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Towards management of *Musa* nematodes in Asia and the Pacific

Country reports presented during the training workshop on enhancing capacity for nematode management in small-scale banana cropping systems held at the Institute of Plant Breeding, University of the Philippines Los Baños, Laguna, Philippines, 1-5 December 2003

F.S. dela Cruz, Jr., I. Van den Bergh, D. De Waele, D.M. Hautea and A.B. Molina, editors

VVOB

The mission of the **International Network for the Improvement of Banana and Plantain** (INIBAP) is to sustainably increase the productivity of banana and plantain grown on smallholdings for domestic consumption and for local and export markets.

The programme has four specific objectives:

To organize and coordinate a global research effort on banana and plantain, aimed at the development, evaluation and dissemination of improved banana cultivars and at the conservation and use of *Musa* diversity.

To promote and strengthen collaboration and partnerships in banana-related activities at the national, regional and global levels.

To strengthen the ability of NARS to conduct research and development activities on bananas and plantains.

To coordinate, facilitate and support the production, collection and exchange of information and documentation related to banana and plantain.

INIBAP is a network of the International Plant Genetic Resources Institute (IPGRI), a Future Harvest center.

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Cover Photos: (counterclockwise starting from the top) a. participants of the training workshop; b. fruit-bearing banana plant; c. banana field in the Philippines, planted with different accessions; d. root and soil sample collection for nematode evaluation; e. (center photo) banana root necrosis.

Citation: F.S. dela Cruz Jr., I. Van den Bergh, D. De Waele, D.M. Hautea and A.B. Molina, editors. 2005. Towards management of *Musa* nematodes in Asia and the Pacific. Country reports presented during the training workshop on enhancing capacity for nematode management in small-scale banana cropping systems held at the Institute of Plant Breeding, University of the Philippines Los Baños, Laguna, Philippines, 1-5 December 2003. International Network for the Improvement of Banana and Plantain - Asia Pacific, Los Baños, Laguna, Philippines.

INIBAP ISBN: 971-91751-6-8

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The opinions in the publication are those of the authors and not necessarily those of INIBAP.

Acknowledgments

The International Network for the Improvement of Banana and Plantain (INIBAP)-Asia Pacific regional office and the University of the Philippines Los Baños (UPLB) are grateful to:

- The *Vlaamse Interuniversitaire Raad* (VLIR) for funding the project and co-sponsoring the publication
- All participants of the training-workshop on enhancing capacity for nematode management in small-scale banana cropping systems for their contribution to these proceedings
- The *Katholieke Universiteit Leuven* (K.U.Leuven), Belgium for providing technical support for this training workshop;
- The Institute of Plant Breeding (IPB), College of Agriculture (CA) for hosting the training workshop and providing the technical and support staff
- The National Crop Protection Center and the Department of Plant Pathology, CA, UPLB for providing technical support
- F.S. dela Cruz, I. Van den Bergh, D. De Waele, D.M. Hautea and A.B. Molina for their conscientious work as editors of the proceedings
- V.N. Roa and K.H. Borromeo who undertook the copy editing and layout of the proceedings
- Virma Rea G. Lee and Laureano B. Lanosia Jr for the cover design

Editorial note
Some references have been submitted without complete publishing data. They may thus lack the full names of journals and/or the place of publication and the publisher. Should readers have difficulty in identifying particular references, staff at INIBAP-Asia Pacific regional office will be glad to assist.

Contents

Foreword

Plant-pathogenic nematodes are considered one of the major constraints in banana production. While nematodes can be controlled by the use of chemicals, these are expensive and thus beyond the reach of small-holder farmers. They also accumulate in the environment and are highly toxic.

Alternative strategies to combat these pests include the use of banana varieties that are resistant or less susceptible to nematodes, the use of clean planting materials and the use of soil amendments and biocontrol agents. These strategies, including the need for more information on the status of nematode problems in the region, were last stressed at the conference workshop on nematodes and weevil borers affecting bananas in Asia and the Pacific in Malaysia in 1994.

In addition, several levels of training requirement were identified: (1) specialized nematology training, to address the shortage of skilled nematologists; (2) extension training, to raise the awareness of farmers of nematodes; and (3) training of trainers, to ensure that the two first training requirements can be met.

The University of the Philippines Los Baños, Philippines (UPLB) and the Katholieke Universiteit Leuven, Belgium (K.U.Leuven) are currently undertaking a project entitled 'Enhancing Capacity for Nematode Management in Small-Scale Banana Cropping Systems' financed by the Flemish Interuniversity Council (VLIR). The project aims to: (1) improve banana production by identifying varieties which are either resistant or less susceptible to nematodes and evaluate their usefulness in small-scale, low-input banana cropping systems; (2) strengthen the nematological training and research capacity at the College of Agriculture of UPLB (CA-UPLB); and (3) train Southeast Asian nematologists in banana nematology.

Training in banana nematology is given special emphasis because there is currently a lack of trained scientists and technicians to address problems of nematology. In the Philippines, for example, several senior nematologists of CA-UPLB have already retired without being replaced by young nematologists.

The training held at UPLB aimed to: (1) enhance capacity for nematode research in the region, specifically on nematode management in *Musa*; (2) compile up-to-date information on the status of nematodes in *Musa* and ongoing nematological activities in the region; and (3) bring together and work out future collaborations among partners in the region.

The training workshop offers an opportunity to summarize the status of *Musa* nematode research in the region through country reports. Technical presentations and hands-on exercises on nematode survey, collection and culture techniques and field trips to the laboratories were also undertaken. The activity concluded with a workshop to discuss and come up with a set of protocols for survey, collection and culture of *Musa* nematodes. The technical presentation and protocols are published in the accompanying technical manual of these proceedings.

As the project will end in 5 years time, we also plan to organize a follow-up workshop within the next years to evaluate the progress made by each country in the region.

The editors

Country reports

Musa nematode problems in Bangladesh

M.G. Kibria* and M.A. Hoque

Banana is one of the most important and widely consumed fruits in Bangladesh. The use of green banana as a vegetable is also very popular. The area and production of major fruits of Bangladesh are shown in Table 1. About 40 500 hectares of land are under banana cultivation, where 572 000 tonnes of fruits are produced (Bangladesh Bureau of Statistics 2000). The average yield of banana is 15 t/ha, which is lower than that of other countries. Various factors are responsible for the low yield, among which plant-parasitic nematodes. These nematodes are widely distributed throughout the banana producing areas of Bangladesh, and cause considerable root damage.

Table 1. Area and production of major fruits in Bangladesh.

Crop	Area (000 ha)	Production (000 t)
Banana	40.5	572
Mango	50.6	187
Jackfruit	26.7	267
Pineapple	14.2	148
Litchi	5.3	14
Papaya	2.0	12
Watermelon	9.7	79
Ber	4.5	16
Guava	10.1	48
Citrus	10.2	32
Other fruits	9.3	29
Total	183.1	1404

Source: BBS 2000

Major insect pests and diseases of banana

The major pests and diseases affecting banana are listed below:

A. Diseases

1. Viral diseases

Banana bunchy top virus

Cucumber mosaic virus

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2. Fungal diseases
   Fusarium wilt – *Fusarium oxysporum* f.sp. *cubense*
   Sigatoka disease – *Mycosphaerella musicola*
   Anthracnose – *Gloeosporium musarum*
   Crown rot – *Botryodiplodia theobromae*

B. Nematodes

C. Insect pests
   Leaf and fruit beetle -- *Colaspis hypochlora*

Nematodes problem

Nematodes have been reported as a major constraint of banana production in Bangladesh. The pest affects banana growth and yield through its damage to the root system and corm. The parasitic nematodes feed, multiply and migrate to the roots. Secondary infection by fungi enhances the process of root necrosis. Plants with necrotic roots are less able to take up water and nutrients, resulting in stunted growth, reduced bunch size, delayed maturation time and/or reduced tolerance to other stresses. Severe root destruction leads to toppling of the plants, especially those carrying a bunch (Stover 1992; Stover and Simmonds 1987).

Research and Development on *Musa* nematodes

Bangladesh lacks available information on the distribution and pathogenicity, as well as the extent of damage, susceptibility and resistance of local cultivars and host range of nematodes in the country. There are four species of nematodes reported in the banana fields in Bangladesh, i.e. burrowing, spiral, root-knot and lesion nematodes (Hoque and Hossain 2001). A survey was conducted by Chowdhury *et al*. (1981) at Joydebpur to identify nematode genera associated with banana. They collected root and soil samples from several banana plantations and identified six nematode genera. They were *Pratylenchus* spp., *Helicotylenchus* spp., *Hoplolaimus* spp., *Hirschmanniella* spp., *Tylenchorhynchus* spp. and *Meloidogyne* sp., which were found to be directly associated with root damage.

Another survey was conducted by Mian (1986) throughout Bangladesh to record the plant-parasitic nematodes associated with some important crop species commonly grown in the country. He recorded 23 genera of the parasites. Among them, *Helicotylenchus multicinctus*, *Hoplolaimus* sp., *Meloidogyne incognita*, *M. javanica*, *Radopholus similis*, *Tylenchorhynchus claytoni* were associated with banana.

Several studies on the control measures of nematodes are in progress:

1. **Control of plant-parasitic nematodes on banana by nematicides and soil-organic amendments (Hossain 2003).** Furadan, neem oil cake, mustard oil cake and poultry refuse were used in this study. Among the treatments, poultry was found best in controlling nematode infection in banana.

Table 2. Effect of soil amendments and nematicides on percent root damage and yield of banana.

Treatment	Root damage (%)		Bunch weight (kg)	
Furadan at planting	36.0	b	9.9	c
Furadan at planting + 3-month interval	24.7	bc	11.7	bc
Furadan at planting + 4-month interval	30.7	c	10.3	bc
Furadan at planting + 6-month interval	23.7	ef	11.0	bc
Furadan at planting + Neem oil cake at 3-mo. intervals	28.3	cd	10.7	bc
Furadan at planting + Neem oil cake at 4-mo. intervals	30.0	c	13.0	ab
Furadan at planting + Neem oil cake at 6-mo. intervals	32.0	c	11.4	bc
Neem oil cake at 15 days before planting	32.0	c	11.1	bc
Poultry refuse at 15 days before planting	19.7	f	14.1	a
Mustard oil cake at 15 days before planting	22.0	ef	12.8	ab
Control/untreated plot	42.3	a	7.5	d
LSD	**3.8**		**2.1**	
CV (%)	**7.7**		**11.3**	

2. **Effect of planting materials and nematicide in controlling the nematode disease of banana.** Three types of planting materials (hot-water treated suckers, pared suckers and normal suckers) and three nematicides (Furadan 5G, Cureterr 5G and Rugby 10G) were used in this study (Ali 2003). The suckers were submerged for 20 min at 55°C in a hot-water bath for cleaning and the black-spotted portions from corms were carefully removed from the suckers for paring. All nematicides were used at 2.5 kg/ha at 3-month interval. Plant height and plant diameter were significantly increased due to hot water and paring treatments over control, but no significant difference was observed in root length, root lesion and gall index (Table 3). It is observed in Table 4 that, except for plant diameter, all other parameters like root length, root lesion, plant height and gall index significantly differed with the control due to the application of three different nematicides. However, there were no significant differences among the nematicides for these parameters.

Table 3. Effect of hot water treatment, paring and normal untreated suckers in controlling banana nematodes and growth parameters of the plants.

Treatments	Root length (cm)	Root lesion (%)	Plant height (cm)	Plant diameter (cm)	Gall index (0-10)
Hot water	37.5	25.6	157.9 a	33.4 B	1.2
Paring	35.5	27.6	141.2 ab	37.2 ab	1.3
Control	32.9	31.1	131.1 b	39.9 A	1.6
F-test	NS	NS	** **	**	NS
LSD			16.57	3.864	

Table 4. Effect of nematicides on the gall index, root damage and plant growth parameters of banana.

Treatments	Root length (cm)	Root lesion (%)	Plant height (cm)	Plant diameter (cm)	Gall index (0-10)
Furadan 5G	39.1 a	24.0 b	152 a	8.6	0.8 b
Cureterr 5G	36.1 ab	24.3 b	150 a	37.0	0.8 b
Rugby 10G	34.3 ab	23.8 b	146 a	36.5	0.7 b
Control	31.2 b	40.2 a	129 b	35.2	3.1 a
F-test	** **	** **	** **	NS	** **
LSD	6.06	11.25	16.12		0.43

Besides these, some encouraging results have been obtained in controlling nematodes using various nematicides. However, no acceptable method has been recommended yet to control nematodes in banana.

Ecology and spread

Almost all plant-pathogenic nematodes live a part of their lives in the soil. Many of them live freely in soil, feeding superficially on roots. The soil environment affects the survival and movement of nematodes in the soil. Nematodes occur in greatest abundance in the top 15 to 30 cm of the soil (Agrios 1997).

Recommendations

To date, there has been no significant research achievement in controlling nematodes associated with banana in Bangladesh. However, there are some recommendations to reduce or control nematode population, in the banana field:

1. trimming of corms to remove contaminated roots before planting
2. safe movement of planting materials

3. use of clean planting materials derived from tissue culture
4. hot water treatment before planting
5. use of nematicides
6. crop rotation and fallowing.

Practically no method is strictly being practised except for crop rotation and fallowing.

Future perspectives

Under the present circumstances in Bangladesh, it is necessary to develop a comprehensive research programme to control nematodes in banana. The following projects must be included:

1. survey of nematode genera/species and population dynamics associated with banana
2. pathogenicity and extent of damage to the crop
3. crop-loss assessment due to major nematodes
4. screening of local cultivars for nematode resistance
5. developing nematode-resistant cultivars
6. chemical control measures against nematodes
7. study on cultural practices that may affect nematode reproduction in the soil
8. developing integrated approach against banana nematodes.

References

Agrios G.N. 1997. Plant Pathology (4th edition). Academic Press, London, 566pp.

Ali M.R. 2003. Annual Report. Plant Pathology Division, BARI, Gazipur, Bangladesh.

Bangladesh Bureau of Statistics. 2000. Ministry of Planning, Bangladesh.

Chowdhury B.C., I.M. Geachie and M.O. Haque. 1981. A preliminary investigation on parasitic nematodes associated with banana at Joydebpur. Bangladesh Hort. 9:41-44.

Hoque M.A. and M.M. Hossain. 2001. Kola Utpadoner Adhunic Kolakoushal (Modern production technology of banana). Horticulture Research Centre, BARI, Gazipur, Bangladesh.

Hossain M.H. 2003. Control of nematodes with nematicides and organic amendments. BARI, Gazipur, Bangladesh. Annual Report. Plant Pathology Division. RARS, Jessore, Bangladesh.

Mian I.H. 1986. Plant-Parasitic Nematode with some Crop species in Bangladesh. Bangladesh J. Plant Pathology 2 (1):7-13.

Stover R.H. 1992. Banana, Plantain and Abaca diseases. Kew: Commonwealth Mycological Institute. 316pp.

Stover R.H. and N.W. Simmonds. 1987. Bananas (3rd edition). Langmans, London. 468pp.

Banana diseases in Cambodia

Ny Vuthy*

Introduction

Cambodia is situated in the tropics with high average temperature (> 25˙ °C) and annual rainfall (~2000 mm). This climate is suitable for banana growing and bananas are one of the most important fruit crops in the country.

Cultivation of bananas in Cambodia is very common and many families grow this crop near their houses. Total production involves a large number of small-scale growers and a few large-scale growers. They produce fresh fruit for local consumption and for export. Prior to the 70s, there were larger banana plantations and more commercial export of bananas (Hiv Sophal 1992).

There are five main varieties of bananas grown in Cambodia, namely Namva, Pong Mone, Ambong Meas, Ambong Kheiv and Slabmuk. Bananas are usually transplanted from March to May. Cambodian farmers generally transplant sword suckers to grow new plants, each mature plant produces 1-2 suckers.

Many diseases are also known to affect the banana plants, causing serious losses. Diseases include viruses, Fusarium wilt, nematodes and others, all of which are transmitted through planting suckers from one crop cycle to the next (Hiv Sophal 1992). Currently, there is no information available about *Musa* nematodes in Cambodia.

Viruses are a major problem in Cambodia. They are usually spread from plant to plant by specific insect vectors. However, transmission over long distances and between crop cycles is often caused by the use of vegetative planting materials (Chheng Nareth 2000). It is also known that viruses can be readily transmitted by tissue culture thus, to produce virus-free plantlets, the source plants for tissue culture must be virus free. Fusarium wilt of bananas is caused by race 4 of *Fusarium oxysporium* f.sp. *cubense* (E.F. Smith) Snyder and Hensen, and it affects nearly all bananas grown in Cambodia. It is the most serious problem affecting banana production in Cambodia (Hiv Sophal 1992).

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Banana varieties in Cambodia

In Cambodia, bananas are grown along the river, in villages and in upland areas. The estimated total land area cultivated for banana production in the country is 20 600 ha (Extension Kampong Cham Report 2000). The following are the most common banana cultivars grown in the country:

- **'Namva'.** This variety is very popular. It can be found anywhere in the country and is grown for local and export markets. It can be eaten fresh, boiled, grilled and fried. This variety is also exported as jam. The plant grows about 4-6 m tall, with a pseudostem diameter of 30-35 cm and a life cycle from 8-10 months. It is susceptible to drought and water stress. This variety is resistant to diseases and insect pests.
- **'Pong Mone'.** This variety is popular with farmers generally for commercial purposes. It is a very popular variety for consumption. The fruit is small, the skin is yellow and the flesh is sweet. Plant height is about 2-2.5 m and pseudostem diameter ranges from 15-20 cm. Its life cycle is 5-6 months. It is susceptible to diseases, drought and water stress.
- **'Ambong Meas'.** This variety is also grown for local consumption and for export. The leaves are large and long. Plant height can reach up to 4.8 m. It produces yellow fruits, the flesh is sweet and aromatic.
- **'Ambong Kheiv'.** This variety is similar to the Ambong Meas variety, but the fruit is yellow and blue in color. Plant height is about 2-3 m. The life cycle is 12-15 months. It is resistant to insect pests, diseases and water stress.
- **'Slabmuk'.** This is the least common of the varieties. The plant can reach up to 4 m high with pseudostem diameter of 25-30 cm. Ripe fruits can be eaten fresh or boiled. This banana variety is resistant to water stress, diseases and insect pests. It can grow well in flooded land.

Insect pests and diseases in bananas

There are several insect pests that attack banana plants in Cambodia. However, banana corm weevil (*Cosmopolites sordidus)*, leaf roller *(Erionota thrax)* and banana stem weevil *(Odoiporus longicollis)* are the only three insect pests known to cause significant damage to all banana varieties in Cambodia (Hiv Sophal 1992).

The banana corm weevil feeds on suckers and destroys the corm tissues. It causes the suckers to die of bore attack. To control this pest,

farmers treat the soil with Furadan (Hiv Sophal 1992). Sanitation and cutting of affected corms are also effective control measures and are environment friendly. Fruit-peel scarring beetle damages the surface of the fruit. Farmers usually spray the banana bunch with Decis 2.5 100 EC to control that particular pest. Diazinon 40/60 EC can easily control the banana floral thrips.

The three major diseases of banana are Sigatoka, Fusarium wilt and Moko. Sigatoka is a leaf-spot disease caused by *Mycosphaerella musicola* (Agriculture and Fisheries Information Service). It causes the premature death of leaves. In severe cases, the size of bunches and fingers are reduced. The fruit also ripens prematurely and develops an abnormal flavor and smell. To control this pest, plants are sprayed with Bordeaux mixture. Infected leaves are removed to avoid contamination.

Dry reddish-brown or black, circular or oval, depressed spots, characteristic of wilting disease is caused by *Fusarium oxysporum*. Sanitation is a way of preventing this disease, which becomes a problem in the wet season. All collapsed leaves should be removed.

Insects and infected tools can transmit Moko disease from plant to plant. The impact of Moko to plants is similar to Sigatoka, however, the former does not emit an unfavorable smell. Infected fruits blacken inside. Disinfecting tools with formaldehyde prevents infection.

In view of environmental considerations, integrated pest management techniques are being introduced. Infected plants and weeds must be uprooted to keep the area free of host plants for 6-12 months.

Preliminary discussions with Cambodian banana farmers

Farmers from Kampong Cham province observed that banana diseases have only been in the country since 1972. Since then, they have become significantly more serious such that plants now can usually produce fruit only for 2-4 years before they are overcome by the disease. This contrasts with the 30-35 year-old mats observed before the disease becomes common. Diseases typically spread from the village to the plantations, suggesting contamination originating from the small-scale growers. Disease problems are most acute during the rainy season but most farmers do not use pesticides on their banana crop. $CaCO_3$ is sometimes used but is not very effective. There is a great need for further research in banana diseases in Cambodia.

References

Chheng N. 2000. How farmers grow bananas in Stung Trong District, Kampong Cham.

Department Forestry of Cambodian Agriculture. 1988.

Agriculture and Information Service. Banana Culture. Department of Agriculture, Elliptical Road, Diliman Quezon City 1100, Philippines. pp 5-6.

Hiv S. 1992. Banana in Cambodia. BSc. thesis, Royal Agricultural University Phnom Penh. pp 41-55.

Office of Agricultural Extension Kampong Cham Province Report.

An overview of banana research and plant-parasitic nematode studies in the Federated States of Micronesia

V.K. Murukesan* and P.C. Josekutty

Introduction

The Federated States of Micronesia (FSM) is located at the northwest Pacific and is a relatively young independent nation. It was a part of the United Nations Trust Territory of the Pacific Islands (TTPI) administered by the United States of America until the two nations signed a Compact of Free Association in 1986, leading to the trusteeship termination by the United Nations in 1991. The Compact treaty established a special relationship with America that provides economic support to the FSM. The total landmass is 438 square miles (702 km^2 with a declared Exclusive Economic Zone (EEZ), covering over one million square miles). The FSM is comprised of 607 islands with land elevation ranging from sea level to the highest elevation of about 2500 feet (760 m). The archipelago lies in the western Pacific Ocean, north of the equator, between 1.0-9.9°N and 138.2-162.6°E.

Agriculture in the FSM

The rich and diverse agroforests and related traditional agricultural systems of the FSM have attracted the interest of scientists from around the world as possible models for sustainable agricultural development. Agricultural production in the FSM is primarily for subsistence, with some semi-commercial and commercial activities. The extensive man-made agroforests are complex and environmental sustainable agriculture systems are a result of thousands of years of development. They mimic natural forest ecosystems and shelter extremely high species/cultivar diversity. The cultivars of taro, yam, breadfruit, swamp and fruit trees such as banana, orange, tangerine, mango, lime etc. interspersed in an integrated system of shifting gardens and tree garden/taro patch systems.

Banana, taro, breadfruit and yams are the major staple food crops in the FSM, of which banana cultivation is significant for local consumption and export. There are over 50 cultivars including *Eumusa* and Fe'i bananas (Raynor and Fownes 1991). Similarly, the FSM is the

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world centre for swamp taro diversity (FSM 2002). Intercropping of bananas, taro and other tuber crops with coconut is more common in the island states of Kosrae, Pohnpei and Yap. While swamp taro and yam cultivation is chiefly for domestic consumption, FSM produced about 2300 metric tonnes of banana in 2000 (FAO 2001). The FSM exported dessert banana for US$ 455 628 in 1994 but then declined to US$ 154 317 in 1997 (FSM 1999). Production constraints (diseases and pests) and marketing problems are the reasons for the decline in export.

Research on bananas

Research on banana in the FSM is progressing in the following five directions:

1. tissue culture and genetic improvement
2. disease-resistance trials
3. introduction and performance evaluation of new cultivars
4. nutritional value of banana
5. germplasm conservation.

Following recommendations from the Asian Development Bank (ADB Report 1997), Kosrae State has invested about US$ 500 000 to develop an agribiotech laboratory, Micronesia Plant Propagation and Research Center (MPPRC). MPPRC has developed tissue-culture procedures for several locally grown cultivars of *Eumusa* and *Australimusa*. Results of field trials confirmed better rate of field establishment, faster growth and shorter pre-bearing period as advantages of tissue-culture bananas (Josekutty *et al*. 2001, 2002, 2003a, b, c, 2004; Josekutty and Nena 2002). Research is also underway to develop variant bananas resistant to fusarium wilt affecting cv. Saba. MPPRC also succeeded in introducing disease-indexed tissue cultures of cv. Macao from Guam, which is undergoing field trial in Kosrae. The College of Micronesia-FSM Land Grant program in Pohnpei has gathered a few improved and new banana varieties introduced by INIBAP which are now under field trials. Early results indicate that some of these cultivars are performing better in comparison with many local cultivars under Pohnpei conditions. Englberger (2001) analyzed several cultivars of banana for the nutritional value and some of them are reported to be high in precursor of vitamin A. MPPRC has also embarked on a drive for conserving banana germplasm *in situ*. Twenty-eight cultivars from Kosrae State have been documented and established in a conservation garden and the majority of them are also being multiplied *in vitro*.

Plant nematological studies

While surveying plant-parasitic nematode problems of several islands in the region, Bridge (1988) reported that nematology is in its infancy in the Pacific region. This is true for the FSM as well. Except for a report of burrowing nematode in swamp taro, no effort has ever been taken to survey or diagnose Micronesian soils. The small-scale farmers of this region, being unaware of the nature and harmfulness of nematode infestations in their fields, do not seriously consider the destructive effect of these pests on their crops. Agricultural research in the FSM is also in its infancy and has not focused on the circumstances and needs of the majority of small-scale farmers, particularly women farmers. With a notable exception of swamp taro, symptoms of nematode damage are unknown for other crops to assess the yield loss. Lack of trained work force is the reason behind the situation. In the FSM, a comprehensive survey is necessary in order to assess the damage caused by nematodes on economically important crop species.

Dry corm rot of swamp taro in Yap: a novel candidate for nematological research

Giant swamp taro (*Cyrtosperma merkusii* (Hassk) Schott) is the most popular root crop and had served the Micronesians for many centuries as a cultivated plant of status and great economic significance (Figure. 1). Its starchy corm is the principal food source, especially of Yapese, consumed several times a day all year long. Some of the yellow cultivars are good sources of vitamin A, thus making it an ideal crop for vitamin A-deficient island population.

The plants with corm rot show little or no above-ground symptoms. However, lesions and extensive loss of feeder roots are very common symptoms of pathogen attack.

Figure 1. Swamp taro patch.

Figure 2. Corm showing lesions.

Figure 3. Cross section of a corm showing symptoms of dry rot.

Figure 4. At an advanced stage, decay reaches center of the corm.

Lesions vary in size, from 1.0 to 3.0 cm in diameter and 0.5 to 3.0 cm deep (Figure 2). Beneath these tissues, a brown-black rot is shown, occasionally channeled deep into the corm (Figures. 3 and 4).

The first report of burrowing nematode, *Radopholus similis,* associated with dry corm-rot of swamp came from Yap (Jackson 1986). Later, Grandison (1990) studied the corm-rot disorder in samples collected from Yap and Palau and confirmed the presence of this ubiquitous pathogen. It is interesting, however, to note that a recent survey conducted by Kagoshima University in Japan revealed the presence of free-living Cephalobid nematodes, associated with infected corms of swamp taro and not burrowing nematodes (Onjo *et al*. 2001). The scientifically interesting aspect of this disorder is that we have a serious nematode pest of many tropical crops that grow in normal drained soils, but here it is infecting corms that grow in swampy areas. Nevertheless, there is little doubt that nematodes, either on their own or in combination with other pathogenic organisms, constitute an important constraint to agriculture of the FSM.

The burrowing nematode has a wide host range in the Pacific and is a major banana root pathogen. It was reported from Fiji, Guam, Niue, Norflok, Papua New Guinea, Palau, Samoa, Solomon Islands and Tonga (Bridge 1988; 1992; Bridge and Page 1984; Kirby *et al*. 1978). Although extensive studies have been carried out in islands like Fiji and Papua New Guinea (Bridge and Page 1984; Kirby *et al*. 1980; Orton Williams 1980), Micronesian islands remain unexplored by nematologists.

Susceptibility symptoms vary with cultivars. There are at least seven cultivars of swamp taro in Yap with varying symptoms of susceptibility. In Yap and many of its outer-lying islands, the extent of the problem is not fully realized by the local farmers and they call the disease '*ngal*', or termite damage, though they know termites are not the causal organism. During the survey, we found about 80–90% infestation, depending on the cultivars. Being the staple food crop, such severe infections may eventually affect food security of the island.

Future perspectives

Plant-parasitic nematodes are a severe constraint for the swamp taro cultivation in Micronesia. Although report of nematodes affecting banana and other crops in the FSM are non-existent, considering the traditional way of cultivation, it is reasonable to speculate that nematodes are a matter of concern for these crops as well. Research conducted so far revealed conflicting reports about the presence of burrowing nematode and free-living nematodes. An extensive study is therefore required to identify the host associations of plant-parasitic nematodes from the FSM. Equally important is the cultivar screening of major crops including banana and swamp taro to determine their susceptibility to nematodes and associated yield loss. Information on nematode diagnosis, biology, population dynamics and host-parasite relationships are an essential prerequisite for the future establishment of nematode control practices.

References

ADB Report. 1997. Kosrae State Agricultural Marketing Assessment and Guidelines. ADB TA Project No. 2484 FSM.

Bridge J. 1988. Plant-parasitic nematode problems in the Pacific Islands *in* J. Nematol. 20:173-183.

Bridge J. 1992. Parasitic nematodes of root and tuber crops in Pacific Islands. P.A.T.P. Newsletter 9:1-5.

Bridge J. and S.L.J. Page. 1984. Plant nematode pests of crops in Papua New Guinea *in* Journal of Plant Protection in the Tropics 1:99-109.

Englberger L. 2001. Significant amounts of provitamin A carotenoids are found in varieties of banana and taro in Micronesia. Pp. 40 *in* Proceedings of the 10th Pacific Science Inter-Congress, University of Guam, Guam, USA, 1-6 June 2001.

FAO. 2001. Banana production statistics of FAO for 2001. Online data from http://www.inibap.org/network/tabprod.html

FSM. 1999. Statistical Year Book, Federated States of Micronesia. 67pp.

FSM. 2002. National Biodiversity Strategy and Action Plan. 66pp.

Grandison G.S. 1990. Investigation of a nematode disorder of giant swamp taro (*Cyrtosperma chamissonis*). Report presented on a visit to State of Yap (Federated States of Micronesia) and Republic of Palau, 3-8 June, 1990. Department of Scientific and Industrial Research, Auckland, New Zealand. 14pp.

Jackson G.V.H. 1986. Corm rot of *Cyrtosperma*. Duty Tour Report - Federated States of Micronesia and Palau, 18 May–18 June, 1986.

Josekutty P.C., N.T. Kilafwasru and S.C. Salik. 2001. Micropropagation of four banana cultivars in Micronesia. Pp 71-81 *in* Proceedings of the 10th Pacific Science Inter-Congress, University of Guam, Guam, USA, 1-6 June 2001 Full paper published in: *Micronesica*. Suppl. No. 7, Jan. 2003 p. 20.

Josekutty P.C., N.T. Kilafwasru, R.A. George and S.C. Salik. 2002. Micropropagation of endangered, vitamin A rich bananas (*Musa troglodytarum*). Pp 173-76 *in* Proceedings of the 7th annual meeting, IAPTC &B, University of New England, Armidale, Australia.

Josekutty P.C. and N.S. Nena. 2002. *Inter-situ* conservation of endangered, vitamin A rich bananas in the Federated States of Micronesia. Third international symposium on cellular and Molecular biology of Banana. Katholieke Universiteit Leuven, Belgium, 9-11 month, 2002. Abstract. p. 55.

Josekutty P.C., H. Andrew, N.H. Nena, R. A. George, T.N. Kilafwasru and S.S. Cornelius. 2003a. Micropropagation saves the endangered *Musa* germplasm in the FSM. 2003 Congress of *In Vitro* Biology, 31 May – 4 June 2003, Portland, Oregon, USA.

Josekutty P.C., S.S. Cornelius, T.N. Kilafwasru, N.H. Nena and R.A. George. 2003b. Micropropagation and field performance evaluation of 8 Micronesian bananas. 2003 congress of *In Vitro* Biology, 31 May – 4 June 2003, Portland, Oregon, USA.

Josekutty P.C., N.T. Kilafwasru and S.C. Salik. 2003c. Micropropagation of four banana cultivars in Micronesia. *Micronesica*. Suppl. No. 7, Jan. 2003:77-81.

Josekutty P.C., S. S. Cornelius, T.N. Kilafwasru, E.B. Langu, M.W. Luckymis and N.S. Nena. Integrated Conservation of Banana Germplasm in the Federated States of Micronesia. International Congress on Banana, Penang, Malaysia, July 2004.

Kirby M.F., M.E. Kirby, M.R. Siddiqi and P.A. Loof. 1978. Outbreaks and new records. Fiji, new records of plant-parasitic nematodes. Plant Protection Bulletin, FAO 26:63-64.

Kirby M.F., M.E. Kirby, M.R. Siddiqi and P.A. Loof. 1980. Fiji nematode survey report: Plant-parasitic nematode distributions and host associations. Bulletin No. 68, Ministry of Agriculture and Fisheries, Fiji.

Onjo M, S. Taura and Y. Sakamaki. 2001. The present situation of agriculture in Yap. Pp. 91-93 *in* The Progress Report of the 1999 Survey of the Research Project 'Social Homoeostasis of Small Islands in an Island-Zone' (T. Aoyama, ed.), Kagoshima University Research Center for the Pacific Islands, Occasional Papers No. 34.

Orton Williams, K.J. 1980. Plant-Parasitic Nematodes of the Pacific. Technical Report Vol.8, UNDP/FAO-SPEC Survey of Agricultural Pests and Diseases in the South Pacific. Commonwealth Institute of Helminthology, England, 192pp.

Raynor W.C., and J.H. Fownes. 1991. Indigenous agroforestry of Pohnpei: 1. Plant species and cultivars. *Agroforestry Systems* 16:139-157.

Status report on *Musa* nematode problems and their management in India

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Introduction

Banana is known to adapt very quickly and produce higher yields under favourable conditions. It is, however, prone to attack by different pathogens like fungi, viruses, bacteria and nematodes. Among the production constraints, nematodes constitute one of the major limiting factors to banana production, causing extensive root damage, resulting in serious economic losses. Crop losses caused by nematodes to bananas are very high, with average annual yield losses estimated at about 20% worldwide (Sasser and Freckman 1987). This country paper deals with the important nematode problems of banana in the country with special reference to their distribution, crop losses, symptomatology and the integrated nematode management approach including host reaction of different genotypes.

Distribution of banana

India has emerged as the largest producer of banana in the world with a total production of 16.9 million tonnes per annum from 49 000 hectares, having a share of 37% of the total fruit production (Singh 2002). The major banana-growing states are Tamil Nadu, Andhra Pradesh, Kerala, Karnataka, Gujarat, Maharashtra, Bihar, West Bengal and Assam. Other states have limited area and production. Among the states, Tamil Nadu has the maximum area with 83 255 ha with an annual production of 300 700 tonnes (Anonymous 2002), whereas Maharashtra tops the list with the highest productivity of 48 t/ha, followed by Tamil Nadu with 44t/ha.

Major nematode pests of banana

A total of 132 species of nematodes belonging to 54 genera have been reported to be associated with the rhizosphere of banana. Out of these, 71 species of nematodes belonging to 33 genera have been recorded from banana in various parts of India. The important nematode problems encountered in banana are the burrowing nematode, *Radopholus similis,* followed by the root-lesion nematode, *Pratylenchus*

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coffeae. The other economically important nematode pests of banana, which have some regional differences, are the spiral nematodes *(Helicotylenchus multicinctus and H. dihystera),* the root-knot nematodes *(Meloidogyne incognita and Meloidogyne javanica*), the cyst nematode *(Heterodera oryzicola)* and the reniform nematode *(Rotylenchulus reniformis)*. Individual nematode problems on banana and their management are discussed in detail in this country paper.

Nematode survey on economically important banana genotypes in India

An extensive survey was undertaken to examine the biodiversity in plant-parasitic nematodes associated with banana from 1997 to 2002. A total of 220 soil and root samples were collected from various varieties of banana, namely Nendran, Red banana, Robusta, Dwarf Cavendish, Ney Poovan, Poovan, Rasthali, Pachanadan and Jahazi. These varieties are grown in different agro-climatic conditions in South India, Gujarat, Maharastra, Bihar and North Eastern hilly regions of India. The nematode populations were assessed (Table 1). Analysis of the root samples revealed that the root-lesion nematode was the predominant species and ranked first in prominence and importance values. This was followed by the root-knot nematode, the spiral nematode and the burrowing nematode. The cyst nematode was reported for the first time in Robusta in Tamil Nadu (Sundararaju *et al.* 2001). Analysis of soil samples collected from bananas revealed the presence of 17 genera of plant-parasitic nematodes. Among them, *R. reniformis*, *Helicotylenchus* spp., *Meloidogyne* spp., *Hoplolaimus* spp., *P. coffeae*, *Tylenchorhynchus* spp., *Criconemoides* spp. and *Tylenchus* spp. were the

Table 1. Occurrence of major plant-parasitic nematodes recorded in major banana-growing states of India.

State	No. of samples	No. of samples containing the following species			
		Radopholus similis	*Pratylenchus coffeae*	*Meloidogyne incognita*	*Helicotylenchus multicinctus*
Tamil Nadu	122	10	74	38	41
Pondicherry	10	0	4	4	2
Kerala	26	12	5	5	6
Andra Pradesh	6	0	4	3	3
Karnataka	12	0	6	8	4
Gujarat	7	4	2	2	0
Maharashtra	9	4	0	3	4
NEH Regions	28	0	4	1	12
Total	220	30	99	64	68

Table 2. Occurrence, absolute frequency and relative frequency of plant-parasitic nematodes recorded from 250 g soil sample in major banana-growing states of India.

Species	No. of samples	Absolute frequency (%)	Relative frequency (%)
Aphelenchus sp.	21	9.5	3.7
Aphelenchoides sp.	15	6.8	2.7
Criconemoides sp.	15	6.8	2.7
Helicotylenchus multicinctus	49	22.3	8.7
Heterodera oryzicola	47	9.5	3.7
Hemicriconemoides sp.	21	21.4	8.4
Hirschmanniella sp.	13	5.9	2.3
Hoplolaimus indicus	35	15.9	6.2
Longidorus sp.	31	14.1	5.5
Meloidogyne incognita	65	29.5	11.6
Pratylenchus coffeae	70	7.7	3.0
Radopholus similis	28	12.7	5.0
Rotylenchulus reniformis	95	18.6	7.3
Rotylenchus sp.	41	43.2	16.9
Tylenchus sp.	25	11.4	4.5
Tylenchorynchus sp.	32	11.4	4.5
Xiphinema sp.	18	8.2	3.2
TOTAL	**220**	**100**	**100**

most predominant species associated with banana. The analysis of plant-parasitic nematodes such as frequency, density and prominence value were also calculated and presented in Table 2 (Sundararaju *et al.* 2002).

The burrowing nematode, Radopholus similis

Radopholus similis enjoys a wide geographical distribution in the tropical and subtropical banana-growing regions of the world. In India, the first occurrence of the nematode was reported on banana from Palghat District of Kerala (Nair *et al.* 1966). Subsequently, this nematode was reported from banana in almost all banana-growing states in the country, including the isolated pockets like Andaman and Lakshadweep Islands. Economic loss due to the nematode infestations was estimated at 50% when the nematode load was 3000 per plant (Davide and Marasigan 1985). A density of 10 000 nematodes per 100 g root was reported to be the damaging level in Central America (Volkers and Gamboa 1988). In India, *R. similis* infestation on banana is responsible for 31-41% yield loss in banana (Nair 1979). The survival and multiplication of the nematode deep in the cortex of rhizomes or

planting material helped in its faster spread to new areas. The suckers removed for transplanting from nematode-infected banana clumps and planted in new areas produced infected plants. The transmission of the organisms is therefore presumed to be through suckers used for propagating the crop vegetatively.

The root-lesion nematode, Pratylenchus coffeae

Pratylenchus coffeae is the next most important nematode to the burrowing nematode. In India, crop losses due to root-lesion nematode in banana cv. Nendran was reported to be 44.4% (Sundararaju *et al*. 2003). The nematode is reported to have spread to different banana-growing regions through the infested corm, with various intensities in different soils. In India, the nematode is known to occur on plantain (AAB) in South India, Gujarat, Orissa, Bihar and Assam. *Pratylenchus thornei*, another important species, was found to infest banana plants from Assam only. The nematode also spreads like burrowing nematode from one locality to another through the planting materials, as well as through the water that drains from infested areas to non-infested areas. This nematode has more similarities with *R. similis* and often, its damage is attributed to *R. similis*. Since the lesion-producing nematodes such as *R. similis* and *P. coffeae* are considered to be the economically important nematode pests of banana and are widely distributed in South India (Koshy *et al*. 1978; Sudha and Sundararaju 1996), studies were initiated to determine the seasonal fluctuations of these nematode populations in different cultivars of banana roots. This was done through the periodic sampling of nematode-infested banana plants at NRCB Farm. The results revealed that maximum population was recorded in the months of October to December and minimum during the months of March to August. Cultivars Nendran and Kalyan Bale were found to be highly susceptible to *P. coffeae* and *R. similis*, respectively (Sundararaju 2002). Studies were also conducted to find out the effect of different soil types, namely alluvial, sandy loam, silty clay, black soil, laterite and red soil on the multiplication of *P. coffeae* and growth of banana plants. The results revealed that maximum plant growth was noticed in alluvial soil followed by sandy loam soil, whereas minimum plant growth and maximum root-lesion index were noticed in silty clay soil. The reproduction factor of nematode population based on root lesions and final root and soil population was maximum in silty clay soil followed by alluvial soil while minimum nematode population was recorded in red soil. The multiple regression equations pertaining to the soil's physico-chemical properties versus nematode populations in both soils and roots were derived (Sundararaju and Jeyabhaskaran 2002).

The root knot nematode, Meloidogyne incognita

Meloidogyne incognita was found to attack banana roots and has wide distribution in major banana-growing regions in the country (Rajendran *et al*. 1979; Tiwai and Dave 1985), whereas *M. javanica* is confined mainly to mid hills and plains where the temperature is higher. The root-knot nematode is highly pathogenic to Poovan banana causing 30.9% yield loss in Tamil Nadu (Jonathan and Rajendran 2000). Since root-lesion and root-knot nematodes jointly affect banana and cause considerable yield loss, studies were initiated to know about the penetration and development of *P. coffeae* and *M. incognita* in susceptible cultivars of banana, namely Nendran and Poovan. The time taken by the root-lesion nematode to penetrate into the roots of a banana was 48 hours in cv. Nendran and 72 hours in cv. Poovan. A similar trend was observed in the case of the root-knot nematode. The multiplication of nematodes was more favoured in cv. Nendran than in Poovan. This suggests that cv. Nendran is more susceptible to both nematodes when compared with Poovan (Sundararaju *et al.* 2002).

The spiral nematode, Helicotylenchus multicinctus

Helicotylenchus multicinctus has been found to infest all varieties of banana throughout the tropics and subtropics. Among the 17 *Helicotylenchus* species reported to occur on banana, *H. multicinctus, H. dihystera, H. africanus and H. erythrinae* are the most important pests in banana, causing severe economic loss. *Helicotylenchus multicinctus* was the major nematode problem in subtropical regions such as Israel and Taiwan where *R. similis* is absent. It caused a serious decline of banana and was responsible for 33.83% loss in yields. The pathogenicity of *H. multicinctus* on banana studied in a pot-culture experiment revealed that plant growth was significantly reduced at 1250 nematodes per plant (Rajendran and Sivakumar 1996).

Studies carried out on the biochemical alterations in 28 accessions of banana plants grown under nematode-infested soil under field conditions revealed that higher levels of tannic acid (phenol), sugars, amylase, cellulose, protein and chlorophyll were recorded in cv. Gros Michel and lower levels in FHIA-23, whereas the remaining germplasm had similar levels (Sundararaju *et al*. 2002).

The nematode population build-up was studied in banana cv. Robusta (AAA) cultivated in different systems such as single row, paired row and three suckers per hill. Analysis of the root samples revealed the presence of *P. coffeae*, *M. incognita* and *H. multicintus*. Maximum populations of all three nematodes were recorded in the system with three suckers per hill with a fertigation level of 50% N and K, whereas

in paired-row system, minimum nematode population was recorded in both soil and root samples (Sundararaju *et al.* 2002).

The cyst nematode, Heterodera oryzicola

Heterodera oryzicola is an important nematode found in banana cv. Nendran in Kerala. It was found that an initial inoculum of 100 to 1000 viable cysts per plant at planting time could reduce the bunch weight by 20.5-56.5%. Another important species, which attacks on banana is *H. oryzae*. The pathogenecity of *H. oryzicola* in banana was studied by Charles and Venkitesan (1993). They reported that all the growth characteristics and fruit yield were reduced in nematode-inoculated plants. *Heterodera oryzicola* increased leaf nitrogen, reduced sugars in fruit and decreased non-reducing sugars. The total sugar content was less in the fruit of infected plants. This nematode was recorded from cvs. Robusta and Nendran in Tamil Nadu (Sundararaju *et al.* 2002).

Nematode fungal complex disease on banana

Fusarium wilt disease caused by *Fusarium oxysporum* f.sp. *cubense* (FOC) is recognized as one of the most widespread and destructive plant diseases in the recorded history of agriculture (Simmonds 1966). It also still remains as a major constraint to banana production worldwide (Ploetz *et al.* 1990). Fusarium wilt is often present together with plant-parasitic nematodes such as *P. coffeae* and *M. incognita* and causes serious economic losses to several crops in India. Since these two nematodes cause considerable yield loss to banana and are closely associated with FOC, an investigation was carried out in order to find out the individual and interactive effects of nematodes (*P. coffeae* and *M. incognita*) along with the fungal pathogen (FOC) in banana cv. Rasthali (AAB). The results revealed that the plants inoculated with nematodes either singly or in combination followed by fungus led to the early onset and increased severity of the fusarium wilt disease. Maximum reduction of plant growth was observed when all three pathogens (FOC, *P. coffeae* and *M. incognita*) were present together compared with when only one or two pathogens were inoculated. This indicates a positive interaction among all three pathogens (Sundararaju and Thangavelu 2001).

Nematode management

Non-chemical methods

Effective prophylactic measures are of considerable importance to reduce the initial inoculum level and to curb their progressive multiplication by intercropping and by some appropriate cultural practices. Nowadays, non-chemical methods are receiving greater attention in view of the cost of chemical control and the pollution potential of the soil environment. Different non-chemical methods for controlling nematodes on banana are carried out at NRCB as well as in other institutions. These are as follows:

Cultural methods

Rajendran *et al.* (1979) found that fallowing for a period of 3 months after banana harvest effectively suppressed the burrowing nematode population, while fallowing for 5 months destroyed not only burrowing nematode but also *Fusarium* sp. Crop rotation with rice, sugarcane, green gram or cotton suppressed the nematode population and increased the yield of banana. Intercropping banana with *Crotalaria juncea* was found to reduce *R. similis* population, besides causing better growth and higher yield (Venkitesan and Charles 1983). Soil covered with black polyethylene, sugarcane trash and banana trash were also reported to reduce *R. similis* and *Pratylenchus* sp. in the soil and roots of banana (Bhattacharya and Rao 1984). Subramaniam and Selvaraj (1990) reported that the application of carbofuran at planting and intercropping with *Tagetes, Crotalaria* or radish significantly reduced the *R. similis* population, with carbofuran having the greatest effect. Jonathan *et al.* (2000) studied the effect of organic amendments on the management of root-knot nematode and the spiral nematode on banana. This resulted in a significant reduction in the nematode population and an increase of yield in plants treated with press mud (a by-product from sugar factory) (15 t/ha) or neem cake (1.5 t/ha). The organic amendments were comparable with the carbofuran treatment. Shanthi *et al.* (2001) reported that sunhemp intercrop in banana field was found to be effective in reducing *R. similis, P. coffeae* and *H. multicinctus* population to 38%, followed by marigold and cowpea which recorded 29% and 22% reduction, respectively. However, the effect of carbofuran 3G and monocrotophos 0.05% were found superior in increasing the fruit yield (47% and 43%, respectively) and reducing the nematode population by 56% and 46%, respectively.

A field experiment was conducted in farmer's field on cv. Nendran (AAB) using intercrop *Tagetes* spp. in comparison with the

recommended practice of paring of suckers, and with Monocrotophos 36 EC dipped at 0.05% at the time of planting. Results showed that significant reduction in root-lesion nematode population (85%) was observed in the banana field where *Tagetes erecta* was grown as intercrop, followed by Monocrotophos dip treatment (75%), whereas maximum nematode population was recorded in untreated control plants. Further, the yield of banana significantly increased (12 kg/plant) when intercropped with *Tagetes* spp., compared with the untreated control (9 kg/plant) (Sundararaju *et al*. 2002).

The effect of organics and inorganics for management of root-lesion nematode, *P. coffeae* was studied in six commercial cultivars of banana *viz*., Nendran, Karpuravalli, Rasthali, Robusta, Monthan and Poovan. The results revealed that a significant reduction in *P. coffeae* population and increase in yield were recorded in plants which received 50% N applied through neem cake (Sundararaju and Kumar 2002). An attempt was also made to study the best treatment and variety based on nematode population on banana using artificial networks (Sundararaju *et al*. 2002). They studied the population pattern of plant- parasitic nematodes from a field trial carried out on locally available organic manures in banana cv. Karpuravalli (ABB). Analysis of soil and root samples revealed the presence of *P. coffeae, M. incognita, H. multicinctus* and *H. oryzicola*. All four nematodes were found to be significantly lower in plants which received distillery sludge at 2.5 kg + vermicompost at 1 kg + neem cake at 1 kg + poultry manure at 2.5 kg at 3, 5, 7 months after planting compared with control plants. It was also at par in treatment with distillery sludge at 2.5 kg + 1 kg neem cake applied at the same time intervals. The root-lesion and root-gall indices were higher in control plants registering 4.0 and 3.7, respectively. Thus, the present study exhibits the significant role of organic amendments in the nematode management strategies on banana (Sundararaju *et al*. 2002).

An investigation was also carried out for the management of major nematodes infesting banana, namely *P. coffeae* and *M. incognita,* using different neem formulations (Econeem, Nimbicidine and Neemgold) and plant growth promoter (Biovita). These were then compared with the standard treatment (Carbofuran 3 G). The results revealed that all treatments were found effective in reducing the nematode population with enhanced plant growth compared with control plants. Among the three neem formulations evaluated, Econeem and Nimbicidine showed maximum efficacy in reducing the nematode population with increased plant growth. However, the plants treated with Carbofuran 3G recorded the maximum plant growth with absolute control of

nematode population. Maximum bunch weight of 18 kg was recorded in plants treated with Carbofuran at 50 g/plant and Biovita at 30 ml/plant applied twice a year. Meanwhile, 17 kg, 16 kg and 15 kg bunch weight was recorded with respect to Biovita at 20 g/plant, Carbofuran at 40 g/plant and Neemgold at 10 and 20 g/plant, Biovita at 15 ml/plant and Nimbicidine at 30 ml/plant. Thus, both nematodes not only delayed the duration of crop cycle but also limited the yield up to 44.4% in cv. Nendran (Sundararaju and Cannayane 2003).

A field experiment carried out for the management of *P. coffeae* using press mud recorded significant reduction in nematode population and increased plant growth as compared to the control. However, press mud application was at par with Carbofuran treatment. The use of press mud is economical and environmentally safe as compared to chemical nematicides (Sundararaju *et al*. 2002).

Another experiment was carried out with locally available plant species against *P. coffeae* under *in-vitro* conditions. Among the ten plant extracts tested, *Azadirachta indica* (Neem tree) exhibited maximum mortality of *P. coffeae* when exposed to 20 h at 80% concentration of plant extract. This was followed by *Vitex negundo* and *C. juncea* (Sundararaju and Cannayane 2002). These plant species were further tested using their dry and fresh leaves against the root-lesion nematode, *P. coffeae* in banana cvs. Nendran and Rasthali under field conditions. All the botanicals were effective in reducing the nematode population and significantly increased the plant growth and yield compared to untreated control. Among the different botanicals tried, *A. indica, Calotropis procera, Datura stramonium, C. juncea* and *V. negundo* were found to be superior and effective in significantly reducing the nematode population and increasing the yield (Sundararaju *et al*. 2003).

Biocontrol agents

Management of banana nematodes with the use of synthetic nematicides poses several problems like ground-water pollution, effect on beneficial organisms, resurgence of pest, etc. Biomolecules having an antagonistic effect on target nematodes is one such approach to solve the aforementioned ill effects of chemical nematicides (Sundararaju 2000). Fungi that colonize the healthy roots exhibiting antagonistic effect to invading nematodes are termed as endophytic fungi. This fungi are regarded as the best alternative to manage banana nematodes.

Studies were further undertaken to isolate endophytic fungi from 12 accessions belonging to different genomic groups of banana; and to

evaluate its bio-efficacy on *P. coffeae* and *M. incognita* under *in-vitro* conditions. The endophytic fungi isolated from banana were identified as *Fusarium* spp and their biocidal effects on *P. coffeae* and *M. incognita* were studied. The culture filtrates of endophytic fungi isolated from diploids exerted higher nematicidal effect than those isolated from triploids *in vitro*. The nematicidal effects of endophytic fungi on *P. coffeae* and *M. incognita* juveniles were increased with increasing exposure period to the culture filtrates (Sundararaju *et al.* 2002).

An attempt was made to mass-produce the nematode egg-parasitic fungal bioagent, *Paecilomyces lilacinus*, on banana wastes (leaf, petiole and pseudostem), castor and pungam leaves and their combinations and a standard check with pre-soaked sorghum grains. Highest spore load of 8 x 10^6 *P. lilacinus* per g of substrate was harvested in sorghum grains, banana petiole and castor leaf mixture. Banana pseudostem and pungam leaves were comparable in their substrate nature to the fungus (Sundararaju and Cannayane 2002). The root-knot nematode was recorded for the first time in an ornamental banana, *Ensete superbum*. The eggs of root-knot nematode were parasitized by the fungus naturally and the fungus was identified as *P. lilacinus*. Although *P. lilacinus* has been reported to be a potential egg pathogen of root-knot nematodes, the present isolate has shown its antagonistic effect on root-knot nematode (Sundararaju *et al.* 2003).

Jonathan and Rajendran (2000) reported that the application of *P. lilacinus* at 15 or 20 g per plant significantly reduced the root gall index, number of egg masses, eggs per mass, females and soil population of *M. incognita* in banana cv. Poovan under greenhouse conditions. The effect of this treatment was comparable with 40 g Carbofuran per plant. *Paecilomyces lilacinus* applied at 30 g/kg of soil at planting (30 days before nematode inoculation) was comparatively effective in controlling the population of *R. similis* in banana (Devarajan and Rajendran 2001). Devarajan and Rajendran (2002a) reported that the greatest reduction in the population of *M. incognita* infesting banana cv. Robusta was obtained with the highest level of application of *P. lilacinus* (30 g/kg of soil) during planting compared with 10, 20 g/ kg of soil during planting or at 30 or 60 days after planting, respectively. Field and greenhouse experiments were conducted by using different doses of bio-agent, *Trichoderma viride* on susceptible cultivars viz., Virupakshi and Rasthali. Significant yield increase and reduction in nematode population were noticed from the treated plants. The effect of *T. viride* on the growth of cv. Rasthali infected with root-lesion nematode, *P. coffeae* and fungus, *F. oxysporum* f.sp. *cubense* in pots under the greenhouse conditions showed a significant reduction

in nematode population. Two applications of biocontrol agent, *T. viride* at 20 g/plant: one at the time of planting and one after 3 months of planting, were found effective in controlling nematodes (*P. coffeae* and *M. incognita*) as well as in reducing the incidence of panama wilt disease in cvs. Rasthali and Virupakshi (Sundararaju *et al.* 2001).

An experiment on the effect of *Verticillium chlamydosporium* culture filtrates on second-stage juveniles and eggs of *M. incognita* was carried out under *in-vitro* conditions. The results revealed that the marked deleterious effect of culture filtrates (25, 50, 75 and 100%) were observed on *M. incognita* second-stage juveniles. Among the different dilutions of *V. chlamydosporium* culture filtrates, 100% concentration of the fungus-culture filtrate showed highest percent mortality of *M. incognita* juveniles (78.7%). The nematode egg-parasitic fungus, *V. chlamydosporium,* was also multiplied on the locally available organic substrates like farm yard manure (FYM), neem cake, wheat bran, cumbu grains, banana wastes (petiole, leaf and pseudostem) and sorghum grains. It was observed that neem cake showed profuse growth of the fungus when compared with the rest of the substrates (Sundararaju *et al.* 2003).

Chemical methods

Since the root-lesion nematode causes serious decline and considerable yield loss in banana, a field experiment was conducted in fields heavily infested with root-lesion nematode on three commercial cultivars of banana *viz.*, Karpuravalli (ABB), Monthan (ABB) and Nendran (AAB). This was done by using two nematicides *viz.*, Monocrotophos and Carbofuran, at different doses and at different periods of application, along with the recommended practice of paring and pralinage of the suckers. Results revealed that both chemicals applied at different periods were found to be effective in reducing the nematode population and in significantly increasing plant growth and yield compared with untreated control. Some treatments were found to be very effective in reducing the nematode population and significantly increasing the yield of Karpuravalli, Monthan and Nendran (26.0 kg, 22.3 kg and 9.9 kg, respectively) compared with untreated control (16.2 kg, 15.1kg and 4.7 kg, respectively) (Sundararaju *et al.* 1999). Among these are the combination of sucker dip with Monocrotophos at 0.5%, Bavistin at 0.1% followed by Carbofuran at 50 g/plant applied at 3 and 6 months after planting or application of Carbofuran at 50 g/plant once at the time of planting in the pit or dipping of the suckers with mud slurry and sprinkling with Carbofuran at 50 g/sucker and two applications after planting at 3-month intervals.

Integrated nematode management

Chennabasappa (1994) reported that the integration of neem cake (400 g/plant), Carbofuran (20 g/plant), mycorrhiza (500 chlamydospores/plant) and *Pasteuria penetrans* (100 g soil containing an average of 20 *P. penetrans)* infected second-stage juveniles of *M. incognita* race I (each of which had an average of 15 spores attached to their cuticle) and were effective in improving the growth parameters of the banana plant, besides giving the highest reduction in nematode population in root and soil as well as a reduction in the lesion index. Parvatha Reddy *et al.* (1996) found that by integrating eco-friendly components such as oil-seed cakes of castor, karanj and neem at 400 g/plant with endomycorrhiza *Glomus mosseae* (containing 25 chlamydospores per g of inoculum) reduced the population of *R. similis* both in soil and roots and increased plant-growth parameters and fruit yield of banana. Roy *et al.* (1998a) reported that dipping disease-free banana suckers in 0.2% solution of Bavistin for 45 min was effective in reducing disease intensity of wilt complex disease (*F. oxysporum*, *Pseudomonas solanacearum* and *M. incognita*). Other effective measures were flooding and application of inorganic fertilizers (NPK at 225, 75 and 60 kg/ha, respectively) in soil, which amended with organic compounds like compost or oil-seed cake and pesticides.

Vidya and Reddy (1998) reported that the integration of neem cake (neem extracts), Carbofuran, *P. penetrans* and *Glomus fasciculatum* was the most effective in enhancing the plant growth and yield of banana, raising the cost:benefit ratio to 1:2.65, and reducing the *R. similis* population both in soil (95.16%) and roots (89.27%). Ravi *et al.* (2000) reported that integration of 250 g neem cake, 20 g *T. viride* and Carbofuran 3G at 10 g/sucker resulted in the reduction of *R. similis* population in soil and roots of banana.

Investigations were carried out on the management of the burrowing nematode, *R. similis*, infesting banana cv. Dwarf Cavendish, by integrating eco-friendly components such as oil cakes (neem and pongamia, each at 500 g/plant), a biological control agent (*T. viride* at 10 g/plant) and a nematicide (carbofuran 3G at 40 g/plant). Among the different treatments, combination of neem cake, Carbofuran and *T. viride* was most effective in reducing the nematode population, improving plant growth and increasing fruit yield (76.3 t/ha) with wider cost:benefit ratio (1:2.9) (Harish and Gowda 2001). Kumar (2001) reported that the *R. similis* population in soil and root was significantly reduced when the banana plants were treated with Carbofuran 3G at

Host reaction of different genotypes

Table 3. Reaction of *Musa* clones for nematode resistance.

Musa clones	Host response	Nematode spp.	Reference
Kadali, Padalimoongil, Ayiranka Poovan, Peykunnan, Vennettukunnan, Tongat, Anaikomban	R	*R. similis*	Rajendran *et al.* 1979
Amas, Senora, Bunga, Lacatan, Alaswc, Dadakan	R	*R. similis, M. incognita*	Davide and Marasigan 1985
Yelakkibale	R	*M. incognita*	Ravichandran and Krishnappa 1986
Karpooravalli	T	*R. similis*	Kulasekaran 1986 Subramaniyan and Selvaraj1990
Patkapura, Mendhi, Kothia	HR	*R. similis*	Ray and Parija 1987
Anaikomban	R	*R. similis*	Sathiamoorthy 1987
Bantala, Dwarf Cavendish	MR	*R. similis*	Ray and Parija 1987
Padali Moongil, Kunnan, Ayiramka Poovan	R	*R. similis*	Saeed *et al.* 1988
Athia	T	*H. dihystera*	Choudhury and Phukan 1990
Kunnan, Poom Kadali, Nalli Poovan	R	*R. similis*	Anitha *et al.* 1996
Palayankodan	MR	*R. similis*	Sudha and Sundaraju 1996
Anaikomban, Adakkakunnan, Kunnan	T	*R. similis*	Johnson and Sathiamoorthy 1999
Ambalakadali, Anaikomban, Eraichivazhai, Paka, Pisang Jari Bouya, Manoranjtham, Chinali	MR	*R. similis, P. coffeae* and *H. multicinctus*	Elain Apshara 2000
Pisang Lilin, Sannachenkadali Co-1, Cheenabale, Dakshinsagar, Kalibow, Kerala – 1, Krishnavazhal, Mysore, Neyvazhai, Sandanavazhai, Thiruvananthapuram, Vannan, Ladan Klue Teparod (ABBB), Bodles Altafort (AAAA), Neyvannan x *M.balbisiana* (ABBB)	T	*R. similis, P. coffeae* and *H. multicinctus*	Elain Apshara 2000
Matti, Kullan, Chinali, Nallabontha, Burharia	MR	*R. similis, P. coffeae* and *H. multicinctus*	Shanthi *et al*. 2001
Anaikomban, Namarai, H 59, H 65 Tongat, H 84, H 109, H 110	MR R	*R. similis* and *P. coffeae*	Devarajan and Rajendran 2001
Agnieswar, Mottapoovan, CO.1, Neyvazhai, Vannan, Ladan Padathi, Melakali, Cheenabale,	T	*R. similis, P. coffeae* and *H. multicinctus*	Shanthi *et al*. 2002
Nendrakunnan, Lambi, Batheesa Ashy, Alshi, Neyvannan, Sambarani, Boothibale, Rajavazhai, Beula, Kanthali, Kothia and Muthia	T	*R. similis, P. coffeae* and *H. multicinctus*	Shanthi *et al*. 2002
Pisang Mas, Pisang Berlin, Kanaibansi, Namarai, Cultivar Rose	T	*P. coffeae*	Sundararaju *et al*. 2002
Namarai, Hatidat	R	*H. multicinctus*	
Burrow Cemsa and hybrid E.A.0322 FHIA-01 in Pome group	R	*R. similis, P. coffeae, M. incognita* and *H.multicinctus*	Sundararaju and Uma 1999

R=resistant; MR=medium resistant; T=tolerant

40 g/sucker followed by *Pseudomonas fluorescens* at 6.25 kg/ha with FYM 500 kg/ha and neem cake 500 kg/ha. The fruit yield was increased by 165.40 kg/40m^2 in Carbofuran 3G at 40g/sucker followed by *T. viride* 2.5 kg/ha with FYM 500 kg/ha (147.25 kg/m^2).

A field experiment conducted with banana cv. Basrai in root-knot nematodes (*M. incognita and M. javanica)* infested field showed that the combined application of *P. lilacinus* (25 kg/ha) and Carbofuran (33 kg/ha) recorded the significantly lowest root-knot index (1.8), with higher plant height and better growth, and also gave the highest fruit yield of 42 t/ha (Vyas *et al.* 2001).

IMTP Phase – III

Twenty one hybrids and cultivars of banana were screened for their reaction to *P. coffeae*, *M. incognita* and *H. multicinctus* in pots under greenhouse conditions as part of IMTP Phase-III. Twenty-one cultivars were found susceptible to root-knot nematode, *M. incognita*, in various intensities. For the root-lesion nematode, *P. coffeae*, 19 out of 21 cultivars were susceptible. This nematode was not recorded in two cultivars, namely Kanai Bansi and GCTCV-215. However, these cultivars are found susceptible to two other nematodes, *M. incognita* and *H. multicinctus.* Similarly, this spiral nematode, *H. multicinctus*, was recorded in 15 out of 21 cultivars in various intensities. Anaikomban, Pisang Berlin, Namarai, Hatidat, FHIA – 03 and Pisang Ceylan did not show symptoms of *H. multicinctus* infection but these cultivars were found susceptible to *P. coffeae* and *M. incognita.* Hence, none of the cultivars tested against these three nematodes were found resistant (or immune).

Future perspectives

1. Development of nematode-resistant cultivars either by conventional breeding or by genetic engineering using identified resistant banana varieties.
2. Identification of effective trap or antagonistic crops with economic value to reduce the severity of nematode problem.
3. Study the nutritional status and biochemical alterations in banana roots infected by major nematode pathogens.
4. Isolation of native virulent strains of bioagents for effective management of nematodes.
5. Induction of systemic resistance through easily available and economically feasible methods.

6. Screening of *Musa* germplasm in pots in the greenhouse and in the field against major nematode pathogens.
7. Eco-friendly management of root-knot and lesion nematodes in banana and plantain through integration of bio-fertilizers and phyto-extracts.

References

Anitha, N., L. Rajamony and T.C. Radhakrishnan. 1996. Reaction of banana clones against the major biotic stress. Planter 72:315-321.

Anonymous. 2002. Season and Crop Report, Department of Economics and Statistics, Government of Tamil Nadu, Chennai. 6pp.

Bhattacharya R.K. and V.N.M. Rao. 1984. Effect of soil covers and soil moisture regimes on nematode population in soil and in root of banana. J. Res. Assam Agri. Univ.5 :206–209.

Charles J.S.K. and T.S. Venkitesan. 1993. Pathogenicity of *Heterodera oryzicola* (Nemata : Tylenchina) towards banana (*Musa* AAB cv. Nendran). Fundamental and Applied Nematology 16(4):359-365.

Chennabasappa B.S. 1994. MSc (Ag) thesis, *University of Agricultural Sciences*, Bangalore. 117pp.

Choudhury B.N. and P.N. Phukan, 1990. Distribution and occurrence of certain plant-parasitic nematodes in different cultivars of banana. Curr. Nematol.1:153–156.

Devarajan K. and G. Rajendran. 2001. Reaction of some banana clones to the burrowing and lesion nematodes. Indian Journal of Nematology 31(2):159-178.

Devarajan K. and G. Rajendran. 2001. Effect of fungus *Paecilomyces lilacinus* on the burrowing nematode, *Radopholus similis* in banana. Pest Management in Horticultural Ecosystems 7:171–173.

Devarajan K. and G. Rajendran. 2002. Effect of fungal egg parasite, *Paecilomyces lilacinus* (Thom.) Samson on *Meloidogyne incognita* in banana. Indian J. Nematol. 32:88–90.

Elain Apshara S. 2000. Breeding bananas for resistance to nematodes and sigatoka leaf spot. PhD (Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore.

Harish M. and D.N. Gowda. 2001. Management of the burrowing nematode, *Radopholus similis* (Cobb) Thorne infesting banana. Indian J. Nematol. 31:23–25.

J.Ent. 28:553-554.

Johnson R.N. and Sathiamoorthy, S. 1999. Reaction of diploid banana cvs. to the burrowing nematode, *Radopholus similis*. South Indian Horticulture, 47(1/6):170-171.

Jonathan E. I and G. Rajendran. 2000. Assessment of avoidable yield loss in banana due to root-knot nematode, *Meloidogyne incognita.* Indian J. Nematol 30(2):162-164.

Jonathan E.I. and G. Rajendran. 2000. Biocontrol potential of the parasitic fungus *Paecilomyces lilacinus* against the root-knot nematode *Meloidogyne incognita* in banana. J. Biol. Control 14:67–69.

Jonathan E.I., G. Rajendran and W.W. Manuel. 2000. Management of *Meloidogyne incognita* and *Helicotylenchus multicinctus* in banana with organic amendments. Nematologia Mediterranea 28(1):103–105.

Koshy P.K., P. Sundararaju, and V.K. Sosamma. 1978. Occurrence and distribution of *Radopholus similis* (Cobb) Thorne in South India. Indian J. Nematol. 8:49-58.

Krishnamoorthy V. 2002. Breeding for resistance to sigatoka leaf spot and nematodes in banana (*Musa* sp.) PhD (Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore.

Kulasekaran M. 1986. Banana breeding. Tamil Nadu Agri. Univ., Tech. Bull. No. 2:24.

Kumar S. 2001. Management of burrowing nematode, *Radopholus similis* in banana. Pp 351-355 *in* Proceedings of the National Seminar on Emerging Trends in Pests and Diseases and their Management held at CPPS, TNAU, 11-13 October 2001.

Nair K.K.R. 1979. Studies on the chemical control of banana nematodes. Agric. Res. J. Kerala. 17:232-235.

Nair M.R.G.K., N..M. Das and M.R. Menon. 1966. On the occurrence of the burrowing nematode *Radopholus similis* (Cobb) Thorne on banana in Kerala, India.

Parvatha Reddy, P., M.S. Rao and M. Nagesh. 1996. Integrated management of the burrowing nematode, *Radopholus similis* using endomycorrihiza, *Glomus mosseae* and oil cake *in* 'Conference on Challenges for Banana Production and

Utilization in 21st Century' held at Trichy on 24-25 September 1996.

Patel A.D., D.J. Patel and N.B. Patel, 1999. Determination of threshold level of *Meloidogyne incognita* and *M.javanica* pt. 1 on banana cv. Basrai. Pp 91-97 *in* Proceedings of national symposium on rational approaches in nematode management for sustainable agriculture, Anand, India, 23-25 November 1998.

Ploetz R.C., J.P. Herbert, K Sebasigari, J.H. Hernandez, K. G. Pegg, J. A. Ventura and L. S. Mayato. 1990. Importance of *Fusarium* wilt in different banana growing regions. Pp 9-26 *in* Fusarium Wilt of Banana, (R.C. Ploetz, *ed.*), APS, St. Paul, USA.

Rajendran G., T. N. Naganathan and S. Vadivelu. 1979 Studies on banana nematodes. Indian Journal of Nematology 9:54.

Rajendran G. and C.V. Sivakumar. 1996. Pathogenicity of the spiral nematode, *Helicotylenchus multicinctus* and effect on yield and nutrient status of banana. Pest Management in Horticultural Ecosystems 2:23–27.

Ravi K., D.Nanjegowda and P.P. Reddy. 2000. Integrated Management of the burrowing nematode, *Radopholus similis* (Cobb) Thorne on banana. Pest Management in Horticultural Ecosystems 6:124 –129.

Ravichandran N.G. and K. Krishnappa, 1986. Reaction of banana cultivars popularly grown in Karnataka to the burrowing nematode, *Radopholus similis,* Indian Journal of Nematology 15:240.

Ray S. and A.K.Parija, 1987. Community analysis of nematodes in the rhizosphere of banana in Puri district, Orissa, Indian J. Nematol. 17:159-61.

Roy S. P.K. Ojha, K.L. Ojha, M.M. Jha and K.N. Pathak. 1998a. Integrated management of wilt complex diseases of banana (*Musa* sp.). J. Applied Biol. 8:46–49.

Saeed M., A. Khan and F. Qamar. 1988. Reaction of two commercial varieties of banana to root-knot nematode, Pak. J. Sci. Indul. Res.31:632–633.

Sasser J. N and D.W. Freckman. 1987. A world perspective on Nematology: the role of resistance of banana cultivars to the nematodes *Radopholus similis* (Cobb) Thorne and *Meloidogyne incognita* Chitwood. Philippine Agriculturist. 68:335-49.

Sathiamoorthy S. 1987. Studies on male breeding potential and certain aspects of breeding bananas. PhD (Hort.) thesis, Tamil Nadu Agricultural University, Coimbatore.

Shanthi A., G. Rajendran, N. Kumar and K. Soorianathasundaram. 2001. Screening of Banana cultivars for nematode resistance *in* Proceedings of National Seminar on Emerging Trends in Pests and Diseases and their management held at TNAU, 11-13 October 2001.

Shanthi A., G. Rajendran, N. Kumar and K. Soorianathasundaram. 2002. Evaluation of promising cultivars of banana against major nematodes *in* Proceedings of National Symposium on Biodiversity and Management of nematodes in cropping systems for sustainable agriculture, 11-13 November 2002, Durgapura, Jaipur (Rajasthan).

Shanthi A., K. Poornima, G. Rajendran, N. Kumar and K. Soorianatha Sundaram. 2001. Management of nematodes in banana. Pp 326-330 *in* Proceedings of National Seminar on Emerging Trends in Pests and Diseases and their Management held at CPPS, TNAU, 11-13 October 2003.

Shanthi A., S.R. Gowen, S. Sathiamoorthy, S.B. Nirmal Johnson and K. Soorianathasundaram. 1999a. Response of certain banana cultivars and hybrids to burrowing nematode and root-knot nematode under glass house condition. Pp 131-133 *in* Proceedings of the Third Int. Sym. Afro-Asian Soc. Nematologists, 16-19 April 1999, Coimbatore.

Shanthi A., S.R. Gowen, S. Sathiamoorthy, S.B. Nirmal Johnson and K.Soorianathasundaram, 1999. Field screening of synthetic banana hybrids for nematpde resistance. Pp. 133-135 *in* Proceedings of the Third Int. Sym. Afro-Asian Soc. Nematologists, April 16-19, Coimbatore.

Simmonds N. W. 1966. *Bananas 2nd ed.*, London, Longmans Scientific and Technical, London, UK. 512pp.

Singh H.P. 2002. Scenario of banana production, utilization and trade. Pp. 1-17 *in* Global Conference on Banana and Plantain, 28-31 October 2002.

Subramaniam S. and P. Selvaraj. 1990. Effect of antagonistic intercrops on burrowing nematode in Robusta banana. South Indian Horti. 38:216–217.

Sudha S. and P. Sundararaju.1996. Reaction of some banana cultivars to the burrowing nematode, *Radopholus similis*. Pp. 341-343 *in*

Proceedings of Banana – Improvement, Production and Utilization (H.P. Singh and K.L. Chadha, *eds.*). National Research Centre for Banana, Trichy.

Sundararaju P. and I. Cannayane. 2002. Production of nematode egg parasitic fungus, *Paecilomyces lilacinus*, on banana wastes and certain plant leaves. Indian J. Nematol.32:188-189.

Sundararaju P. and I. Cannayane. 2002. Antinemic activity of plant extracts against *Pratylenchus coffeae* infecting banana. Indian J Nematol. 32:121-124.

Sundararaju P. and I. Cannayane. 2003. Evaluation of different biopesticides against major nematode pathogens infesting banana cv. Nendran. National Symposium on Organic Farming in Horticulture for Sustainable Production. 29-30 August, 2003. CISH, Lucknow. pp. 66-67.

Sundararaju P. and R. Thangavelu. 2001. Influence of *Pratylenchus coffeae* and *Meloidogyne incognita* on the Fusarium wilt complex of banana cv. Rasthali. Nematol medit.(accepted for publication)

Sundararaju, P. and S. Uma. 1999. Evaluation of promising hybrids and cultivars of banana against Major Nematode pathogens. Pp. 122-125 *in* Proceedings of Third International Symposium of Afro-Asian Society of Nematologist, (TISAASN) (U.K.Mehata, *ed.*), Sugarcane Breeding Institute, Coimbatore.

Sundararaju P. 1996. Nematode pests of banana and their management *in* 'Challenges for Banana Production and Utilization in 21st Centrury', NRC for Banana, Trichy, 24-25 September 1996. pp.17-19.

Sundararaju P. 2000. Biocontrol agents of Plant-parasitic nematodes in Banana. Paper presented in 'Inod-UK Workshop on Innovative Pest and Disease management in Horticultural and Plantation Crops: Technology Improvement, Validation and Transfer' organized by British Council at SPIC, Chennai on 10-11 March 2000.

Sundararaju P. 2002. Seasonal fluctuations of *Radopholus similis* and *Pratylenchus coffeae* in certain cultivars of banana. Infomusa 11:16-18

Sundararaju, P. and I. Cannayane. 2002. Management of root-lesion nematode, *Pratylenchus coffeae* in banana cv. Nendran by using trap crop. National Symposium on biodiversity and management

of nematodes in Cropping Systems for Sustainable Agriculture, Nematological society of India, Jaipur, 11-13 November 2002, 91pp.

Sundararaju P. and V. Kumar. 2003. Management of root-lesion nematode, *Pratylenchus coffeae* in six commercial cultivars of banana through organic and inorganic amendments. Infomusa 12:21-25

Sundararaju P., B.Padmanaban and S. Sathiamoorthy. 2001. An eco-friendly approach for the management of root-lesion nematode, *Pratylenchus coffeae* in plantain (Nendran AAB) fields.

Sundararaju P., B. Padmanaban and S. Sathiamoorthy. 2003. Efficacy of certain botanicals against root-lesion nematode, *Pratylenchus coffeae* in banana. Nematol. medit. (accepted for publication).

Sundararaju P., B. Padmanaban and S. Uma. 2001. Field evaluation of *Musa* germplasm against major nematode pathogens.

Sundararaju P., B. Padmanaban, and S. Sathiamoorthy. 1999. Control of root-lesion nematode, *Pratylenchus coffeae* in certain cultivars of banana. Pp. 46-47 *in* Abstracts of 'National Seminar on Nematological Research in India' at C.S. Azad University of Agri & Tech., Kanpur, 17 December 1999.

Sundararaju P., I. Cannayane and R. Ramesh. 2002. Penetration and development of *Pratylenchus coffeae* and *Meloidogyne incognita* in susceptible cultivars of banana. Pp. 189 *in* Abstracts of 'National Seminar on Nematological Research in India' at C.S. Azad University of Agri & Tech., Kanpur, 17 December 1999.

Sundararaju P., I. Cannayane and S. Sathiamoorthy. 2001. New pests of banana reported in Tamil Nadu, India:Cyst nematode, *Heterodera oryzicola* Rao & Jayaprakash,1978. Infomusa 10:44–45.

Sundararaju P., I. Cannayane and S. Sathiamoorthy. 2002. Evaluation of promising diploids banana against major banana nematodes. Global conference on banana and plantain, 28-31 October 2003, Bangalore, p.176.

Sundararaju P., I. Cannayane and S. Sathiamoorthy. 2002. Occurrence and distribution of plant-parasitic nematodes associated with banana in India with special reference to North-Eastern Hills region. Global conference on banana and plantain, 28-31 October 2003, Bangalore, p.192.

Sundararaju P., I. Cannayane and S. Sathiamoorthy. 2002. Occurrence

and parasitism of root-knot nematode, *Meloidogyne incognita* in ornamental banana, *Ensete superbum* and its associated antagonist. Infomusa (In press).

Sundararaju P., I. Cannayane, and S. Sathiamoorthy. 2002. Investigations on the biodiversity of plant-parasitic nematodes associated with banana in India. Global conference on banana and plantain, 28-31 October 2003, Bangalore, p.5.

Sundararaju P., I. Cannayane, and S. Sathiamoorthy. 2002. Investigations on the biodiversity of plant-parasitic nematodes associated with banana in India.

Sundararaju P., I. Cannayane, S.D. Pandey, and S. Sathyiamoorthy. 2002. Effect of population levels of plant-parasitic nematodes on high density planting with different fertigation levels in banana cv. Robusta *in* Emerging Trends in Pests and Disesase and their management (S. Doraiswamy, G. Rajendran, G. Ramakrisdhan, S. Palaniswamy and A. Subramanian, *eds*). Tamil Nadu Agricultural University, Coimbatore.

Sundararaju P., I. Cannayane., T. Senthilkumar and S. Kalpana. 2002. Biochemical alterations in different accessions of banana in response to nematode infection. *Ibid*, p.188.

Sundararaju P., M.M. Mustaffa, V. Kumar, I. Cannayane and B. Tanuja Priya. 2002. Effect of organic farming on plant-parasitic nematodes infesting banana cv. Karpuravalli, Current Nematology 13: 39-43.

Sundararaju P., R. Leela Devi and M. Manimekalai. 2002. Analysis of best treatment and variety based on nematode population on banana using artificial neural networks. Indian J. Nematol. 32:84-85.

Sundararaju P., R. Selvarajan and S. Sathiamoorthy. 2001. Management of nematode-Fusarium wilt complex in banana through bioagent, Trichoderma viride(Bio-T). Paper presented in 15th Nematological Congress at Skukuza Kruger National Park, South Africa during 20-24 May, 2001.

Sundararaju P., R. Thangavelu and I. Cannayane.2002. Management of *Pratylenchus coffeae* and *Meloidogyne incognita* on banana by using endophytic fungi. Current Nematology 13: 77-81.

Sundararaju P., T. Sasikala, and I. Cannayane. 2003. Effect of *Verticillium chlamydosporium* on second stage juvenile mortality and egg hatching of *Meloidogyne incognita* under *in vitro* conditions. Current Nematology 13: 67.

Sundraraju P. and K. J. Jeyabhaskaran. 2002. Evaluation of different soil types on multiplicatin of *Pratylenchus coffeae* and growth of banana seedlings var. Nendran. Nematol medit.(accepted for publication)

Sundraraju P. and I. Cannayane. 2002. Management of root-lesion nematode, *Pratylenchus coffeae* in banana cv. Nendran by using trap crop. National Symposium on biodiversity and management of nematodes in Cropping Systems for Sustainable agriculture, Nematological society of India, Jaipur, 11-13 November, 2002. 91p.

Tiwai S.P. and Dave, G.S. 1985. Burrowing nematode *Radopholus similis* (Cobb) Thorne on banana in Madhya Pradehs. *Curr. Sci.* 54: 1286.

Venkitesan T.S. and J.S.K. Charles. 1983. Sucker dip treatment for banana nematode control *in* Abstracts of Third Nematology Symposium, Solan, India. 24-26 May 1983. 45p.

Vidya K. and B.M.R. Reddy. 1998. Integrated management of *Radopholus similis* infecting banana using plant product, nematicide and biocontrol agents. Mysore J. Agric. Sci., 32 : 186–190.

Volkers E.E.L. A. and Gamboa. 1988. Nematodes on plantain. Boletin informative Manejo integrado de plagas No. 7, 3-4.

Vyas R.V., N.B. Patel and D.J. Patel. 2001. Management of root-knot nematodes in banana. Indian J. Nematol., 31 : 86–87.

Status and future R&D of nematodes in banana in Indonesia

Jumjunidang*

Introduction

Banana is one of the most important agricultural crops in Indonesia, with a production greater than any other single agricultural commodity. In 2000, more than 3 376 660 tonnes of bananas were produced from 269 778 hectares planted to banana in Indonesia (Nasir and Jumjunidang 2002). In terms of the nutrient contents, banana contains high amounts of carbohydrates, vitamins, fibre and other minerals (Picq and Raymond 1996). Therefore, banana has a great potential to be used as a diversified food in Indonesia, if not the main staple food.

According to the Central Research of Soil and Agroclimate of the Department of Agriculture, more than 20 million hectares of potential areas for banana are available in Sumatra, Kalimantan, Sulawesi and Irian. By improving production systems, this crop will support Indonesians' food-security programme significantly. These areas will not only produce banana for food, but also for agribusiness purposes. However, diseases and pests are responsible for the decline in banana productions in Indonesia.

Being one of the centres of origin of banana, the problem of pests and diseases in Indonesia may be more pronounced since a number of pests and diseases have evolved with this crop.

Major pests and diseases

The major insect pests of banana found in Indonesia are banana weevil (*Cosmopolites sordidus*), leafroller (*Erionata thrax*), banana scab (*Nacoleia* sp.) and *Thrips* sp. These pests are recognized as the most destructive, significantly affecting yield of banana. However there are no reports regarding the total area affected by these pests, nor the extent of economic loss.

The major diseases are fusarium wilt and bacterial wilt. According to the Department of Agriculture, these diseases have destroyed 7 876.3 mats from 1995 to 2001, valued at US$0.8 million. Other important diseases affecting banana production in Indonesia are Sigatoka disease (caused by *Mycosphaerella musicola*), black leaf streak disease (caused

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by *Mycosphaerella fijiensis*), banana bunchy top virus and parasitic nematodes.

Several studies have been conducted on parasitic nematodes in some parts of Indonesia. Plant-parasitic nematodes reported to be attacking banana in other countries such as *Radopholus similis*, *Pratylenchus* spp., *Helicotylenchus multicinctus* and root-knot nematode *Meloidogyne* spp. (Gowen and Quénéhervé 1990) are also found in the country. While these species are widely spread in several banana-producing areas in the country, reports regarding their distribution, the cultivars resistant to it and yield loss are limited. Some studies on species and cultivars affected by nematode are presented in the following discussion.

Important nematode species affecting banana in Indonesia

A survey conducted by Wisnuwardana (1976) in Sumatra, Java and Bali showed that the spiral nematode, *Helicotylenchus* spp., was found in more than 86% of the 236 soil samples collected. It was followed by *Meloidogyne* spp., *Rotylenchulus* sp., *Radopholus similis* and *Pratylenchus* spp. with a prevalence of 81.8%, 44.5%, 41.1% and 35.6%, respectively. In contrast, Jumjunidang *et al.* (1998) reported that *Pratylenchus* spp. and *R. similis* were the dominant parasitic nematodes in West Sumatra (Table 1).

Table 1. Species and prevalence of nematodes in bananas in West Sumatra.

Location	*Pratylenchus*	*R. similis*	*Helicotylenchus*	*Meloidogyne*	*Rotylenchulus*	*Tylenchus*
Kod. Padang	37.5	25.0	62.5	12.5	0.0	0.0
Kod. Pariaman	100.0	71.4	42.8	28.6	0.0	0.0
Kab. P. Pariaman	100.0	68.6	40.0	51.4	28.6	5.7
Kab. Pasaman	38.1	71.4	47.6	23.8	19.1	0.0
Kab. Ps. Selatan	61.5	30.7	53.9	57.7	23.1	0.0
Kab. Solok	53.9	7.7	53.9	38.5	0.0	0.0
Kab. S. Sijunjung	30.4	8.7	13.0	4.4	4.4	0.0
Kod. Bukittinggi	80.0	60.0	20.0	60.0	40.0	40.0
Kab. Agam	77.3	68.2	40.9	59.1	45.5	27.3
Kab. T.Datar	100.0	83.3	83.3	91.7	41.7	8.3
Kab. 50 Kota	84.2	73.7	63.2	36.8	10.5	0.0
Average	69.4	51.7	47.4	42.2	19.3	7.4

Other studies were conducted to screen banana cultivars resistant to parasitic nematodes. Marwoto and Djatnika (1992) screened some 30 banana cultivars and reported that all cultivars tested were susceptible to *Meloidogyne* sp. and *Helicotylenchus* sp. However, cultivars Pisang Susu, P. Emas, P. Bangkahulu and P. Kastroli were found to be

moderately resistant to *Pratylenchus coffeae*, the cause of root lesion. Jumjunidang *et al*. (2002) found no resistant cultivars to *R. similis* amongst the ten edible cultivars and *Musa* diploids tested (Table 2).

Table 2. Assessment of banana cultivars and *Musa* species to *Radopholus similis* infection.

Cultivar/ Species	Rf (Pf/Pi)		Resistance	Dead roots (%)		Root necrosis (%)		Corm necrosis (%)	
A. Hijau	10.2	a	Hs	22.6	b	55.8	a	2.8	b
Kepok	9.8	a	S	16.7	bc	41.3	ab	2.3	bc
Mas	9.4	a	S	21.7	b	38.0	b	2.5	bc
Tanduk	7.2	b	S	16.3	b	44.7	ab	2.5	bc
Barangan	7.1	b	S	17.9	bc	47.5	ab	2.7	b
Raja Sere	6.7	b	S	11.9	c	41.5	ab	1.8	cb
BKT11	5.4	c	S	46.8	a	60.8	a	4.0	a
BSK	4.3	c	S	39.8	a	45.0	ab	3.8	a
Abaca	4.3	c	S	24.4	b	45.3	ab	2.7	b
M. gracilis	3.9	c	S	23.4	b	30.2	b	3.0	b

Numbers followed by the same letters in the same column are not significantly different at p=0.05 according to Duncan's Multiple Range Test

Hs = Highly susceptible, S = Susceptible; Pf = final population; Pi = initial population

Future research programmes

Based on previous studies conducted in Indonesia, it was considered that nematodes are important factors limiting banana production in the country. To control these parasitic nematodes, several important studies are needed:

1. The distribution of banana nematodes in Indonesia
2. The assessment of yield loss caused by root parasitic nematodes on banana in Indonesia
3. The identification of banana cultivars and other *Musa* species with resistance or tolerance to nematodes
4. The reproductive fitness and pathogenicity of Indonesian parasitic nematodes population on banana.

References

Gowen S. R. and P. Quénéhervé. 1990. Nematode parasites of banana, plantains and abaca. *in* Plant parasitic nematodes in subtropical and tropical agriculture (Luc, M., Sikora R.A., and Bridge J., *eds*.) CAB International. UK. pp. 431-460.

Jumjunidang A. Hasyim, Desmawati, Harlion and A. Soemargono. 1998. Geographical distribution of root parasitic nematodes on banana and the relationship with banana weevil borer *Cosmopolites sordidus* Germ. in West Sumatra. J. Hortikultura 8(2):1095-1101.

Jumjunidang A. M. Adnan, I. Musika and M. S. Sinaga. 2002. Response of *Musa* germplasm to root parasitic nematode *Radopholus similis* (Cobb) J. Hortikultura 12(3):172-177.

Marwoto B. and I. Djatnika. 1992. Pengujian ketahanan berbagai kultivar pisang terhadap nematoda parasitik i*n* Prosiding Seminar Sehari Pisang sebagai Komoditas Andalan, (A. Muharam., I. Djatnika, I., Sulyo, Y. dan Sunarjono, *eds*.). Prospek dan Kendalanya. Puslitbanghor. Balithor Segunung.

Nasir N. and Jumjunidang. 2003. Short-term strategies to control banana wilt diseases in Indonesia *in* First national symposium in controlling banana wilt diseases in Indonesia. 22-23 October 2002, Padang – West Sumatra, Indonesia. 10pp.

Picq C. and Raymond, R. 1996. Making the most of *Musa*. INIBAP. Montpellier, France. 15pp.

Wisnuwardana A. A. 1976. Report of survey on plant-parasitic nematodes associated with banana in Sumatra, Java and Bali islands. National Congress of Association of Plant Pathology Indonesia IV, Gambung 20-22 December 1976. 14pp.

Nematodes in banana in Malaysia

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Introduction

The Third National Agricultural Policy of Malaysia (1998–2010) listed banana as one of the 15 fruit crops prioritized for commercial cultivation. This widely grown and important fruit crop, both for domestic and export market, occupies about 10–12% of the total acreage under fruit. This translates to about 30 000 hectares under banana and the acreage has somewhat stabilized over the past 10 years (1992–2001). Annual production has been slightly above one-half million tonnes, mainly consumed domestically, and less than 10% are exported.

Constraints in banana production

Banana production has been constrained by inefficient production system based primarily on production by small-holders characterized by small acreage, low input, low yield and lower quality as opposed to the efficient, large-scale banana plantations.

The destruction by pests and diseases limits the areas of production. Insect pests associated with bananas are banana root and corm weevil (*Cosmopolites sordidus*), banana stem weevil (*Odoiporous longicollis*), leaf roller (*Pelopidas (Erionata) thrax*), thrips (*Thrips* sp.) and spider mites (*Tetranychus* sp.). Banana weevils are most damaging to the corms and pseudostems, resulting in severe losses. The other insect pests are minor and do not cause serious damage.

The most important disease of banana is fusarium wilt caused by *Fusarium oxysporum* f.sp. *cubense*, a soil-borne fungus. This disease is widespread and most of the commercial cultivars are very susceptible. The cooking cultivars are somewhat tolerant. The other damaging diseases are yellow sigatoka and black leaf streak disease or black sigatoka. These diseases cause extensive damage to the leaves, thus, reducing yield. Other leaf diseases such as leaf freckle and cladosporium leaf speckle can also be serious depending on the cultivars planted. Another often neglected problem is nematodes, which can cause severe damage in banana.

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Nematodes in banana

Loh and Ting (1970) compiled the first list of nematodes and their associated hosts. In 1982, Winoto and Sauer showed that 16 species from nine genera were associated with banana, based on a nationwide survey. Based on a survey covering several banana-growing districts in the states of Selangor, Perak, Pahang and Johore, Abdul Karim and Mohd Zaidun (1983) reported three additional species of nematodes effecting banana. Razak (1994) reviewed the different species of nematodes affecting banana and added five new species (Table 1).

Table 1. Plant-parasitic nematodes associated with banana in Malaysia.

Nematode species	Reference
Hoplolaimus seinhorsti Luc	Winoto R. & Sauer 1982, Abdul Karim & Mohd. Zaidun 1983
Helicotylenchus abunaami Siddiqi	Winoto R. & Sauer 1982
H. dihystera (Cobb) Sher	Winoto R. & Sauer 1982, Abdul Karim & Mohd. Zaidun. 1983
H. erythrinae (Zimmerman) Golden	Winoto R. & Sauer 1982
H. pasohi Sauer & Winoto	Winoto R. & Sauer 1982,
H. multicinctus (Cobb) Golden	Winoto R. & Sauer 1982, Abdul Karim & Mohd. Zaidun. 1983
*Hemicriconermoides cocophilus (*Loos) Chitwood & Birchfield	Abdul Karim & Mohd. Zaidun. 1983
Meloidogyne incognita (Kogoid & White) Chitwood	Abdul Karim & Mohd. Zaidun. 1983
M. javanica (Treub) Chitwood	Abdul Karim & Mohd. Zaidun. 1983
Mesocriconema denoudeni De Grisse (Raski) De Grisse & Loof	Winoto R. & Sauer 1982, Abdul Karim & Mohd. Zaidun. 1983
M. ornata (Raski) De Grisse & Loof	Winoto R. & Sauer 1982
M. onoensis (Luc) De Grisse & Loof	Abdul Karim & Mohd. Zaidun 1983
Paralongidorus sacchari Siddiqi Hooper & Khan	Razak 1994
Paratrophurus causicaudata	Razak 1994
Pratylenchus brachyurus (Godfrey) Filipjey & Schuurmans Stekhoven	Winoto R. & Sauer 1982, Abdul Karim & Mohd. Zaidun. 1983
P. coffeae (Zimmerman) Filipjev & Schuurmans Stekhoven	Winoto R. & Sauer 1982, Abdul Karim & Mohd. Zaidun. 1983
Radopholus similis (Cobb) Thorne	Winoto R. & Sauer 1982, Abdul Karim & Mohd. Zaidun. 1983
Rotylenchulus reniformis Linford & Oliveira	Winoto R. & Sauer 1982, Abdul Karim & Mohd. Zaidun. 1983
Tylenchorhynchus martini Fielding	Winoto R. & Sauer 1982
Xiphinema orthotenum Cohn & Sher	Winoto R. & Sauer 1982
X. radicicola Goodey	Winoto R. & Sauer 1982
X. insigne Loos	Razak 1994
X. elongatum Schuurmans Stekhoven & Teunissen	Razak 1994
X. americanum group	Razak 1994

Distribution of nematodes in banana

In a survey conducted by Abdul Karim and Zaidun (1983), the genera *Helicotylenchus* and *Rotylenchulus* were the most commonly found and widely distributed nematodes on banana and were found to be present in 30 and 27 farms surveyed, respectively. The distribution of other genera was as follows: *Meloidogyne* (22 farms), the Criconematid group (21 farms), *Radopholus* and *Pratylenchus* (17 farms) and *Hoplolaimus* (15 farms). The survey also showed that the soil population of *Rotylenchulus* was highest, followed by *Helicotylenchus, Meloidogyne, Radopholus, Pratylenchus* and *Hoplolaimus.* The nematode count in banana roots was highest for *Helicotylenchus,* followed by *Meloidogyne, Radopholus, Pratylenchus,* Criconematid and *Hoplolaimus.*

The study also showed that there was a close relationship between crop growth and nematode population in the roots. Banana plants which showed poor crop growth gave high nematode population in the roots. There was also genotype-preference relationship whereby the AAA genotype had a higher nematode population in the roots followed by ABB (Pisang Abu), AA (P. Emas, P. Kera) and AAB (P. Rastali, P. Tanduk). It was also observed that bananas grown on different soil types had a different population level in the roots. Bananas grown on sandy loam soils have higher nematode population in the roots followed by clay loam, clay and peat soil, in descending order.

In another survey involving 148 samples from nine different locations, five nematode genera were found to be associated with banana (Abd. Karim 1994). Among these, *Meloidogyne incognita* was the most prevalent. This nematode feeds on the pericycle of the banana roots and causes galling of the roots. *Meloidogyne incognita* caused severe yield loss in two locations especially when nematode-infested planting materials were used. The burrowing nematode, *Radopholus similis,* is potentially damaging with high population in two locations. This nematode feeds on the parenchyma cells in the root cortex causing formation of cavities in the cortex and cracks and lesions on the roots surface. The lesion nematode, *Pratylenchus* sp., causes similar damage as the burrowing nematode. The two species of helical nematodes, *Helicotylenchus dihystera* and *H. multicinctus,* were numerous and widespread on banana. They feed on the outer root surface causing small, necrotic lesions.

Nematode control

Nematicides Carbofuran and Fenamiphos were tested for the control of *M. incognita, Rotylenchulus reniformis* and *Helicotylenchus* spp. on

Pisang Mas. The endemic population of these nematodes did not significantly reduce yield (Abdul Karim 1995). However, both nematicides lowered the population of *M. incognita* and *Helicotylenchus* spp. in the roots. The population of *R. reniformis* in the soil and roots was not significantly reduced.

References

Abd. Karim S. and B.M. Mohd. Zaidum. 1983. Nematode parasit tumbuhan utama pada tanaman pisang, *Musa sapientum* di Semenanjung Malaysia, MARDI Report No. 85.

Abd. Karim, S. 1994. Plant-parasitic nematodes of banana in Malaysia. Pp. 250-251 *in* Proceedings of the 4th International Conference on Plant protection in the Tropics (A. Rajan and Yusof Ibrahim, *eds.*).

Abd. Karim S. 1995. Effect of carbofuran and fenamiphos on three nematodes infesting banana. MARDI Res. J. 23:71-74

Abdul Rahman R. 1994. Plant-parasitic nematodes, a potential threat to commercial cultivation of banana in Malaysia. 258 pp. *in* Banana nematodes and weevil borers in Asia and the Pacific: Proceeding of a conference workshop on nematodes and weevil borers affecting bananas in Asia and the Pacific, Serdang, Selangor, Malaysia, 18-22 April 1994 (R.V. Valmayor, R.G. Davide, J.M. Stanton, N.L. Treverrow, V.N. Roa, *eds.*). INIBAP/ ASPNET, Los Banos, Laguna, Philippines.

Loh C.F. and W.P. Ting. 1970. A host list of plant parasitic nematodes in West Malaysia. Ministry of Agriculture and Cooperation Bull. 123, 15pp.

Winoto S.R. and M.R. Sauer. 1982. Plant-parasitic nematodes associated with cultivated plants in Peninsular Malaysia.

Status of nematode problem affecting banana in the Philippines

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Introduction

Banana is the prime fruit commodity of the Philippines in terms of production and commercial value. It is widely grown throughout the country, either as a component of existing farming systems or as the main crop in commercial plantations in Mindanao. It is also an important source of income for small-scale farmers who constitute 75% of the banana growers (National Fruit Crops R&D Team 2002).

The Philippines ranked fifth among the world's major suppliers of banana in 2000 with 3.56 million tonnes or a share of 6.1% of the world production (FAO 2001). India had the biggest production (18.9% share), followed by Brazil (9.3%), China (8.9%) and Ecuador (8.6%). The major banana by-products being exported are fresh banana, chips/ crackers and catsup. The fresh bananas constitute the main bulk of the Philippines export, representing almost 98% of the total volume exported. In 1996-2000, the average volume exported reached about 1.31 million tonnes valued at US$ 261 million (Foreign Trade Statistics 2001). The major importing countries of the fresh banana in 1999-2000 were Japan (61%), China (16%), Korea (8%), Taiwan (6%) and the United Arab Emirates (6%). On the other hand, the average exported chips/crackers amounted to only 18 280 tonnes valued at US$ 20.83 million in 1996-2000. Of the total volume of chips exported from 1999 to 2001, 38% went to Hongkong, 25% to Japan, 17% to Singapore, 11% to the Netherlands and 9% to Korea (National Fruit Crops R&D Team 2002).

However, banana is host to many important insect pests and diseases that significantly reduce the yield and quality of fruits. Many of these pests and diseases have co-evolved with the crop because of banana's long history of cultivation in the Philippines, thus adding a more difficult dimension to the pest and disease problem (Valmayor 1990).

The nematode problem

According to Davide (1992), even before the Giant Cavendish banana

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was brought to the Philippines, the nematodes *Radopholus similis* and *Meloidogyne* species already existed in Philippine soils. Their populations increased dramatically when large volumes of Giant Cavendish banana planting materials from Central American soils were commercially raised by farmers in the early seventies. Since plant-parasitic nematodes have been considered a serious threat to the banana industry in the country, a group led by Dr Romulo G. Davide, a professor at the Department of Plant Pathology, University of the Philippines Los Baños, conducted a series of studies to understand their ecology, biology and control.

Results of a nationwide survey conducted in 1974-1977, covering the banana-growing provinces in Luzon, Visayas and Mindanao, showed that *Meloidogyne, Helicotylenchus, Rotylenchulus, Pratylenchus, Hoplolaimus, Rotylenchus* and *Tylenchorynchus* were generally associated with native cultivars like Lakatan, Latundan, Cardaba, Saba, Buñgulan and others (Davide and Gargantiel 1974; Davide and Zarate 1977). *Radopholus similis* was commonly found in the introduced Cavendish banana in Davao but seldom detected in the native cultivars (Table 1). The genera *Meloidogyne* and *Radopholus* were found widely distributed, more dominant and more destructive to Cavendish banana than other nematode species (Tables 2 and 3).

Table 1. Distribution and population density of plant-parasitic nematodes associated with Cavendish banana roots and soil in Davao del Norte, Philippines based on 90 root and soil samples (Boncato and Davide 1980).

	Roots			Soil		
Nematode Genera	Mean no. per 100 g roots	% in the population[b]	% distribution in samples[c]	Mean no. per 400 cc soil	% in the population[b]	% distribution in samples[c]
Radopholus	13 128	58.0	84	25	4.0	68
Meloidogyne	3 539	16.0	82	356	55.0	99
Rotylenchus	5 883	26.0	57	107	17.0	62
Hoplolaimus	29	0.1	4	3	0.5	19
Pratylenchus	17	0.1	2	0	0.0	0
Tylenchorhynchus	11	0.1	2	25	4.0	34
Helicotylenchus	6	0.0	1	2	0.4	36
Rotylenchulus	0	0.0	0	129	20.0	12

[a]% in the population = total no. of individuals in each genus divided by the total no. of all genera x 100.

[b]% distribution in samples = total no. of soil samples in which each genus was detected divided by total no. of samples x 100.

Table 2. Distribution and population density of plant-parasitic nematodes associated with Latundan banana in Davao, Samar, Leyte, Cebu and Negros Occidental, Philippines.

Nematode Genera	Mean number per 400 cm^3 soil	% Distribution	% in the Population
Meleiodogyne	48.0	57.0	19.0
Rotylenchus	142.0	14.0	57.0
Rotylenchulus	18.0	14.0	8.0
Pratylenchus	3.0	43.0	1.0
Hoplolaimus	27.0	71.0	11.0
Helicotylenchus	7.0	57.0	3.0
Hemicycliophora	3.0	29.0	1.0
Criconemoides	0.1	14.0	0.1
Scutellonema	2.0	29.0	0.8
Pratylenchus	3.0	14.0	0.1

Table 3. Distribution and population density of plant-parasitic nematodes associated with Lakatan banana in Davao, Samar, Leyte, Cebu, and Negros Occidental, Philippines.

Nematode Genera	Mean per 400 cm^3 soil	% Distribution	% in the Population
Meleiodogyne	472.0	67	81.0
Rotylenchus	10.0	17	2.0
Rotylenchulus	4.0	17	0.6
Pratylenchus	2.0	17	0.3
Hoplolaimus	11.0	67	2.0
Helicotylenchus	68.0	83	12.0
Tylenchorhynchus	3.0	17	0.5
Xiphinema	0.3	17	0.1
Hemicycliophora	1.0	17	0.2
Criconemoides	6.0	17	1.0
Scutellonema	6.0	17	1.0

Yield loss assessment and nematode damage

To evaluate the pathogenic capability of nematodes commonly associated with banana, a number of studies have also been undertaken. Claudio and Davide (1967) reported that *M. incognita* can cause the root-knot disease on Saba cultivar by infecting the roots and forming galls or swellings. A study on Cavendish banana showed that an inoculum level of 1000 *M. incognita* larvae per plant resulted in 26.40% yield loss while at 10 000 nematodes per plant, yield loss increased to 45.4% (Davide and Marasigan 1985). These results indicate that the higher the nematode population in the soil, the greater the damage to the crop.

On the other hand, *R. similis* can cause black head, root rot or tip-over disease of banana (Davide 1994). The infected roots show necrosis or discolored spots as early as two weeks after inoculation. Severe root infection results in stunted growth and reduced yield (Boncato and Davide 1980). Results of field tests indicated that an inoculum level of 1000 - 4000 *R. similis* per plant could cause a yield loss from 14.3% to 60.5% (Davide and Marasigan 1985).

According to Davide (1992), when *R. similis* population reaches 10 000 per gram roots, many Cavendish banana growers in Davao apply nematicides. However, based on the results of their field tests, significant damage might have been done to the plants already at a level of 10 000 nematodes per gram roots. There is therefore a need to determine the critical or threshold level of *R. similis* under field conditions in Davao.

Susceptibility and resistance of banana cultivars to nematodes

Results of a study conducted by the National Research Council of the Philippines (NRCP) showed that there were 23 cultivars and two *Musa* species that gave a resistant reaction to *R. similis* (Davide and Marasigan 1985). Among them were Amas, Galamay, Senora, Katsila, Lakatan, Manang, Pamoti-on, Tanggung, Katali, Kinawayan, Tiparot, Binendito, Binaliw, Bunga, Cardaba, Mundo, Pulutan, Siusok, Turangkog, Baukas, Pisang Lemak Manis, Sabang Puti, Pinipita, *Musa velutina* and *M. ornata.* On the other hand, nine cultivars appeared resistant to *M. incognita*. These were Alaswe, Dakdakan, Inambak, Pastilan, Pugpogon, Maia-Maole, Paa Dalaga, Sinker and Viente Cohol. However, the majority of the cultivars screened were either susceptible or had an intermediate reaction to *R. similis* and *M. incognita*. Giant Cavendish was used as the susceptible standard test plant for the two nematode species.

Host range and distribution patterns of nematodes associated with banana

As far as the host range is concerned, *R. similis* can infect not only banana but also black pepper, peanut, red bean, lima bean, abaca, mecan pea, okra, desmodium (*Desmodium adscendens*), katurai (*Sesbania grandiflora*) and pacol or *Musa balbisiana* (Boncato and Davide 1980). *Meloidogyne incognita*, on the other hand, has a much wider host range as it also attacks many varieties of vegetables, fruits and field crops. Other nematode genera also have a wide host range (Castillo and Davide 1974).

Data on the distribution pattern of nematodes showed that *M. incognita*

was predominantly present in all local banana cultivars grown throughout the country. *Radopholus similis,* on the other hand, was more predominantly associated with the Cavendish banana in Davao (Davide and Gargantiel 1974; Boncato and Davide 1980).

Generally, *R. similis* infects and reproduces faster in Cavendish banana, which is a highly susceptible cultivar. It was observed that *M. incognita* tends to dominate and behave more actively than *R. similis* in the 1- to 2-year old Cavendish plantations. However, in older plantations, *R. similis* becomes the predominant nematode species. It was shown that *R. similis* feeds on and destroys the galls of *M. incognita,* thereby depriving the latter of available food and host for its reproduction (Santor and Davide 1982).

The distribution patterns of nematodes are influenced not only by the age of plantation and banana cultivars but also by soil pH and textures. Both *R. similis* and *M. incognita* prefer sandy loam soil with pH 5.0-5.6. In addition, the population density of *R. similis* is much higher in Class II or intermediate soil and Class III or poor soil for banana (Boncato and Davide 1980).

Management options

Use of chemicals. Early studies of nematode control in banana mainly focused on the use of nematicides as they are more effective and practical to use in large-scale plantations. A study on the performance of Temik 15G (Aldicarb) conducted in commercial Giant Cavendish banana plantations in Davao showed that this nematicide significantly controlled the nematodes, *R. similis, M. incognita* and other species, thus resulting in considerable yield increase (San Juan and Lozano 1978).

Moreover, a field test of several nematicides such as Temik 15G, Vydate 10G, Mocap 5G, Nemacur 10G, Furadan 3G and UC 21865 conducted in large plantations of Giant Cavendish banana in Davao indicated that all the nematicide treatments, which were applied three to four times a year significantly controlled the nematodes (Boncato and Davide 1980). This practice considerably improved the growth and yield of the treated plants (Table 4).

In 1990 alone, the reported use of nematicides in banana plantations totaled 2600 tonnes. The effects of nematicides on the environment, human beings and animals, however, cannot be disregarded anymore. The government has realized the hazards and lately imposed restrictions on the use of DBCP (Nemagon) and Aldicarb (Temik).

Table 4. Mean fruit size of Cavendish banana treated with six nematicides (Boncato and Davide 1980).

Treatment	Rate (ai/ mat)	Number of Appl'n per Yr.	Mean monthly measurement[a] (cm)						
			Mar	Apr	May	Jun	July	Aug	Sept
Temik 15G	3	2x	27 bc	46 bc	46 bcd	46 a	46 ab	46 ab	46 abc
Vydate 10G	3	3x	47 a	46 a	46 ab	46 a	46 abc	46 a	46 ab
Mocap 5G	5	2x	46 cd	46 cd	45 de	46	45 bcd	45 bc	45 bc
Nemacur 10G	3	3x	45 cd	45 cd	45 e	45 c	45 d	45 c	45 c
Furadan 10G	3	3x	46 ab	47 a	46 a	46 a	46 a	46 a	46 a
UC 21865 5G	7	2x	46 bc	6 ab	46 abc	46 a	45abcd	45 abc	46 bc
Mocap 5G	4	3x	45d	45 ab	45 de	45 bc	45 cd	45 bc	45 bc
Control		-	44 c	45 e	45 f	45 d	44 e	44 d	45 d

[a]Means in each column with the same letter are not significantly different under Duncan's Multiple Range Test.

In addition, the government has placed all nematicides in the country for institutional use only, where plantation companies exercise close supervision of laborers handling and applying the chemicals.

Due to hazardous effects of nematicides, a search for alternative control measures have become necessary. Thus, studies were conducted to explore the potentials of botanical nematicides and the natural or biological control agents against the nematodes.

Use of botanical nematicides. Studies have shown that extracts from certain plants have the potential for nematode control and therefore are good sources of botanical nematicides. For example, root extracts from African marigold (*Tagetes erecta*), ipil-ipil (*Leucaena leucocephala*), Bermuda grass (*Cynodon dactylon*) and makahiya (*Mimosa pudica*) were highly effective against egg hatching and infectivity of *M. incognita* (Table 5) (Hoan and Davide 1979). Guzman and Davide (1985) evaluated the solvent extracts of eight plant species for their toxicity against *R. similis* and *M. incognita*. The extracts of *Anthocephalus chinensis* (Kaatoang- bangkal), *Eichornia crassipes* (water lily) and *Allium cepa* (onion) gave the best results in the toxicity test against the nematodes (Table 6). The active nematicidal compounds found in the extracts were identified as phenolic aldehyde in *A. chinensis*, carboxylic acid in *E. crassipes* and ketone in the extract of *A. cepa.*

Use of biological control agents. Many studies have shown that some soil fungi can trap or parasitize nematodes. However, earlier reports indicated that none has been found to be practically applicable in the field because of difficulty in mass-producing them (Reyes and Davide 1975). The discovery of the soil fungus, *Paecilomyces lilacinus*, in Peru and the Philippines, which could effectively control the root-knot nematodes, *Meloidogyne* spp. and the potato-cyst nematode, *Globodera rostochiensis,* has once again sparked the researchers' interest in biological

Table 5. Effects of plant extracts on egg hatching of *Meloidogyne incognita* (Hoan and Davide 1979).

Treatment	Larval Count[a]	Reduction (%)[b]
E. tenella	0	100 a
L. leucocephala #5	0	100 a
C. dactylon	0	100 a
M. pudica	0	100 a
T. erecta	0	100 a
C. papaya	0	100 a
C. odorata	0	100 a
C. pubescens	0	100 a
C. spectabilis	1	100 ab
C. citrates	2	99 ab
D. elliptica	5	98 ab
M. pterygosperma	6	98 ab
L. leucocephala #30	7	97 b
R. communis	7	97 b
I. cylindrica	32	86 c
O. sativa IR 26	55	75 cd
P. oleracea	66	70 d
C. rotundus	69	69 d
150 ppm DBCP	70	68 d
300 ppm DBCP	72	67 d
50 ppm DBCP	116	48 e
Control	221	-

[a]Average of three egg masses.

[b]Treatments with the same letter are not significantly different at 5% level Duncan's Multiple Range Test.

Table 6. The effects of different plant extracts on infection and population density of *Radopholus similis* on banana (Guzman and Davide 1985).[a]

Treatment	Mean Percent Reduction[b]		
	Lesion number	Nematode count in soil	Nematode count in root
A. chinensis	77 ab[2]	77 a	75 abc
D. gangeticum	80 ab	63 a	90 ab
A. vulgaris	66 ab	73 a	84 abc
E. crassipes	79 ab	63 a	76 abc
L. leucocephala (leaves)	84 ab	3 b	79 abc
L. leucocephala (roots)	70 b	76 a	77 abc
M. oleifera	85 ab	83 a	76 abc
A. sativum	87 ab	79 a	85 abc
A. cepa	80 ab	69 a	93 ab
Nemacur (500 ppm)	79 ab	88 a	87 abc
Nemacur (200 ppm)	14 c	5 b	63 c
Rotenone (500 ppm)	89 a	58 a	93 ab
Rotenone (200 ppm)	68 b	61 a	72 bc
Temik (500 ppm)	92 a	91 a	99 a
Temik (200 ppm)	81 ab	86 a	92 ab

[a]Data were collected 5 weeks after treatment and means of three replicate plants were computed.

[b]Means in the same column with the same letters are not significantly different at 5% level Duncan's Multiple Range Test.

control studies (Villanueva and Davide 1984; Davide and Zorilla 1983). The reported efficacy of the said fungus was also evaluated against the *R. similis* infected banana. Results of laboratory and greenhouse studies showed that soil fungi such as *P. lilacinus, Penicillium anatolicum* and *Arthrobotrys cladodes* can effectively control *R. similis* (Generalao and Davide 1986; Tandingan and Davide 1986).

The possibility of using micro-organisms as sources of nematicides was also explored. Results showed that *Penicillium oxalicum, P. anatolicum, Aspergillus niger* and *Penicillium* sp. secrete compounds with exceptionally high nematicidal action against *M. incognita* and *R. similis* (Molina and Davide 1986).

The biological control technology developed from these studies was then referred to as the BIOCON technology or BIOCON 1 (Davide 1992). The technology utilizes a soil fungus, *P. lilacinus* (Philippine isolate No. 4), to parasitize eggs, larvae and adult nematodes. Considering the market potential of the BIOCON technology, the University of the Philippines Los Baños legally transferred its right to develop and commercialize it to a company, the Asiatic Technologies, Inc. (now the BIOACT Corporation) on 7 August 1986. The Company henceforth took the lead in the improvement of the product and its registration for commercial use in the Philippines and other countries under the trademark BIOACT by the Philippine Fertilizer and Pesticide Authority (FPA). Since 1989, BIOACT has been successfully applied by banana companies in Davao to control banana nematodes. For the international market, the BIOACT was registered in Australia, U.S.A. and other countries as NEMACHECK. However, for some reasons, the technology was sold to a Company in Germany and now the product is being exported to Mindanao (Davide, personal communication). This is quite unfortunate considering the fact that it is a Filipino technology.

Another bionematicide product, BIOCON II, was developed at UPLB for commercial development by private sector. This technology utilizes the soil fungus *P. oxalicum* isolated from Philippine soils in 1984 (Molina and Davide 1986). Compared with BIOACT and some nematicides, it has double action effects against the nematodes since it acts as a parasite and at the same time, secretes substances toxic to the nematodes. However, due to financial constraints, the above technology has never been commercialized.

Future perspectives

To produce bananas with high level of acceptable quality necessary for strategic global competitiveness, it is imperative to address the nematode problem besetting the industry. Hence, the development of site- and situation-specific IPM technology package for plant-parasitic nematodes is needed. This would surely minimize chemical use and maximize biological and cultural control. In implementing this approach, more studies on the following aspects need to be undertaken (Davide 1992):

- Laboratory and field testing of micro-organisms such as *P. lilacinus*, *P. oxalicum*, *P. anatolicum* and *A. cladodes*, which are known to control nematodes
- Further screening of banana cultivars and species for nematode resistance under field condition
- Cultural practices that may affect nematode reproduction in the soil
- Biological relationships between nematodes and other flora and fauna in soil planted to banana.

References

Boncato A.A. and R.G. Davide. 1980. *Radopholus similis* on Cavendish banana in Davao del Norte: Host range and relative distribution and density. Phil. Agr. 63:111-119.

Boncato A.A. and R.G. Davide. 1980. *Radopholus similis* on Cavendish banana in Davao del Norte: Culture and pathogenicity. Phil. Agr. 63:120-125.

Boncato A.A. and R.G. Davide. 1980. *Radopholus similis* on Cavendish banana in Davao del Norte: Laboratory and field evaluation of nematodes for *R. similis* control. Phil. Agr. 63:120-125.

Castillo M.B. and R.G. Davide. 1974. Host index of plant-parasitic nematodes in the Philippines. PPS Bull. No. 3:45.

Claudio M. and R.G. Davide. 1967. Pathogenicity and identity of root-knot nematodes on banana. Phil. Agr. 51: 241-251.

Davide R.G. 1992. Studies on nematodes affecting bananas in the Philippines. Los Banos, Laguna: Philippine Agriculture and Resources Research Foundation, Inc. 175pp.

Davide R. G. 2003. Personal communication.

Davide R. G. and F. T. Gargantiel. 1974. Survey of nematodes associated with banana in the Philippines. Phil. Phytopath. 10: 1-2.

Present status and future research needs on banana nematodes in Sri Lanka

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Introduction

Banana is one of the most important and popular fruit crops with year-round production in Sri Lanka. Of the numerous fruits grown in the country, banana claims about 55-70% of the total area under cultivation for fruit crops. The total area cultivated to banana in Sri Lanka has an increasing trend during the past. In 2002, the land area under banana was nearly 47 850 ha and the annual production was 444 066 metric tonnes (Table 1). It was estimated that approximately 100 000 Sri Lankans are engaged in the banana industry (Weerasinghe and Ruwanpathirana 2002). However, according to Kudagamage (2002), although there is a gradual increment in area cultivated, there is a very clear and sharp decline trend in productivity after the year 1980. Clear explanation has not been given for the reasons for the decline, however, pests and diseases could be one of the major constraints.

Table 1. Area cultivated to fruit crops and production during year 2002.

Crop	Area cultivated (ha)	Production (mt)
Banana	47 850	444 066
Mango	27 071	80 393
Papaya	3 564	17 102
Pineapple	4 800	53 040
Orange	3 914	3 510
Lime	7 629	5 400
Passion fruit	403	13 400

Source: Deptartment of Census and Statistics

In Sri Lanka, 29 cultivars of banana and two wild species have been reported (Chandraratne and Nanayakkara 1951; Simmonds 1966). Of the 29 banana cultivars, five are cooking types and the rest are dessert types. Ekanayake *et al.* (2001) recorded another banana cultivar, which has not been recorded earlier.

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Major insect pests and diseases

The major insect pests found in Sri Lanka are banana weevil (*Cosmopolites sordidus*), stem weevil *(Odoiporus longicollis),* banana aphid (*Pentalonia nigronervosa*), banana thrips (*Hercinothrips* sp. and *Chaetanaphothrips* sp.) and fruit fly (*Bactrocera kandiensis* and *B. dorsalis*). However, diseases are more damaging as they reduce yield of banana more than insect pests. The major virus diseases recorded in Sri Lanka are banana bract mosaic virus, banana bunchy top virus, banana streak virus and cucumber mosaic virus (Dassanayake 2002). Ariyaratna (2002) reported that 82% and 59% of the cultivated banana are infected with banana bract mosaic and banana streak virus, respectively. The prominent fungal diseases prevalent are black sigatoka, yellow sigatoka, septoria leaf spot and panama disease (Udugama 2002).

Status of nematode problem

Nematodes are considered as an important unseen enemy of banana. This is because no one has paid much attention to consider them as a major pest of banana in Sri Lanka even though banana is a good host to many nematodes species. The Department of Agriculture in Sri Lanka conducted a general survey to identify plant-parasitic nematodes associated with agricultural crops and reported the presence of many plant-parasitic nematode species, which are considered as pests of banana (Table 2).

Table 2. Some important plant-parasitic nematodes recorded in Sri Lanka.

Nematode species	Associated crop
Helicotylenchus multicinatus	*Musa*
Helicotylenchus pseudorabustus	*Musa, Vigna spp.,* capsicum, citrus
Hoplolaimus pseudorobustus	Musa, capsicum, Vigna spp*., citrus*
Meloidogyne sp.	*Musa, Vigna* spp., *Solanum* spp*., Capsicum* spp.
	Musa, Vigna spp., *Phaseolus* spp.
Radopholus similis	*Musa, Vigna* spp., *Phaseolus* spp., soya bean
Rotylenahulus reniformis	*Musa, Vigna* spp., citrus, coffee, coconut
Xiphinema spp.	

Ekanayake (1993) surveyed 16 districts in Sri Lanka and reported that plant-parasitic nematodes are associated with 54 economically important crops. A total of 38 genera comprising of 25 plant-parasitic and 13 free-living forms were recorded during the survey.

However, more studies have been conducted on root-knot nematodes in vegetables and on cyst nematode in potato, and their management

tactics (Reports of DOA). The genus *Meloidogyne* was observed to be causing considerable damage to many important crops. However, no data are available on the pest status and economic importance of the nematodes on banana. On the other hand, Sarah *et al*. (1993) reported that the pathogenicity test of *Radopholus similis* isolated from Sri Lanka gave no significant effect on plant growth as compared with the isolates from Guadeloupe, Costa Rica, Kenya and Ivory Coast, which significantly suppressed growth of banana planted in pots.

Therefore, although nematodes have not been identified as an economic pest of banana in Sri Lanka, they may be an important factor responsible for poor plant growth, yellowing, production of small bunches and low yields experienced in some banana-growing areas. Further, they can play a major role in the vulnerability of banana to soil-borne diseases such as fusarium wilt (panama disease), which is recognized as one of the most destructive plant diseases in agriculture. Panama disease is often present with higher intensity when nematodes are associated with banana.

Future research needs

As we do not have even the basic information on banana nematodes, attention should be given to the following research areas:

1. Occurrence of nematodes: Field survey should be conducted to identify important nematode species associated with banana. This should be conducted in major banana-growing areas, as well as other parts of the island.
2. Host range and distribution pattern: Most nematodes associated with banana may have a wide host range and are widely distributed. This information will help identify highly infested areas and potentially useful candidates for a crop rotation with banana.
3. Pathogenicity and extent of damage to the crop: This will provide information on pathogenicity, the nature and symptoms of damage of associated nematodes and their economic importance to the crop.
4. Susceptibility and resistance of banana cultivars: This information may be a better alternative to chemical control of nematodes. We have our own banana cultivars with wide genetical variation. While some are susceptible to nematodes, some may possess tolerance or resistance. Identified resistant/tolerant cultivars may be introduced to highly infested areas.
5. Control measures: Evaluation of management or control measures such as chemicals/alternatives will help suppress the nematode population in affected areas.

References

Ariyaratna I. and T. Liyanage. 2002. Survey on incidences and severity of virus diseases of banana in Sri Lanka. Annals of the Sri Lanka Department of Agriculture 2002 (4):245-254.

Chandraratne M.F. and K.D.S.S. Nanayakkara. 1951. Cultivated varieties of banana in Ceylon. Tropical Agriculturist 107:70-91.

Dassanayake E.M. and B.M. Rathnabharathis. 2002. Development of virus free banana foundation stock. Annals of the Sri Lanka Department of Agriculture 2002. (4):255-259.

Ekanayake E.M.D.S.N., *et al*. 2001. An unrecorded banana cultivar from Sri Lanka. Annals of the Sri Lanka Department of Agriculture 2001 (3):37-42.

Ekanayake H.M.R.K. (1993). Islandwide survey and identification of plant-parasitic nematodes in Sri Lanka. Project Report (SAREC/ 11/ZSSL-06), Department of Agriculture, Peradeniya, Sri Lanka.

Kudagamage C., *et al.* 2002. Analysis of long-term trends in banana sector of Sri Lanka. Annals of the Sri Lanka Department of Agriculture 2002 (4):21-32.

Sarah J.L., C. Sabatini and M. Boisseau. 1993. Differences in pathogenicity to banana (*Musa* sp. cv Poyo) among isolates of *Radopholus similis* from different production areas of the world. Nematropica, vol. 23(1):75-79.

Simmonds N.W. 1966. Bananas, 2nd ed. Tropical Agriculture Series, Longman, London, 5120pp.

Udugama S. 2002. Septoria leaf-spot disease of banana (*Mycosphaerella eumusae*); a new record from Sri Lanka Department of Agriculture 2002 (4):337-341.

Weerasinghe S.S. and K.H. Ruwanpathirana. 2002. Influence of bagging material on bunch development of banana (*Musa* spp.) under high density planting system. Annals of the Sri Lanka Department of Agriculture 2002 (4):47-53.

Occurrence of *Pratylenchus coffeae* and occurrence, damage and reproduction of *Radopholus similis* in the Northern and Central Highlands of Vietnam

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Introduction

Banana is a common fruit crop in Vietnam. It has been planted all over the country for thousands of years. Among the fruit crops, banana ranks first in terms of gross output and production area (FAO 2002).

Climatic conditions in Vietnam are favourable not only for producing banana but also for the occurrence of pests and diseases. Nematodes are considered as one of the most important pests in Vietnam. According to Gowen and Quénéhervé (1990), *Radopholus similis* and *Pratylenchus coffeae* are considered the most important nematode species associated with banana. Moreover, they have a worldwide distribution and have a wide host range (Bridge *et al*. 1997).

Since the late 1970s, field surveys of nematodes associated with banana roots have been undertaken in various parts of Vietnam (Chau *et al*. 1997). A survey to assess the occurrence and damage potential of nematodes in bananas in North and Central Vietnam was recently conducted. During these surveys, 53 plant-parasitic nematode species belonging to 19 genera were associated with banana in the major banana-producing regions of Vietnam. The species *P. coffeae*, *Helicotylenchus multicinctus, Meloidogyne incognita* and *Meloidogyne javanica*, considered to be most detrimental to banana, were found in banana in Vietnam (Chau *et al*. 1997; Van den Bergh *et al*. 2002). However, *R. similis* was not found, although this species is widespread in almost every tropical and subtropical banana-producing region of the world (Bridge 1993).

Radopholus similis was first reported in Vietnam in 1999. It was isolated from durian in Dak Lak province, belonging to the Central Highlands

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(Tay Nguyen region). *Radopholus similis* is one of top 15 nematodes in the world and was also listed in group 1 of the 'quarantine pest list of Vietnam' before 1998. In 2000, it was transferred to group 2 of this pest list.

Between 2000 and January 2003, survey trips were conducted in North Vietnam and in three provinces belonging to Tay Nguyen to investigate the occurrence and distribution of *P. coffeae* on different crops and to confirm the occurrence of *R. similis* on different crops in Tay Nguyen region. The reproduction and damage potential of *R. similis* population on AAA bananas, durian, coffee and ginger in the quarantine house were also assessed.

Materials and methods

Collection of samples

In each site, about 10-15 g of root and soil samples were taken on each crop.

Collection of samples on banana and pineapple was carried out according to the Technical Guidelines of Speijer and De Waele (1997). A hole of 20 x 20 x 20 cm^3 was dug next to the corm of the mother plant and all banana roots in this volume were collected and placed in a marked plastic bag. On other crops, secondary roots and cortex of main roots were collected. Soil around these roots was also collected.

Extraction of nematodes from carrot discs for inoculation

Nematode populations used in the experiments were reared monoxenically on carrot discs and incubated at 27 ^{0}C in the dark for several generations (Moody *et al*. 1973, Pinochet *et al*. 1995). The carrot discs were blended three times for 10 s (at 5 s interval) and poured through 106 and 25 µm pore sieves. Carrot tissue collected on the 106 µm sieve was discarded, while the nematodes were collected from the 25 µm sieve. Prior to inoculation, nematodes were sterilized overnight using streptomycin 6000 ppm (Speijer and De Waele 1997).

In-vivo *experiments*

Two banana cultivars, ginger, coffee and durian were used in screening experiments.

In-vitro plantlets used in the experiments were cultured and propagated on Murashige and Skoog medium. They were transferred to trays, filled with sterilized sand, then the fungicide Daconil was sprayed several times. After 2 to 3 weeks, the banana plants were transferred to

plastic pots, filled with a mixture of sterilized soil and humus. After 10 weeks, the plants were infested with *R. similis.*

For the experiments on coffee, durian and ginger, the seeds of coffee and durian and tubers of ginger were treated in hot water at 55 ^{0}C for 25 minutes. Then, the samples were planted in plastic pots, filled with sterilized soil. The plants were inoculated with *R. similis* after 10 weeks for ginger and 24 weeks for coffee and durian. The experiments were carried out with six levels of density of the *R. similis*: 500, 1000 1500, 2000, 2500, 3000 vermiform nematodes/plant. The control plant has no nematodes.

The plants were harvested 10 weeks after inoculation. Based on the method described by Speijer and De Waele (1997), the following data were recorded:

1. Nematode reproduction: nematodes per 10 gram of roots or per root system.
2. Root damage assessment

The damage of roots can be categorized into five groups according to the percentage of root lessions.

Score 0: No lesions
Score 1: 1- 25% lesions
Score 2: 26 - 50% lesions
Score 3: 51 - 75% lesions
Score 4: 76 - 100% lesions

The two key parameters to be measured according to National Institute of Plant Protection (1997).

$$\text{Disease incidence (\%)} = \frac{\text{Number of necrotic roots}}{\text{Total number of roots assessed}} \times 100$$

$$\text{Disease severity (\%)} = \frac{\Sigma[(N_1 \times 1) + (N_2 \times 2) + \ldots + (N_4 \times 4)}{N \times 4} \times 100$$

Note: N_1: The number of roots with necrosis at score 1
N_2: The number of roots with necrosis at score 2
N_4: The number of roots with necrosis at score 4
N: Total number of roots

The maceration–sieving method was used for the extraction of *R. similis* (Speijer and De Waele 1997).

In-vitro *experiments*

Table 1. *Radopholus similis* populations for *in-vitro* studies.

R. similis populations	Host	Source
Indonesia	*Musa* spp.	Lab. of Tropical Crop Improvement, K.U. Leuven
Uganda	*Musa* spp.	Lab. of Tropical Crop Improvement, K.U. Leuven
Vietnam	Durian roots	Plant Quarantine Station of Vietnam

Determination of the favourable temperature for reproduction of a *Radopholus similis* population from Vietnam on carrot discs

Twenty-five females were inoculated per carrot disc. Eight replicates were incubated at 21, 25 and 28°C in darkness. Nematode populations were harvested at 2, 4, 6, and 8 weeks after inoculation. Total nematode population (including eggs, vermiforms) at each harvest time was estimated.

Comparison of reproductive capacity of *Radopholus similis* populations from Vietnam, Indonesia and Uganda on carrot discs as a function of time

Twenty-five females were inoculated per carrot disc. Nine replicates for each population were incubated at 27°C in the dark. Nematode populations were harvested at 2, 4, 6 and 8 weeks after inoculation. Final population (including eggs, juveniles, males and females) at each harvest time was defined.

Comparison of the reproductive fitness of single females of *Radopholus similis* populations from Vietnam, Uganda and Indonesia on carrot discs

One female was inoculated per carrot disc. Fifty replicates for each population were kept at 27°C in the dark. Carrot discs were harvested 6 weeks after inoculation. All forms of nematodes (living, dead, mobile and immobile) were observed.

Assessment of nematode populations

Nematode populations were obtained from the carrot-disc cultures by maceration-sieving method as described above. The nematode suspension was diluted to 50 ml and 2-ml aliquots and three 2-ml aliquots were analyzed under a light microscope.

Prior to statistical analysis, the numbers of nematodes were converted to $\log_{10}(x+1)$. All data were subjected to analysis of variance (ANOVA) and means of the parameters were separated using the Tukey-HSD test at $P \leq 0.05$ or Duncan's test.

Results and discussion

Assessment of the occurrence and distribution of Pratylenchus coffeae *on different crops in North Vietnam*

Two survey trips were conducted in November 2000 and February 2001 to assess the occurrence and distribution of *P. coffeae* in Ha Tay and Phu Tho provinces, where two *P. coffeae* populations were identified in banana in 1995 and 1998. No *P. coffeae* population was found from this survey, probably because this survey was undertaken in the winter season. North Vietnam has two main seasons: the winter season with dry and cold temperature (the lowest temperature can be 7-8 ^{0}C) and the summer season with high temperature and heavy rainfall. The low temperature in the winter season can inhibit nematode reproduction. According to Gowen (2000), temperatures of 25-30 ^{0}C are the optimum temperatures for the development of *P. coffeae*.

Another survey in North Vietnam was conducted in two provinces (Thanh Hoa and Yen Bai). Samples were collected on banana, coffee, pineapple, cinnamon, ginger and tea. During this survey, *P. coffeae* populations were found on banana and coffee with high frequency in all the areas. In Yen Bai province, a *P. coffeae* population was also found on cinnamon. *Radopholus similis* was not found in these surveys.

Assessment of the occurrence and distribution of Pratylenchus coffeae *and* Radopholus similis *on different crops in Central Highlands*

Two surveys were conducted in May and November 2001 in three provinces belonging to Tay Nguyen region (Dak Lak, Gia Lai and Kon Tum) to get a better idea about the occurrence of *R. similis* and *P. coffeae* in these areas. Samples were taken on coffee, durian, black pepper, banana, citrus, grapefruit, ginger and wild vegetation in the neighbourhood of these fields. The results are presented in Table 2.
The results show that *P. coffeae* was found on seven crops. Moreover, *P. coffeae* was found in banana and coffee in all the three provinces. This shows a wide host range and wide distribution of *P. coffeae* in these areas.

On pineapple, *P. coffeae* was rarely found. *P. coffeae* was identified in only one sample in Gia Lai province among hundreds of samples collected in the North Vietnam and the Tay Nguyen region.

On ginger and pepper, *P. coffeae* and *R. similis* were not found in any of the provinces during the surveys.

In Dak Lak province, *R. similis* was found on durian in 1999. The population on durian has been associated with imported plant material

from Thailand in 1998, where *R. similis* is common on several crops including banana. During this survey, *R. similis* was not found in local durian or any other crops except coffee. *Radopholus similis* was found on coffee in two districts of Dak Lak province and one district of Gia Lai province. The *R. similis* population in coffee has been recovered from roots of coffee planted in recently cleared land covered before with natural vegetation. This suggests that this *R. similis* population is present in local coffee of Vietnam.

Table 2. Occurrence of *Radopholus similis* and *Pratylenchus coffeae* on different crops in Tay Nguyen area.

Crops	Dak Lak		Gia Lai		Kon Tum	
	R. similis	*P. coffeae*	*R. similis*	*P. coffeae*	*R. similis*	*P. coffeae*
Banana	0	+	0	+	0	+
Coffee	+	+	+	+	0	0
Pepper	0	0	0	0	0	0
Durian	0	0	0	0	0	+
Citrus	0	0	0	0	0	+
Pineapple	0	0	0	+	0	0
Ginger	0	0	0	-	0	0
Longan	0	+	0	-	0	0
Mango	0	0	0	0	0	0

+: Nematode was found 0: No nematode was found -: No sample was collected

Assessment of reproduction and damage potential of Radopholus similis *on banana and ginger under quarantine-house conditions*

The first experiment

Two Vietnamese AAA banana cultivars (Dai Loan and Cao Hong, very common genotypes for home consumption and export) and one ginger cultivar were inoculated with *R. similis* (population from imported durian in Dak Lak province) at three concentrations: 500, 1000 and 1500 vermiforms per plant. The number of *R. similis* recovered from roots of plants and assessed parameters are presented in Tables 3 and 4.

To assess the pathogenicity of *R. similis*, the percentage of root necrosis, number of nematodes in certain root weight and soil were gathered. The results in Table 3 show that there was no significant difference in percentage of root necrosis, number of nematodes in certain root weight and soil for the three batches. In screening for resistance to *R. similis* in *Musa*, with an inoculation density of 1500 vermiforms of *R. similis* per plant, pathogenicity was not observed.

There was no interaction between banana cultivars and ginger with infection for the various plant growth parameters (plant height, shoot weight and standing leaves). The results in Table 4 show that there was no significant difference in plant-growth parameters (plant height, shoot weight and number of standing leaves) between infected and uninfected plants with *R. similis* in all three densities.

Table 3. Damage assessment and reproduction of *Radopholus similis* on two Vietnamese banana cultivars and one ginger cultivar.

	Density of *R. similis* inoculated								
	500 vermiforms of *R. similis*/plant			1000 vermiforms of *R. similis*/plant			1500 vermiforms of *R. similis*/plant		
	RNI (%)	R	S	RNI (%)	R	S	RNI (%)	R	S
Dai Loan	0.4a	7a	13a	0.9a	91a	120a	1.9a	238a	147b
CaoHong	0.3a	11a	4a	0.8a	77a	31a	1.8a	98a	33a
Ginger	0a	64a	4a	0a	91a	11a	0a	224a	15a

Data are means of 9 replicates. Data of nematodes were transformed to $\log_{10}(x+1)$ and data of percentage of root necrosis were converted to arcsin (x/100) for statistical analysis. Means in the same column followed by the same letter do not differ significantly according to Tukey-HSD test ($p \leq 0.05$).
RNI= root necrosis index, R= number of nematodes per 10 g of roots, S= number of nematodes per 100 g of soil.

Table 4. Plant growth parameters of two Vietnamese banana cultivars and one ginger cultivar with and without *Radopholus similis.*

Cultivars		Density of *R. similis* for inoculation											
		500 vermiforms/plant				1000 vermiforms/plant				1500 vermiforms/plant			
		PH (cm)	SW (g)	RW (g)	SL	PH (cm)	SW (g)	RW (g)	SL	PH (cm)	SW (g)	RW (g)	SL
Dai Loan	Inoculated	33a	258b	26a	10a	34a	242b	26a	9a	40a	200a	28a	8a
	Control	40a	203a	25a	9a	40a	203a	25a	9a	40a	203a	25a	9a
Cao Hong	Inoculated	37a	214a	37a	8a	45a	322b	34a	8a	38a	248a	39a	8a
	Control	38a	248b	36a	8a	38a	248a	36a	8a	38a	245a	36a	8a
Ginger	Inoculated	65a	210b	53a	13a	57a	179a	36a	11a	62a	202a	56a	13a
	Control	73a	157a	48a	14a	73a	157a	48a	14a	73a	157a	48a	14a

Data are means of 9 replicates. The data was analyzed two by two (inoculation compare with non-inoculation). The data were not transformed before analysis. Means in the same column followed by the same letter do not differ significantly according to Tukey-HSD test ($pd \leq 0.05$).
PH=plant height (cm), SW= shoot weight (g), RW= root weight (g), SL= number of standing leaves.

The second experiment

From the results of previous experiment in 2001, the second experiment was carried out on the same two banana cultivars and ginger using higher density of *R. similis* (2000, 2500 and 3000 vermiforms/plant) in 2002. Screening for resistance to *R. similis* on coffee and local durian was also carried out at the same density of this nematode population. In this experiment, the damage of the root was assessed according to NIPP (1997).

The results in Table 5 show that local durian was the most susceptible host of the *R. similis*. The disease incidence and disease severity reached 100%. Root damage caused by *R. similis* was low on two banana cultivars (Dai Loan and Cao Hong) in 2001 and increased in 2002 with the highest disease severity of 16, 4 and 24.8%, respectively. The symptoms caused by *R. similis* were also observed on tubers and roots of ginger, but these did not show at low inoculation density.

Table 5. Damage of *Radopholus similis* on selected host plants.

	2001						2002					
	500 vermiforms/ plant		1000 vermiforms/ plant		1500 vermiforms/ plant		2000 vermiforms/ plant		2500 vermiforms/ plant		3000 vermiforms/ plant	
	DI (%)	DS (%)	DI (%)	DS (%)	DI (%)	DS (%)	DI (%)	DS (%)	DI (%)	DS (%)	DI (%)	DS (%)
Dai Loan	6.7a	2.7a	11.1a	6.2a	17.8a	10.7a	20b	11.6b	24b	12b	30b	16.4b
Cao Hong	6.7a	5.9a	13.3a	7.1a	31.1b	16a	38b	18b	42c	23.6c	46b	24.8b
Ginger	0	0	0	0	0	0	4a	0.8a	8a	2.4a	8a	4a
Durian							100c	100c	100d	100d	100c	100c
Coffee							0	0	0	0	0	0

Means in the columns followed by the same letter do not differ significantly ($P \leq 0.05$) according to Duncan's test. DI – Disease incidence (%) DS – Disease severity (%).

No root necrosis was found on coffee, but the plant-growth parameters (weight of roots) were significantly different between the inoculated and non-inoculated plants (Table 6). In fact, when these surveys were carried out in Tay Nguyen region, the symptoms on coffee roots were only observed in 3-year-old coffee plants.

Table 6. Effect of *Radopholus similis* on the weight of coffee roots.

Number of nematodes	Mean root weight (g/plant)
2000	3.5a
2500	3.7a
3000	3.9a
No nematodes	10.2b

Means in the same columns followed by the same letter do not differ significantly (P≤0.05) according to Duncan's test.

In-vitro *experiments*

Effect of temperature on the reproduction of *Radopholus similis* population from Vietnam grown on carrot disc

Table 7. Effect of temperature on the reproduction of *Radopholus similis* population from Vietnam grown on carrot discs at 2, 4, 6 and 8 weeks after inoculation with 25 females (Pi) per disc.

Time (weeks)	T°C	Eggs	Vermiforms	Pf	Rr= Pf/Pi	n
2	28	175	25	200a A	8.0	8
	25	317	392	709c A	28.3	8
	21	158	42	200a A	8.0	8
4	28	158	67	225a B	9.0	8
	25	1033	3000	4033c B	161.3	8
	21	225	142	367b B	14.7	8
6	28	183	250	433a C	17.3	8
	25	11467	23075	34542c C	1381.7	7
	21	258	408	666b C	26.6	8
8	28	125	350	475a C	19.0	8
	25	9783	22592	32375c C	1295.0	8
	21	792	850	1642b C	65.7	8

Pf: final nematode population

Rr: reproduction ratio; n: number of replicates used in analysis

Original data are presented. Number of nematodes were converted into log10(x+1) before analysis. Means were separated by Tukey-HSD test at P≤0.05. Temperature effect: comparison of different temperature at each time by small letters. Time effect: comparison at different times by capital letters.

Means in the same column followed by the same letter do not differ significantly (P≤0.05) according to Duncan's test.

The results of reproduction of *R. similis* from Vietnam at different temperatures are presented in Table 7. No interaction was observed between temperature and time. Therefore, the main effects of temperature and time were estimated separately. The results show that temperature had an effect on the reproduction of *R. similis*, such that reproductive ratio was higher at 25°C than at 28°C and 21°C at all the observed times. At 2 weeks after inoculation, nematodes adapted to

the new environment, hence, a lag phase was observed through a low number of nematodes at three temperature regimes. At week 4, *R. similis* reproduced faster at 25°C, giving a growth rate of 161.3 times. At the temperatures 21°C and 28°C, the final populations of *R. similis* were still very low, reaching 367 and 225 nematodes, respectively. At week 6, the highest population build-up for *R. similis* was obtained at 25°C, reaching 34 542 specimens. Eight weeks after inoculation, a decrease of nematode number was observed at 25°C, while at 2°C and 28°C, growth rate still increased but it was relatively low (65.7 and 21 times, respectively). However, a higher significant difference of the nematode number was found at 21°C in comparison with those at 28°C.

Together with the effect of temperature on reproduction of nematode, time was also an important factor. At 2°C and 28°C, nematode population increased gently from 2 to 8 weeks after inoculation. At 25°C, this population increased sharply at 6 weeks. Due to the high growth rate this *R. similis* population reached after 6 weeks, the 32 375 nematodes, which was observed at 8 weeks, showed a stationary phase at temperature 25°C.

To date, several authors have conducted researches on the effect of temperature on the reproduction of *R. similis*: Fallas *et al.* (1995), Pinochet *et al.* (1995). However, the Vietnamese isolate was not included in their studies. This result is the first announcement about the optimum temperature for the reproduction of *R. similis* from Vietnam.

Comparison of the reproductive capacity of *Radopholus similis* populations (Indonesia, Uganda and Vietnam) as function of time

The number of nematodes and the reproduction ratio of *R. similis* populations increased significantly with increasing time after inoculation (Table 8). At the beginning time (2-4 weeks after inoculation), nematodes adapted to the new environment and a low multiplication was observed. After 6-8 weeks, nematode's growth rate increased very fast. A maximum growth rate was defined at 8 weeks for all the populations. The final population at this time ranged from 21 551 (Vietnamese population) to 23 630 (Ugandan population).

Comparison of reproduction of three *R. similis* populations at different times showed that nematode multiplication at week 2 was fairly low (Table 9). There were no significant differences of nematode number among three populations at this harvest time. At week 4, the population build-up for Vietnamese population (5518 nematodes) was higher than

that in Indonesia and Uganda. However, 6 and 8 weeks after inoculation, the number of nematodes in the three populations increased distinctively and no significant differences in their final populations was observed.

Table 8. Reproduction of three *Radopholus similis* populations (Indonesia, Uganda and Vietnam) at 2, 4, 6 and 8 weeks grown on carrot discs at 27°C after inoculation with 25 females per disc.

Populations	Time (weeks)	Eggs	Juveniles	Males	Females	Pf	Rr= Pf/Pi	n
Indonesia	2	102	413	0	0	515a	20.6	9
	4	938	505	103	52	1598b	63.9	9
	6	3035	10001	547	19	13602c	544.1	8
	8	6553	14225	1483	742	23003d	920.1	9
Uganda	2	89	241	0	0	330a	13.2	9
	4	544	734	32	18	1328b	53.1	9
	6	986	9142	358	47	10533c	421.3	9
	8	1676	20652	748	554	23630d	945.1	9
Vietnam	2	17	312	0	0	329a	13.1	9
	4	2616	2792	54	56	5518b	220.7	9
	6	2799	7285	157	25	10266c	410.6	9
	8	4972	15756	461	362	21551d	862	9

Pf: Final population; Pi: initial population; Rr: reproduction rate; n: number of replicates
Original data are presented. Number of nematodes were converted into log10(x+1) before analysis. Means for each population that followed by the same letters are not significantly different according to the Tukey-HSD test at P≤0.05.

Table 9. Comparison of the reproduction of three *Radopholus similis* populations (Indonesia, Uganda and Vietnam) as function of time at 2, 4, 6 and 8 weeks after inoculation with 25 females grown on carrot disc.

Populations	Number of weeks since inoculation			
	2 weeks	4 weeks	6 weeks	8 weeks
Indonesia	515a	1598bc	13602a	23003a
Uganda	330a	1328ab	10533a	23630a
Vietnam	329a	5518d	10266a	21551a

Original data are presented. Number of nematodes were converted into log10(x+1) before analysis. Means in the same column followed by the same letter do not significantly differ according to the Tukey-HSD test at P≤0.05.

The three populations showed the same pattern of increase in population with increase in time. Growth rate increased sharply at 6 to 8 weeks. Vietnamese populations grew faster at week 4 compared with others. However, no significant differences were found in the number of nematodes after 8 weeks for all populations.

Reproduction of a single female of Radopholus similis *from Indonesia, Uganda and Vietnam*

The results obtained from single female reproduction of three *R. similis* populations from Indonesia, Uganda and Vietnam are presented in Table 10. Reproductive fitness of the Indonesian population was significantly lower compared with the Ugandan and Vietnamese populations. After 6 weeks, a female from the Indonesian population produced 170 nematodes, while a female from the Ugandan and Vietnamese population produced 1478 and 1208 nematodes, respectively. Among 50 tested females of Indonesian population, only 20 females (40%) produced eggs. In contrast, a higher percentage of females, which produced new offspring, were obtained for Ugandan (90%) and Vietnamese (68%) populations. It is unknown if the inoculated females had a high egg content or whether there were differences in the females' development at inoculation.

Table 10. Reproductive fitness of a single female (population from Indonesia, Uganda and Vietnam) at 27°C on carrot discs 6 weeks after inoculation.

Population	Eggs	Juveniles	Males	Females	Pf
Indonesia	8	156	5	1	170a
Uganda	195	1338	64	36	1633b
Vietnam	327	806	45	30	1208b

Pf: final nematode population; n: number of replicates
Original data are presented. Number of nematodes were converted into log10(x+1) before analysis. Means with the same letters in the same column are not significantly different according to the Tukey-HSD test at P≤0.05.

Elbadri (2000) found that Ugandan population gave a higher multiplication rate compared to the Indonesian. In contrast, Ara (2000) found, in her study, that Ugandan population produced more females than Indonesian population. However, no significant differences were observed between Ugandan and Indonesian populations.

From this study, Vietnamese population revealed a pathogenicity as high as the Ugandan population, as expressed by the number of offspring produced. It also showed a lower reproductive fitness of Indonesian population compared with Ugandan and Vietnamese populations.

Conclusions

From these surveys, *P. coffeae* was found in Thanh Hoa, Yen Bai and Central Highland on seven crops. *R. similis* was found in coffee in Dak Lak and Gia Lai provinces of Vietnam, but not in local durian.

The damage caused by *R. similis* population in two banana genotypes, coffee, ginger and durian was different depending on the host-plants. The harmful effect increased with higher infection levels. Among them, durian was the most susceptible host-plant with the *R. similis* population, while banana, ginger and coffee were not susceptible.

The optimal temperature for reproduction of *R. similis* from Vietnam was 25°C. A lower multiplication rate of this species was obtained at 21°C and 28°C.

Time is an important factor in biological research, especially in obtaining the number of nematodes for experiments. Two weeks after inoculation, *R. similis* from three populations multiplied with low rate but Vietnamese population showed a higher reproduction rate compared with others. At weeks 6 and 8 after inoculation, *R. similis* revealed a high growth rate. There were no significant differences in the nematode number at this time among populations.

The single female of Indonesian population showed a lower reproduction rate in comparison with Ugandan and Vietnamese populations.

More aspects need to be studied on *R. similis* population found in Vietnam, such as:

1. study on the morphological aspects of *R. similis*, such as shape, size and body structure
2. evaluation of the resistance/tolerance of Vietnamese *Musa* germplasm to *R. similis* populations under *in-vitro* conditions and in pots
3. evaluation of the resistance/tolerance of IMTP *Musa* germplasm to *R. similis* population under *in-vitro* conditions and in pots.

Moreover, an effective management strategy for nematode species in Vietnam is necessary.

References

Ara N. 2000. Reproduction of two *Radopholus similis* populations on carrot discs, thesis, University of Gent. pp 19-20.

Bridge J. 1993. Worldwide distribution of the major nematode parasites of bananas and plantains *in* Biological and integrated control of highland banana and plantain pests and diseases (Gold C.S. and Gemmill B. *eds*). IITA, Nigeria:185-198.

Bridge J., R. Fogain and P. Speijer. 1997. The root lesion nematodes of banana. *Musa* Pest Fact Sheet No.2. INIBAP, France. 4 pp.

Chau N.N., V.T. Thanh, D. De Waele and E. Geraert. 1997. Plant-parasitic nematodes associated with banana in Vietnam. International Journal of Nematology 7:122-126.

Elbadri G.A.A. 2000. Diversity of *Radopholus similis* (Nematoda: Tylenchida. Ph.D dissertation, University of Gent, Belgium.

Fallas G. and J.L. Sarah. 1995. Effect of temperature on the *in vitro* multiplication of seven *Radopholus similis* isolates from different banana producing zones of the world. Fundamental Application Nematology 18:445-449.

FAO. 2002. FAOSTAT database. http://www.fao.org

Gowen S. and P. Quénéhervé . 1990. Nematode parasites of bananas, plantains and abaca *in* Plant-parasitic nematodes in subtropical and tropical agriculture (M. Luc, R.A. Sikora and J. Bridge, *eds*). CAB International, UK:431-460.

Moody E.H., B.F. Lownsberry and J.M. Ahmed. 1973. Culture of the root-lesion nematode *Pratylenchus vulnus* on carrot disks. Journal of Nematology 5:225-226.

NIPP - National Institute of Plant Protection, 1997. Methods for plant protection research. Agricultural publishing house, 100p.

Pinochet J., C. Fernandez and J.L. Sarah. 1995. Influence of temperature on *in vitro* reproduction of *Pratylenchus coffeae*, *P. goodeyi*, and *Radopholus similis*. Fundamental and Applied Nematology 18:391-392.

Thuy T. T.T., *et al.*, 2003. Distribution of *Radopholus similis* in Central Highlands and some nematicides for application to control *in* Summary record applied researches on plant protection. Plant Protection Department, Agricultural Publishing House.

Speijer P. R. and D. De Waele. 1997. Screening of *Musa* germplasm for resistance and tolerance to nematodes. INIBAP Technical Guidelines 1. INIBAP, Montpellier, France, 42pp.

Van den Bergh I., D.T.M. Nguyet, N.T. Tuyet, H.H. Nhi and D. De Waele. 2002. Screening of Vietnamese *Musa* germplasm for resistance to root knot and root lesion nematodes in the greenhouse. Australasian Plant Pathology 31(4):363-371.

Appendices

Appendix 1: Programme of the training workshop on enhancing capacity for nematode management in small-scale banana cropping systems

30 November 2003 (Sunday)

05:00 p.m. Arrival of Participants

01 December 2003 (Monday)

06:35 a.m. Breakfast at IRRI cafeteria

08:00 a.m. Registration
Venue: IPB Seminar Room Corridor

09:00 a.m. **Opening Program**
Venue: IPB Seminar Room
Invocation and National Anthem
Dr. Teodora O Dizon
University Researcher, and
Study Leader, Banana Nematode Project
Welcome Remarks from the Organizers
Dr. Desiree M. Hautea
Director, IPB and
Project Co-Coordinator
Dr. Dirk De Waele
Professor, K.U. Leuven, and
Project Promoter
Dr. Agustin B. Molina
(to be represented by)
Dr. Inge Van den Bergh
Associate Scientist and
Project Technical Consultant, INIBAP
Messages
Dr. Candida B. Adalla
(to be represented by)
Dr. Orville L. Bondoc
Associate Dean, College of Agriculture
Dr. Wilfredo P. David
Chancellor, UPLB
(to be represented by)
Dr. Augusto C. Sumalde
Vice Chancellor for R & E, UPLB

Prof. Nestor C. Altoveros
University Researcher and
Research Coordinator, IPB
Dr. Teodora O. Dizon
Master of Ceremony

10:00 a.m. Picture Taking
Venue: IPB Seminar Room Stage

10:15 a.m. Break/Snack

10:30 a.m. Orientation and Tour of IPB
IPB Slide Show
Dr. Maria H. Magpantay
Head, IPB Extension Division
INIBAP Presentation
Ms. Ma. Angeli G. Maghuyop
Program Coordinator and
Technical Assistant, INIBAP
Nematology Laboratory
Dr. Teodora O. Dizon
National Plant Genetic Resources Laboratory
Dr. Felipe S. dela Cruz, Jr.

12:00 p.m. Lunch

1:00 p.m. Introduction of Participants
Dr. Felipe S. dela Cruz, Jr.

1:15 p.m. Overview and Mechanics of Training Workshop
Dr. Inge Van den Bergh

1:30 p.m. Country Reports - China and South Asia

Bangladesh	***Mr. Md Golam Kibria***
	Scientific Officer
	HRC, BARI
India	***Dr. P. Sundararaju***
	Senior Scientist (Nematology)
	NRCB
	Mrs. A. Shanthi
	Assistant Professor
	Department of Nematology
Sri Lanka	***Dr. Gamini Ratnasinghe***
	Research Officer/Entomologist
	Fruit Crops Research Centre,
	Kananwila, Horana, Sri Lanka

2:30 p.m.	Discussion	
	Mr. Joey I. Orajay	
	Ms. Cleofe L. Bicar	
	Mr. Dennis C. Pantastico	
	Rapporteurs	
3:00 p.m.	Break/Snacks	
3:15 p.m.	Country Reports - South Asia	
	Venue: IPB Seminar Room	
	Cambodia	***Dr. Ny Vuthy***
		Researcher
		CARDI
	Myanmar	***Mr. Hla Than***
		Instructor
		Yezin Agricultural University
	Vietnam	***Mr. Trinh Thuy Thi Thu***
		Quarantine Officer
		Technical Plant Quarantine
		Centre- -MARD
		Ms. Duong Thi Minh Nguyet
		Quarantine Officer
		Agro-Biotechnology Department, VASI
	Micronesia	***Dr. Vazhaveli K. Murukesan***
		Researcher-Agriculture
		College of Micronesia-FSM
4:16 p.m.	Discussion	
	Dr. Rustico A. Zorilla	
6:00 p.m.	Welcome Reception	
	Venue: Sacay Grand Villas Club House	
8:00 p.m.	Staff Meeting	

02 December 2003 (Tuesday)

6:35 a.m.	Breakfast at IRRI cafeteria
8:00 a.m.	Nematode Survey and Collection ***Dr. Romulo G. Davide*** Professor Emeritus, and Consultant
8:45 a.m.	Nematode Extraction ***Dr. Rustico A. Zorilla*** University Researcher, and Study Leader

9:30 a.m.	Break/Snacks	
9:46 a.m.	Practicum: Survey and Collection ***Dr. Felipe S. dela Cruz, Jr.*** Venue: Pasong Kipot (Field)	
11:16 a.m.	Practicum: Extraction ***Dr. Rustico A. Zorilla*** Venue: Nematology Laboratory	
12:00 p.m.	Lunch	
1:00 p.m.	Nematode Processing and Mounting ***Mr. Joey I. Orajay*** Assistant Professor, and Study Leader, Banana Nematode Project	
2:00 p.m.	Practicum: Nematode Processing and Mounting ***Mr. Joey I. Orajay*** Venue: Nematology Laboratory	
3:30 p.m.	Break/Snacks	
5:00 p.m.	Testing of Presentations	
5:15 p.m.	Country Reports Venue: IPB Seminar Room	
	Indonesia	***Ms. Jumjunidang***
	Malaysia	***Dr. Nik Masdek B. Hassan*** Research Officer MARDI
	Philippines	***Dr. Luciana M. Villanueva*** Benguet State University
7:00 p.m.	Discussion ***Dr. Teodora O. Dizon*** Venue: IPB Seminar Room	
7:30 p.m.	Dinner Venue: IPB Seminar Room Corridor	
8:30 p.m.	Staff Meeting	

03 December 2003 (Wednesday)

6:35 a.m.	Breakfast at IRRI cafeteria
8:00 a.m.	Nematode Identification ***Mr. Joey I. Orajay***
9:00 a.m.	Practicum: Nematode Identification ***Mr. Joey I. Orajay***
12:00 p.m.	Lunch
1:00 p.m.	Nematode Culture ***Dr. Inge Van den Bergh***

2:01-5:00 p.m.	Practicum: Nematode Culture ***Dr. Annemie Elsen/*** ***Dr. Inge Van den Bergh*** Venue: Nematology Laboratory
5:00 p.m.	Participants-Back to CEC
5:00 p.m.	Staff Meeting
7:00 p.m.	Fellowship Night Venue: Bistro TJ

04 December 2003 (Thursday)

6:35 a.m.	Breakfast at IRRI cafeteria
8:00 a.m.	Conservation and Management of *Musa* Germplasm ***Dr. Rachel C. Sotto*** University Researcher, IPB
9:00 a.m.	Tissue Culture of Banana ***Dr. Olivia P. Damasco*** University Researcher and Head, PCTC-IPB
10:15 a.m.	Practicum: Tissue Culture of Banana ***Dr. Olivia P. Damasco*** Venue: PCTC Laboratory, NPGRL
12:00 p.m.	Lunch
1:00 p.m.	Screening for Nematode Resistance (Field and Greenhouse) ***Dr. Inge Van den Bergh***
2:00 p.m.	Practicum: Screening for Nematode Resistance ***Dr. Annemie Elsen/Dr. Teodora O. Dizon*** Venue: Plant Pathology Greenhouse
5:00 pm	Free night

05 December 2003 (Friday)

6:30 a.m.	Breakfast at IRRI cafeteria
7:30 a.m.	Tour of IPB Banana Field Gene Banks ***Dr. Felipe S. dela Cruz, Jr.*** Venues: M.Balbisiana Collection - Pasong Kipot INIBAP IMTP Varieties-Mainit, Bay
9:00 a.m.	Practicum: Screening for Nematode Resistance: Data Collection and Evaluation of Host Response ***Dr. Annemie Elsen/Dr. Teodora O. Dizon*** Venue: Plant Pathology Greenhouse
12:00 p.m.	Lunch
1:00 p.m.	Workshop: Networking on Nematode R and D -The Way Forward Venue: IPB Seminar Room ***Facilitator: Prof. Dirk De Waele***
3:00 p.m.	Break/Snacks

3:15 p.m.	Special Presentation Arbuscular Mycorhizal Fungi: A Sustainable Method to Manage Banana Nematodes ***Dr. Annemie Elsen***
4:30 p.m.	Evaluation of Training-Workshop ***Ms. Virma Rea G. Lee*** Venue: IPB Seminar Room
5:00 p.m.	Participants-Bact to CEC
5:50 p.m.	Participants-Pick up from CEC
6:00 p.m.	Closing Ceremony and Dinner Venue: SU Makiling Ballroom

Closing Program

Message ***Dr. Dirk De Waele***

Awarding of Certificates

Dr. Desiree M. Hautea

Dr. Dirk De Waele

Dr. Inge Van den Bergh

Response from Participants

Representative from the Participants

Closing Remarks

Dr. Felipe S. dela Cruz, Jr

Ms. Virma Rea G. Lee
Master of Ceremony

8:00 p.m. Participants-Back to CEC

06 December 2003 (Saturday)

Departure of Participants

Appendix 2 : List of participants / trainors / resource persons

Participants

Bangladesh

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Appendix 3 : List of acronyms and abbreviations

a.i.	active ingredient
ANOVA	Analysis of Variance
ASPNET	Asia and Pacific Network
BAPNET	Banana Asia Pacific Network(formerly ASPNET)
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBTD	Banana Bunchy Top Disease
BBTV	Banana Bunchy Top Virus
BBrMV	Banana Bract Mosaic Virus
BLS	black leaf streak
BPI-DNCRDC	Bureau of Plant Industry - Davao National Crop Research and Development Center, Philippines
BRS	Banana Research Station, India
BS	black sigatoka
BSV	Banana Streak Virus
CA-UPLB	College of Agriculture, University of the Philippines Los Baños, Philippines
CARDI	Cambodian Agricultural Research and Development Institute
CGIAR	Consultative Group on International Agricultural Research
cm	centimeter
CMV	Cucumber Mosaic Virus
DA-BAR	Department of Agriculture - Bureau of Agricultural Research, Philippines
DOA	Department of Agriculture, Sri Lanka
EEZ	Exclusive Economic Zone
FAO	Food and Agriculture Organization of the United Nations, Italy
Foc	*Fusarium oxysporum* f.sp. *cubense*
FFTC	Food and Fertilizer Technology Center, Taiwan
FHIA	Fundacion Hondureña de Investigacion Agricola, Honduras
FSM	Federated States of Micronesia
ft	foot/feet
FYM	Farm Yard Manure
GMO	genetically modified organism
GIS	Geographical Information System
ha(s)	hectare(s)
ICAR	Indian Council of Agricultural Research

ICHORD	Indonesian Center for Horticultural Research and Development
IMTP	International *Musa* Testing Program
INIBAP	International Network for the Improvement of Banana and Plantain, Montpellier, France
IPB-UPLB	Institute of Plant Breeding, University of the Philippines, Los Baños, Philippines
IPR	Intellectual Property Rights
ITC	INIBAP Transit Centre, Leuven, Belgium
IPGRI	International Plant Genetic Resources Institute, Macaresse, Italy
IPM	integrated pest management
kg	kilogram
K.U.Lueven	Catholic University of Leuven, Belgium
m	meter
MARDI	Malaysian Agricultural Research and Development Institute, Serdang, Malaysia
MGIS	*Musa* Germplasm Information System
mo(s)	month(s)
MPPRC	Micronesia Plant Propagation and Research Center
NARS	National Agricultural Research System
NBPGR	National Bureau of Plant Genetic Resources, India
NGO	non-government organization
NPK	nitrogen phosphorus potassium
NRCB	National Research Centre for Banana, India
PCR	polymerase chain reaction
PGR	plant genetic resources
PJB	Pisang Jari Buaya
PNG	Papua New Guinea
PRO*MUSA*	Global Programme for *Musa* Improvement
RC	Regional Coordinator
REC	Relative electric conductivity
RGC	Regional Germplasm Centre, Fiji
RISBAP	Regional Information System for Bananaa and Plantain - Asia and the Pacific
RNA	ribonucleic acid
RT PCR	reverse transcriptase polymerase chain reaction
sp/spp.	species
R&D	research and development
RDE	research, development and extension
SCUs	state colleges and universities
SOFRI	Southern Fruit Research Institute, Vietnam
SPC	Secretariat of the Pacific Community, Fiji
t	tonnes
TCP	tissue-cultured plant

TNAU	Tamil Nadu Agricultural University, India
TTPI	United Nations Trust Territory of the Pacific Islands
UPLB	University of the Philippines, Los Baños Laguna, Philippines
UN	United Nations
VASI	Vietnam Agricultural Science Institute
VLIR	Flemish Interuniversity Council, Belgium
VVOB	Vlaamse Vereniging voor Ontwikkelingsamenwerking en Technische Bijstand, Belgium (or Flemish Association for Development Cooperation and Technical Assistance)
WTO	World Trade Organization
YS	yellow sigatoka

INIBAP ISBN 971-91751-6-8