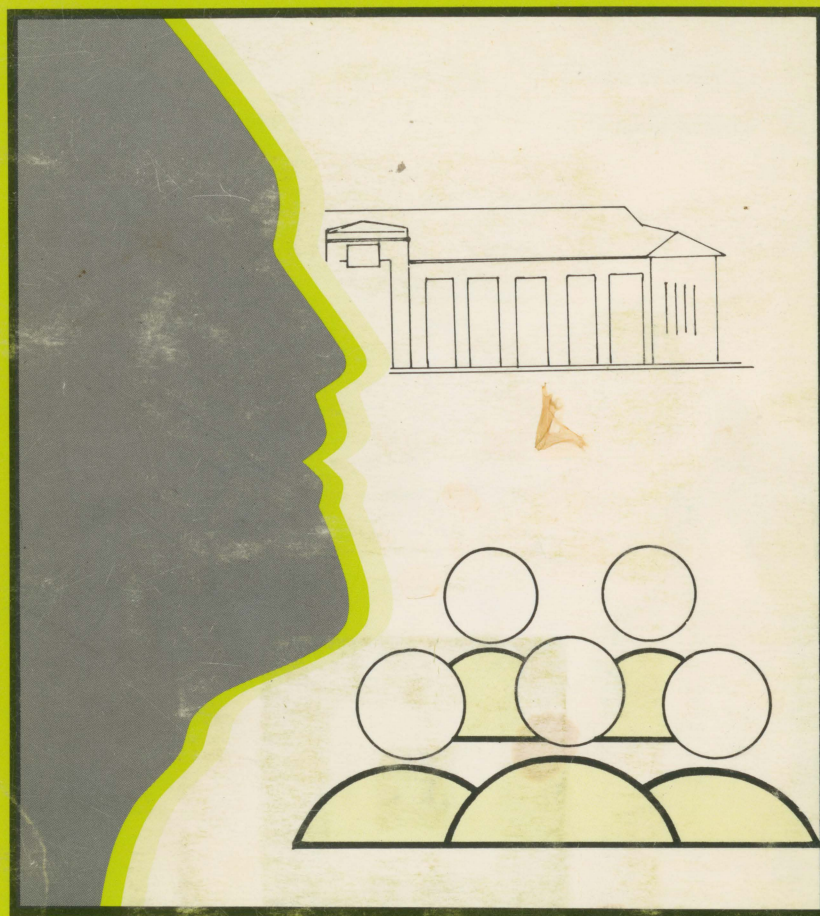




Syarahan **INAUGURAL**

Oleh

PROF. DR. ABDUL RAHMAN ABDUL RAZAK
Timbalan Dekan Fakulti Pertanian
Universiti Pertanian Malaysia

LG
173
S45
S981
no.3

1000256304



Perpustakaan, Universiti Pertanian Malaysia
TARIKH DIPULANGKAN (DATE DUE)

1000256304

[illegible]

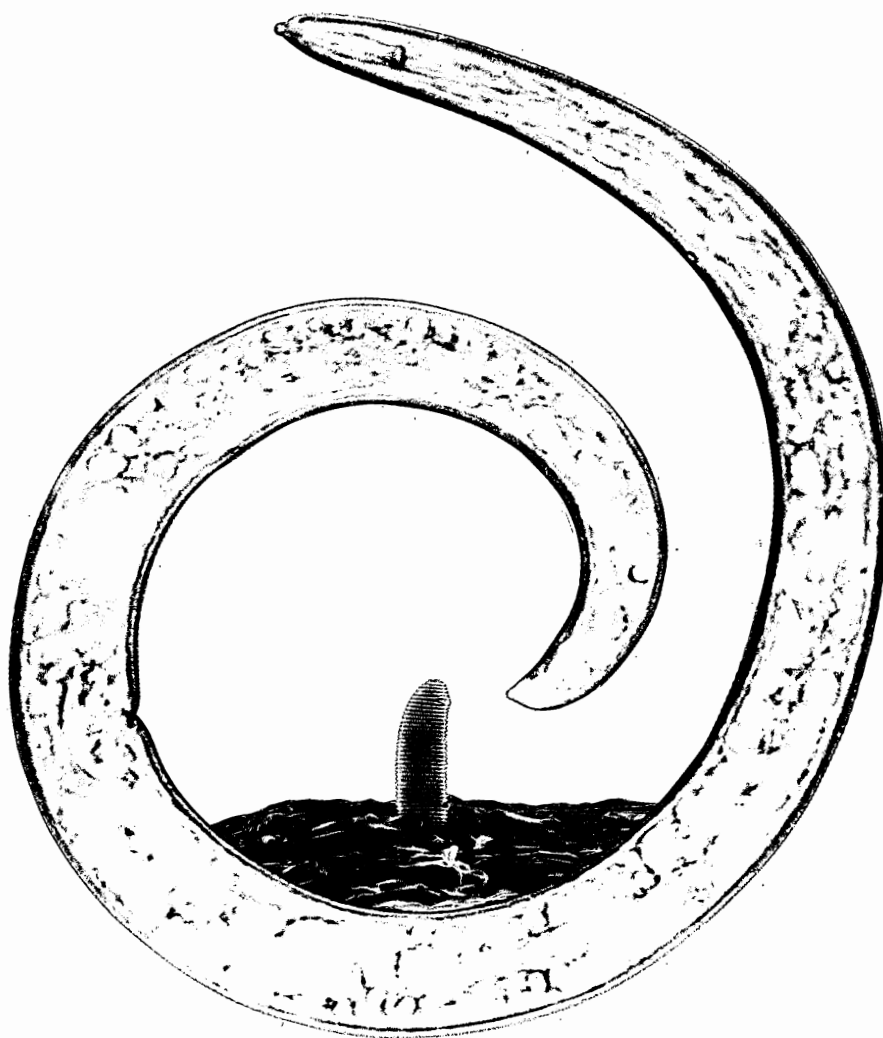


PERPUSTAKAAN
UNIVERSITI PERTANIAN MALAYSIA

28 APR 1994

Universiti Pertanian Malaysia

Plant Parasitic Nematodes, Lesser Known Pests of Agricultural Crops



PROF. DR. ABDUL RAHMAN ABDUL RAZAK

30 Januari 1993

PLANT PARASITIC NEMATODES, LESSER KNOWN PESTS OF AGRICULTURAL CROPS

by

Prof. Abdul Rahman bin Abdul Razak

Introduction

Nematodes cause much human misery affecting man himself, his animals and his crops. The sufferings inflicted by nematodes on man were documented in the Bible and in writings on papyrus 3500 years ago. Nematodes infecting man cause ailments such as trichinosis and elephantiasis. The more familiar hookworm is a blood sucking nematode which lives off both man and his animals causing emaciation and loss of vitality, perhaps even death. The barber's pole worm or blood worm of sheep, *Haemonchus contortus*, causes infected sheep to lose their appetite to the extent that they may even die.

The damage caused to crops by nematodes can be very serious although this is seldom appreciated. Globally, crop losses attributable to plant parasitic nematodes are estimated to cost US\$77.7 billion annually (Sasser, 1989). Plant nematodes are appropriately referred to as the "farmer's hidden enemy" and a "global menace" to crops (Sasser, 1989; 1980).

The economic importance of plant nematodes is usually not appreciated because damage is generally insidious. A nematode infection typically results in yield reduction and loss of quality in the produce, symptoms which are also caused by other factors such as unsuitable soil or lack of nutrients. Furthermore, a nematode infection may predispose the plant to secondary pathogens such as fungi

and bacteria, and these other pathogens may be mistaken to be the primary ones because of their more obvious symptoms. In Malaysia, the lack of appreciation of the importance of nematodes in agriculture is aggravated by the extreme dearth of expertise in the field of plant nematology.

In this paper I give a brief account of the historical development of plant nematology; introduce the habits of plant parasitic nematodes; provide some details on the effect of nematodes on host tissues; proceed to describe the damage, symptoms and impact on Malaysian agriculture; and round up with a discussion on control strategies and what research at UPM hopes to contribute towards progress in plant nematology. Much of what is given here as it applies to Malaysia are based on my own research and observations.

Historical Development of Plant Nematology

Plant parasitic nematodes was discovered accidentally by Turbevill Needham in 1743 in smutty wheat grains. In his letter to the President of the Royal Society London, he described the nematodes in the grains as "longitudinal fibres bundled together" and which, to his surprise, when placed in water "separated from each other, took life, moved irregularly, not with a progressive, but twisting motion ..."

It was not until the middle of the 19th century with the industrialisation of Europe that plant nematodes were recognized as pests of economic importance. Sugar beet was cultivated intensively, and the monocrops were plagued by "beet-sickness" or "beet-weariness". The malady was found to be caused by nematodes (Schacht, 1859) and identified as *Heterodera schachtii* by Schmidt in 1871 (Thorne, 1961). It was soon realised that nematodes were also responsible for losses in other

economically important crops such as cucumber grown in glasshouses in England (Berkeley, 1855) and coffee in Brazil (Jobert, 1878).

The discovery of fumigants for control of plant nematodes in 1943 (Carter, 1943) accelerated the development of plant nematology. The fumigants, D-D mixtures (1, 3-dichloropropene and 1,2 dichloropropane) and 1,3-D (1,3-dichloropropane), were found to be effective and relatively inexpensive. Using these fumigants, it was possible to demonstrate the extent of damage caused by nematodes in the field. The results were so spectacular that growers adopted fumigation even before it was recommended.

The dramatic effect of the nematicides attracted researchers who soon solved some long standing problems. It was revealed that plant nematodes can also be ectoparasitic. Prior to this it was assumed that nematodes must enter the plant tissue before it can inflict injury. The mysterious "docking disorder" of sugar beet in England was found to be caused by the feeding of the stubby root nematode and lance nematode (Whitehead, 1965). Ectoparasitic nematodes such as the dagger nematode, *Xiphinema* sp., the stubby nematode, *Trichodorus* sp. and the lance nematode *Longidorus* sp. (Christie & Perry, 1951), not only cause direct damage to crops, but can also act as vectors for viruses which afflict strawberry and hops (Hewitt et al., 1958). Nematodes were also found to interact with fungal pathogens and phyto bacteria with devastating effect. For example, in tobacco, the root knot nematode, *Meloidogyne* spp. increases incidence of black shank disease caused by the fungus, *Phytophthora parasitica* var. *nicotiana* (Lucas et al., 1955). The same nematode was also responsible for causing the breakdown in resistance of tobacco bred for resistance to Granville's wilt bacterium (*Pseudomonas solanacearum*)

(Sasser et al., 1955).

In Malaysia, plant nematodes have been recorded for some time now in a number of publications such as those by Shaples (1923), Beeley (1939), Thompson & Johnston (1953), Rao (1964), and Low & Ting (1970). However, serious interest in plant nematology only began in 1970 when the subject was taught by Dr Winoto Suatmadji as part of the plant protection course in the Bachelor of Agricultural Science programme at the Faculty of Agriculture, University of Malaya. There was some gain in public awareness of the economic importance of plant nematodes in the first half of the 1980's when the young and vigorous guava industry suffered a serious setback due to widespread decline of trees of all ages. The slow decline was found to be caused by root knot nematodes (Razak & Lim, 1987).

Plant Nematodes and Malaysian Agriculture

Plant nematodes have probably existed since when crops were first cultivated in this country. The ancient practice of shifting cultivation is commonly believed to be brought about by the need to move on after soil nutrients have been depleted. Equally plausible could be that the practice is imposed by the need to avoid the build up of plant pathogens, including nematodes.

Similarly, vegetable farmers in the lowlands practise some form of crop rotation to avoid the problem of "soil sickness". Samples collected from vegetable farms show the root knot nematode, *Meloidogyne* spp., to be widespread. Farmers growing *Colocasia* usually experience a gradual reduction in the size and quality of tubers despite adequate fertilizer application; this is especially common when the crop is continuously grown in the former rice field. The examination of sampels

PERPUSTAKAAN
UNIVERSITI PERTANIAN MALAYSIA

from stricken plots of *Colocasia* reveal the causal agent to be *Hirschmaniella oryzae*.

The losses in perennial crops can be devastating. Among the perennial crops of economic importance and which are susceptible to nematode attacks are guava, pepper and banana. It was not uncommon to see guava trees being uprooted in Perak (Figure 1). In Johore many of the once thriving pepper farms have now been planted to cocoa and oil palm. To a lesser degree this is happening in Sarawak too. Bananas all over the country, especially those grown in smallholdings, produce low quality fruit, and yields are well below the potential of the crop.

Despite the frequency of occurrence and severity of nematode infections such as those mentioned above, farmers and, even worse, the extension agents are often unable to ascribe the damage to the cause correctly. This unsatisfactory state of knowledge among agricultural workers can be attributed to three possible reasons.

Firstly, for many years, Malaysian Agriculture has been largely dependent on the plantation crops, namely rubber, oil palm and cocoa. Accordingly, the infrastructure and support for research and development was to a very great extent devoted to the major plantation crops. Fortuitously, these crops appear to be tolerant or resistant to the nematodes present. At the same time it meant that little attention was given to nematodes as plant pests. Hence, the decline in the young guava industry, in Perak, and complete loss of the pepper cultivation in Johore due to yellow disease caused by nematodes did not receive as much attention as the cocoa pod borers on cocoa. The promulgation of the Malaysian Agricultural Policy in 1984 stressed the need to diversify into other crops but did not really improve the situation. The initiation of the programme Intensification of Research in

Priority Areas (IRPA) in 1986 should bring about real progress in this direction.

Secondly, the above ground symptoms of nematode infection is not as eye-catching as that caused by insect leaf feeders, fungal pathogens or phyto-bacteria. Nematodes cause a slow decline in the growth and development of the affected plant and rarely kill it outright over a short period.

Lastly, nematodes are tiny colourless translucent organisms that are barely visible to the naked eye. They can be as short as 0.003 mm (*Paratylenchus*) and as long as 5 mm (*Paralongidorus*).

Habit of Plant Parasitic Nematodes

Plant parasitic nematodes can be classified into three groups based on their feeding habits: ectoparasites, endoparasites and semiendoparasites.

The ectoparasites such as *Xiphinema* sp. feed on the root surface by inserting the stylet into the root tissue while the whole body remains outside the root. All the immature stages, and females and males are found in the soil but not in the roots.

The endoparasitic nematodes enter the root tissues to feed. Some genera, the migratory endoparasites (Figure 2), are able to migrate within the root tissues or move out into the soil and reenter new roots. Migratory endoparasites can be found both in the root and in the soil. In contrast, the larvae of sedentary endoparasitic nematodes such as *Meloidogyne* spp. after having selected its feeding site in the root remain stationary and develop into the gravid female; the female induces the root to form a gall at the site (Figure 3). Within a gall the immature stages, gravid females, and often the males may be present; except for the males,

all the other stages have lost their mobility. Only the vermiform infective second stage larvae and the males are present in the soil.

The reniform nematode, *Rotylenchulus reniformis* is one example of a semiendoparasite. In this species the larva embeds thirty percent of the anterior part of its body in the root tissue, becomes sedentary and develops into a kidney shaped female (Figure 4). Except for a slight browning of the tissue around the feeding site there are no other apparent symptoms on the root.

Effect of Nematodes on Host Tissues

A feeding nematode can result in one of a variety of effects on the root at the cellular level. It can feed by withdrawing the cell contents without causing any apparent damage to the root system, as in the case of *Tylenchorhynchus* when it feeds on the root hairs of grass. It can cause massive destruction by invading the root tissues, and feeding and moving within, as in the case of *Radopholus similis* in banana roots. It can modify the cells to make them suitable as a source of nutrients, as in the case of *Meloidogyne* spp. on a wide range of plants.

Cell destruction through nematode invasion and feeding is a simple direct physical damage. The displacement of cells by the nematodes disrupt the supply of nutrients between the distal and proximal parts of the root thus affecting its function.

However, the ability of nematodes to alter the host cells into enlarged feeding cells involve a more complex association between the parasite and the host. All members of the family Heteroderidae and some members of the Tylenchidae have this ability. Together, they constitute an important group of plant nematodes

which count most of the important economic crops as their hosts. *Meloidogyne incognita*, is easily the most notorious of the species of plant nematodes present in Malaysia. The nematode induces the formation of multinucleate syncytial giant cells (Figure 5) from which it derives its nutrients necessary for its growth and development. The giant cells remain active for as long as the nematode continues to feed on them. Once the nematode dies or stops feeding the cells collapse. Survival of the giant cell is thus regulated by the nematode.

The highly developed parasitic association between the host and the nematode is reflected in the histology of the giant cells. The nematode induces the host cells to undergo endomitosis without cytokinesis, forming a group of enlarged cells, each containing several irregularly shaped nuclei. The cytoplasm becomes dense and granular containing abundant cell inclusions such as Golgi apparatus, mitochondria, ribosomes, polysomes and endoplasmic reticulum, very much resembling active meristematic cells (Jones, 1981). Each giant cell is enclosed within an irregularly thickened cell wall produced by the invagination of the plasmalemma. Wall invaginations increase the surface of inflow of the nutrient from the xylem vessels to the giant cells. The part of the cell wall adjacent to the xylem vessel is typically thicker than that bordering unaltered parenchymatous cells or other giant cells. The continuity of the xylem vessels are disrupted by the giant cells (Figure 6). The giant cells have been referred to by Jones & Gunning, (1976) as syncytial transfer cells, synonymous to the transfer cells in the roots of epiphytic plants.

On guava and chilli, although several nematodes may be present in a single large gall, not more than one saccate female could be found feeding on a single

group of giant cells. And each group of giant cells do occur immediately adjacent to another group; there appears to be a clear separation of giant cells produced by each nematode.

Evidently, the physiology of the galled root differs from that of normal roots. The modified cells were reported to have higher respiratory activity, increased cytokinin and auxin levels, and higher accumulation of nutrients compared to the normal cells. Translocation of nutrients from the root to the shoot is impaired by the giant cells, and the host plant becomes more sensitive to moisture stress (Hussey, 1985).

The feeding cells of the reniform nematode (*R. reniformis*) differ histologically from that of the giant cells of *Meloidogyne* spp. The reniform nematode, can establish the feeding cells in the phloem as in papaya and tomato, or in the pericycle layer of the root as in leguminous plants (Figure 7). Feeding cells found in the phloem region of the root are similar to the giant cells of root knot nematodes in the ultrastructural changes, and appear to affect the growth and yield of the crop. But when the feeding cells are produced in the pericycle layer, the effect on the plant is insidious: the plant does not appear to be obviously affected even though the infection rate may be very high. Regardless of whether the feeding cells are produced in the phloem or pericycle, a structure called the feeding tube can be found. The feeding tube appears to be of nematode origin and is helically coiled in the main cell of the feeding area (Figure 8A). The tube seems to be porous and is postulated to act as a filter to prevent the large mitochondria and lipid bodies from blocking the lumen of the nematode stylet. Since the embedded part of the nematode body is held tightly by the cell walls, the nematode

will die of starvation if the lumen of the stylet is blocked (Razak & Evans, 1976).

The modified cells in the feeding area contain a large concentration of smooth endoplasmic reticulum and various sizes of lipid bodies which suggest that these cells are active (Figure 8B). These modified cells stain heavily for protein and carbohydrates.

It is not surprising that a heavy nematode infection seriously affects plant growth and production. Between the infective vermiform larva to the saccate mature female, the nematode increases by about 1000 times, and this development is accompanied by a corresponding increase in the energy demand of the nematode. The energy requirement increases further during egg production. The feeding cells act as the sink which mobilises photosynthates from the shoot to support the development of the nematode. A large proportion of plant nutrients is diverted from the adjoining xylem vessels and parenchymatous cells to the feeding cells. The nematode, in effect, competes with the host plant for nutrients. Further damage is done because the galls affect the root by disrupting development, suppressing branching, and reducing the rate of elongation.

Damage and Symptoms on Selected Malaysian Crops

Plants infected by nematodes show symptoms of unthrifty growth, leaf chlorosis, and are generally stunted. Severity of damage depend on the susceptibility of the host plant, the nematode species, and environmental factors.

Field symptoms vary. For example, in a golf green a nematode infection results in dead and dying patches of grass (Figure 9). In a crop of infected chilli, the plants show uneven plant growth and are prone to wilting under stress; due to

premature defoliation, branches tend to be bare and carry few fruits (Figure 10).

The deterioration perennial crops is usually slow. The effect of the nematodes is frequently made obvious when the tree is under stress, for example during a prolonged dry period or with increased demands in plant nutrients during particular periods of the crop phenology. For instance, a durian tree infected by nematodes may undergo considerable defoliation when subjected to water stress. The net result is that many of the branches are bare and foliage is confined to the periphery of the crown. When the rain returns clusters of shoots are produced at the base of the remnants of fruit stalks (Figure 11). A significant loss in quality and yield of produce is more distinct in bananas. Nematode-affected plants bear small bunches with few combs and reduced number of fruits (Figure 12).

While nematodes are known to attack aerial parts of the plant, attacks on tropical crops are mostly limited to the roots. The above ground symptoms are an expression of a damaged root system. Formation of root galls of varying sizes is the common host response to the feeding of the polyphagous nematode, *Meloidogyne* spp. If infection is light to moderate the galls are evident but can be still be mistaken for nodules produced by nitrogen-fixing bacteria. On susceptible hosts like guava and chilli, gall formation can disfigure the root system so that what remains is a dark corky, grotesque looking mass of tissues devoid of lateral roots (Figure 13). However, in other nematode species the symptom is less obvious. Durian plants attacked by the lance nematode, *Xiphinema* sp., show poor growth (Figure 14); roots stubby because they have stopped elongating. In the case of an infection by the lesion nematode, *Pratylenchus* spp., the roots carry lesions similar to that caused by mechanical damage or when infected by fungal pathogen.

Control Strategies

The obvious method for controlling a nematode infection is by the application of a nematicide. A few nematicides are available locally but they suffer from some disadvantages: Relative to other pesticides, nematicides are expensive; to be effective, nematicide application needs to be repeated one or more times; and the plant only begins to show signs of recovery when new roots are free from nematode attacks.

It is easier and cheaper to control nematode by using uninfected planting materials because once a population of the pathogen establishes in a field it is nearly impossible to eradicate. Our studies on guava, pepper, banana and tobacco show that a nematode infection usually begins in the nursery because of the use of nematode-infected top soil to raise planting materials. Depending on the susceptibility of the host and the length of time the plant is in the nursery, the roots may be heavily infected by the time the seedling is transplanted into the field. The widespread occurrence of root knot nematodes on guava in Malaysia probably resulted from infected planting materials. Besides being an important guava producing area, Bidor was a primary source of planting materials. A survey of nurseries in Bidor revealed that practically all the seedlings were infected by the root knot nematode (Figure 15).

Legislations should be introduced that require all nurseries in this country to be registered. Planting materials should have certificates to assure buyers that such materials are free from selected pests and diseases, including nematodes. Ensuring nematode-free planting materials should be easily achieved if the growing medium is first treated. In this way a number of important pests and diseases are

managed without the excessive use of pesticides in the field.

A long term nematode control strategy is to breed nematode-resistant varieties. Considerable success has been achieved in breeding varieties resistant to *M. incognita* and *M. javanica* for some temperate vegetables and fruits. But for many tropical crops, especially the perennial crops such as guava and pepper, little progress has been made in this area. Nevertheless, the prospects seem to be good as suggested by our initial work on guava. Though the results showed that all the 15 guava varieties tested were susceptible to *Meloidogyne incognita*, the variety cherry (*Psidium friedrichsthalianum*) appear to be highly resistant. The resistant gene of the this variety could be incorporated into existing commercial varieties or the variety could be used as a rootstock.

Strategies for nematode control will not be successful unless they are accompanied by training of agricultural workers. There should be a programme of regular training for extension agents to improve and uptake their knowledge on the ever changing problems facing our crops.

Research and development support is vital for sustainable crop production in the country. Currently, work on plant parasitic nematodes is only carried out at the Malaysian Agricultural Research and Development Institute, the Universiti Sains, Malaysia and Universiti Pertanian Malaysia. At Universiti Pertanian Malaysia the research covers the taxonomic identification of species and races based on morphological characters, biochemical techniques, and nematode ecology. A reference collection of permanent slides and cultures of major plant parasitic species in Malaysia has been established. Studies are being carried out on plant susceptibility and resistance to nematodes and on the understanding of the host-

parasitic relationship of the major nematode pests.

Conclusion

The importance of plant nematology in Malaysian agriculture is considerable although it has not received the attention it deserves. Plant nematodes can have serious adverse effects on a variety of crops, both annual and perennial. The failure to identify nematodes as causal agents when they occur leads to insidious but significant losses. Wrong control measures may be taken which results in waste, while the health of the plant continues to decline. Control strategies which are appropriate for Malaysian situation need to be improved for better efficacy and cost-effectiveness. The coming years should see a change in the agricultural scenario in Malaysia from one which is largely dependent on the traditional plantation crops of oil palm, rubber and cocoa to one involving a greater diversity of crops, in particular food crops. In the new scenario, education and research in plant nematology will assume greater importance to ensure that agriculture will meet the needs of the increasing population in Malaysia.



Figure 1: Uprooted Nematode infested guava plants

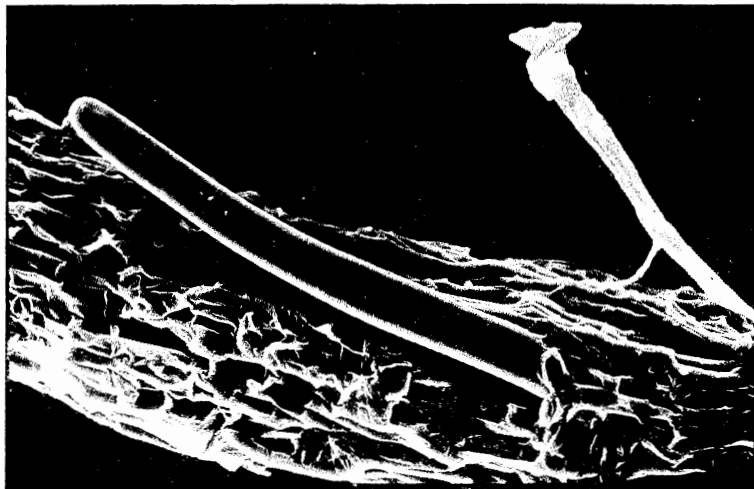


Figure 2: The migratory endoparasitic nematode, Hoplolaimus sp. entering the root of grass, tiff dwarf variety.

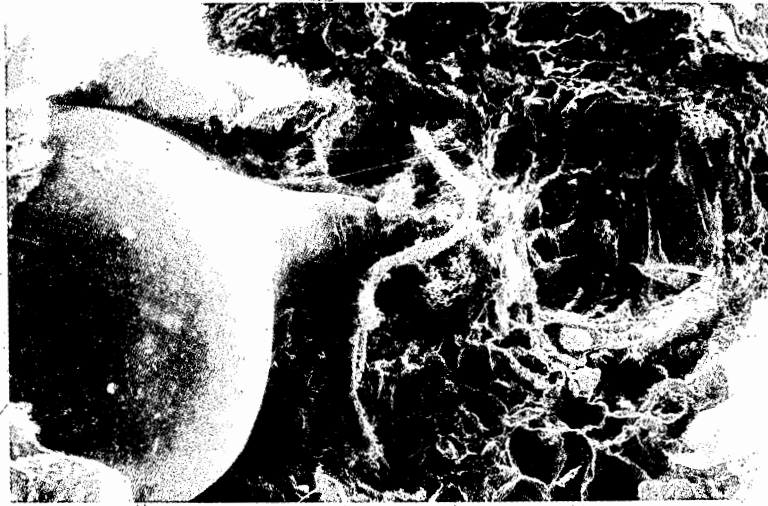


Figure 3: The gravid female of a sedentary endoparasite, M. incognita partly exposed in the guava roots.



Figure 4: The semiendoparasitic nematode, R. reniformis, at banana root surface. The exposed posterior region of the females are becoming kidney-shaped.

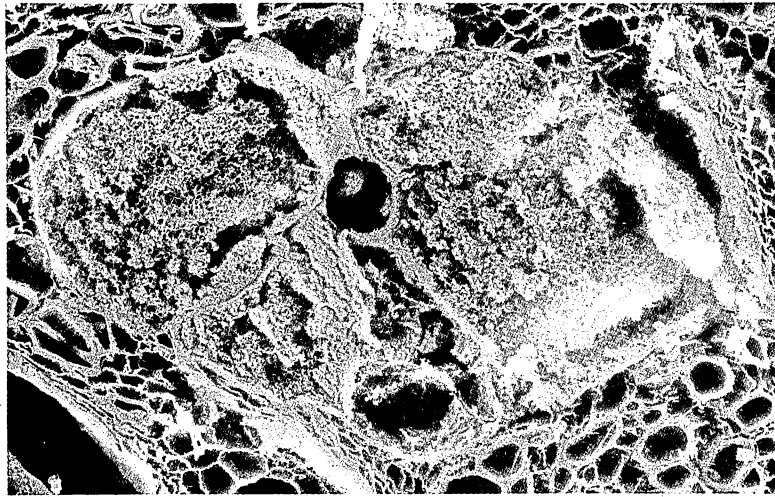


Figure 5: A group of giant cells surrounding the head of the nematode in chili root

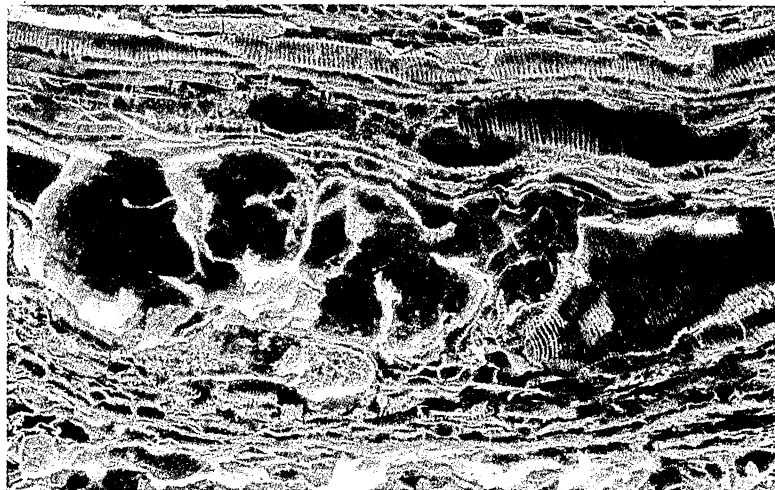


Figure 6: Disruption in the continuity of the xylem vessels of pepper root by the giant cells induced by root knot nematode, M. incognita.

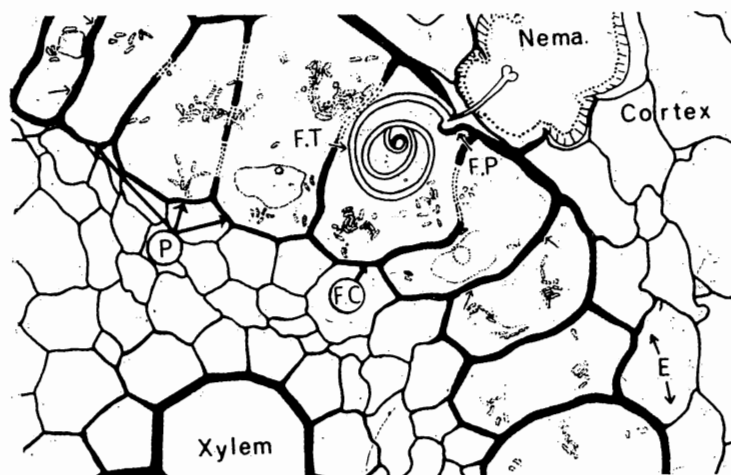


Figure 7: Composite camera lucida drawing of the feeding tube in the feeding area of the pericycle layer in the root of cowpea var. New Era infected by R. reniformis.



12:50

Figure 8A: Ultrastructure of the feeding tube attached to the feeding peg of the feeding cells.

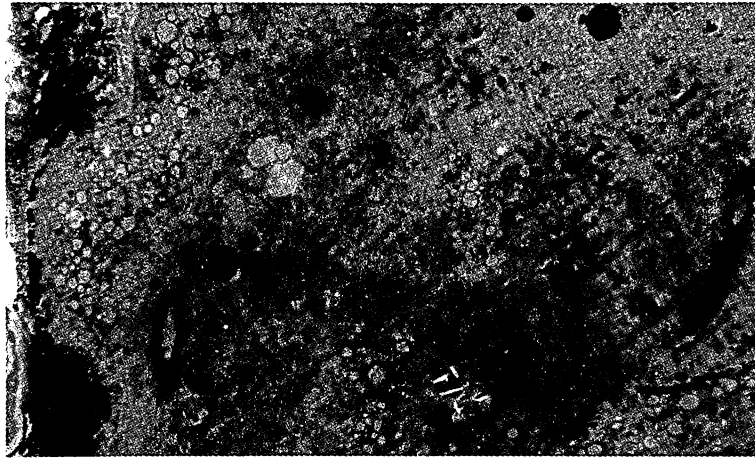


Figure 8B: Ultrastructure of the feeding cell
of R. reniformis

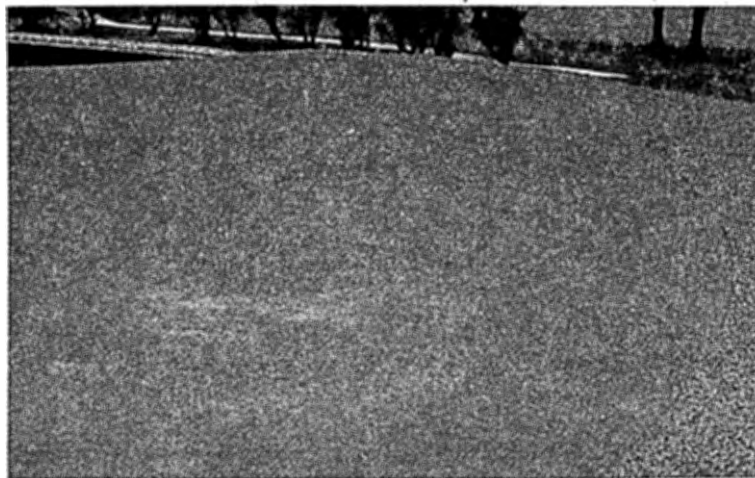


Figure 9: Brown patch in a golf green
caused by plant parasitic nematodes.



Figure 10: A defoliated chilli plant caused by M. incognita.



Figure 11 A: A cluster of new shoots produced at the base of the remnants of the fruit stalk of durian in a poorly maintained farm.

II B: Damage to durian seedlings inoculated with Xiphinema sp. extracted from the soil of an unthrifty tree.



Figure 12: Banana fruit of Mas variety produced by a nematode infested plant

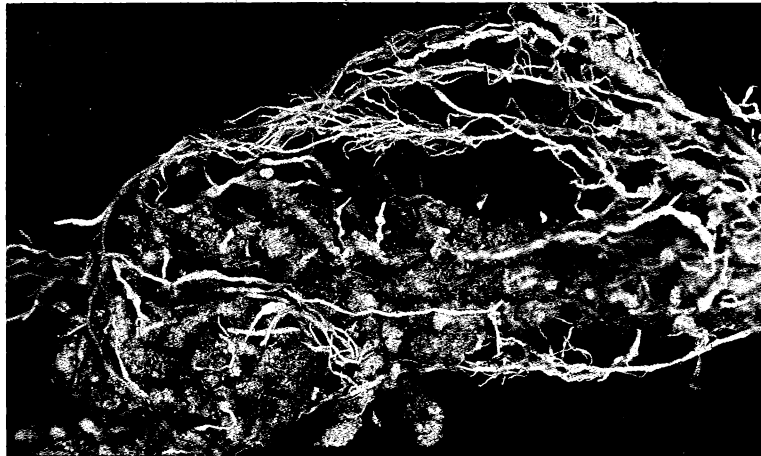


Figure 13: A deformed guava root system caused by severe infection of root knot nematode, M. incognita.

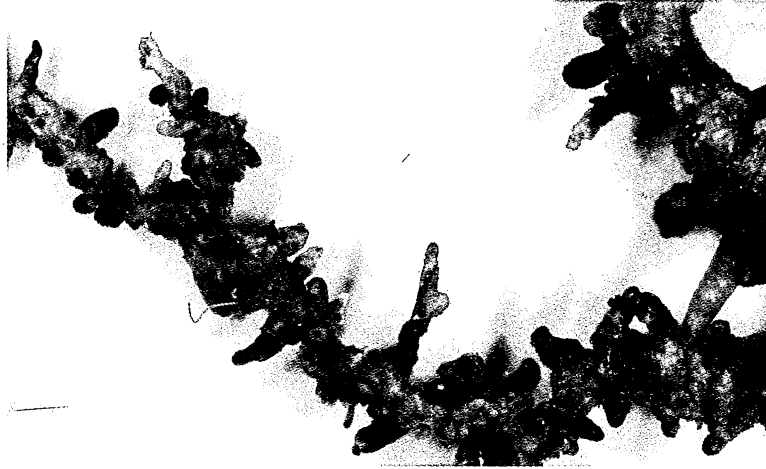


Figure 14: A piece of durian root showing stubby root symptoms. Note the pseudoroots emerging through the epidermal layer of the stubby root



Figure 15: Discarded guava seedlings from a nursery in Bidor badly infected by M. incognita.

References

1. Beeley, F. (1939). A nematode pest of roots of cover plants. J. Rubb. Res. Inst. Malaya 2: 51-58.
2. Berkeley, M.J. (1855). Vibrio forming cysts on cucumber. Gardener's Chronicle 14: 220.
3. Carter, W. (1943). A promising new soil amendment and disinfectant. Science 97: 383-384.
4. Christie, J.R & Perry, V.G. (1951). A root disease of plants caused by a nematode of the genus *Trichodorus*. Science 113: 491-498.
5. Hussey, R.S. (1985). Host-parasite relationships and associated physiological changes. In An Advanced Treatise on *Meloidogyne*, Vol. I, Biology and Control. J.N. Sasser and C.C. Carter, eds. A cooperative publication of the Department of Plant Pathology, North Carolina State University and US Agency for International Development, Raleigh. 421pp.
6. Hewitt, W.B. Raski, D.J. and Goheen, A.C. (1958). Nematode vector of soilborne fanleaf of grapevines. Phytopathology 48: 586-595.
7. Jobert (1878). Sur un maladie du Cafeier observu un Bresil, Comp. rend. hebdom. Seanc. Acad. Sci. Paris 87: 941-943 [Cited from Taylor, A.L. & Sasser, J.N., 1978. Biology, Identificatins and Control of Root-knot nematodes (*Meloidogyne* species) N.C.S.U. Graphics 111pp. 1978].
8. Jones, M.G.K. (1981). Host cell responses to endoparasitic nematode attack: structure and function of giant cells and syncytia. Ann. Appl. Biol. 97: 353-372.
9. Jones, M.G.K. and Gunning, B.E.S. (1976). Transfer cells and nematode - induced giant cells in *Helianthemum*. Protoplasma 87: 273-279.
10. Loh, C.F., and Ting, W.P. (1970). A host list of plant parasitic nematodes in West Malaysia, Bull. 123. Min. of Agric. Coop. 15pp.
11. Lucas, G.B., Sasser, J.N., and Kelman, A. (1955). The relationship of root knot nematodes to Granville wilt resistance in tobacco. Phytopathology 45, 537-540.

12. Rao, B.S. (1964). Root-knot nematodes of leguminous covers in rubber plantations. J. Rubb. Res. Inst. Malaya 18: 146-150.
13. Razak, A.R. and Evans, A.A.F. (1976). An intracellular tube associated with the feeding by *Rotylenchulus reniformis* on cowpea root. Nematologica 22: 182-189.
14. Razak, A.R. and Lim, T.K. (1987). Occurrence of the root-knot nematode, *Meloidogyne incognita* on guava in Malaysia. Pertanika, 10: 265-270.
15. Sasser, J.N. (1980). Root-knot nematodes: A Global menace to crop production. Plant Disease 64: 36-41.
16. Sasser, J.N. (1989). Plant-Parasitic Nematodes: The Farmer's Hidden Enemy. University Graphics, North Carolina State University, 115pp.
17. Sasser, J.N., Lucas, G.B, and Powers, Jr., H.R. (1955). The relationship of root-knot nematodes to black-shank resistance in tobacco. Phytopathology 45: 459-461.
18. Sharples, A. (1923). Report of the Mycologist. Dept. of Agric. S.S. & F.M.S., 1922. Malay. Agric. J. 11.267.
19. Thompson, A. and Johnston, A. (1953). A host list of plant diseases in Malaya. Mycological papers No. 52. Commonwealth Mycological Institute, Kew, Surrey.
20. Thorne, G. (1961). Principles of Nematology. McGraw-Hill, N.Y. 553pp.
21. Whitehead, AG. (1965). Nematodes associated with Docking disorders of Sugar beet. Brit. Sugar Beet Rev. 34, 77-78, 83-84.