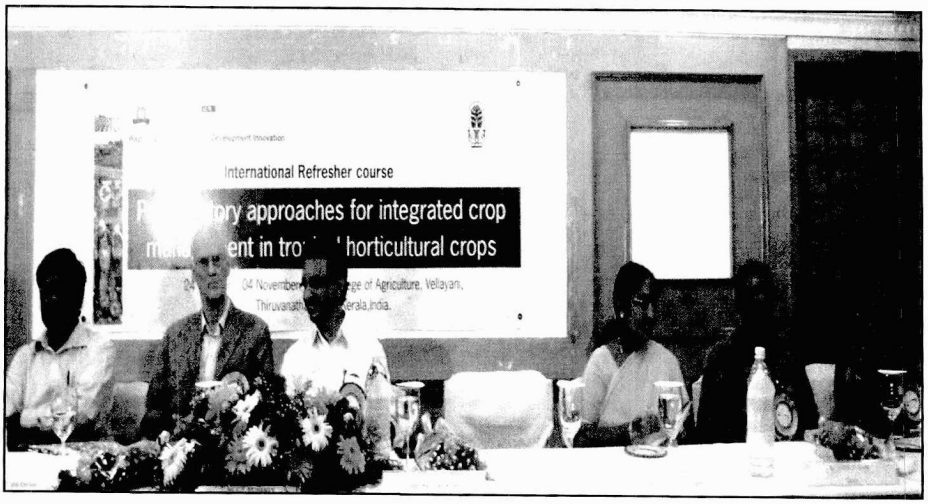
Dr. M.S. Sheela, attended the National symposium on green pesticides for insect pest management at Loyola College, Chennai 2005

Dr. M.S. Sheela and Dr. Prathapan. K.D. attended the National Symposium on Nematology in 21st Century: Emerging Paradigms from 22 to 23rd November at Jorhat 2009.

Dr. M.S. Sheela attended National conference on Innovations in Nematological Research for Agricultural sustainability – Challenges and a road map ahead from 23rd to 25th February, 2010 and presented two papers -Nematode menace in medicinal plants and efficacy of certain plants for the management of *Meloidogyne incognita* in okra.

International Refresher Course on Integrated Crop Management on Horticultural crops (24th Oct- 4th Nov, 2011)

Inaguration by Mr. K.P. Mohanan Minister for Agriculture on 24-10-2011



Farmers training on awarenes of nematode problems in vegetable and banana

National Symposium on Nematodes
16 - 18th November 2011

Biennial Workshop on Plant Parasitic Nematodes with Integrated Approach for their Control
5 - 7th November, 2005

Book release by Dr. M.S. Swaminathan

CD release by Dr. K.R. Viswambharan Vice Chancellor
Kerala Agricultural University

8. STUDENTS PRODUCED

Name	Title of the thesis problems
Ph.D Programme	
Job Sathyakumar Charles (1989)	Bio ecology and management of rice cyst nematode, *Heterodera oryzicola.*
Sheela. M.S (1990)	Control of root-knot nematode by bacterial pathogens.
Santhosh Kumar (2004)	Host Parasite Relation and Management of important nematodes associated with Chethikoduveli (*Plumbago rosea L.*)
Nisha. M.S (2005)	Integrated management of root-knot nematode, *Meloidogyne incognita* (Kofoid & White) chitwood in coleus, *Solenostemon rotundifolius* (Poir) Morton
M.Sc. (Ag) Programme	
Varghese. K.C (1967)	Studies on the nematode associated with banana in Kerala
Ramakrishnan Nair (1968)	Studies on the parasitic nematodes associated with vegetables in Kerala.
Ravindran Nair. K.K. (1969)	Studies on the population of soil nematodes in relation to certain chemicals and biotic factors in soil.
Varghese. P.C (1970)	Control of nematode parasites of brinjal with insecticide and nematicide granules.
Premkumar.T (1971)	Effect of some organic soil conditioners on the control of nematodes infesting bhindi.
Joseph. J (1972)	Effect of oil cakes on soil nematodes of bhindi in relation to fungal and bacterial flora and pH of soil.
Sumangalakutty amma (1975)	Studies on the effect of different soil types and inoculum levels of larvae on the development of *M. incognita* (Kofoid and white, 1919) Chitwood, 1949 on bhindi.
Arthur Jacob (1977)	Studies on the root-knot nematode of pepper (*Piper nigrum L.*)
Job Sathyakumar Charles (1978)	Studies on the nematode disease of ginger (*Zingiber officianale* Rosc)
Sheela. M.S (1980)	Investigations on the interaction of nematode infesting black pepper vine (*Piper nigrum L.*) and the fungus *Fusarium sp.)*

Ushkumari. R (1980)	Studies on the cyst nematode of rice in Kerala.
Susannamma Kurien (1980)	Control of root-knot nematode in brinjal
Hebsybai (1981)	Integrated control of nematode pest of bhindi with special reference to root-knot nematode.
Sathyanarayana. P (1984)	Pathogenicity of burrowing nematode (*Radopholus similis* (Cobb. 1893) Thorne 1949) on banana.
Kamalakshiamma. P.L. (1986)	Use of organic amendments for the control of root-knot nematode in brinjal.
Anitha. N (1988)	Effect of root-knot nematode *M. incognita* (Kofoid and white) Chitwood and reniform nematode *Rotylenchulus reniformis* (Lindford Oliveira) on cowpea.
Sosamma. P (1989)	Crop loss caused by root-knot nematode (*M. incognita* Kofoid) infesting *Coleus parviflorus and its control.*
Neelambaran. S (1989)	Crop loss caused by cyst nematode, *Heterodera oryzicola* infesting rice.
Rameshkumar.V (1990)	Nematode associated with the tuber crops in Kerala.
Ajith. K. (1992)	Effect of organic amendments on plant parasitic nematode and soil micro organisms.
Asha John (1997)	Photochemical and yam for management of nematodes in brinjal (*Solanum melongena*)
Rajani. T.S (1998)	Bio ecology and management of root-knot nematode, *M. incognita* (Kofoid and White) chitwood in Kacholam, *Kaempferia galanga* Linn.)
Nisha. M.S (2001)	Eco-friendly management of root-knot and burrowing nematodes associated with Kacholam, *Kaempferia galanga* Linn.
Remya. K.R (2007)	Potential of entomopathogenic nematodes for the management of weevil pests of banana (Musa sp.)

Research

Ph.D Thesis

Bio ecology and management of rice cyst nematode, *Heterodera oryzicola*.

The occurrence of rice cyst nematode, *H. oryzicola* infesting banana was first reported as part of a Ph.D research programme and detailed investigations were conducted. The studies revealed the biology, ecological requirements (soil type, pH and moisture) pathogenicity, extent of damage and loss caused by the nematode. An effective management strategy was also formulated. Host range studies conducted indicated that some common weed plants as favourable hosts of cyst nematode. Resistance screening trials of banana against rice cyst nematode was also taken up. None of the varieties were found completely resiostant to this nematode. (Job Sathyakumar Charles, 1989)

Control of root-knot nematode by bacterial pathogens.

The occurrence of six bacterial pathogens, *Bacillus macerans, B. circulans, B. coagulans, B. subtilis, B. pumilus* and *B. licheniformis* on root-knot nematode was reported for the first time in India as part of Ph. D research programme. The possibilities and potentialities of these bacteria were studied in detail. The distribution pattern in natural habitat, pathogenicity in different stages of nematodes like eggs and larvae were investigated. The pathogenicity studies in pepper plants @ 1.2 x 10^8 cells per pot significantly reduced the neamtode population in soil and root giving significant improvement in the length of vine, number of leaves, weight of shoot (fresh and dry) and root. Compatibility of the bacteria with commonly recommended pesticides were studied. Safety testing on higher animals revealed that it was highly safe to animals and birds. Another advantage of this bioagent as against the other bacterial pathogen available was its amenability to culturing in artificial media. Majority of the above *Bacillus* spp. can be grown in nutrient broth and sporulation takes place at room temperature. Techniques for mass multiplication of these pathogens in cheaper media were also developed for large scale adoption. (Sheela M.S, 1990)

Host Parasite Relationship and Management of important nematodes associated with Chethikoduveli (*Plumbago rosea L.*)

Experiments were conducted to ascertain the pathogenic level of the nematode, *Meloidogyne incognita* and their effects in loss in yield.

There was significant reduction in biometric characters at two and six months after inoculation onwards in the case of *R.similis* and *M. incognita* respectively. In the case of loss there was an avoidable yield loss of 43.96 per cent at 1000 J_2 level of *M. incognita* and 35.32 per cent in the case of *R. similis*. At 100 J_2 level the losses were 36 per cent and 29 per cent in *M. incognita* and *R. similis* respectively.

The histopathological studies revealed that the entry of second stage juveniles of *M. incognita* took place within five days. Hypertrophy and hyperplasia developed from 10 to 15 days at the surface of the root and they produce egg mass in gelatinous matrix. In the case of *R.similis* nematode entered the root and started feeding in the cortical region. Burrows were formed due to the disintegration of cytoplasm and coalescence of cells after 15 days of entry. The phenol production was increased with increase in initial inoculum levels in both the cases.

The field experiment on management of nematodes revealed that *G. fasciculatum* @ 20 g m^2 having 100 chlamydospores per gram of media was found the best treatment. In comparison with plants raised in denematised soil, effect of *G. fasciculatum*, *P. fluorescens* and carbosulfan were found better. The nitrogen and phosphorus contents were maximum in the leaves of *P. lilacinus* treated plants. (Santhosh Kumar, T. 2004)

Integrated management of root-knot nematode, *Meloidogyne incognita* (Kofoid & White) chitwood in coleus, *Solenostemon rotundifolius* (Poir) Morton

Crop loss studies conducted under microplot condition revealed that the yield attributing characters showed significant reduction at 100 J_2 level onwards (15.77 to 19.13 per cent) in coleus. Under storage condition tubers obtained from 5000 and 1000 J_2 inoculated plants started rotting and get deteriorated at 15 and 45 days respectively under storage condition.

Germination of tubers collected from 100 and 500 J_2 inoculated plants showed 42.37 and 47.47 percent reduction over the uninoculated. The biochemical changes of tubers collected from plants inoculated with different levels of *Meloidogyne incognita* revealed significant reduction in starch, sugar and crude fiber content. The percentage reduction being 6.32 to 33.33, 8.06 to 17.47 and 18.99 to 62.03 respectively as the population of nematodes increased from 100 to 5000 J_2. Amoung coleus cultivars, variety Sree Dhara performed better in reducing the multiplication of nematodes in soil, root and tuber, production of root-knots, females, egg masses and eggs per egg mass.

In integrated management, the selected treatments in the nursery and main field were evaluated using the resistant variety Sree Dhara. Based on the overall performance in reduction of nematode population (soil and root), the improvement of biometric characters and yield of coleus tubers, integration of soil solarization in nursery for 15 days using 150 gauge LDPE film and main field application of *P. lilacinus* ($15\ g\ m^{-2}$) in combination with either neem cake($100\ g\ m^{-2}$) or *B. macerans*($15\ g\ m^{-2}$) were the best treatment for recommendation in the integrated nematode management strategy of *S. rotundifolius*. This strategy, protected the crop against *M. incognita* and improved the per ha yield to the tune of 64.33 to 66.18 per cent. In addition to this, by reducing the nematode population in root (97.89 to 99.73 per cent), the quality parameters of tubers like starch, sugar and crude fiber content were also maintained. **(Nisha M.S. 2005)**

MSc Thesis

Studies on the nematode associated with banana in Kerala

The survey revealed the association of four genera viz., *Radopholus, Rotylenchus*, *Helicotylenchus* and *Criconemoides* in banana. Of these, *Criconemoides* was found only in the loamy soil tracts in rainy season. The genus *Helicotyienchus* was distributed in all the soil tracts, and in all the localities. The genus *Radopholus* was present in the Lateritic, clayey and clayey Loam soils and was widely distributed. (Varghese, K.C, 1967)

Studies on the parasitic nematodes associated with vegetables in Kerala.

A survey was conducted to ascertain various types of parasitic and non-parasitic nematodes associated with the important vegetable crops of Kerala. The parasitic forms found infesting various vegetable crops in Kerala were *Helicotylenchus, Hoplolaimus, Pratylenchus, Rotylenchus* and *Meloidogyne*. Of these *Hoplolaimus* and *Meloidogyne* do not infect the gourds namely bitter gourd and snake gourd. (Ramakrishnan Nair, N, 1968)

Studies on the population of soil nematodes in relation to certain chemicals and biotic factors in soil.

Soil samples were collected and analyzed to study the variations in the population of plant parasitic and non-parasitic soil nematode with reference to the chemical and biotic environments existing in soil.

The populations of both parasitic and non-parasitic forms were high in vegetable crops. This was followed in the descending order in soils of banana, coconut areca nut and paddy. The parasitic forms observed fall under 11 genera, *viz. Helicotylenchus, Meloidogyne, Hoplolaimus, Aphelenchus, Nothotylenchus, Pratylenchus, Criconemoides, Tylenchus, Tylenchorhynchus, Boleodorus* and *Hirschimanniella*.

The genus *Helicotylenchus* was found distributed in all types of soil in association with most of the crops. *Hirschmanniella oryzae* was observed only on paddy soils. The population of the parasitic forms was high in laterite soils, followed by black soil, red soil, and sandy loam. The population of the non-parasitic forms was maximum in black soil, followed by sandy loam, laterite, red and forest soils. (Ravindran Nair, K.K, 1969)

Effect of some organic soil conditioners on the control of nematodes infesting bhindi.

A field experiment was conducted to determine the effect of certain organic soil conditioners on the population of plant parasitic and non-parasitic nematodes associated with bhindi and on its growth and yield. All the organic substances suppressed the formation of root galls caused by *Meloidogyne* sp. significantly over the control. Plants receiving coconut oil cake yielded nearly eight times more fruits than

that of the control plants. (Prem Kumar. T, 1971)

Effect of oil cakes on soil nematodes of bhindi in relation to fungal and bacterial flora and pH of soil.

The field studies to acertain the effect of eight oil cakes and two nematodes on the fungal and bacterial flora of soil, soil reaction and on the population of the parasitic and non-parasitic nematodes of bhindi were take up. The oil cakes encouraged the growth of fungal and bacterial populations as well as the population of non- parasitic nematodes. However, the treatments with oil cakes suppressed the population of *Meloidogyne sp.* and *Helicotylenchus sp* equal to that of D,D- mixture and Nemagon.

The pH of the soil was significantly and positively correlated with the parasitic and non-parasitic forms of nematodes within the range of 4.9-5.6. The population of the parasitic nematodes in soil was negatively correlated with that of the bacterial population. (Joseph. J, 1972)

Studies on the effect of different soil types and inoculum levels of larvae on the development of *M. incognita* (Kofoid and white, 1919) Chitwood, 1949 on bhindi

Among the six different soil types, forest soil and sandy loam soil were found ideal for the development of the root knot nematodes *M. incognita*. However, the development was poor in black soil.

The pH of the soil was found to affect the nematode development. Soil with high pH and electrical conductivity was not favoured by the root knot nematode. Predominance of clay silt and fine sand fractions of the soil was also found to retard the development of *M. incognita*.

Forest soil having comparatively high fertility status with moderate pore space, water holding capacity, acidity and high amount of organic matter was most favourable for the development of *M. incognita*. (Sumangalakuttyamma.S, 1975)

Studies on the root-knot nematode of pepper (*Piper nigrum L.*)

Eight cultivars of pepper were screened against *M incognita* and found that Panniyur 1 and Cheriakanikandan were highly susceptible. Kalluvally, Kottanadan, Balancotta and Karimunda were susceptible and the varieties Narayakodi and Padappan were less susceptible. Histopathological studies showed that the starch grains were

more or less depleted in the case of affected plant roots,

Dasanit 5G 60 kg ai/ha. mocap 10 G-10 kg ai/ha, Nemagon 60 EC-40 lit ai/ha, Temik 10 G-10 kg ai/ha and Neemcake 2000 kg/ha, gave good control of this nematode. Nemagon recorded the best result. (Arthur Jacob.J, 1977)

Studies on the nematode disease of ginger (*Zingiber officinale* Rosc)

A survey of Plant parasitic nematodes associated with ginger revealed that root-knot nematode *M. incognita was* the most important nematode affecting this crop, followed by *R. similis, Pratylenchus* and *Helicotylenchus.* Twenty varieties of *Z.officinale* were screened against *M.incognita.* Burdwan, Uttar Pradesh and Thodupuzha varieties were highly susceptible (11 to 15 galls per g root). China, Karakkal, Assam, Sierraleone, Rio-de- Janeiro, Maran, Tafengive, Taiwan, Nadia, Ernad, Manjeri, Thinladium, Ernad, Chernad, Tura, Bajpal and Thingpuri varieties were moderately susceptible (4 to 10 galls per g root). Valluvanad and Himachal Pradesh varieties were least susceptible to the attack of *M. incognita* with three galls per g root. (Job Sathyakumar Charles, 1978)

Investigations on the interaction of nematodes infesting black pepper vine (*Piper nigrum L.*) and the fungus, (*Fusarium sp.*)

Studies were undertaken to ascertain the effect *M.incognita, R.similis* and *Fusarium sp* individually and in various combinations of pepper vines exhibiting slow wilt symptoms.

The results revealed that combining *Fusarium sp.* with *M incognita* did not increase the growth retardation of the plants over that caused by nematode alone. But the progress of the fungus infection was higher when the fungus was combined with the nematode. This could be attributed to the fact that the nematode was providing suitable situation for easy infection by the fungus which was a secondary invader. The same type of interaction was observed with *R.similis* also (Sheela M.S, 1979)

Studies on the cyst nematode of rice in Kerala.

The extent of crop loss caused by cyst nematode *Heterodera oryzicola* at different levels of inoculum in rice variety, Triveni was estimated. The extent of damage caused to the crop progressively increased with the increase of inoculum levels of

6,000,9,000,12,000 and 18,000 larvae per m^2. In field experiment and 5, 10, 20 and 30 cysts per pot in pot culture experiments. In the host range studies, out of the 14 weed plants found in paddy fields only *Ehinochloa colonum* (Linn.) Link, was found as host. (Usha Kumari, R. 1980)

Control of root-knot nematode in brinjal

The effect of nursery treatment with four nematicides *viz.* DBCP, aldicarb, carbofuran and metham sodium in the control of root-knot nematode *M. incognita* in brinjal seedlings and their subsequent performance in the main field was investigated. Maximum control with increased yield was obtained by the use of carbofuran 0.4 g/m^2 followed by aldicarb 0.4 g/m^2 and metham sodium 25 ml/m^2 in the main field. (Susannamma Kurien, 1980)

Integrated control of nematodes of bhindi with special reference to root-knot nematode

A field experiment was undertaken to ascertain the effect of the treatments, deep ploughing, seed treatment with carbofuran and aldicarb treatment in soil, when applied individually and in combinations on the control of the root-knot nematode *M.incognita* infesting bhindi.

Results indicated that deep ploughing by itself was effective in reducing galling of the roots by the nematode and increased yield by 33 per cent. (Hebsy Bai, 1981)

Pathogenicity of burrowing nematode (*Radopholus similis* (Cobb. 1893) Thorne 1949) on banana.

Pathogenicity of the burrowing nematode, *R. similis* on banana was studied with three levels of population viz.1000,10,000 and 1,00,000 nematodes at five different growth stages of the crop starting from 45 days after planting and with 45 days interval. A reduction of 36.84 per cent was seen in the yield of plants inoculated earlier with 1,00,000 nematodes and as high as 60.52 per cent reduction in weight of the roots in the plants inoculated with 10,000 nematodes.

Nematode population was found to reach its peak during the flowering season of the plant and decreasing thereafter. The multiplication of nematode was observed to be inversely proportional to the initial inoculum level. Even 1000 nematodes at

active growth stage was enough to cause severe reduction in the plant growth and yield. (Sathyanarayana,P. 1982)

Use of organic amendments for the control of root-knot nematode in brinjal.

The field experiments for evaluating efficacy of oil cakes and organic waste for the control of root-knot nematode infecting brinjal revealed that nematode population in root and soil was significantly reduced by the application of oil cakes(neem cake and mahua cake @ of 500 kg / ha) and organic waste (saw dust and coconut husk powder @ 2500 kg / ha). (Kamalakshi Amma, P.L. 1986)

Effect of root-knot nematode *Meloidogyne incognita* (Kofoid and white) Chitwood and Reniform nematode *Rotylenchulas reniformis* (Lindford Oleveira) on cowpea.

Experiments were laid out to study the individual and combined effect of *M. incognita* and *R. reniformis* on cowpea. The results indicated that at initial inoculum levels of 100, 200, 400 and 600 larvae 100/ml of soil of the two nematodes, *M.incognita* and *R. reniformis* exerted severe damage on cowpea. The higher inoculum levels of 800 and 1000 larvae per100 ml soil did not show any progressive increase in crop loss. In the combined inoculation of the nematodes, an inoculum level of 400 *M. incognita* followed by 400 *R. reniformis*/ 100 ml soil 15 days later exerted and highly deleterious effect on cowpea. (Anitha, N. 1989)

Crop loss caused by cyst nematode, *Heterodera oryzicola* infesting rice.

The incidence of *H. oryzicola* was observed in soils and roots of rice from the fields of 21 panchayats of Trivandrum District. The nematode was present through out the season in the soils and roots of paddy, the highest population in Rabi and lowest in Puncha season. Their population builds up between rice varieties differ significantly, the highest in long duration and lowest in the short duration varieties. The nematode population also varies with soil types. Maximum in sandy loam and minimum in clayey soils. (Neelambaran, S. 1989)

Effect of organic amendments on plant parasitic nematode and soil micro organisms.

Field experiments were conducted to evaluate the effect of neem and

eupatorium leaves at two levels on plant parasitic and non- parasitic nematodes and soil micro- organisms in the root zone of bhindi and cowpea in rainy and summer seasons respectievely. The results revealed that neem and eupatorium leaf treatments (300 g/ plant or 15 t/ha) were found effective in controlling *Helicotylenchus spp.*, *R. reniformis* and *M incognita* in the root zone.

The predatory and saprophytic nematode population build up in the root zone was enhanced by higher dose of eupatorium. The microbial populations (bacteria, fungi and actinomycetes) were increased in the root zone of bhindi and cowpea in two seasons by the application of eupatorium leaf at higher dose where as neem leaf reduced the microbial population. The biometric characters and yield of bhindi and cowpea increased significantly by higher dose of neem and eupatorium leaf. The population of nematodes in the roots at the termination of experiment was significantly reduced by the higher dose of neem and eupatorium in bhindi while lower dose was found effective in protecting cowpea roots. (Ajith, K 1992)

Phytochemicals and VAM for the management of nematodes in brinjal (*Solanum melongena*)

Aqueous neem leaf extract, neem oil and marotti oil at different concentrations were tested as bare root-dip treatments for their efficiency in reducing root- knot nematode infestation in brinjal. Significant reduction in gall index was also seen in neem leaf extract treated plants. Higher concentrations of extract (50 and 25 per cent) significantly reduced the number of egg masses produced. But none of the phytochemicals had any adverse effect on the hatching of the egg masses but these phytochemicals irrespective of the doses reduced population of the nematode in the soil.

Different isolates of VAM fungi like, *G. fasciculatum*, *G. entunicatum*, *G. mosseae*, *G. constrictum* *G. monosporum* and *A. morroweae* did not show any significant difference in the growth parameters of brinjal plants. (Asha John, 1997)

Bio ecology and management of root-knot nematode, *M. incognita* (Kofoid and White) Chitwood in Kacholam, *Kaempferia galanga* Linn.)

The biology of root-knot nematode on kacholam, its histopathological effects

and the effect of soil type on pathogenicity of *M. incognita* infecting *Kacholam* were studied. *M. incognita* took 37 days for the completion of one life cycle. The eggs were laid in egg masses embedded in gelatinous matrix and the mean number of eggs present per egg mass estimated was as low as 130.

Histopathological studies revealed that the nematode mainly infest stellar region especially the xylem vessels and the phloem were found intact. The hatching of eggs and survival of larvae at different moisture levels viz, field capacity, permanent wilting point and flooding was studied *in vitro* in micro plots. Soil moisture level at field capacity was found most suitable for the hatching of eggs of *M. incognita*. There was no significant variation in the hatching of eggs and survival of larvae at different pH levels ranging from 5 to 7.5. Sandy soil (Entisol) was found as the best soil type for the effective multiplication of root-knot nematode. The reduction in leaf number, root weight and yield were highest in sandy soil.

Among the three treatments, neem cake treatment ranked first as it produced the maximum plant growth and there was no statistically significant variation in the number of egg masses per root-knot in various treatments. The number of larvae emerged per egg mass was lowest in VAM treatment. The root-knot count was lowest in neem cake treated plants. The gall index was uniform (one) in all the treatments. (Rajani.T.S, 1998)

Eco-friendly management of root-knot and burrowing nematodes associated with Kacholam, *Kaempferia galanga* Linn

Field experiments were conducted to evaluate the efficiency of bioagents plant products, neem leaf extract, botanical pesticide and organic amendments as rhizome and main field treatments against the nematodes in kacholam. The results revealed that rhizome treatment with *P. fluorescens* at 3 per cent w/w significantly improved the plant growth parameters and yield (cent percent). Arbuscular Mycorrhizal Fungi (AMF) at 3% w/w and hot water treatment (55°C for five minutes) were effective giving 86 and 81 per cent yield increase respectievely.

Neem cake @ 200g per m^2 and AMF @ 10 g/m^2 were found equally effective as carbofuran (1g a.i. per m) in reducing the nematode population and increasing the yield. Mulching with neem and chromolaena leaves @ 5 kg per m^2 significantly improved

the yield. (Nisha.M.S. 2001)

Potential of entomopathogenic nematodes for the management of weevil pests of banana (*Musa sp.*)

Native isolates of EPN were collected from banana rhiosphere from the Instructional farm, Vellayani covering an area of 75 ha. Out of the hundred samples processed, ten native isolates were obtained. Based on the mortality of grubs of pseudostem weevil in the Laboratory, the native isolates N1 and N2 were selected for further studies.

For mass multiplication of native EPN, the rate of multiplication of infective juveniles was assessed in *Galleria mellonella* rared in different cheap media along with standard medium. The result showed that all the EPN (*Heterorhabditis indica, Steinernema glaseri*, N1 and N2) reared in standard medium recorded maximum emergence of infective juveniles. Maximum mortality of grubs and adults of the pesudostem and rhizome weevils were recorded at 72 hrs after treatment.

EPN strains were available in different agro ecosystems and were more virulent than the standard ones. Comparative efficacy of native isolates (N1 and N2) and standards were worked out for the management of grubs and adults of weevil pests of banana. An inoculum level of 100 IJ per insect recorded a mortality of above 80 per cent *in vitro* condition in rhizome and pseudostem weevils but it was reduced to 52 to 56 per cent inside the rhizome and pseudostem. (Remya.K.R, 2007)

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10. RESEARCH FINDINGS FROM OTHER PROJECTS THAN AICRP

10.1 NEMATOLOGICAL INVESTIGATIONS UNDER NARP (SR) (1982-1989)

A glimpse of the contributions in different areas of nematology based on the location specific field problems is given.

Nematological investigations started with analysis of phytonematodes associated with coconut based cropping system in Kerala. A multi stratified random survey of nematodes associated with different crops in homesteads (coconut based cropping system) of Kerala was conducted from 1986-1988. The distribution pattern, population fluctuation of nematodes in different seasons, crop combinations and soil types were studied in detail. The frequency of occurrence and economic threshold levels of *M. incognita*, *R. similis*, *R. reniformis and H. oryzicola* were worked out from the data obtained from 100 homesteads. Nematological investigation of this type with reference to the homestead concept was the first of its kind in the state. The pathogenic ability of the nematode pests in different crops was established. The crop loss due to nematode pests in various agro climatic zones was assessed. An avoidable yield loss of 19-29 per cent and 10-14 per cent in bhindi, brinjal and bitter gourd were obtained at an initial inoculum level of 200-250 *M. incognita* juveniles per 200g soil sample. The reduction in yield of chewable leaves of betel vine ranged from 38-68 per cent. Root –knot nematode a serious pest of bhindi causing 19-29 per cent yield loss in the state of Kerala stressed the need for a management strategy. Hence a control trial was taken up. Though various methods of control are available, due to its high fecundity, attempts to maintain the population below the economic threshold level through non nematicidal methods often failed. Hence all the available granular nematicides were screened for the control of the nematode in the early stage of the crop. In the initial screening carbofuran, phorate and aldicarb @ 1 kg a. i. / ha as spot application at seeding was found effective. Subsequent trials under field condition revealed that aldicarb and carbofuran were equally effective in managing the root-knot

problem in bhindi and increasing the yield (more than 70 per cent). Time of application is restricted to 15 days before sowing in endemic areas .

10.2 RESEARCH WORK UNDER ICAR AD-HOC SCHEME ON "CYST NEMATODE INFESTING RICE IN KERALA" (1985-1990)

The project aimed to study the extent of occurrence and damage by cyst nematode *H. oryzicola* on rice in Kerala and to evolve suitable control measures.

Systematic survey in all the 14 districts of Kerala state was conducted and 646 soil and root samples were collected and processed for nematode estimation. Cyst nematode *H. oryzicola* was recorded from 58 locations with a range of 0-82 nematodes in 100 ml soil and 1-107 in 5 g root. Eight more plant parasitic nematodes were found associated with rice. Life cycle studies had shown that it took 32 days to complete one life cycle under a temperature of 23.3°C to 30.1°C and about nine generations were completed in a year. They were more abundant during July and August. The cysts were lemon shaped and light to dark brown in colour. They mostly reproduced sexually. These nematodes preferred sandy soils for their existence and the cysts were viable even after 3 years. Histopathological studies had shown that the inner tissues of the root were completely destroyed by the penetrating larvae. It was found that the nematode caused 38 per cent reduction in dry grain weight and 26 per cent reduction in straw. Carbofuran and photate at 1 kg a.i. per ha applied at seven and 50 days after planting could significantly reduce the nematode infection in rice and increase yield. Few rice varieties were found resistant to this nematode.

10.3 RESEARCH UNDER STED PROJECT, GOVERNMENT OF KERALA UNDER YOUNG SCIENTISTS AWARD SCHEME (1993-96)

This project aims to confirm the potential of two bacterial pathogens, *Bacillus macerans* and *B. circulans* infesting root-knot nematode under field conditions. Status of these bioagents in pot culture condition was already established in pepper plants, hence field evaluation of this was done in bhindi (okra). The bioefficacy was compared with the effect of nematicides and organic amendments at recommended dose as well as 50 per cent of the recommended dose. The sustainability of the pathogens in the succeeding crop was also observed. The results indicated that *B. macerans* (1.2

X 10^6 cells per ml) and *B. circulans* (1.3 X 10^6 cells per ml), two days before sowing of bhindi seed significantly improved the yield of bhindi (42 per cent increase) and also reduced the root-knot nematode population in soil and root.

The effect of these two treatments were statistically on par and superior to half dose of carbouran (0.5 kg a.i. per ha) and neem cake (1.25 ton per ha). The residual effect or long term effect on the management of nematode was also observed in next two seasons. Bhindi crop was raised in the same plot without the pathogens and others. Highest yield was observed in plots previously treated with neem cake (2.5 ton per ha) followed by carbofuran (1 kg a.i. per ha). The effect of carbofuran and neem cake, at half the recommended dose was on par with untreated control. This concluded that *B. macerans* and *B. circulans* can be used effectively for the management of root-knot nematode in the field. The effect of the pathogen could remain potential for one more season with same cropping pattern.

10.4 RESEARCH UNDER STED PROJECT ON NEMATODE ASSOCIATION IN KACHOLAM *Kaempferia galanga*. L AND ITS MANAGEMENT (2000-2003)

A survey was conducted to find out the distribution of nematodes and insect pests from different agro-climatic zones, soil types and cropping patterns prevalent in the State. The percentage frequency of distribution of nematodes in different zones ranged from 33 to 75 per cent in soil, while in root it ranged from 32 to 80 per cent. Among the nematodes, root- knot nematode, *Meloidogyne incognita* is the predominantly occurring species. The population of *M. incognita* exceeded above the economic threshold level in 13 locations, which were designated as hot spot areas of infestation, requiring effective management. In the case of *R. similis* four locations were identified as hot spot areas. The results are depicted in the map of the State. Insect pests collected were root mealy bugs and scale insects. Since they are of minor importance detailed investigations were not taken up.

Pathogenicity trial conducted showed that at a larval inoculum of 10,000 J$_2$ per plant the percentage reduction in leaf

number is 37, 34, 36 and 35 in sandy, laterite, red and forest soils respectively revealing that there were no variations in plant pathogenicity in different types of soil. The reduction in yield of kacholam in terms of weight of rhizome ranged from 59, 48, 39 and 42 per cent in sandy, laterite, red and in forest soil. The root- knot indices were also uniform (root- knot index of 2). The crop loss studies revealed 14 to 43 % loss in yield (weight of rhizomes) at an initial population of 200 and 1000 J_2 of *M. incognita*.

Micro plot studies were conducted to establish the efficacy of bioagents. *Psuedomonas fluorescens* treated plants recorded highest rhizome yield (per plant) giving cent per cent increase over the untreated. This treatment was on par with AMF with a yield increase of 93 per cent. When the rhizome yield was computed in per plot basis, yield per plot (2m x 2m) ranged from 2.23 kg to 4.37 kg. Maximum yield was obtained in *P. fluorescens* followed by AMF and hot water treatments. The later two were giving 86 and 81 per cent yield increase respectively over the untreated and statistically effect of these treatments were on par. Root- knot count was lowest in *P. fluorescens* treatment (1.21 per 5 g root), followed by the AMF treatment (1.94 per 5 g root) and these two treatments were on par and significantly superior to other treatments with 94 to 96 per cent reduction in root- knot count. *T. viride* treatment was on par with hot water treatment and neem leaf extract (NLE) + garlic and nimbecidine giving more than 62 per cent reduction. The effect of the chemical, dimethoate as rhizome treatment was inferior to *T .viride* but on par with NLE. Maximum reduction in population was observed in *P. fluorescens* treated plants (85 per cent). The effect of this was on par with treatments *viz.*, AMF, NLE + garlic, hot water treatment and *T. viride*. The effect of *P. fluorescens* was found superior in reducing the population of nematodes in soil throughout the crop period (78 to 83 per cent).

Experiment on main field treatment showed that highest yield (rhizome weight) was recorded in carbofuran treated plants (185 g), which was closely followed by neem cake (175 g) and AMF treatments (170 g). The average yield per plot (1mx1m) varied from 1 kg to 1.68 kg. The effect of application of carbofuran, neem cake, AMF, saw dust and *P. fluorescens* in the main field was statistically on par. The number of galls ranged from 1 to 16 per 5 g root in various treatments as against 26 galls in untreated.

The results of experiments on mulching showed that per plot yield of rhizome was maximum in neem leaf mulched plots which was closely followed by the chromolaena with an yield of 13 to 14t /ha respectively. Effect of glyciridia leaf mulching was statistically on par with calotropis and clerodendron. Maximum reduction in root-knot count was observed in neem leaf mulching followed by chromolaena. Mulching with green leaves of neem, glyciridia, calotropis, chromolaena and clerodendron significantly reduced the population of nematodes in the roots of kacholam at harvest.

10.5 RESEARCH UNDER NATP ON MASS PRODUCTION AND FIELD EVALUATION OF BIOAGENTS FOR THE ECO-FRIENDLY MANAGEMENT OF NEMATODES ASSOCIATED WITH VEGETABLES (2001-2004)

In the present scenario of biocontrol programme mass production and farmer's field level evaluation are necessary for adoption of technology. After an extensive screening native isolates of bacteria and fungi, *Bacillus macerans* and *Paecilomyces lilacinus* were evolved as potent biocontrol agents effective against nematodes infesting vegetables. Mass production and application technologies were developed and revalidated in farmer's field.

Fifteen native isolates of Arbuscular Mycorrhizal Fungi (AMF) and twenty one isolates of *Pseudomonas fluorescens*, five isolates each of *Pasteuria penetrans* and *B. macerans* were screened in the laboratory as well as glass house conditions. Based on the effect, two isolates of AMF and one isolate each of *B. macerans*, *P. fluorescens*, *P. penetrans* were selected for field study. In the field, the potential of these bioagents were tested along with the standard bioagent, *P. lilacinus* recommended chemical, carofuran, organic amendments like neem cake and neem leaf. After the field evaluation the following recommendations were evolved for different vegetable crops. The method of application of bioagents as well as doses were also fixed. For the management of nematodes on the following crops.

Bhindi: Seed treatment with *B. macerans* @ 3per cent w/w (2.5 kg/ha) or seed treatment with *B. macerans* @ 3per cent w/w (2.5 kg/ha) + drenching with *B. macerans* @ 3per cent solution seven days after sowing.

Brinjal: Nursery treatment with *B. macerans* (25g/m^2) + drenching 3 per cent solution of the same seven days after sowing (150 g/51/m^2) or nursery treatment with *P. lilacinus* (25 g/m^2) + drenching seven days after sowing (150 g/51/m^2).

Coleus: *B. macerans* or *P. lilacinus* drenching @ 35 kg/ha.

Amorphophallus : Seed material treatment with *B. macerans* @ 3g/kg or seed material treatment with *P. lilacinus* @ 3g/kg can be recommended.

Assessment of synergistic effect by the combined application of arbuscular mycorrhizal fungi with bacteria (*B. macerans, P. fluorescens and P. penetrans)* revealed that there was significant improvement in biometric characters and yield of bhindi, brinjal and coleus. The effect ranges from 30-35 per cent 50-60 per cent and 40-60 per cent respectively in the above crops. The reduction in nematode population in root ranged from 50-75 per cent in different crops.

The compatibility of *B. macerans,* a potent pathogen of nematode to different group of nematicides and fungicides was tested *in vitro* by filter paper disc method. Two nematicides, metham sodium and formaldehyde were inhibitory to the bacteria, at 500 and 1000 ppm levels. Phorate, carbofuran and carbosulfan were non inhibitory. Carbofuran and carbosulfan were the two safest nematicides which can be applied along with *B. macerans*. Among the insecticides, HCH (BHC), endosulfan and malathion were non inhibitory to *B. macerans* at 500 and 1000 ppm levels. Malathion, a relatively safe chemical among the organic phosphates and endosulfan, a member of cyclodiene group already reported safe to parasites, predators and pollinators. But regarding the safety to *B. macerans* this is the first report in *B. macerans*. HCH (BHC) a member of organo chlorine group was also found safe to *B. macerans*. Another two recommended insecticides in vegetables, viz. quinalphos (organophosphate group) and carbaryl (carbamate group) were also non inhibitory to *B. macerans* at lower level (500 ppm and below). Among the fungicides methoxy ethyl mercuric chloride inhibited the growth of *B. macerans* at all the concentrations studied (125 to 2000 ppm) The systemic fungicide, carbendazim was non inhibitory up to 500 ppm and the higher levels showed significant increase in inhibition. The zinc and manganese based dithiocarbamate fungicides mancozeb, zineb

were inhibitory to the growth of *B. macerans* from very low dose onwards (125 ppm).

The technique for mass production of the bio agents were standardized. Talc based formulation was evolved for *B. macerans* and rice bran media for *P. lilacinus*. The survival, shelf life, pH, temperature requirement and spore load per g of substrate were also standardized.

Before the farmer participatory research, training of three days duration on the diagnosis of nematode diseases of vegetables and their eco-friendly management was conducted. As an initial step for the farmer participatory research, leaflets and handouts in regional languages (Malayalam) were prepared and distributed to the farmers after training to get awareness on the diagnosis of field symptoms of nematode infestation. Demonstrations on the method of application of bioagents were also conducted in their own field after training. Ten demonstration trials each were laid out in farmers field in bhindi, brinjal, coleus and amophophallus in an area of 40 m^2 (1 cent) per treatment. The yield data was compared with the farmers practice. The incremental yield and income in comparison to farmers practice was also worked out. In bhindi the increase in yield due to recommended treatments, *B. macerans* seed treatment @ 3 per cent w/w alone and seed treatment of *B. macerans* + drenching 2 per cent solution 7 days after sowing was7000 and 6825 kg per ha respectively. The incremental income due to these treatments was Rs. 42,000 and Rs. 40,950 respectively. Considering the economics *B. macerans* seed treatment alone can recommended for large scale application in the field. In brinjal the nursery treatment with either *B. macerans* or *P. lilacinus* @ 25g/m^2+ drenching with 2 per cent solution at 7 days after sowing was very effective. Comparing these two, incremental yield with respect to farmers practice was highest in *B. macerans* (6205 kg/ha) when compared to *P. lilacinus* (5163 kg/ha). Since the cost of application being the same the incremental income was high in *B. macerans* (Rs. 37,230), it can be recommended for managing nematodes in brinjal.

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